THE CERAMIC FIRING PROCESS IN AN L&L KILN

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AUTOMATIC VS MANUAL

These instructions refer to the use of our DynaTrol control "Easy-Fire" programs. If you have a manual kiln you will need to adjust the switches to achieve various cycles. See our instruction sheet on "Firing Instructions for a Manual Kiln" (*fire-manual.pdf*).

LOADING AND FIRING ISSUES

LOADING KILN WITH GREENWARE

When placing greenware in kiln, all pieces may touch each other. Place lids on the pieces they go with when firing to bisque, this will prevent possible distortion. It is important to place tallest pieces on the center of the shelf and work outward to the shortest pieces. This will give you complete heat circulation. Be sure the ware is totally dry before firing (unless you use a very long drying cycle). Moisture in the work can cause cracking or even an explosion. We suggest using either the **SLOW BISQUE** program for heavy loads with a Preheat time of between two to three hours or the **FAST BISQUE** program for lighter loads (again with a Preheat time of two to three hours). If you want to make up your own program use the preset program as a guide (see Appendix F in the DynaTrol instructions (*dynatrol-instruct-blue.pdf*) for a description of the segments in the preset programs). It is not a bad idea to Preheat the kiln overnight. Its only purpose is to thoroughly dry the ware and to start the expansion of the ware to take place, so that the higher heat will not affect the ware.

Note that water turning to steam expands 1170 times and if water that is in the clay expands too fast you can explode your ware. Even though your ware may seem dry there is probably moisture in the ware that needs to be force dried. By preheating and then using a fairly slow program during heat up the danger of cracking or distortion is reduced.

VENTING

If you are using the **Vent-Sure** automatic vent system you can turn it on and leave it on during the entire firing. If you use an automatic vent you do not normally need to prop the lid open or remove peephole plugs. If manually venting (with out a powered vent) fire in the beginning with all the peepholes out. Then put bottom peephole plugs into peepholes after the low firing is over (you will know it is over when you start to see red heat through the peepholes). You typically want to leave the top peephole out during the entire firing if you not have an automatic downdraft vent. NOTE: HEAVY GREENWARE MAY TAKE LONGER TO DRY. Be sure to use the Preheat feature in the DynaTrol for ensuring dry work. NOTE: If you have a lot of moisture in your work you may want to prop open the lid for the first hour of preheat even if you have an automatic vent system. (**CAUTION**: Keep in mind that propping open a lid in this way can cause the lid to crack if you are not careful and that is not covered in our warranty).

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LOADING KILN WITH GLAZE WARE

When placing ware into the kiln to be glaze fired, we suggest that the pieces should be placed 1/2" apart, so that when they are heated and expanded (which all pieces do when being fired) there is no danger of them touching each other. If pieces are placed too close together, they may touch and stick to each other, thereby ruining both pieces of ware.

Except for placing ware the proper distance from each other and placing the ware for good heat circulation, follow the instructions for the firing of greenware. Be certain when placing ware in the kiln, that no piece while expanding, can touch the thermocouples. Use either the **FAST GLAZE** or **SLOW GLAZE** program depending on your glaze needs (experiment if you are not sure) or make up your own program. Ask the supplier of your glaze if you use a commercial glaze. There are come good firing recipes in various glaze books (including Mastering Cone 6 Glazes available from us (see the ACCESSORIES section). Your clay and glaze supplier will know the cone number that you should fire your work to.

OVERGLAZE FIRING

When firing overglazes such as Gold, Palladium, Mother of Pearl, China Paints, etc. the kiln must be vented during the firing up to 1100°F. If you are manually venting leave the peepholes open during the venting period. (NOTE: this is if you are not using a vent system such as an L&L VENT-SURE vent system which automates the venting process). Check with your clay and glaze supplier for recommended cycles.

SPEED OF FIRING

Although the kiln may be capable of firing relatively fast this does not mean you should fire it as fast as it is capable of firing. The speed of firing will depend on what you are trying to accomplish. Check with the glaze or clay manufacturer or supplier as to a recommended firing cycle.

SOAKING

Soaking is holding the kiln at any given temperature for a set amount of time. The purpose is typically to get the inside of the pieces the same temperature as the outsides of the pieces. Other benefits to soaking include smoothing out of glazed surfaces, getting rid of pin holes, or craters in the glazed surface. During the bisque firing people often hold at different points to allow the clay body to outgas out more of its organic material than it would if the firing had otherwise proceeded too quickly. Holding is useful at a low temperature like 200°F (actually 150°F with thermocouple offsets that are programmed into the DynaTrol) to dry out pottery or kilnwash on shelves.

The down side to holding only happens at high temperatures, there is almost no downside to holding at low temperatures except increased firing time and slight element and thermocouple degradation from the extra firing time. At high temperatures the amount of the degradation happening to the elements and thermocouples is exponentially greater. Therefore leaving the kiln holding at a high temperature will affect the element and thermocouple life significantly.

Try soak times in the range of 5 or 10 minutes at the most. Any more and care should be exercised as the kiln may over fire. Compensating by reducing the cone's temperature in the cone offset setting, or raising the thermocouple offset can help account for a longer hold. Use witness cones that you can see through your peephole (and be sure to use dark safety glasses when doing so). If you see the cones bending (which would indicate proper heat-work achieved) then you can always turn off the control at that point manually. The Orton website has a great program available for free which helps you calculate how different temperature ramps and hold times will affect the “heat-work” and cone bending in a kiln.

FIRING LOG

We recommend keeping a firing log. Keep track of firing times, approximate load weight, firing temperatures and notes on results of the firing. There is a sample log in the LOG, CONES, TIPS & CERAMIC PROCESS section of your manual (*log.pdf*).

APPLYING KILN WASH

Kiln wash the floor of the kiln and the upper sides of the shelves only. Apply the kiln wash to the thickness of a post card. The only purpose of kiln wash is to prevent any glaze that drips from a piece from sticking to the floor or shelves. This saves both the

piece and the floor or shelves. If dripping should occur, simply remove dripping and cover the spot with new kiln wash. Kiln wash is a powder mixed with water to a light creamy consistency. L&L sells kiln wash: see the included Parts List.

For the kilnwash to really protect the kiln shelves it is best to apply three separate coats. If you brush one coat on, let it dry and then brush on another, you could actually be brushing off the first in the process, so ideally each coat should be fired on. The shelf can be used while firing the kiln wash on, so theoretically you would put one coat on, load the shelves and do your test firing of the kiln. The second coat would be fired on in the first bisque and the third coat in the second bisque or first glaze (whichever comes next). Fire at least to cone 018 - hot enough to give the kiln wash enough adherence to the shelf to prevent it from coming off in the second coating. Note that some people get away fine without three firings of the kiln wash. However, we include this recommendation as a "best practice".

Here is a program that will dry the kiln wash in a hurry:

In the Vary-Fire section:

Press **Enter Prog**, Press '**1**'

Press **Enter**, Press '**1**'

Press **Enter**, Press '**60**'

Press **Enter**, Press '**200**'

Press **Enter**, Press '**600**' (for 6 hours, 400 for 4 hours, 800 for 8 hours etc of hold time at 200 degrees)

Press **Enter**, Press **9999**

Press **Enter**, Press **START**

WHAT HAPPENS WHEN YOU BISQUE AND GLAZE IN YOUR KILN

When you fire a kiln you chemically and physically alter clay and glaze compounds in a way that, to some degree, can be anticipated and accounted for. There is quite a bit more going on during firing than meets the eye. It is useful to divide up the processing cycle into separate distinct stages or segments. The stages that clay and glaze go through in a typical firing can be divided as follows:

COMPLETE DRYING

Even after you room-dry your work there will be some moisture left in the seemingly dry ware. Your ware will pick up moisture from the air, even if it is left for weeks on a warm, dry shelf. Bisque ware can also absorb moisture during glazing, and the newly applied glaze is really a very fine-grained clay coating at this point; it will retain the water it was mixed with and the water in the air until it is completely dry.

When you put this piece in the kiln it will first go through a complete drying stage. This is where any water that was in your ware evaporates and expands to 1170 times its original volume. This moisture must escape from your ware before the kiln temperature gets to 212°F. It is important that the kiln temperature climb very slowly at first, and the lid can be propped 1" with several soft pieces of firebrick or ceramic posts and the peepholes opened if there is no forced venting system. (CAUTION: Keep in mind that propping open a lid in this way can cause the lid to crack if you are not careful and that is not covered in our warranty). If you have a lot of moisture in your work you may want to prop open the lid for the first hour of preheat even if you have an automatic vent system. The amount of drying needed depends on factors such as how much mass is in the kiln and how wet the ware is. Factors that lead to a longer drying time include fine-grained clay and thick-walled ware. Be sure to use the Preheat feature in the DynaTrol which automatically sets the kiln temperature at 200°F (actually 150°F with thermocouple offsets). Preheating overnight is recommended. It is best to be conservative to prevent the ware from exploding in the kiln. After a while you will get a feel for how long is necessary. Remember to carefully vacuum out your kiln if you do get an explosion from a piece that is not fully dried.

THE "CERAMIC CHANGE"

This happens to each crystal and mineral particle in the clay body. Even though water between the crystals and minerals has already evaporated (hopefully during the slow preheat time), there is still water in these crystals and minerals that is venting off. This can occur all the way until the kiln reaches red heat. Slow firing is not as critical as there are pathways for the steam to travel through where the water molecules

between the particles used to be. Venting, however, is critical to remove the water vapor.

QUARTZ INVERSION

This is a generic name for the twenty-odd changes quartz goes through as the temperature increases and the molecules/ particles/ atoms become increasingly mobile. Most phases that a particle of quartz goes through as the kiln is heating will reverse itself during cooling. One of the largest and quickest changes the quartz goes through is roughly at 1060°F with about a 2% increase in the size of the particles during heating. The process is reversed during cooling. Also, during cooling another 2% contraction takes place at about 439°F. This is caused by the formation of 'crystobalite' in some clay bodies. There is a lot of other material in your clay besides quartz, so it is not always that important to account for the quartz while the kiln is heating up. The structure of unfired clay is full of pores and non-glass bound particles, so it can withstand the expansion of a few of its quartz particles. Once the clay is fired, though, the particles become part of a solid mass of glass. This mass is extremely intolerant of the expanding quartz particles. This is especially true in the glaze firing (even more so if the bisque was even slightly under-fired). In under-fired ware the quartz never has a chance to react with the fluxes and remains intact during a second firing, ready to expand and contract as your kiln heats and cools. This is one cause of dunting (fine cooling cracks). The glass mass simply has no room for the expanding quartz crystals.

BURNOUT

This is the burning off of any trapped organic matter in the clay. Burnout generally takes place at and above red heat. Sufficient airflow and time are necessary to burn off all the organic matter. If a bisque piece is under-fired, or fired too quickly any unburned organic matter will bubble up through the glaze during the second firing. Even if the bisque is properly fired, there will still be some organic matter in the clay that will burn out once you pass the bisque's firing temperature. A glaze that fluxes too early will block off the exits for the gasses in the clay body and cause bloating or pitting.

SINTERING

This is the point at which powdered clay particles will begin to form chemical bonds with each other. Although the clay is not melting yet, it is forming a lump from the powdered clay. The point at which this begins to happen is called the 'sintering point'. This, like burnout, happens right around red heat.

DECOMPOSITION

This is where fluxes really start to react and clay and glaze ingredients are deconstructed into their basic building blocks. This process can give off gasses such as sulfur and carbon dioxide which must travel out of the clay body. Once the firing is finished and the kiln cools, reconstruction takes place and the glaze and clay body recompose into a glass.

VITRIFICATION

This is a process that develops in the clay body during firing. At one point a piece of clay might be under-fired and at a higher point it may have good strength, but not good color; at another point it may be perfect and at another, even hotter point, the piece may warp, or melt. What is important to understand is that as the firing progresses, more and more activity is taking place on a molecular level. This is good only to a certain point, after which you are left with a warped blob, or a puddle. You want to achieve the 'glassification' of the clay. This occurs right before the clay body begins to slump. At this point the molecular bond between fluxes, quartz, silica and other materials makes the 'glass'. However, it is the formation of the long mullite crystals (which only occurs above 2000°F) from the decomposing clay crystals that gives the ware its strength.

GLAZE SET, COOL & FREEZE

Unlike the clay body, the glaze melts completely, and the bond between it and the clay becomes more complete as the temperature rises; eventually, the glaze starts to run. Things like fluidity and surface tension are determined first by the chemistry of the glaze, then by the layer formed by the heightened interaction between the glaze and clay molecules. When the ingredients of the clay and glaze have been properly matched to each other, the nature of the molten layer between the two is such that when the

kiln is at the maximum temperature in the firing, things like pinholes and bubbles can rise through this layer and out to the surface from the clay body within, and not remain trapped in the surface when the glaze sets and begins to cool. Once the maximum temperature is reached and the kiln begins to cool, the glaze and clay body will follow. The glaze will not solidify until some time after the kiln begins to cool. When this happens depends on the rate of cooling and the chemistry of the glaze. Right before the glaze solidifies, however, crystals can form. Depending on its chemistry, the glaze can solidify quickly and form crystals. Or, with some glazes, crystal formation can take place throughout the initial cooling until the glaze finally solidifies several hundred degrees lower than the highest temperature. By adjusting the glaze recipe slightly one can maximize or minimize the forming of crystals in the glaze during cooling. Once the glaze solidifies it is still important for the kiln to cool slowly. Crazing (fine cracking) can occur if cooling is too rapid. Heat shock, which is usually catastrophic, is something that can happen in the kiln or a few days after; it also may occur gradually over time.

In truth, simply test-firing the kiln and the ware to be fired is usually enough to deal with the complexity of the process. Every kiln and kiln-load fires differently, and a new kiln is no exception. The use of a vent system is recommended simply because it will exhaust any detrimental particles and fumes from the kiln, circulate air in the kiln and provide an oxygen-rich atmosphere.

FOR MORE INFORMATION ABOUT FIRING CERAMICS

CERAMIC BOOKS

n addition L&L has available a book called Electric Kiln Ceramics written by Richard Zakin, a book called What Every Potter Should Know by Jeff Zamek and Mastering Cone 6 Glazes by Ron Roy and John Hesselberth. These are described in the ACCESSORIES section (*books.pdf*).

MAGAZINES

The magazines Ceramics Monthly (*ceramicsmonthly.org)* and Clay Times (*claytimes.com*) have many good articals and resources.

WEB RESOURCES

Also check out the great web resource, the Clayart discussion group at *potters.org.* Check the links page on our web site.

ORTON TIPS

We include many firing tip brochures from Orton. For a more in depth explanation Orton has a great booklet called Successful Firing Practices. They also have a number of other booklets available such as Cones and Firing (20 pages), Using Orton Cones/Temperature Charts, Kiln Safety Booklet, Kiln-Sitter Maintenance & Repair and Porcelain Firing Guide. Contact Orton at 614-895-2663 for more information. See *ortonceramics.com* for lots of very helpful information on how to use cones and for many firing tips and great information on firing kilns. They have a great program available for free which helps you calculate how different temperature ramps and hold times will affect the “heat-work” and cone bending in a kiln.