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# ELECTRIC KILN

# OPERATING INSTRUCTION MANUAL

# AND FIRING NOTES

# Contents

# Kiln Shelf Basics

Kiln shelves are important, and expensive, pieces of pottery equipment. They need to be the correct type for your firing needs. They also need to handled, stored, and used in ways that will extend their working life. Kiln shelf failure during a firing can be catastrophic for all ware in the kiln, and can damage the kiln itself, as well.

**Types of Kiln Shelves**

Kiln shelves are made from highly refractory materials.

- High-alumina shelves: Dry-pressed high-alumina shelves are tougher and last longer than slip-cast high-alumina shelves. Generally speaking, high-alumina shelves are best used in electric kilns. They especially should not be used for raku, salt, or wood firings.
- Silicon carbide shelves: Silicon carbide is a conductor; I strongly recommend they *never* be used in electric kilns. If silicon carbide shelves are used in an electric kiln, the kiln should be disconnected to all power before the shelves are placed or removed.

**Kiln Shelf Storage**

*Photo © 2008 Beth E Peterson*

Like glass sheets, all kiln shelves do best if stored on their edges. Flat storage makes it more likely that they will break or develop stress cracks. Infinitesimal cracking in the shelf during storage may result in catastrophic failure of the shelf during firing.

If you don't already have one, build a kiln shelf rack in which you can safely store your shelves. All they really need is a sturdily-built box or railed enclosure where they can rest on their edges without danger of being knocked over. I also like to line the bottom of my rack with packing foam sheets or other cushioning material.

Make sure that all kiln shelves remain dry at all times. If they do get wet, heat them slowly up to 300° F and soak four to eight hours.

**Kiln Shelf Usage**

Kiln shelves should be set using a three-post method. Using three posts instead of four or more gives the most stable set and reduces the possibility of the shelf moving during the firing.

**Kiln Wash Your Shelves**

Kiln wash protects your kiln shelves during glaze firing. *Note: even unglazed pots can stick to the kiln shelf if the clay body vitrifies enough.* Always either kiln wash the shelves themselves, or set your pottery on kiln washed, bisqued setting slabs or shallow dishes.

If you wish to flip your shelves, do not use commercially available kiln washes. They will bond to the shelves and make using both sides problematic. (Kiln wash can flake off during firing and land on glazed pottery below it, as well as potentially bonding the shelf to the kiln post it is resting on.)

For optimum shelf life, kiln shelves should also be flipped over after each firing; the top surface should become the bottom surface for the next firing. Along with this, posts should be placed so that they connect with the kiln shelf in the same area (albeit on the opposite side).

Both the rotation and the consistent post placement will ease stresses and warpage caused within the shelves' structure and lengthen the life of the shelf.

No matter what kind of kiln you are loading, you do not want to load ware directly on the kiln's floor. Doing so can damage the floor, especially in glaze firings, and can seriously disrupt the proper heating of the kiln by restricting air flow. Check the kiln's floor for cracks, debris, glaze drips, or other problems. If the floor is solid, make sure that it has a good coating of kiln wash. Do not kiln wash floors with electrical elements embedded in them. If the floor has a vent system port or burner port, make certain no kiln wash gets into those areas.

Begin the stack by setting posts for a bottom layer of shelving. You can use one-inch posts if the kiln does not have heat coming from below it. If your kiln does have a floor element, ventilation port, or floor-burner, I suggest using two-inch posts.

Before loading the kiln, make certain that all shelves are clean and free of cracks. Especially for glaze and test firings, also make sure they have been well kiln washed. Read Kiln Shelf Basics for more about these essential pieces of kiln equipment.

## Stack (or Load) the Kiln

Although we load pottery into the kiln, potters often refer to stacking the kiln. This is because of the importance of keeping all weight distributed straight downward. Unsupported clay that has any pressure on it is highly likely to crack.

**Weight Distribution in the Kiln Load**

Stacking to keep weight supported in straight downward lines is also extremely important as you load the kiln furniture. Look at the posts on the left side of the photograph. See how they are perfectly aligned with each other? This completely straight vertical arrangement reduces the stress on the kiln shelves. Each shelf's weight is supported by the posts, which in turn is directly supported by the posts below them.

Take this weight distribution into account. It is absolutely essential if you are stacking ware without kiln shelves, as can be done in bisque kilns or with unglazed ware. As you can see in the photo, there are two bowls nested inside of each other for this bisque stack. Note, however, that one bowl is slightly tilted. If left this way, the lower bowl may crack due to the weight that is resting on its wall, rather than being directly supported by its foot.

**Tight Stacks Are Better**

For both bisque and glaze firings, pack the kiln as tightly as possible, given the circumstances. Full kilns heat more efficiently then loosely stacked kilns do.

As you may surmise, you can stack pottery to be bisqued very tightly. As long as there is no unsupported weight resting on the clay, pot walls can be as close as an eighth of an inch between them. This is only true of pottery that is being bisqued or fired unglazed. Pots that has been glazed need to have at least a quarter of an inch of space around them so as to avoid pots becoming welded to each other when the glaze melts. Remember, pottery expands in the kiln as it heats.

As much as possible, you should also stack the kiln so there is not over-much empty space above the top of each layer of pots and the bottom of the next shelf, and between the top of the last layer and the ceiling (or lid, for a top-loader). In practical terms, this is much easier to accomplish if you deliberately load each shelf layer with pots that are roughly the same height. The pots in the lowest level in the photograph show this clearly.

Do remember that you need to take expansion into account. The top of the tallest pot does need to be at least a quarter of an inch head room between its rim and the bottom of the shelf above it.

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## An Overview of the Firing Process

It is important to have an overview of the firing process. Firing clay transforms it from its humble, soft beginnings into a new substance, ceramic. Ceramics are tough, strong, and very similar in some ways to stone. Pieces of pottery have survived for thousands of years, all due to clay that met fire.

**What Is Firing?**

Firing is the process of bringing clay and glazes up to a high temperature. The final aim is to heat the object to the point that the clay and glazes are "mature" – that is, that they have reached their optimal level of melting. (Pots and other clay objects won't look melted; their melting is on the molecular level.)

This final aim, however, is usually done in two steps.

**Bisque Firing**

Bisque firing the first time the pots go through high temperature heating. It is done in order to vitrify the clay pots enough that they won't be harmed when glazes are applied, but not vitrified to such an extent that the glaze won't adhere correctly.

The bone-dry greenware is very fragile and must be loaded into the kiln with a great deal of care. The kiln is closed and heating is slowly begun.

A very slow temperature rise is critical. During the beginning of the bisque firing, the last of the atmospheric water is driven out of the clay. If heated too quickly, the water will turn into steam while inside the clay body, causing the clay to burst.

### Clay Transformation in the Bisque Firing

When a kiln reaches about 660°F (350°C), the chemically bonded water will begin to be driven off. By the time the clay reaches 930°F (500°C), it will have become completely dehydrated. At this point the clay is changed forever; it is now a ceramic material.

The bisque firing continues until the kiln reaches about 1730°F (945°C). At this temperature, the pot has sintered, making it less fragile while still porous enough to accept the application of glazes.

Once the desired temperature has been reached, the kiln is turned off. The cooling is also slow, to avoid the pots breaking due to stress from the temperature changes. After the kiln is completely cool, it is opened and the newly created bisqueware removed.

# How to Bisque Fire Pottery

The purpose of bisquing is to change the clay into ceramic material, without fully fusing it. Most pottery goes through a bisque firing before it is glazed and then fired again to melt the glaze and fuse it to the clay body. Bisque firing pottery is important. This allows the potter to do much more decorative work with stains, underglazes and glazes with a greatly reduced risk of the pot being damaged. Because the bisque firing is brought to temperature much more slowly, bisquing also reduces the chances of pots cracking or exploding in the glaze firing.

**What Kind of Kiln Do You Bisque In?**

Although you can bisque fire in either electric or fuel-burning kilns, electric is preferred. The main reason for this is that an electric kiln is much easier to control at the very low, preheating settings. Fuel-fired kilns, such as those using natural gas or propane, tend to rise in temperature much faster due to the amount of fuel that must come through the fuel nozzle in order for the burner to remain lit.

**What Temperature Should a Bisque Firing Go To?**

Generally, bisque firing is done between cone 08 and cone 04, no matter what the maturation temperature of the clay and of the glazes that will be used later.

By cone 08, the ware is sintered and has become a ceramic material. At the same time, the clay body still is quite porous and absorbent enough for easy glazing. It does remain more fragile, however, and extra care will need to be taken when handling this bisqueware.

Bisque firing can be done up to cone 04. While this makes the bisqued pots a bit less fragile, it can increase glazing time and may adversely effect glaze adhesion, as the pot's fabric has tightened and become less porous and absorbent. The higher the temperature, the less porous the ware becomes.

**Glaze Firing**

Once glazes have been applied to the bisqueware and have had a chance to dry, the ware is carefully loaded into the kiln for the glaze firing. Pots cannot be allowed to touch at all, or the glazes will melt together, welding the pots together.

The kiln is heated slowly to the proper temperature to bring the clay and glazes to maturity, and then slowly cooled again. Only after the kiln has cooled will it be opened and unloaded.

# Heat Work

When firing pottery and ceramic objects, we tend to think in terms of temperature. That is only one factor, however, involved in maturing a clay body and glazes. Heat work is the real objective...the transfer of heat from the kiln's interior atmosphere to the pottery within it.

**Limitations of Temperature Alone**
Did you know that as a glaze melts, its temperature will not go above its melting temperature until all the solid particles have become liquefied? No matter how much hotter the kiln's atmosphere gets, until all the particles have melted, the glaze itself cannot go any higher than that melting point.

This means that the difference between atmosphere temperature and the pot's temperature really only effects how quickly the glaze particles melt. As you can see, raw temperature (of the kiln's atmosphere) is not the best way to judge whether a load is done or not. Temperature is a huge factor, but not the only one.

**Time**
In some firing schedules, the ramp is slow enough that a separate soak is not needed. As we have seen, however, a kiln's interior may reach the desired temperature before the pottery does. Because of this, many potters add a soak period to the end of their firing schedules. This period of maintaining temperature allows the glazes to fully melt and mature.

Clay bodies have a wider maturation range. Because of this, a soaking period is not as important for a clay body to mature, but in some cases it can have an effect. Generally, this is seen when a clay body is soaked at the upper range of its maturation range. Such an occurrence may cause the clay to blister, warp, and slump.

**Kiln Atmosphere**
Kiln atmosphere can have a strong effect on how quickly glazes and clay bodies mature, especially those containing iron. As the oxygen-deprived air pulls oxygen from the clay and glazes, the metal oxides are converted as they lose oxygen atoms. This makes many of them into stronger fluxes.
On the converse, reduction is an inefficient firing method, as far as temperature is concerned. It does not burn the fuel completely, and heavy reduction cycles can actually decrease the interior temperature of a kiln considerably.

# Temperature Ranges for Firing Glazes

Ceramic glazes each have a temperature range that they should be fired to. If the glazes are fired at too low a temperature, the glaze will not mature. If the temperature goes too high, the glaze will become too melted and run off the surface of the pottery. For success, a potter must know their glazes' temperature ranges at which they become mature.

When potters talk about ceramic firing ranges, they are usually referring to the three most common: low-fire, mid-range, and high-fire ranges. In regards to glazes, we need to add two other ranges: very low-fire, and lower mid-range firing ranges.

**Very Low-Fire**

- from cone 022 (approx. 1112'F - 605'C)
- to cone 013 (approx. 1566'F - 850'C)

This range is usually used for luster glazes and very low-firing overglazes. Ware must be fired at least once at a higher temperature first, in order for the clay body to mature. The ware will often not only go through a bisque firing, but also a higher temperature glaze firing. Very low-fired overglazes and lusters are then applied to the already fired primary glaze. The ware is returned to the kiln for a very low temperature firing in order to fuse the overglazes.

**Low-Fire**

- from cone 012 (approx. 1623'F - 882'C)
- to cone 02 (approx. 2048'F - 1120'C)

The low-fire range has historically been the most commonly used firing range. In the past this was mainly due to limitations in kiln technology. However, low-fire temperatures allow potters to use a variety of colorants that either burn off or become unstable at higher temperatures.

Low-fired ware can present some difficulties, including

- the clay body may remain overly porous
- low-fire glaze colors can appear rather harsh and raw-looking
- the high percentage of flux or stronger-acting fluxes used can result in a softer, less durable glaze, and
- many of the traditional glaze materials used in this range are quite toxic in their raw state.

**Lower Mid-Range**

- from cone 01 (approx. 2079'F - 1110'C)
- to cone 3 (approx. 2134'F - 1145'C)

The lower mid-range is one of the most overlooked, yet perhaps one of the potentially most exciting, of the temperature ranges. Within this range, most earthenware and other low-fire clay bodies actually mature to their strongest and most durable state. At the same time, many of the colorants that are available at lower temperatures are still useful within the lower mid-range temperatures.

**Mid-Range**

- from cone 4 (approx. 2167'F - 1165'C)
- to cone 7 (approx. 2264'F - 1210'C)

This range is being used more and more as potters become more concerned about energy and fuel usage. Another factor has been the availability of electric kilns that can comfortably reach this range without severely decreasing the kiln's and the kiln elements' lifespans.

Other advantages to firing in the mid-range include

- ability to adjust and use stoneware clay bodies to this range
- in turn, mid-range stoneware bodies increase the durability of the ware
- mid-range glazes are also more durable than those fired at lower temperatures, and
- there is still a fairly extensive color range available.

**High Fire**

- from cone 8 (approx. 2305'F - 1260'C)
- to cone 14 (approx. 2530'F - 1390'C)

This range includes the stonewares and porcelains. Glazes and clay bodies are dense and durable; however, the color range is limited. Because of the varying effects of oxidation and reduction on glaze colorants, the few coloring oxides that are viable at this range can still produce a rich, if much more limited, palette.

**The Firing Ramp and Firing Schedule**

The terms "firing schedule" and "firing ramp" are strongly related. Both refer to the rate at which the firing is done, including the heating, soaking period (if there is one), and cooling. For a bisque firing, there will be no soak, and the ramp (increase in temperature) should be very slow. Generally, the firing schedule should be similar to the following:

- Overnight warm up at very low heat
- Two hours at low heat (an increase in temperature of no more than 200°F per hour)
- Two hours at medium heat (an increase in temperature of no more than 300°F per hour)
- High heat (an increase in temperature of 300 to 400°F per hour) until the required temperature has been reached.

**Cool the Kiln**
After the kiln has reached temperature, make sure all heat sources are off. Close any openings and leave the kiln to cool at its own rate. Generally, expect your kiln to cool for as long as it was heating (minus the overnight warm up). As a good rule of thumb, if you fire the kiln one day, let it cool overnight and unload it the next.

When you think the kiln has cooled enough, crack open the door. If any heat comes out, place a piece of paper in the opening. If it lights, the kiln is still too hot to open. If the paper does not light, but you hear pinging sounds, the kiln is still too hot to open. In either case, close the door immediately and allow the kiln to cool for several more hours.

# How to Choose the Right Clay for You

There are so many choices of pottery clays, it can be baffling. How do you choose which clay is right for you and your needs as a potter? What do you need to know? How do you find out?

**What Type of Pottery Do You Do?**
The type of pottery you want to create has an absolutely critical impact on the clay body you choose. For example, some clay bodies are great for throwing, but would be a disaster if you wanted to create an outdoor hand built piece.

you may find that you want to use more than one clay body. When you use a variety of construction methods, that is often the best solution.

# Characteristics of Throwing Clay Bodies

Throwing on the potter's wheel makes some heavy demands on clay bodies. There are three key characteristics necessary for a clay body to work well for throwing.

Throwing clays must have a high degree of plasticity, they cannot absorb too much water while being thrown, and they must be strong enough to hold their shape while being worked.

**Plasticity**
The absolutely crucial characteristic of all clays used for throwing is that of plasticity. Without a very high level of flexibility, the clay simply won't be workable on the wheel. Even moderately plastic clays can take a toll on the potter's hands and wrists, due to the strength and pressure required to make the clay move.

Ball clays are highly plastic and are often used in throwing clay bodies. However, this is a trade off; the more plastic a clay is, the more it will shrink and the greater its tendency to warp while drying. Plasticity must be maintained in a balance with other clay body characteristics.

**Strength**
Throwing clays must be highly plastic, but also retain enough strength to stand upright when thrown into thin-walled, tall forms. To this purpose, throwing clay bodies contain some coarser particles to give it strength. Throwing clay bodies are likely to contain fire clays, fine sand, grog, or a combination of these.

When grog is used in a throwing body, it is best if it is sized to pass through a 30-mesh screen, but not through an 80-mesh screen. This "30-80" grog allows for the strength needed for throwing, without being so coarse as to be painful on the potter's hands.

In general, a throwing clay body should contain no more than 8% to 10% of coarsely particled material.

**Water Absorption**
Clay absorbs water while it is being formed on the potter's wheel, which is why the longer a clay is worked on the wheel, the softer it becomes. Water absorption, then, can become a problem.

Plastic clays that are on the stiff side when being wedged will absorb less water when they are on the wheel. Unfortunately, this also means that the clay is harder to work with and is tiring to the potter. Working with stiff clay can also hurt muscles and joints.

Plastic clays do absorb less water than coarse materials such as fire clay or grog, which open a clay body up. Again, a good throwing clay must be balanced between plasticity, strength, and water absorption.

**Effects of Aging**
Aging lends better workability to a clay body. To age clay, it is left open to the air for a day or two after mixing and before covering. This allows microscopic organisms to move into and grow within the clay.

These organisms produce organic polymers which add more plasticity to the clay with none of the drawbacks of using too much fine-particled clay to achieve the same level of plasticity. The one drawback aged clay has is that is stinks like swamp mud.

Many potters mix their clay, let it develop a colony of organisms, then store it for one to six months before using it. Clay bodies that have nepheline syenite in them, however, should never be stored more than three months, due to possible ionization of the clay particles.

**Find Your Right Throwing Clay**
Finding the right clay for you is very important. Some clays are basically unthrowable, even by the best potters. It is a real tragedy when a person underestimates their own skills simply because they are working with unsuitable clay.

Within the above framework of what makes a clay body good for throwing, it is up to you to decide what temperature range and what coloration you are looking for in your perfect throwing clay body.

# Characteristics of Hand Building Clays

Hand building with clay is fun. Good hand building clays make the experience even better. What are the characteristics of a good hand building clay body?

The primary requirement of a hand building clay body is strength, with plasticity running a close second. Happily for us, and unlike a throwing clay body, water absorption is not an issue.

**Strength**
Because many hand built forms need a high degree of strength in the green stage, hand building clay bodies often have 20% to 30% grog or other non-plastic filler. The grog can either be fine or coarse, depending on the surface qualities the potter wants. Such high additions of grog also results in an open clay body. This means the clay will dry quicker and with a reduction in the possibility of cracking.

**Plasticity**
A hand building clay still needs to be plastic enough to be workable. The more extreme the shapes being built or being used in the building, the more plasticity the clay will need. For example, it takes a high degree of plasticity in the clay body in order to roll out long, thin coils that do not have any cracks.

**Weight**
Hand built forms can be vary large. When that is the case, it is a good idea to decrease the weight a finished product will have. This is accomplished by mixing combustible substances into the clay. Some materials that have been used successfully by a number of potters are sawdust, coffee grounds, ground nut shells, and ground fruit pits.

Organic additions generally burn out of the clay body without any difficulty if a normal firing schedule is followed. Perlite (pearlite) is also sometimes used to reduce weight. For perlite and the organic fillers, as well as grog, it is best to add them when the clay body is being mixed.

**Finding the Right Hand Building Clay for You**
The right hand building clay for you will depend on your artistic needs as well as the technical requirements. Using the above as overall guidelines, you will also want to determine what temperature range you wish to work in, what surface(s) you want in your finished pieces, and what color you want the fired clay to be.

# Why Clay Bodies Shrink

All clays shrink. But not all clays are created equal. Different clay bodies experience different amounts of shrinkage. It depends upon the clay's particle size and on how many and what type of impurities are present in the clay body.

**Shrinking From Wet to Bone Dry**
When a clay is wet and very pliable, it contains a great deal of water. The clay particles ride within the water, which is what makes clay plastic, or easily workable. As the clay drys the water evaporates, escaping from those spaces in between particles. The particles move closer together, resulting in the entire pot shrinking.

How much the clay shrinks depends on the characteristics of the clay. Highly plastic wet clays have a very fine particle size and will shrink more. On the other hand, clays with large particles will shrink less. Also, clay bodies that include non-plastic additives, such as grog or sand, will shrink less.

Shrinkage due to drying is generally between 4% and 10%.

**Shrinkage Due to Vitrification**
When clay is fired at a high enough temperature, it begins to gradually vitrify. This process of melting and fusing also compacts the clay body. The clay shrinks as the particle sizes slowly decrease as they fuse. In addition, the particles also compress into a tighter, more dense configuration within the glassy material that fills up all the nooks and crannies.

The amount of shrinkage due to vitrification is very dependent on which type of clay is involved. Refractory clay bodies may have a very low degree of shrinkage at this stage, while highly vitreous clay bodies such as a high-fire porcelain may shrink up to 8%.

# How Temperature Changes Clay

**First Stage: Atmospheric Drying**

| Temperature (approx.) | | Cone | What's Happening |
|---|---|---|---|
| °F | °C | | |
| 212 | 100 | | Any remaining atmospheric water converts to steam. |
| 420 | 220 | | When cooling, cristobalite suddenly shrinks. |
| 572 - 1470 | 300 - 800 | | Burn-off of carbon, sulfur and organics. |
| 660-1470 | 350 - 800 | | Chemically combined water driven off. |
| 1060 | 573 | | Quartz inversion occurs. |
| 1650 | 900 | 011 | Sintering begins to occur. |
| 1730 | 945 | 08 | Common bisque temperature. |
| 1850-2135 | 1005-1145 | 06 - 3 | Earthenware vitrification range. |
| 2160-2290 | 1165-1210 | 4 - 7 | Mid-range vitrification range. |
| 2315-2535 | 1225-1390 | 8 - 14 | High-fire vitrification range. |

When pottery is placed into the kiln, it is almost always bone dry. However, there is still water trapped within the spaces between the clay particles.

As the clay is slowly heated, this water evaporates out from the clay. If the clay is heated too quickly, the water will turn to steam right inside the clay body, expanding with explosive effect on the pot.

By the time the boiling point of water (212'F and 100'C at sea level) is reached, the atmospheric water should have all evaporated out of the clay body. This will result in the clay compacting and some minimal shrinkage.

**Second Stage: Burn Off of Carbon and Sulfur**
Clay bodies all contain some measure of carbon, organic materials, and sulfur. These all to burn off between 572' and 1470'F (300' and 800'C). If for some reason (such as poor ventilation within the kiln) these are not able to burn out of the clay body, carbon coring will occur, weakening the clay body considerably.

**Third Stage: Chemically Combined Water Driven Off**
Clay can be characterized as being a molecule of alumina and two molecules of silica bonded with two molecules of water. Even after the atmospheric water is gone, the clay still contains some 14% of chemically bonded water by weight. The pot will be substantially lighter, but with no physical shrinkage.
This chemically combined water's bond loosens when heated. Overlapping the carbon and sulfur burn off, the chemically bonded water escapes from the clay body between 660' and 1470'F (350' and 800'C). If the water heats too quickly, it again can cause the explosive production of steam inside the clay body. It is for all these changes and more that the firing schedule must allow for a slow build up of heat.

**Fourth Stage: Quartz Inversion Occurs**
Potters call it silica, but silica oxide is also known as quartz. Quartz has a crystalline structure that changes at specific temperatures. These changes are known as inversions. One such inversion occurs at 1060'F (573'C).

The change in crystalline structure will actually cause the pottery to increase in size by 2% while heating, and loose this 2% as it cools. Ware is fragile during this quartz inversion and the kiln temperature must be raised (and later cooled) slowly through the change.

**Fifth Stage: Sintering**
Before the glass-making oxides begin to melt, the clay particles will already stick to each other. Beginning at about 1650'F (900'C) the clay particles begin to fuse. This cementing process is called sintering. After the pottery has sintered, it is not longer truly clay but has become a ceramic material.

Bisque firing usually is done at about 1730'F (945'C), after the ware has sintered but is still porous and not yet vitrified. This allows wet, raw glazes to adhere to the pottery without it disintegrating.

**Sixth Stage: Vitrification and Maturity**
The maturation of a clay body is a balance between the vitrification of the body to bring about hardness and durability, and so much vitrification that the ware begins to deform, slump, or even puddle on the kiln shelf.

Vitrification is a gradual process during which the materials that melt most easily do so, dissolving and filling in the spaces between the more refractory particles. The melted materials promote further melting, as well as compacting and strengthening the clay body.

It is also during this stage that mullite (aluminum silicate) is formed. These are long, needle-like crystals which acts as binders, knitting and strengthening the clay body even further.

**Maturation Temperatures**
The temperature a clay is fired to makes a tremendous difference. A clay fired at one temperature may be soft and porous, while that same clay fired at a higher temperature may be hard and impervious.

It is also imperative to note that different clays mature at different temperatures, depending on their composition. A red earthenware contains a large amount of iron which acts as a flux. An earthenware clay body can fire to maturity at about 1830'F (1000'C) and can melt at 2280'F (1250'C). On the other hand, a porcelain body made of pure kaolin might not mature until about 2500'F (1390'C) and not melt until over 3270'F (1800'C).

# Carbon Coring

Carbon coring (noun) is a clay body defect produced by an overly quick bisque firing or the introduction of a reduction kiln atmosphere too early into a firing. The defect occurs because carbon and sulfur are not able to escape from the clay body and become trapped instead.

Carbon coring will often discolor the clay body and glaze; it may also result in bloating (raised pockets of gas) in the fired clay body.

In part because of the probability of carbon coring, the temperature in a kiln should be raised slowly, especially at the beginning of a firing.

**During Cooling**
There is another event that clay goes through, this time as it cools. That is the sudden shrinkage of cristobalite, a crystalline form of silica, as it cools past 420'F (220'C). Cristobalite is found in all clay bodies, so care must be taken to cool the kiln slowly as it moves through this critical temperature. Otherwise, pots will develop cracks.