



FOURTH EDITION

ELECTRIC KILN

A GUIDE TO CLAYS, GLAZES, AND ELECTRIC KILNS

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RICHARD ZAKIN and FREDERICK BARTOLOVIC



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3.3 Firing the Kiln

Ceramists will always have specific preferences when it comes to how to fire their work. That is for good reason, as all ceramists work is at least slightly, if not greatly differently from one another. Nevertheless some basic firing schedules can be set down as a starting point and then you can make adjustments based on firing temperature, clay body, glaze, decorative techniques, and other variables. It is true there are many ways to fire a kiln, If you have a digital/computerized kiln, you may simply want to start by using the preset programs already loaded into the control box. This is easy and very straight forward. If you seek a bit more control though, or have a manual kiln, you can begin with the programs outlined in this section and then adjust according to your results.



Kari Radasch, *Dinner and Sandwich Plates*, to 10 inches and 8 inches in diameter, terra cotta, glaze, cone 03, 2013. Radasch states, "I fire all of my glaze work in electric kilns with visual cones and have no doubt that the most consistent method of firing is to use them. I am always present when my kiln is scheduled to shut off. Not only is this a safety measure but I want to make sure that the work is fired to the correct temperature. Just like a gas kiln an electric kiln can be hot or cold in different spots depending on the shape and density of the stack. Firing with a visual cone insures that no matter where or what you fire, your results will be as true as possible." *Photo by artist*

Bisque Firing

Contemporary ceramists almost always fire their work in a first and a second firing: the first firing, the bisque firing, is essentially a preparation for the glaze application. While you don't have to bisque fire, most contemporary ceramists do because it makes life much easier. Greenware is much more difficult to glaze; the raw clay of an unfired piece breaks down in water and glazes are suspended in a water medium. Bisque-fired pieces are permanently dehydrated and will not crack or break if immersed in a watery glaze. Furthermore, bisqueware is a stable ground for glazes because it has a very consistent absorbency rate. Most contemporary ceramists fire the bisque kiln to cone 08 or 06. They then apply surface finishes and finish fire the piece.

There are circumstances when contemporary ceramists fire to higher temperatures for the bisque than for the final firing. One of these is particularly important to ceramists who fire their work to low-fire temperatures in the electric kiln. Ceramists who work with very low-temperature glazes, such as cone 06 or 08, will often fire to a cone 04 or even a cone 02 bisque. The body is still absorbent at this point but is more durable than it would be if it were fired only to the maturation point of the glazes.

Preparing the Bisque Firing

Before you begin the bisque firing you must make sure that the ware is bone dry dry to avoid cracking and shattering. Make sure as well, that enclosed forms have a pinhole for heated air and steam to escape. While loading the ware, place it at least 1 inch away from the coils. Ware in the bisque firing may touch or even be stacked on top of each other. If stacking; place similar clay bodies together and heavier pieces directly on the bottom working up to lighter pieces to avoid breakage.

Preheating or Candling

Preheating or candling is often done for bisque firings as it is common for greenware being loaded into the the kiln to have a small amount of moisture left in it. The preheat adds a level of insurance that the work in the bisque kiln will not explode when the kiln reaches 212°F/100°C (which is the boiling point of water). To tell if greenware still has moisture in it hold the back of your hand up to it, or hold the greenware piece up to your cheek. If the piece feels cool then that is a sure sign the piece still has water in it. If any of the work loaded into a bisque kiln feels this way then you definitely want to preheat the kiln to steam off any of that residual moisture. Conversely, If the work is absolutely bone dry then a preheat is not needed, though because it is difficult to tell moisture content in greenware, many ceramist will still do a short preheat.

The amount of time for a preheat is usually based on the kind of work inside the kiln. Thinner walled pottery pieces may require a 1–2 hour preheat, while thicker sculptural forms may need 3–4 hours. Densely loaded kilns will require more time than lightly loaded ones.

Note: If you can visually see a piece is still wet as it has a darker hue to it (or is still malleable) then you should let the piece dry further and load and fire it later. Try and avoid extremely long preheats to dry wet work out as it both uses electricity, and in computerized kilns will wear the relays out in the kiln prematurely. If the piece requires more than 4–6 hours of preheating, a good rule of thumb is to wait an additional day for the work to dry on its own.

Preheating a glaze firing can also be useful. Immediately after glazing or finishing forms the bisque ware will often have moisture left in it from the glazing process. Many ceramist make sure their work sits overnight to dry before loading just glazed work into the kiln. Preheating is another way to make sure residual water is driven off without affecting unfired glazes on the forms.



Kip O'Krongly, *Tiered Cake Stand*, 20 inches tall, hand-built low-fire earthenware, slips, underglaze, terra sigillata, sgraffito, and latex resist decoration, single fired to cone 04, 2014. O'Krongly once fires many of her pieces. For her, eliminating the bisque firing allows for a faster turn around time and less consumed energy for firings. Although once firing is not common practice for studio ceramists there are a number of sculptors and potters who prefer this firing method for a variety of reasons. O'Krongly in particular is actively engaged in critically examining various socio-political issues as with this tiered cake stand. This piece plays with scale as a way to explore the quantities of different meats, grains, and seeds we consume. *Photo by artist*

Manual Kiln Preheat

1. With the kiln loaded prop the lid/door of the kiln open 1 inch.
2. Keep all peepholes open and free of plugs so the kiln can breathe.
3. Turn the bottom dial on to the lowest possible setting. After an hour you should be able to feel the heat coming off the kiln by quickly running your hand by the opening of the lid. If it still feels cool, turn the next section of the kiln to the lowest setting for an additional hour.
4. Once you feel a low heat coming from around the kiln opening leave the kiln on this setting for the desired amount of time.
5. Check that the ware in the kiln has dried out by holding a mirror or small piece of transparent glass just over the propped lid or door. It will fog up immediately if moisture is still being driven off the ware.
6. Once the ware is dry, close the lid and plug all but the last peephole before commencing with the rest of your firing.

Digital Interface Kiln Preheat

7. With the kiln loaded prop the lid/door of the kiln open 1 inch.
8. Keep all peepholes open and free of plugs so the kiln can breathe.
9. Some digital interfaces have a separate button specifically for preheating, though others have the preheat programs contained within the main firing program. Though accessing the preheat setting may be somewhat different depending on your particular digital interface, the preheats all work the same way. The heating elements are turned on intermittently to bring the temperature of the kiln up to somewhere between 180–200°F. It then holds at this temperature. Set the preheat on your digital interface at the desired time while programming the entirety of the firing.
10. Most digital interfaces have a timer that counts down to the end of the preheat. Once the preheat has reached its conclusion, close the lid and plug all but the last peephole before commencing with the rest of your firing.

Manual Bisque Firing Cone 06 (1823°F/ 995°C)

Manual bisque firings can be accomplished in two days. The firing time with a preheat, plus the cooling cycle makes the total length 24–36 hours from start to finish. This would include a conservative 12–14 hour firing and about the same amount of time for cooling. If care is taken to ensure that the work is completely dry a preheat would not be needed. Preheating in a manual kiln can be done quite easily by beginning your preheat the night before the firing, running the kiln overnight on a very low setting.

- 0:00 Start: Turn the bottom most section of the kiln on low for an hour. If you preheated the kiln prior to starting the firing simply close the lid and plug the peep holes except the top one at this point.
- 1:00 Turn the middle section of the kiln to the lowest heat setting.
- 2:00 Turn the top section of the kiln to the lowest heat setting.
- 5:00–6:00 hours after start: Turn all sections of the kiln to a medium heat setting.
- 9:00–10:00 Turn all sections of the kiln to a high heat setting. Begin checking cones inside the kiln every 20–30 minutes.
- 12:00–14:00 Kiln firing should be complete.
- 24:00 Open the lid/door the rest of the way and unload when completely cool.

Notes on this firing: *This is a very conservative firing program which should successfully fire even the largest and thickest walled pieces of work. It is based on a 9 cubic ft barrel kiln. Be aware, kiln size affects heating and cooling times, smaller kilns heat and cool much faster than larger ones because there is usually less insulating brick and overall thermal mass in a smaller kiln.*

Computer Controlled Bisque Firing Program, Cone 06 (1823°F/ 995°C)

Most computer controlled kilns operate in a similar manner, regardless of the manufacturer. They require you to input values into the kiln for different segments of the firing. As the programmer, you get to choose how many segments your firing will have. For an average bisque firing, 5 segments should be enough to safely get through all the stages of the firing to bisque temperature.

- Segment 1: 80°F per hour to 250°F
- Segment 2: 250°F per hour to 1000°F
- Segment 3: 150°F per hour to 1300°F
- Segment 4: 180°F per hour to 1685°F
- Segment 5: 80°F per hour to 1823°F

Notes on this firing: This is a typical program which can be used as a starting point. Adjust accordingly; longer for thicker walled sculptural work, shorter for thinner pottery forms.

Finish Firing or Glaze Firing

The glaze firing carries with it an air of finality. This is one of the most dramatic parts of the ceramics process because you place the ware in the kiln in its unfinished state and when you remove it from the kiln a few days later you see its shiny or satin glaze surfaces and its color and texture for the first time. It is here that the character of the finished piece is defined. If you are firing manually, the final firing requires your concentration and attention to make sure that the work is not allowed to heat or cool too quickly and the kiln is not underfired or overfired.

Preparing for the Glaze Fire

Before you begin the final firing make sure the glazes are dry. Wet or moist glazes will often flake or crawl if heated too quickly. If the glazes are still wet incorporate a preheat into your firing program. While loading the ware, place it at least 1 inch away from the heating coils. Glazed ware may not touch and cannot be stacked.

Manual Glaze Firing Cone 04–10

Manual glaze firings can usually be accomplished in about the same amount of time as a bisque firing. Turn-ups for the glaze firing can progress at a slightly quicker pace (it is difficult to thermal shock bisque ware), but cooling must be slow! If the ware loaded into the kiln dried out after glazing a preheat shouldn't be needed.

- 0:00 Start: Close the lid or door. Plug all but the top peep hole. Turn all sections of the kiln on low.
- 2:00–3:00 hours after start: Turn all sections of the kiln to a medium heat setting.
- 5:00–6:00 hours after start: Turn all sections of the kiln to a high heat setting.
- 8:00–12:00 Kiln firing should be complete.
- 24:00 Crack open the kiln lid/door when kiln is below 450°F.
- 27:00 Open the lid/door the rest of the way below 250°F.
- 28:00 Unload the kiln when ware is cool to the touch.

Notes on this firing: The hotter the temperature range you are firing to the longer the firing will be. In addition these times could be lengthened or shortened depending on the density of the load in the kiln. A more densely packed kiln will heat and cool much slower than a loosely packed kiln. Glaze kilns are particularly susceptible to thermal shock so be patient and don't open the kiln before it's ready.



An example of a control panel on a computerized kiln. Though computerized kilns may take some of the know how out of the firing procedure, they do make firings less time consuming and more energy efficient.



Sam Chung, *Cloud Bottle Couple*, 11 inches tall, wheel-thrown Grolleg porcelain, china painted to cone 017, 2014. Chung bisques his work in an atmospheric kiln in reduction at cone 10. This is a fairly unique process for a studio ceramist, although it is not uncommon in industrial potteries to bisque ware at hotter temperatures and then use lower temperature glazes. This process vitrifies the ware in the bisque firing, and for Chung it entirely eliminates any crazing during a cone 6 glaze firing which follows. Glazing pottery which is near vitrification is tricky though, and Chung sprays his glaze onto pots which have not entirely cooled down from the firing and are still warm. This assists in evaporating the water in the glaze allowing it to dry much faster on the surface of the form. *Photo by artist*

Computer Controlled Glaze Firing Programs, Cone 04–10

On the following page, there is a chart showing different program values for three of the more common firing temperatures. You will see that the values input into the computer are the same until you get to the high end of the firing range. Most clays and glazes are similar enough that progressing through the low end of the firing should be the same regardless of the temperature you end up firing to.

Notes on these firings: *The programs listed above do not incorporate any hold times during the segments. These programs should be considered merely as starting points for firings. Take notes of each firing and begin adjusting your programs based on your needs. This may take time and plenty of firings for you to develop alterations to these schedules. If you are firing in smaller or less insulated kilns you may wish to consider a controlled cooling to achieve depth to your glazes.*



Andrea Gill, *Basin and Vase Series: Manganese*, varying dimensions, low-fire red clay with glaze and engobe surface, 2011. Gill states, "The surfaces I am able to create are best achieved in an electric kiln. When I started using my large electric kiln with a computer control, I realized I could program the kiln very specifically. I am able to re-fire work several times if needed, reducing the firing temperature slightly to keep what has happened in previous firings. I use both glazes and engobes, which have different results depending on what temperature I fire them to. I have the best luck with the majolica glaze if I fire to 1870°F; other glazes and the engobes may need 1920°F for the result I want. This takes a bit of strategy. Luckily, I also have a test kiln with a computer control. I try to test the combinations and layering before committing to an entire piece. I still get surprises, both good and bad. I always use the vary-fire option on the computer, and often change the firing cycle to see what will happen." Photo by artist.

Cooling Electric Kilns

Most electric kilns are insulated boxes without a sophisticated way to dissipate heat. Although some electric kiln manufacturers are beginning to build cooling fan systems into their kiln designs, this has not become common practice as of yet. Cooling is especially a problem for front-loading electric kilns, which are characterized by massive construction and very effective insulation that results in a long drawn out rate of cooling. Some front-loading electric kilns have a small vent in the roof. During the early stages of the cooling you can cover it with a soft brick. In the later stages of cooling you can remove the brick to move the cooling process along without threatening the ware.

Cooling can also be a problem in a top-loading kiln. At one time, many top-loading kilns were poorly insulated and cooled too rapidly. Recently the design of top-loading electric kilns has improved markedly and in such kilns cooling proceeds in a more measured manner. In the latter part of the cooling process the ceramist who works with a top-loading kiln has the ability to simply prop up the kiln door/roof to speed cooling. Since heat rises, this allows heat to dissipate in a controlled manner. It is, however, important not to stress the door/roof structure of these kilns. You can do this by propping up the door/roof with soft brick struts preformed in graduated sizes if you don't have a mechanical lifter built into your kiln.

Other important factors are the thickness of the ware, the form you used, and the density of the clay body. Ware with thick walls ($\frac{1}{2}$ inch or more) will hold heat longer than ware with thin walls. On the other hand, thick walls can often be strong and resistant to cracking during cooling. Work that is

	Cone 04 Firing	Cone 6 Firing	Cone 10 Firing
Segment 1	120°F per hour to 250°F	120°F per hour to 250°F	120°F per hour to 250°F
Segment 2	300°F per hour to 1000°F	300°F per hour to 1000°F	300°F per hour to 1000°F
Segment 3	150°F per hour to 1100°F	150°F per hour to 1100°F	150°F per hour to 1100°F
Segment 4	180°F per hour to 1676°F	180°F per hour to 1949°F	180°F per hour to 2095°F
Segment 5	120°F per hour to 1926°F	120°F per hour to 2200°F	120°F per hour to 2345°F

very thick walled (over 1 inch thick) should be given a conservative, long cooling time. The form of the piece is important because some forms retain heat. For example, closed forms with a narrow constricted opening must be allowed to cool slowly. If a piece such as this is allowed to cool quickly, the contrast in temperature between the inside and the outside of the form may cause cracking. The clay body density is important because open, absorbent, slightly underfired bodies resist heat shock. Dense clay bodies, such as dense stoneware and porcelain bodies, are highly subject to heat shock. Follow a conservative cooling program if you use a dense clay body to form your ware.

Cooling Rates at the End of the Firing

The chart below will help you control the rate of cooling so it doesn't occur too rapidly. Keeping heat loss to a rate of 100°F an hour is conservative and will ensure minimum losses.

- 50°F/hour = very slow
- 100°F/hour = conservative
- 150°F/hour = quick
- 200°F/hour = overly quick for firing many types of work

Cooling the Kiln by Down Firing

The term *down firing* refers to lowering the heat setting for an hour or two to begin the cooling cycle rather than turning the electricity/heat off completely. This is usually done for glazes where crystalline glaze structures form with slow cooling. Many glazes in fact have crystalline structures (not just crystalline glazes) and benefit from firing down. Electric kilns (especially smaller ones) have a tendency to lose heat rapidly. By firing down, you slow the loss of heat in the firing chamber. The rate of cooling is far more deliberate. As the kiln slowly cools, the glazes are given the time they need to develop visual textures due to the development of microcrystalline formations on their surface.

For manual kilns, instead of turning off the current completely after the cone has fallen, keep the current on but on a low or medium heat setting. You will need to bypass the kiln sitter to do this. Computerized kilns will require adding a segment or two for the firing down process. Try the following.

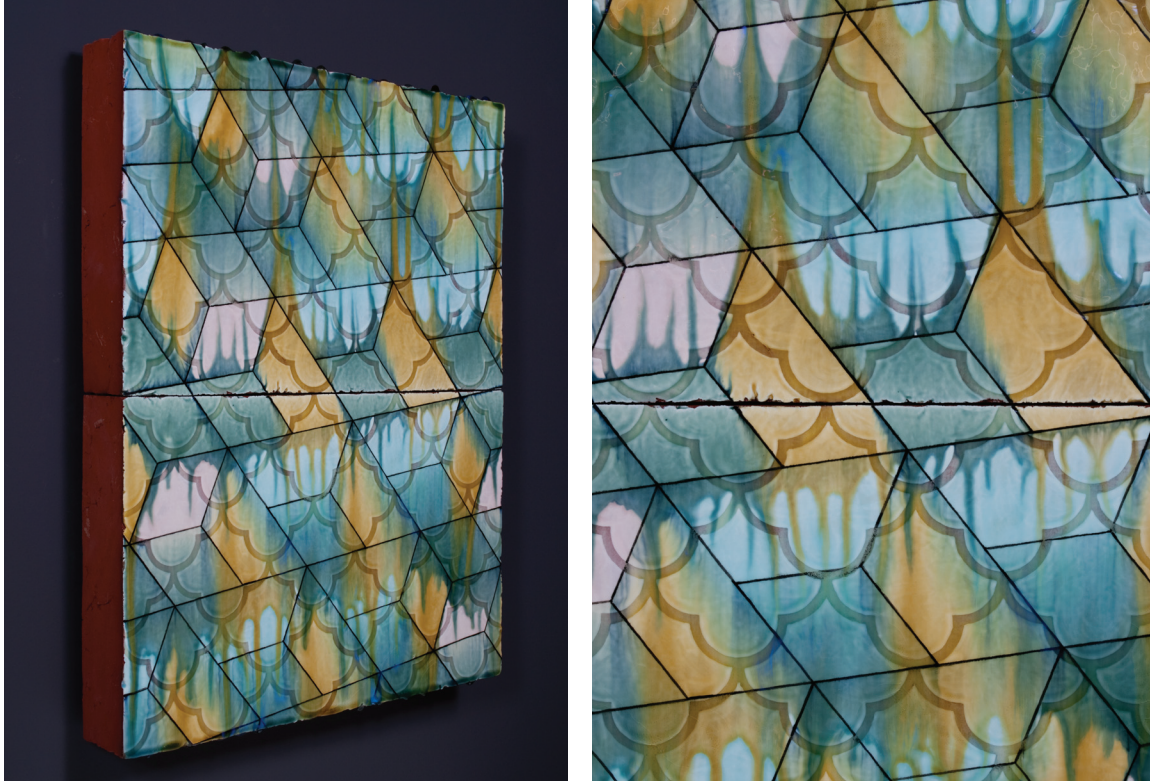
Additional segment: 150°F per hour to 400°F less than your top firing temperature.

Opening the Kiln Door

Just as it is important to know how to load and fire the electric kiln, it is important to know how and when to allow the kiln to cool and when you can take the ware from the kiln. The process of cooling the kiln requires becoming familiar with how quickly you can proceed. It is often based on the size of the kiln, the ware inside the kiln and the density of the load related to the thermal mass.



Kevin Snipes, *Nature Boy*, 9 inches tall, slab-built and pinched porcelain, underglaze, oxide wash, surface developed using mishima and sgraffito techniques, glaze, 2013. Photo by artist



Jason Green, *Recovered Geometry No. 13*, 24½ inches tall, terra cotta, slip, underglaze, glaze, press molded and hand painted tiles, cone 04, 2014. Green hand presses his terra cotta clay into wood molds so they have a hollow back. He then paints a layer of white slip onto the surface and then projects the background patterns onto the surface and paints them using underglaze. The final pattern is also projected and hand painted onto the surface. The pieces are bisque fired, then glazed with transparent glazes and finish fired. Green fires to cone 04 and once top temperature has been reached he then fires down 150 degrees/hour for 4 hours. The added time and temperature makes the firing more equivalent to cone 03. *Photo by artist*

- When the kiln temperature falls to 600°F, open all the peep holes.
- When the temperature reaches 450°F prop the lid 1 inch.
- When the temperature reaches 350°F, the lid/door can be opened 3 or 4 inches.
- At 250°F you may completely open the kiln allowing it to finish cooling prior to unloading.

A steady, even cooling is ideal. Cooling too rapidly threatens cracking the ware due to thermal shock. It seems to be part of everyone's ceramic education to break a piece by taking it from the kiln while it is too hot. Furthermore, in a quick cooling the glaze surface may not get a chance to fully develop the rich pattern of visual textures that we look for in glazes. A cooling pattern that is too slow, on the other hand, can be irritating.

Note: If you don't have a pyrometer, a very useful guide is the point when paper burns—451°F. You can twirl a sheet of newspaper and push it into the kiln through the spy hole. If it bursts into flame after a few seconds, the kiln is still too hot to open the door. If it smokes but doesn't burn, open the kiln door/lid about ½ an inch. If it doesn't burn or smoke, open the kiln a few inches or more.

Taking the Ware from the Kiln

The ware still should not be taken from the kiln until it has cooled a great deal. Many ceramists take their ware from the kiln when the temperature hovers around 200°F and most of the time this does not place the ware in jeopardy. To be perfectly safe, however, it is best to wait until you can hold the piece without gloves.

Experience with your own kiln and your own work is the most reliable guide for when you can safely remove the ware from the kiln.

Care in unloading is especially important when you are firing a new type of ware or firing in a kiln you have not used before. Particular care should be taken if you are using a new highly insulated kiln. Such kilns retain heat and may have a slower cooling pattern than the kiln you are used to.

Important Stages of the Firing

There are several important temperature ranges to be aware of during the firing. During the firing process the molecular structure of the clay is changing as the kiln heats up and then cools back down. These changes can cause great stress on the physical structure of the ware in the kiln and progressing through these stages too quickly can cause drastic results. Here are some guidelines.

Quartz Inversion

The ware inside both bisque and glaze firings are subject to quartz inversion as their temperatures reach (106°F/ 573°C). At this temperature

quartz changes from the alpha to the beta state, which means that the molecules rearrange themselves and expand 1–2% during heat-up, and contract the same amount during cooling. Though quartz inversion affects bisque ware both in bisque kiln and in glaze kilns during heating, quartz inversion has a much greater impact on glazed ware which has reached a point of maturation. This means that it is important to be cautious of cooling a glaze kiln through quartz inversion and heating an already finish fired piece back up again.

Cristobalite

Cristobalite is a form of crystalized silica which occurs naturally in some clays (particularly high iron non-vitreous stoneware bodies) when fired above cone 3. At 428°F/ 220°C during cooling these crystals rapidly contract and shrink 3%, potentially causing dunting or cooling cracks. Though the ware inside the kiln may not be composed entirely of cristobalite crystals, this is point where the ware (if cristobalite is present) undergoes a great amount of stress and needs to be cooled slowly.



This image shows one of Tom Turner's perfectly even glaze firings from his 12-cubic-foot front-loading electric kiln. Notice the cone placement and how there is no difference between any of the cones. Placing cones all around the firing chamber like this allows you to see if there are hot or cool spots in your kiln. These pieces are glazed with copper red oxblood, oilspot, and non-running zinc crystal glazes developed by Turner. 2012. *Photo by Steve Mann*

ELECTRIC KILN CERAMICS



Tom Turner, Triangular Porcelain Bottle Vase, 6¾ inches tall, paddled, fluted, and stamped, Tom Turner Porcelain with multiple Oilspot/Yuteki glaze, cone 9, 2010. Photo by Steve Mann.

Temperature	Stage of Firing
212°F/100°C	Water boils causing wet greenware to explode.
428°F/220°C	During cooling if cristobalite crystals are present in clay they rapidly shrink 3% potentially cracking ware.
662°F–932°F/350°C–500°C	Permanent dehydration of clay occurs. Clay is chemically changed.
1063°F/573°C	Quartz inversion happens causing quartz in clay and glazes to expand when heating and contract during cooling.
1112°F–1652°F/600°C–900°C	Organic and inorganic matter is being burned off out of the clay.
2012°F/1100°C	Mullite crystals begin forming in porcelain clays.



Erin Furimsky, *Keepsake*, 18 inches wide, earthenware, Nichrome wire, wood, acrylic, 2013. Photo by Tyler Lotz

Dunting or Cooling Cracks

Cracks may be caused by an overly rapid firing cycle (especially during the early stages of the fire) or by rapid cooling. To deal with cracks that occur during heating, the kiln should be heated more slowly. To deal with cracks that occur during cooling, the cooling cycle needs to be slowed down. It can be difficult to tell whether cracks were formed during heating or cooling cycles. If possible look at the glaze around a crack. A cooling crack will usually be sharp like broken glass whereas a crack formed during heating will show signs of the glaze healing over and even possibly running or dripping into the crack.

Multiple Firings

For many ceramists there is one, and only one firing to the maturation point. Though this does not mean that you cannot glaze fire your work several times, the initial glaze firing makes further glaze application more difficult and successive glaze firings also increase the chances pieces will crack.

Multiple firing is the process of firing a piece to different temperatures during successive firings, starting with the highest temperature and then moving on down the scale. This process is generally used in color-oriented work: the guiding theory here is that each part of the firing spectrum is most effective for the production of some colors and that in multiple firing the whole range of the color spectrum will be covered.

The process requires great care, patience, and technical skill. The ceramist must be willing to spend a good deal of time and energy on each piece. Furthermore, multiple firing puts the ware in jeopardy: each successive firing increases the risk of cracking due to quartz inversion. The best work of this sort, however, has an inventive character and a rich layered appearance.



This fourth edition of *Electric Kiln Ceramics*, Richard Zakin's seminal work on understanding and using the electric kiln to its fullest potential, has been completely rewritten, reorganized, and expanded by Frederick Bartolovic. Hand picked by Zakin to carry the title forward, Bartolovic has added new sections with step-by-step instruction on forming and finishing pieces for electric firing, schedules for firing both manual and computerized kilns, and has lavishly illustrated the book with completely new images that highlight many of the most exciting results that are possible with electric firing. *Electric Kiln Ceramics* has become the path countless professionals and enthusiasts have followed to gain understanding and proficiency working with electric kilns in the ceramics studio. From Zakin embracing and promoting the electric kiln as a tool that yields exciting results to Bartolovic presenting it within the frame of contemporary practice, technology, and aesthetics, *Electric Kiln Ceramics* promises to continue inspiring and educating ceramic artists for generations to come.

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