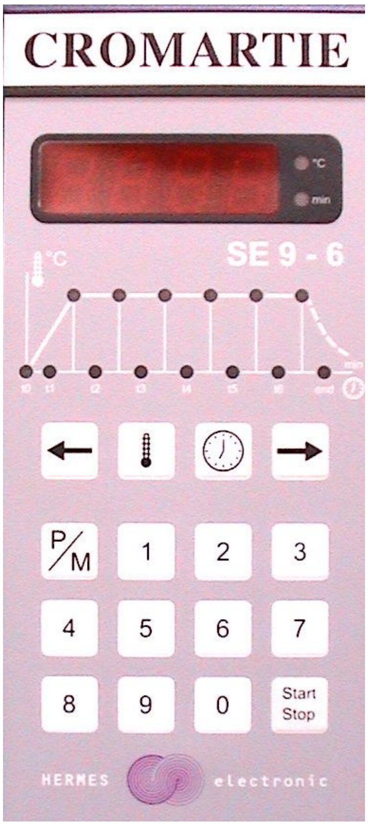
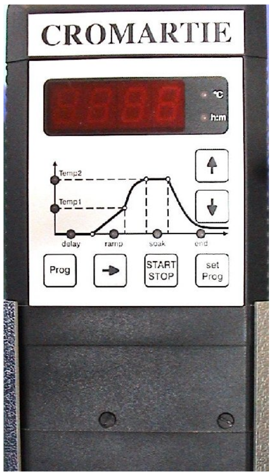
Programming Your Kiln

A guide to firing programs for your electric pottery kiln.





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Cromartie

Introduction

These notes are designed to help you decide what firing program is suitable for your clays, glazes and the way that you work. The size and thickness of your claywork is critical in deciding on a suitable firing programme, as is the maturing temperatures of your clay and glazes. Once you have determined a suitable program you will have to refer to your kiln controller's operating manual for information on how to enter the program. At Cromartie we can pre-program the controller when you are buying a new kiln as long as you can tell us the relevant temperatures and your method of working.

What is a Firing Program?

Firing Program, *Firing Schedule* or *Firing Cycle* are names given to the process of heating up and cooling down of the kiln during firing. Different clay products have different requirements depending on the way they are formed; the clays that you use and the temperature required to mature the clay and glazes. We will look at some examples of typical products to see why they need different rates of heating, soaking and cooling.

Program Controller

The instrument that controls the firing program is called a *kiln controller*, or *Program Controller*. All modern kilns are sold with controllers with a digital display showing the temperature inside the kiln and a mimic graph display indicating progress through the program. The illustration shows a simple controller sold by Cromartie, model H3. You can see the mimic display, which lets you know where you are on the program, the screen at the top will show the temperature in the kiln throughout the firing.

Program controllers interpret the output from a thermocouple, the ceramic probe in the kiln chamber, which measures the heat inside the kiln chamber. By comparing the heat over periods of time the controller measures the speed of heating, and it switches the power supply to the kiln on and off to maintain the correct heating rate, (ramp). Older kilns may only have a manual facility for varying the rate of power, (and therefore heat) to the firing chamber. On reaching the required temperature the controller turns off the kiln.

All Cromartie controllers have two safety features; an over-temperature safety cut off and a smoothing circuit. The Over-temperature device will shut down the kiln if a temperature of twenty degrees hotter than required is reached. The smoothing circuit guards against electrical power surges that can damage the controller.

Heating Ramp, Cooling Ramp and Soak

The rate at which a kiln heats is called the *heating ramp*, mimic displays on some controllers show this as an upward sloping hill, literally a ramp. Ramps are defined as the temperature rise in degrees per hour; for example 150°C per hour. Some controllers specify heating ramps in terms of hours and minutes, or just minutes, taken to achieve a specific temperature. For example 4 hours or 240 minutes, to 600°C equates to 150°C per hour. With all ceramics it is usual to start the firing at a slower rate for the first ramp and then speed up for the subsequent ramp or ramps.

Soak is the name given to the period of the firing when the temperature is held for a period of time. *Soak* is sometimes referred to as *hold* or *dwell*. This is usually programmed to occur at the top temperature when it would allow the glaze to mature.

Cooling ramp is the rate that the kiln cools down when the firing is finished, a controller cannot of course make the kiln cool faster but it can slow down the rate that the kiln cools by inputting heat periodically.

Heating ramp, cooling ramp and soak are all the component parts of a Firing Program. The other feature that is sometimes used is a *delay start*; this is the ability to program the controller to start firing at a later time after a delay of a selected period of time. It is also useful where a kiln is being fired on economy electricity.

Why is the First Heating Ramp Slower?

1. Biscuit Firings.

Biscuit firing is the first firing that converts clay to ceramic. In Biscuit firings it is important to heat the work slowly to ensure that any remaining moisture is driven out of the clay and does not reach boiling point within the clay. When water boils there is a huge and rapid expansion as it turns to steam. As an example of the power of this expansion, consider that it is the formation of steam within corn that makes popcorn pop. Similarly it is responsible for reducing carefully crafted clay work to small fragments of clay, instantly!

The thickness of the clay work and the density of the clay used are important considerations in deciding the first heating ramp. “Open” clays with large grain size and a high grog or sand content; e.g. Crank or Raku clays, will allow moisture to pass from the work freely, so a faster speed of firing is possible. Very dense, fine grained clays such as porcelain and white earthenware will release moisture more slowly so the rate of heating must be much more gentle. All clays also have chemically combined water, as the firing progresses, chemical changes in the clay release this water so this must also escape from the clay.

As well as getting rid of moisture it is also important to burn away any combustible materials that may be present in the clay. Clays have a variety of combustible carbonaceous matter; this may be coal, oil or vegetable material. A slow biscuit firing will be sure to drive all these materials and the gases that they form, out of the clay. If the biscuit firing is very fast these materials can become trapped within the clay and can cause problems in the glaze firing such as bloating, (bulging of the surface) and pin holes in the glaze surface.

Why is the First Heating Ramp Slower?
2. Glaze Firings.
In the glaze firing you are of course heating up clay that has undergone the ceramic change and is therefore one solid piece of material. All pottery expands with heat, you must therefore be cautious that this expansion takes place evenly across the piece. If the heat is markedly greater on one side of the piece than the other, for instance if the piece is sitting close to the elements, then there is a potential for the rate of expansion on the hot side to create a level of stress beyond the strength of the clay causing the work to crack. At a slower rate of heating, conduction, will even out the heat distribution within the ceramic minimising the risk of cracking.

This risk of cracking increases sharply as a specific temperature, 573°C is reached. At this point the crystalline quartz content of the clay changes shape causing a rapid expansion. It is therefore advisable to ensure that the rate of increase through 573°C is relatively slow giving the temperature time to even out throughout the whole pot. Clays with high silica content are more at risk from this problem.

Heatwork and Pyrometric Cones
The effect of temperature and time together is called *heatwork.* Pure temperature only tells half of the story, to understand the firing process it is essential to grasp that the time taken to carry out a firing has nearly as much bearing on the end result, as has the temperature. For example, if two identical pieces are fired, one taking eight hours to reach temperature, the other only six hours, the results will be very different. Even though the same temperature has been achieved the shorter firing has not “cooked” the piece enough, i.e. it has not had enough *heatwork.*

Heatwork can be measured with Pyrometric cones. These are small pieces of clay resembling tall pyramids, see right, that are made from precisely formulated materials. Cones soften and bend when the exact amount of heatwork has been achieved; there are many different values covering a large temperature range. A cone has been fired correctly when the tip just touches the ground. Cones have a temperature values that assume a constant heating ramp, e.g. 150°C per hour. For example the cone 06 has a value of 1011°C if fired at 150°C; however if it is fired at a ramp of only 60°C the top temperature needs only to be 995°C to achieve the same results. The slower rate of heating has “cooked” the work more.

It is useful to use cones when first establishing new programs in your controller, as a cone will give you a measure of the heatwork actually achieved in the kiln. Once you have established a program that puts the appropriate cone down then the controller will replicate it for each firing.

Programming For Different types of Ware

The following programs are offered as guidelines, kilns have differing properties and may produce quite different results so there is an element of trial and error with a new program. When designing your programs be cautious, if you are unsure as to firing times make them longer rather than shorter. In glaze firings the first ramp serves only to protect the fired clay from thermal shock, it will not affect the look or texture of the glaze, it is only the last one or two hours of firing that mature the glaze producing its particular qualities. **You will need to consult your materials supplier as to the recommended top temperatures of specific glazes and clays**, **temperatures listed below are only examples and may not be valid for your clay or glaze.** In the examples below we always list the first set point as 600°C; although there are many instances where this is over-cautious always using this temperature as the top of the first ramp is easy to remember and at worst can only extend firings by a small amount.

1. Slip Cast ware Bisque Firing

Ware made in plaster moulds by the slip cast process is very even in section and is generally quite lightweight. These qualities will allow moisture to escape easily from the clay therefore a relatively fast firing time is possible for the bisque firing. This example would be suitable for American hobby slips.

2. Slip Glaze Firing

The faster first ramp in this example reflects the lighter, more even clay thickness. This program would be suitable for American brush-on glazes. They are usually listed as cone 06 which is 1011°C, but as the second ramp is very fast a higher end temperature is needed, see Heatwork above.

3. Hand modelled Bisque Firing for Stoneware

We assume a thicker section of clay so the first ramp is slow to be sure to drive out all the moisture and burn the combustible materials.

4. Hand modelled Bisque Firing for Brush-On Glaze

The same slow ramp as for the stoneware bisque but a higher top temperature is used to mature the clay as the subsequent glaze firing will be lower.

5. Hand modelled Stoneware Glaze Firing

The first ramp is slow reflecting the thickness of the work, a stoneware glaze is assumed.

6. Hand modelled Glaze Firing for Brush-On Glaze

As with the stoneware glaze firing, the first ramp is slow to guard against thermal shock, the second ramp and temperature will mature the American hobby glazes.

7. Wheel Thrown Biscuit Firing
Pottery thrown on the potters wheel will vary according to the skill of the thrower, we have assumed a fairly even section of clay for this example, for novices it is advisable to follow the firing program for Hand Modelled clay

8. Wheel Thrown Glaze Firing
The speed of the ramp very much depends on the size and thickness of the clay, this program is fairly cautious for average sized work.

9. Flat Ware Glaze Firing
Large flat work is even more at risk in the glaze firing because the edges are likely to be nearer to the elements while the centre will lag behind creating a difference in temperature and therefore expansion. There is also a risk of cracking in cooling as the base stays hot longer where it is closer to the kiln shelf while the edges are likely to be higher and more exposed to cooler air.

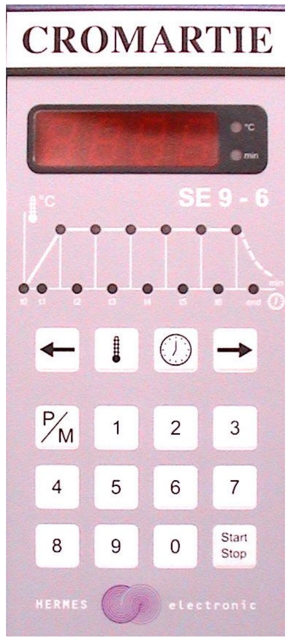
10. China Painting Firing
With On-glaze, or China painting the ware is being fired for the third time having previously been bisque and then glaze fired. The process of china painting may involve several firings as different colours and gold in particular, have different firing temperatures. Each firing creates a stress in the ware and in particular there is a danger if the ware is cooled too fast through the temperature range 220°C to 280°C. Larger pieces are more at risk; it is a wise precaution to stilt them so there is air circulation between the ware and the kiln shelf.

	1st Ramp °C p/h	Hours mins	1st Temp °C	2nd Ramp °C p/h	Top Temp °C	Soak mins.
1.	100	6hr.00	600	200	1080*	10
2.	150	4hr.00	600	250	1020*	10
3.	60	10hr.00	600	200	1000*	15
4.	60	10hr.00	600	200	1120*	10
5.	100	6hr.00	600	200	1260*	15
6	100	6hr.00	600	200	1020*	10
7.	80	7hr.30	600	200	1000*	10
8.	120	5hr.00	600	220	1260*	10
9.	100	6hr.00	600	200	1020*	10
10.	150	4hr.00	600	250	790*	0

* Check the recommended firing temperature with your materials supplier.

Advanced Firings

Programs described above are simple firings with two heating ramps and a soak, there are circumstances where more sophisticated firings are required for example for crystalline glazes, glass slumping and also very large work.



Cystalline glazes need to be carefully controlled through part of the cooling cycle, for up to six hours to get the best results. This can only be achieved with a Program Controller with facility to control the cooling ramp. Glass slumping is even more complicate with a heating ramp to around 500°C, another heating ramp to about 790°C, rapid cool to 540°C, soak, and two annealing ramps over several hours. It is wise to fire large sculptural pieces with a very slow pre-biscuit warming ramp before starting the biscuit proper. This will ensure that any moisture in the clay dries out and will also give a better chance of the heat spreading through the clay by conduction.

Pictured is an example of a more sophisticated controller, the SE9-6 from Cromartie. This controller has six segments in each of nine programs. A segment can be a heating ramp, a cooling ramp or a soak. The mimic display shows the six possible temperature settings at the top of the controller and the six time settings together with a delay start facility at the bottom of the instrument. This controller would be able to fire any program that a ceramist would want and be suitable for most glass purposes and is surprisingly easy to use. Even more sophisticated controllers are available with up to eighteen segments.

Venting the Kiln

All Cromartie top loading kilns now have permanently open side vents to allow moisture and gases from the firing to escape from the kiln. Front loaders have vents on top of the kiln that can be opened and closed with a brick damper during the firing cycle. It is possible to have automatic dampers fitted to vents on front loaders so that the controller opens and closes them at the appropriate time.

Where a kiln is fitted with a damper it will need to be left open for the first part of the firing to allow moisture and gases to leave the kiln, the damper may then be closed at 450 to 500°C to avoid heat loss. The damper may be opened when the firing has ended to aid cooling. This is best done at around the 500°C point. Always ensure that there is nothing combustible above the damper, at least one metre clearance is advised.

Unpacking the Kiln
When is it safe to unpack a kiln? The answer is that it depends what's in it. As explained above, different clays and different methods of making require differing approaches to heating. Similarly some pottery can withstand rapid cooling whereas other ware is more subject to cracking through thermal shock. The key stage in the cooling cycle occurs between 220 and 280°C. At point between these temperatures the structure of Cristobalite particles, (a form of silica present in most clays), changes causing a sudden shrinkage in the ware. It is therefore important that the whole piece cools at the same rate and that there are not parts of the pot that are, for example, exposed to cool airflow from an opened door. If half of a pot cools and contracts while the other half remains hot, stresses build up that could cause the piece to crack.

Once the Cristobalite inversion point has been passed i.e. 220°C the ware is less likely to be damaged and it is usually safe to introduce air into the kiln by opening the door or lid slightly. However it would be unwise to unpack a kiln entirely until under 100°C as there is still a risk to some ware not to mention the risk of getting burned!

Ken Shelton.
Cromartie Kilns 2003.

Cromartie Kilns Limited
Park Hall Road, Longton, Stoke-on-Trent, Staffordshire. ST3 5AY England.
Telephone: 01782 313947 Fax: 01782 599723
e mail:enquiries@cromartie.co.uk
site: www.cromartie.co.uk