BISQUE FIRING

Bisque: an initial (or biscuit) firing of clay **greenware**, usually to a temperature between cone 010 and cone 05. Work may then be glazed and glaze-fired.

Why bisque?

- reduces fragility of ware and makes glazing easier
- pots will no longer slake down
- carbonaceous matter in the clay is burned out before glaze-firing

Bisque temperature: **usually cone 010 to 05** depending on clay body. Although industrial china is often bisqued high (so it can be supported while being fired to the clay body's maturity) then glazed lower (using binders and gums in the glaze to help it adhere to a body that is no longer porous), studio potters usually bisque lower so that the work remains absorbent and easily glazed.

Firing issues

Choosing bisque temperature

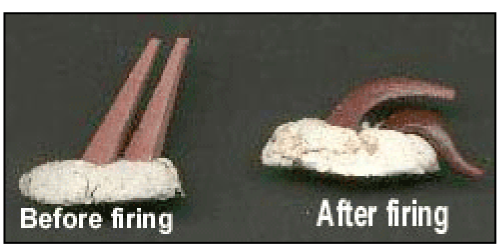
- Ware bisqued too low may be overly soft, prone to damage during handling, and too absorbent. Carbonaceous matter may not be burned out, and may cause pinholing in glazed ware from gasses escaping through the glaze.
- Ware bisqued too high may be partially vitrified and not very absorbent. This is more likely a problem with well-fluxed earthenwares, where the bisque temperature is closer to the maturing temperature than stoneware or porcelain.

Heating

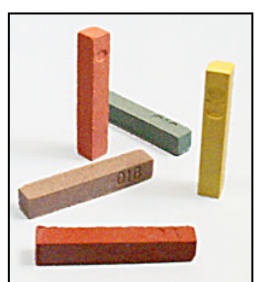
There are three ways that heat is transferred in a kiln:

- **Convection**: air heated rises and air currents circulate heat. This kind of heat transfer happens early in firing. Unless air circulation is even, the kiln will not be even at this point. Convection promotes more heat at the top of the kiln and a cooler bottom.
- **Conduction:** transfer of heat through solids from the outside inward by interaction with molecular structure. Must be done gradually to maintain even heating. Transfers radiant or convection heat into the ware.
- **Radiation**: Effective at higher temperatures. Transfer of heat by waves of energy that are absorbed with they meet cooler objects. Hot objects (ware, kiln furniture, kiln brick) radiate energy in all directions. Radiation helps even out kiln temperature in still atmospheres.

Pyrometers measure temperature, usually through a probe inserted into the kiln. This tells us the temperature at the place of the probe and the time read. This may not indicate whether the materials in the kiln have sufficiently melted.



Pyrometric cones measure **work-heat** (the effect of time and temperature on materials) and are the usual indicators for firing. Cones were originally developed by **Herman Seger** (1839-94), a German ceramist and chemist.



Orton bars for kiln-sitters

American cones are manufactured by the **Orton Foundation**. The Orton web site offers information on kilns, firing and cones: https://www.ortonceramic.com/dir.cfm/en/Pyrometric%20Cones/

Temperature equivalent chart for cones from Clay King:

http://www.clay-king.com/kilns/pyrometric_cone_temperature_chart.html

Cones are a combination of clay and glaze materials, calibrated to melt at a specific temperature. The interval between cone numbers is about 32 degrees Fahrenheit. Cones are made in large and small (or junior) format. Melting temperature is somewhat different between large and small cones of the same number because of the added mass of the large cones, heating, and gravity. Small cones are often used in electric kilns for visual cones because peeps are small and it's hard to see several large cones. You may use large or small visual cones, but should calibrate your desired temperature by consistently using the same size. **Small cones are used in electric kiln kiln-sitters.** Large cones are usually used for high-fire gas kilns, as it's very hard to see a small cone through the hazy kiln atmosphere. Orton also makes bars, rather than tapering cones, for use in kiln sitters to give more consistent results. At U.F. we use the cones because they may be used for visual cone packs in front of a spy hole, as well as in the kiln sitter.

Most general ceramic texts list temperature equivalents for cones, or see the chart in the kiln room or on the Orton web site above. Note that the end temperature of a specific cone is dependent on the rise-per-hour of the temperature. In cooking, an analogy would be baking a potato. Cooking slowly at a lower temperature will mean a longer cooking time and lower final temperature to achieve a cooked potato, or you can cook faster at a higher temperature, and have a higher final temperature and a shorter cooking time to achieve a cooked potato. For this reason, the ramp (or temperature rise per hour) on a computer-controlled kiln is a very important factor in the firing, and is just as important as the final temperature set. In the end, you should be guided by the visual pyrometric cones bending in front of the spy hole as the real indicator of how much your materials are melted.

Reading cone numbers
Cones with a "0" in front of the number are read like negative numbers, e.g. ascending temperature would be 022, 018, 010, 06, 03. Cones without a "0 " are read in ascending order as ordinary numbers e.g. 1-10. There is no cone zero, cone numbers going from cone 01 to cone 1.

Sample cones for various clay processes and materials

Cone	**Use**	**Approx. temp**
022-016	china paint, lusters, decals	1000-1400 °F
06	raku, bisque, commercial low-fire glazes	1860 °F
03	popular for earthenware tableware - lowfire	1950 °F
4-6	mid-range	2150-2260 °F
8-10	stoneware, porcelain, most salt and wood-fired ware - highfire	2300-2370 °F

A cone pack is a small pad of clay with several cones in sequence. This is placed in front of a spy, or peep hole to give visual confirmation of the **work-heat**, or effect of time and temperature, on the ceramic materials in the kiln. In electric kilns, a single cone pack is usually located at a middle peep. Cone packs are put in front of both top and bottom peeps of the gas kilns because a fuel-burning kiln with burners at the bottom may be uneven in temperature. Cones should be tilted at a slight angle (8°) so that you will see them soften and bend before melting. Large cones should extend 2" beyond the cone pack, small cones 15/16th". Place cones close to each other so the group may be easily seen through the peep, flat side facing forward, number facing you, cone that melts soonest first (i.e. in the direction of the lean 08, 07, 06). If cone order is accidentally reversed, the first cone to melt will knock the others over. Make a "boat" at the end of the cone pack to collect

Timer and sitter with trip lever tripped

drips if there is any chance of going several cones above the first cone to melt. In high-fire, the low-temperature cones used to gauge when to reduce will be melted into a liquid by the time the glaze-maturity temperature is reached, and unless contained in a “boat”, will leak onto the kiln shelf and drip down.

Cone packs include a **guide cone** (a cone lower than the firing cone to tell you when you are close to the temperature desired), a **firing cone** (the desired temperature), and a **guard cone** (a cone higher than the firing cone to gauge how much hotter the kiln may have gotten).

Cone packs should be made ahead of time so that they are well-dried and not in danger of blowing up. **Water turns to steam at 212 °F** and a damp cone pack as well as damp ware will *explode* if heated quickly past this point. Glaze kilns are usually heated faster than bisque (and gas burners are often harder to control at low temperatures), and **wet cone packs may blow up**, scattering bits of clay onto ware. If this happens in a glaze kiln, TURN IT OFF, cool it, unload and clean up the shards, then re-load (using new cone packs) and re-fire. Pyrometric cones that have been subjected to heat will not register heat accurately a second time. Used cones should be discarded, even if they have not deformed, as they will no longer register accurately once heated.

A **kiln sitter,** made by the Dawson company**,** and a **timer** are back-up safety devices. Any kiln may over-fire. A person needs to make sure the kiln has turned off as the ultimate safety device, as all mechanical devices may fail.

Small/junior cones are used in the **kiln sitter.** The cone in the sitter is horizontal and has a bar on top of it, so it will deform sooner than a visual cone in a cone pack. **The cone that bends visually is usually a cone LOWER than the one in the sitter** (e.g. an 06 in the sitter usually give an 07 bending in front of the peep). This will vary depending on how the metal trip plate is adjusted and how a tapered cone is set in the sitter.

Timer and Kiln Sitter w/trip lever set

To set the sitter,

- **Turn all kiln switches of OFF**.
- **Raise the trip lever** on the outside of the kiln. (raised in illustration)
- **Lower the claw** to hold it in place, and hold this.
- **Insert a junior cone or bar (**usually **06** for bisque unless otherwise chosen) flat side down, centered between the cone supports, holding up the sensing rod. The cone should rest against the "step" on the metal supports, and the midline of the cone should be parallel with the end of the sitter tube. You may now let go of the claw on the outside, as the cone or bar is holding it up.
- **Turn up the timer** to near the maximum. If the timer runs out, it will shut the kiln off. If the white timer indicator dot on the dial is on OFF, the button on the next step will NOT engage.
- On the outside of the kiln, insert your finger into the hole in the trip lever and **depress the button** until it locks. The kiln is ready for firing.

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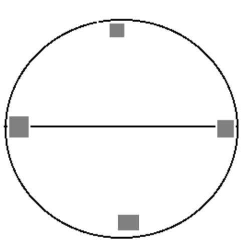

The bottom shelf of the kiln should be placed on short posts (or pieces of broken kiln shelf) above the kiln floor for adequate heat circulation at the bottom of the kiln. Place the shelves so the posts do not block the peep holes or sit in front of the kiln sitter. The next shelf should be at least 6" above, or the work on the bottom shelf may be under-fired. Shelves should be tri-posted, with each half sharing a post at the outside center edge (i.e. it will take four posts to stack a level of two half shelves). **Stack posts above posts** as you add more shelves so that the posts, not the shelves, support the weight.

Work that feels cold has not completely air-dried yet, and care should be taken in firing to avoid blowing up work.

Since there is no glaze that will melt during a bisque firing, sticking is not a problem and pots or sculptures may be stacked if the shape and weight make it safe to do so. Greenware is fragile. To avoid cracking, support the greenware while handling, **do NOT pick greenware up by the handles**, **or single-handedly pick up a work by grasping the wall at one point.**

Nest items inside each other, but be conscious of not extending weight out beyond the base or foot ring of the bottom piece. Pots may be "boxed" or stacked rim to rim, foot to foot, if they are the same size. Pieces may be stacked like this if the thrust of the weight is downward, not lateral. Lids on pottery are usually fired in place to avoid warping. Tall, knobbed lids can be inverted to save space. Broad, flat items may need to be put on a clay "waster" (clay support made at the same time as the piece that is used for a support during firing, then discarded) or on grog or sand to aid movement during firing and prevent warping and cracking.

Remember to **turn the timer up** when you turn up the electric kiln switches. Kilns with a timer will shut off when the timer winds down, regardless of temperature reached. The kiln-sitter may be over-ridden if it shuts off too early. **Please be aware** that the *kiln will **NOT** shut off if the sitter is over-ridden*, and should be monitored very carefully.

Kiln-sitters on electric kilns should be considered back-up devices. Use visual cones in front of the peep hole. Do not shut a kiln off by forcing the kiln sitter lever to drop. This may bend the sensor rod and ruin the sitter.

Firing

Temperature rise should be gradual. **Physical water (between clay particles) turns to steam at 212 deg F**, and suddenly crossing this point will create steam with a force that may blow out the wall or bottom of heavy, damp work. Thicker ware or damp work should be fired slowly. Dense clays will hold water longer than more open or grogged clays. Many sculpture bodies add extra grog or combustible materials to help open the body up and facilitate drying. In climates with high humidity, even a "dry" piece still holds considerable physical water and is in danger of blowing up if not heated gradually to complete evaporate physical water before reaching 212°.

Candle ware overnight or for several hours with the bottom switch on low, the others off. Often the kiln is left with the lid propped open a crack and/or the top peep out to let moisture escape and to keep the temperature from rising above 212°. Draft patterns w/the lid cracked will distribute heat unevenly and not all pieces will dry uniformly. After candling with the lid up or door open to dry work, put the lid down (or close the door) and put in all but the top peep in for an hour before beginning to turn up the switches or gas. Switches are usually stepped up one turn per hour, bottom to top on 3-step switches (Low/Med/Hi). On kilns with infinite (adjustable) switches, after candling, the switches are stepped up in sequence, one per hour, until all are on 1, then all are increased one increment per hour. Large kilns, tightly packed loads, and/or old elements may slow firing. Several of the larger electric kilns fire VERY slowly and can be turned up more assertively than normal. Check the kiln charts.

NOTE that kilns with a controller are NOT candled with the lid open. The setting on the controller will keep the temperature where it needs to be. Leaving the lid up causes the kiln to cycle on more often (like trying to heat your house with the windows open) heats unevenly, wastes electricity, and may cause pieces next to the elements to heat above the set temperature. A usual initial setting for a computer-controlled kiln is below 212 deg F, so that the pieces next to the elements don't go over that temperature while the elements are on and trying to heat the rest of the kiln space. E.g., setting the controller to 180 deg F to dry things out for several hours, before having the temperature increase to over 212 degrees.

From about 600-**1000**°F (visible **red heat**), **combustibles are burning out** of the clay, and **chemically-combined water is being released**, causing shrinkage. The ware in the kiln should be heated slowly to red heat to adequately burn out carbonaceous matter.

Cooling should be gradual. At about **1000°, quartz inversion** takes place, and quartz changes shape from alpha to beta, shrinking 1-2%. **Cristobalite inversion** takes place at **439° F**, and causes the cristobalite in the body to expand or contract about 3%. Cooling quickly during either phase may cause **dunting** (cooling cracks). Dunting is more of a problem in firing over about cone 03 due to the temperature where cristobalite forms, and is less of a problem at most bisque temperatures. Speed-cooling may be hard on kiln equipment, even at bisque temperatures. Once the kiln is below 439° F, the peeps can be pulled to aid cooling. **Paper burns at about 451° F,** so **if a paper stuck into the peep ignites, it's too hot to open.** Next, prop the lid a crack with a piece of kiln shelf or soft brick. Later open the lid to finish cooling if necessary.

Stoneware and porcelain are often bisqued in gas kilns. In many places, electric firing is cheaper, and work is bisqued in electric kilns. Slight reduction in gas bisque firing (or tightly packed electric kiln with combustables to be burned off, e.g. newspaper wadding) will turn normally pink stoneware bisque white from localized reduction (incomplete combustion with more fuel than oxygen to burn completely) of iron in the body. This may make it slightly denser, but color differences disappear in the glaze firing. If terracotta is bisqued in a gas kiln, it needs to be a completely oxidizing atmosphere. Accidental reduction will turn the iron in terracotta to a gray-green color and make hard spots that don't accept glaze well.

Unloading

Be careful not to handle bisque ware with oily or greasy hands (or with lotion on your hands), as these spots may resist glaze application later.

If anything blows up in the kiln, vacuum out the kiln. It is especially important to vacuum out the element grooves of the electric kilns, as materials in clays will eat into the elements in subsequent firings and destroy them. Remember that the elements in an electric kiln are brittle unless heated. Use care in moving them.

Wear safety glasses to scrape off loose kiln wash. If there are any glazed spots left from previous firings, use a hammer and chisel to tap off. If you cannot clean the shelf, a grinder may be needed. Re-apply kiln wash where needed. Several thin coats work better than one thick coat. Wash the tops of the shelves ONLY.

Other resources for information about firing, kilns, and cones may be found in *The Potter's Dictionary of Materials and Techniques* by Frank Hamer.