An Oxidized Bisque Firing by Steve Davis

Many clay and glaze faults in ceramic wares are caused by incomplete burnout of carbon during the bisque firing. This can be attributed to a kiln operator's lack of understanding about the chemistry that occurs in this first firing.

Many materials used in ceramics contain carbon, including clays, whiting, and dolomite. This carbon must be burned out (oxidized) during the bisque firing to ensure the best results possible in glaze firings. Bloating, black coring, pin holing, blisters, and poor color development are all the result of incomplete carbon burnout. To achieve the complete burnout of carbon, you must have the following elements in place: oxygen, time, and temperature.

Oxygen

Oxygen is the most critical element. Without oxygen, carbon in the clay will not form carbon dioxide gas and vacate the clay. Carbon will strip oxygen from oxygen sources including red iron oxide (Fe_2O_3) in trace amounts from ball clays, kaolins, and fireclays, and substantial amounts from red clay bodies. When carbon atoms strip oxygen atoms from red iron oxide (Fe_2O_3), the red iron is converted into 2 atoms of black iron oxide (FeO), a powerful flux. At high temperatures, the walls of the wares become sealed by the fluxing action of the black iron oxide, causing escaping gas to form pockets in the walls of the wares (Bloating). In low fire ceramics, temperatures are not high enough for bloating or melting to occur, but the carbon can cause faults such as black coring in the clay wall, pinholes, blisters, and poor color development in glazes.

Time

Carbon burnout requires time for the oxygen to penetrate the ware and form carbon dioxide gas. Much thicker pieces or dense loads require substantially more firing time for proper oxidation of the carbon. Sometimes the carbon content of the ware can be much higher than normal due to changes in raw materials. This increased carbon content can cause problems that would not normally occur with established firing procedures.

Temperature

The temperature that carbon burns out at is from 600'F-1400'F. Kilns must be well vented throughout this temperature range, especially from 600-700'F. Simply stated, the kiln needs to be well vented until the interior of the kiln achieves a bright, orange glow.

Venting Electric Kilns

Just because a kiln is electric does not mean that it is oxidizing during firing. Oxygen must be supplied to the kiln through venting by one of two methods. One method is to install a kiln vent, which is the most effective way to introduce oxygen. The other method is to prop the lid open at 3/4s of an inch and remove all of the peephole plugs. This venting should be done from the start of the firing and continued until the inside of the kiln chamber has achieved a bright, orange glow. A good prop for the lid is a 10" x 10" x ¾" kiln shelf. If placed on the rim of the kiln wall directly below the lid handle, it will shield the lid handle from the heat and corrosive vapors from the kiln. After a bright orange glow is achieved (1400F), the lid can be closed and all of the peepholes left open. Be sure no combustibles are within 24 inches of the kiln.

Bisque Firing with a Gas Kiln

In a gas kiln, oxygen supply is a little trickier. Gas fired kilns are basically a box where air and fuel are mixed and ignited. The air-fuel ratio is what we are concerned with. In natural draft kilns, fuel comes through the body of the natural draft burner under pressure. This flow of gas entrains 50% of the air requirement (primary air) through the burner. Air and fuel are mixed in the burner and the kiln chamber. The other 50% of the required air comes through the burner ports (secondary air). The damper on both up draft and down draft kilns controls this secondary air and the atmosphere of the kiln.

To achieve a reliable, oxidized bisque firing with a gas kiln, a **kiln chart** that list the gas pressure and corresponding damper settings, must be employed. As the kiln temperature increases, a greater expansion of the gases occurs in the kiln chamber. The air-fuel ratio will change towards a reduced atmosphere (lack of oxygen), due to the greater pressure of the fuel verses the pressure of the air. In order to guarantee that there is always ample oxygen supplied to the wares, a firing chart should be established at a temperature equal to, or above the bisque temperature. It is critical to use repeatable methods of measuring the gas pressure and damper settings. Start by cleaning out the kiln, burner ports, and burners. Check the orifices for spider nests, and inspect the flue area for obstructions. Debris in the burner port can cause an area of local reduction within the kiln that may not be noticed during a firing. Next, install a gas gauge between the burners and the gas control valve. Make marks indicating the location of the damper openings of inch or half inch increments. Fire the kiln empty up to cone 04 and make notations on a kiln chart. Notations should include “time, temperature, gas pressure, damper setting, and comments”. At cone 04, note the maximum amount of gas pressure used. Then push the damper in until a flame is visible in the damper area. If the damper area is not visible, observe the flame coming out of the peephole. Now incrementally back out the damper until the flame disappears. It may take a minute for the kiln to adjust to the new atmosphere. A peek-a-boo flame is a neutral flame and the kiln is not quite in oxidation. Once the kiln is in an oxidizing mode, make a note of the damper setting that corresponds with the gas pressure reading. Turn down the gas pressure a half inch and follow the same damper adjustments to establish the corresponding damper settings for the lower gas pressure readings. Continue this process until you are down to one inch of gas pressure. This chart is created at a temperature that guarantees your kiln atmosphere will be oxidizing at lower temperatures. It is best to make the kiln chart at night when the flame is more visible. Once this chart is established, it should be easy to achieve a well oxidized bisque. Remember that “oxygen, time, and temperature” must be taken into account when bisque firing.

Kiln Chart

Time	Temp	Gas	Damper	Comments

Steve's Bisque Firing Program for a Skutt Touch Pad

"PROG"	**1**	**Enter**	
"SEGS"	**3**	**Enter**	
"RA 1"	**60**	**Enter**	
"F 1"	**180**	**Enter**	(Water forms steam at 212F)
"HLD 1"	**12.00**	**Enter**	(Variable depending on water content and thickness of the wares)
"RA 2"	**240**	**Enter**	
"F 2"	**1500**	**Enter**	
"HLD 2"	**0**	**Enter**	
"RA 3"	**360**	**Enter**	
"F 3"	**1941**	**Enter**	(Cone 04 for most clay bodies)
"HLD 3"	**0**	**Enter**	
"ALRM"	**9999**	**Enter**	
"IDLE"		**START**	

A segment (SEGS) includes a rate (RA), a temperature (F), and a hold (HLD) setting.
Alarm and Delay can be set after you have inputted a program.

The rate (RA) is the rate of temperature climb per hour.
The temperature (F or C) is the temperature that a segment will fire to.
The hold (HLD) is how long the temperature will be held for that segment.

Heat Transfer

1. **Radiation**: When electromagnetic waves travel through space, they transfer heat to objects they come into contact with. The sun and kiln elements produce these waves.
2. **Conduction**: The transfer of heat between substances that are in direct contact with each other. Better conductors such as copper, transfer heat more rapidly than other substances.
3. **Convection**: Heat transfer caused by the up and down movement of gases and liquids. Flues gases moving up a kiln chimney is an example of convection.