By Steve Davis,Aardvark Clay and Supplies

An Oxidized Bisque Firing

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

Clays and other materials used in ceramics contain various amounts of carbon. 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, poor color development in low fire reds, etc. are all the result of insufficient carbon burnout. Carbon is removed in the form of carbon monoxide and carbon dioxide gases. In order to obtain this transformation, you must have the following elements in place: oxygen, time, and temperature.

Oxygen

Oxygen is the most critical element. Without oxygen, carbon monoxide and dioxide gas can not form and the carbon will remain trapped in the ware. When carbon is heated above 600'F, it will readily combine with oxygen from whatever oxygen source is available. If ample oxygen is not provided to the carbon through venting of the kiln, the carbon will strip oxygen from other oxygen sources in the ware. These oxygen sources in cone 10 clay bodies included red iron oxide ($Fe2O3$) which primarily comes in trace amounts from ball clays, kaolins, and fire clays that can make up 50% or more of a clay body formula. When the carbon strips the oxygen from the $Fe2O3$, the iron is converted into black iron oxide (FeO) which is a powerful flux. This flux is distributed throughout the ware and produces the bloating seen in cone 10 reduction firings. The walls of the pieces become sealed by the fluxing action of the black iron oxide, causing escaping gas to form pockets in the walls of the ware. Many ceramists are not aware that this problem is caused in the bisque, and is not the result of a bad batch of clay or excessive reduction in the glaze firing.

In low fire ceramics, temperatures are not high enough for bloating or melting to occur, but faults such as black coring in the clay wall and pinholes, blisters, and poor color development in glazes can occur.

Time

Carbon burnout requires time for the oxygen to penetrate the ware and form carbon monoxide and dioxide gases. Much thicker pieces or dense kiln loads require substantially more 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 normally not occur even though the same firing schedule and procedures have been followed for many years.

Temperature

The temperature that carbon burns out at is from 600'F-1400'F. The kiln must be well vented throughout this temperature range. The temperature inside the ware is lower than the ambient temperature of the kiln, so it is wise to keep the kiln well vented to at least 1400'F to ensure proper burnout. Simply stated, the kiln needs to be well vented until the interior of the kiln achieves a bright, orange glow.

Firing with gas vs. electric

In an electric kiln, carbon is not introduced by the firing process as it is with a gas kiln. However, high levels of carbon can exist within the ceramic wares. Just because the kiln is electric does not mean that the kiln is oxidizing. 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 by half an inch and remove all of the peep holes 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 bright, orange glow ensures a temperature well above the temperature at which carbon burns out. A good prop for the lid is a broken or small 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 of the kiln. After a bright orange heat is achieved, the lid can be closed and all of the peepholes plugged, except for the top peephole. Be sure no combustibles are within 24 inches of the kiln.

In a gas fired 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. The 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.

Establishing a kiln firing chart for an oxidation firing

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 observations”. 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 half an 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 these adjustments 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.