carbon trapping

by Dave Finkelnburg

The late master potter, Malcolm Davis, called the process of carbon trapping, "frustrating and unpredictable." The challenge, Davis once told me, is getting the firing right. Without that, there is little or nothing to show for all the rest of the effort in the process.

Defining the Terms

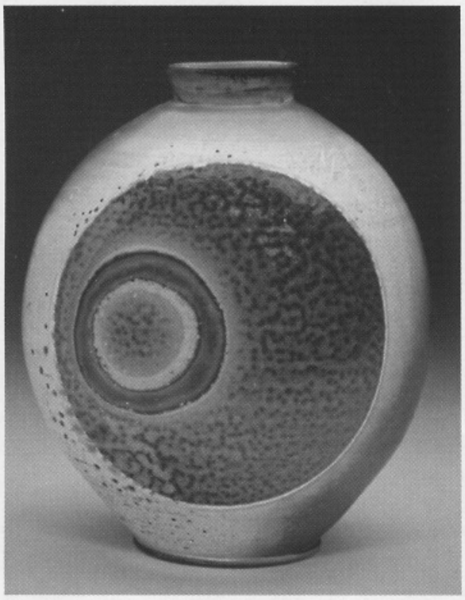
Seal Point: The combination of time and kiln temperature at which a glaze just melts into a glass, thus sealing the surface of the glaze.

Reduction Firing: A kiln firing in which there is insufficient oxygen (thus not all fuel burns) to fully oxidize all the reactive materials in the kiln.

Oxidation Firing: A kiln firing in which there is enough oxygen (at least 3% in the kiln exhaust) to fully oxidize all the reactive materials.

Methane: CH_4, the principle fuel compound in natural gas.

Draw Trial: A test tile of some shape that can be pulled from the hot kiln during the firing by means of a slender metal rod.



Sam Hoffman's *Orbital*, 12 in. (30 cm) in height, wheel-thrown, soda-fluxed porcelain. *Photo: Bill Bachhuber.*

A Tricky Process

Carbon trapping uses the presence and absence of carbon, trapped by a glaze, to achieve ceramic decoration. It's a unique process that can be tricky to execute. The chemical reaction that takes place to produce carbon soot is uncomplicated. In a natural-gas kiln, the fuel is a compound of carbon (C) and hydrogen (H) called methane (CH_4). In the presence of heat but limited air (thus limited oxygen) the methane is reduced to carbon and water vapor. The reaction is:

$$\textbf{Mild Reduction: } CH_4 + 1.5O_2 \longrightarrow CO + 2H_2O$$

The other hydrocarbon fuels commonly used to heat kilns—wood and propane—also yield soot in strong reduction. The chemical reaction involved is similar:

$$\textbf{Sooty Reduction: } CH_4 + O_2 \longrightarrow C + 2H_2O$$

It can be very frustrating when one is firing a kiln with the temperature climbing nicely only to see the temperature stop climbing or even fall as soon as the kiln is placed into heavy reduction. However, this is exactly what one should expect to happen. Here's why: Full oxidation of fuel in a kiln can be represented by the chemical reaction:

$$\textbf{Oxidation: } CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

Oxidation produces considerably more heat than reduction because in reduction, the burning of the fuel is incomplete. As soon as oxidation ends and reduction begins, the amount of heat being produced per unit of fuel drops dramatically. At this point, the person firing may increase the fuel but not the air in an effort to maintain temperature or cause it to rise while still producing soot. An alternative is to decrease the air but not the fuel (or a combination of these two methods) and suffer the loss of temperature while producing a sooty flame that will generate the carbon needed for the process. The good news is that the carbon will remain, provided further increases in air and fuel still keep the kiln in at least moderate reduction. Judging just how much reduction is sufficient to both keep the carbon and produce enough heat for temperature rise requires experience with the kiln being fired.

Seeking a Sooty Surface

Carbon trapping is just what it says. Pure carbon (soot) is produced from fuel in a kiln and deposits on glazed ware. When the glaze melts, it traps the carbon.

To make soot, a hot, fuel-fired kiln is starved of air so it makes a smoky, sooty flame. The kiln will typically be around 1600°F (870°C) to make soot. However, the temperature must not be so much hotter than this that the glaze has already melted. That would entirely prevent trapping carbon. How hot is too hot depends on the glaze.

Once heavy reduction is achieved and soot is produced, it is critical to the process that the kiln remain in, or at least at some level of, reduction until it reaches the temperature at which the glazes on the ware melt. If the kiln is allowed to go into oxidation at any time between making soot and when the glaze melts, the soot will almost instantly burn off. The result? No carbon will be trapped.

However, as soon as the glazes melt enough to seal over, the carbon is permanently trapped under the glaze. Once the glaze melts, the kiln can be safely placed back into oxidation to finish the firing and any oxygen in the kiln can no longer reach the carbon to burn it away.

Knowing when the glaze has melted requires experience or testing. Pulling a series of draw trials from a kiln during the course of a firing