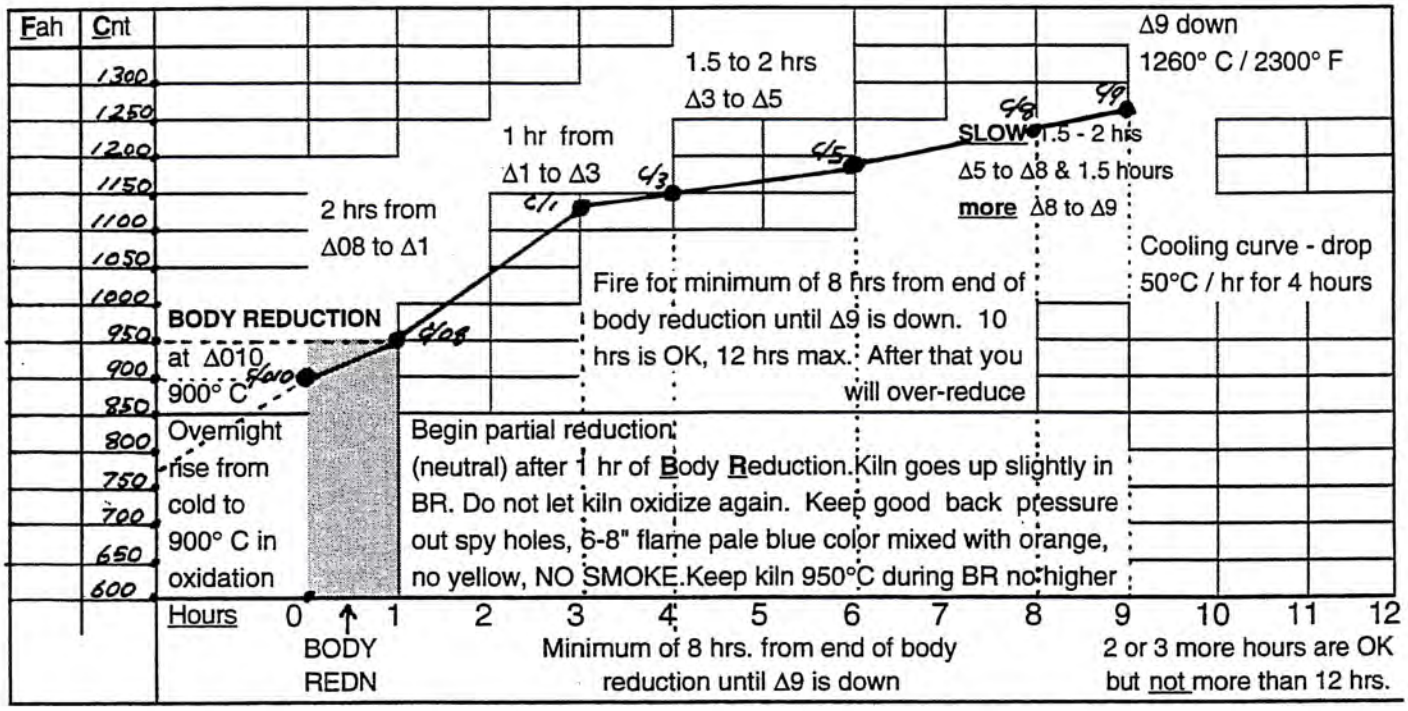
✿ GLAZE FIRING -- Cone 9 Reduction ✿ by Val Cushing
(down draft kilns with natural gas & inspirating burners)



FIRING UP TO TEMPERATURE Cone 9 reduction
Begin body reduction at C/010 (900° C). Stay in body reduction one hour. Don't go higher than C/08 (950° C). In body reduction, set burner flame to slight yellow fingers at flame tip. By giving the gas less air, you diminish the combustion of the fuel which needs oxygen to burn efficiently. An intense cone shaped blue flame indicates complete combustion and oxidation. As you decrease the air, the flame tip develops an orange color and eventually turns solid yellow if the air is reduced too much. By causing incomplete combustion, you form CO, carbon monoxide. This carbon monoxide is a dangerous gas. It can kill you. **NEVER** fire in reduction without proper ventilation and exhaust systems. But the CO is the main gas that creates reduction effects. You need to produce some CO. The CO is unstable and wants more oxygen to become CO_2 (carbon dioxide) and become a stable gas which goes out the stack. The carbon monoxide will take oxygen from you without the proper precautions but it also takes oxygen away from the various clays and glaze materials and colorants. These changes in the oxides cause color changes and produce the reduction atmosphere.

Close primary air at burners slightly to create a reduction atmosphere. Then push in damper until a 6" to 8" flame comes out top spy hole. (Flame may be 8" to 10".) Flame will be less at lower spy holes with perhaps even none at lowest spy but do not allow air to be sucked in at the bottom spy hole. Light a piece of paper and hold it by the bottom spy hole. If the flame is drawn into the spy hole, you will need to close the damper a little more. If you don't, there will not be enough reduction at the bottom of the kiln.

Kiln temperature will rise on pyrometer - but do not let it go over C/ 08 in body reduction. If you go over C/ 08 within the hour of body reduction, some clay bodies will start to mature and will not take the reduction conversion from iron oxide (Fe_2O_3) to ferrous oxide (FeO). Without the loss of oxygen from various clays and glaze materials, you will not have a proper reduction firing. The glaze may also begin sintering over C/ 08 forming a crust of partial glass that will also either prevent the body from reducing or if the body is reducing, then carbon may be trapped and cause black coring. Stay in body reduction one hour.

After one hour of body reduction, set kiln in partial reduction. Pull damper open slightly. Flame shortens a little. Flame may be around 6" to 8" at all spy holes. Leave burner flames as they were in body reduction. They need not be set again. **Do not reoxidize.** Keep kiln in partial reduction from now on until C/ 9 is down.

Go slowly and gradually to C/9. You should have a minimum of 8 hours from the end of body reduction to C/ 9 down. Without the slow rise to C/ 9, the reduction may be incomplete or only partially effective. You need both **time** and **temperature**. A fast rise in fuel kilns often implies oxidation. If you use an oxygen analyser and keep the proper CO/CO_2 levels, then you could probably get to C/ 9 in five or six hours instead of eight or ten hours. Ten to 12 hours is OK but not more than that.

Fire with the damper. I prefer firing the kiln by moving the damper in or out after body reduction. Pushing the damper in will cause **back pressure** which indicates that the **reduction atmosphere** is reaching all parts of the kiln. You need to see this flame out all spy holes to be sure you have back pressure. If the damper is in too far, you will have too much reduction, too much carbon & smoke and so much incomplete combustion of the fuel that the kiln will either soak indefinitely or lose temperature. If you open the damper too much, the flame out the spy holes will diminish and the back pressure lessen. You will begin going into oxidation and the kiln may jump up in temperature. The more complete the combustion, the more heat is produced and the kiln will get hotter. Some kilns are fired and the amount of reduction controlled by opening and closing the air and gas ratio. Less air gives incomplete combustion and slower firings with more reduction. More air goes toward oxidation, cleaner flame, better combustion and faster firing. I would rather adjust the air and gas once, at the beginning of body reduction and then have only to use the damper to control the kiln for the rest of the firing. If kiln climbs too slowly, open damper slightly. If kiln climbs too fast, close damper slightly.

Allow about 2 hours from C/ 08 to C/ 1; about 1 to 1.5 hours from C/ 1 to C/3; about 1.5 to 2 hours from C/ 3 to C/ 5; about 1.5 to 2 hours from C/ 5 to C/ 8; and about 1.5 hours from C/8 to C/9 down with C/ 10 tipping to about three o'clock.

After a minimum of 8 hours (maximum 12 hours), when C/9 is down & C/10 tipping - turn burner flames to oxidation by opening primary air at the burners to give blue flames at burners. Then open damper so there is no back pressure at spy hole. This is **reoxidation.** Leave the kiln this way for 3 - 5 minutes. Then turn off the gas at each burner and close the air intake at each burner. Then close the main gas to off. Then close the damper pushing it all the way in. Leave the air intake above the damper **unbricked** i.e. open so chimney draft pulls air from the room, rather than hot air from the kiln thus cooling kiln too fast. Kiln should cool less than 50° per hour for the first four hours to get the proper reoxidized colors. This slow reoxidation allows some oxides to regain oxygen and thus shifts colors slightly toward a brighter oxidation pallette. Some of the FeO, for example, in glazes will revert back to Fe_2O_3 which is red in oxidation. Orange, red/brown, cinammon, apricot & similar earth colors are best in slow cooling. Copper blues and blue-greens are also improved with richer brighter colors. Satin and matt glazes also benefit from slow cooling because the extended time allows for the growth of micro crystals.

Fast cooling can make reduction glazes grey and dingy looking. Fast cooling kilns (as are most kilns at Alfred University due to the ventilation system in the kiln room) may need to be fired down for four hours to get the proper slow cool.

To summarize firing up to temperature for C/ 9 reduction - Kiln is fired in oxidation from 0° to 900° C. Unless you have greenware or very large bowls, platters, etc., the temperature can be advanced from about 100° to 170° per hour up to C/ 010. Then body reduction begins. After body reduction ends, the kiln should climb at approximately one degree per minute, no faster. Refer to chart above. Keep bluish to blue and orange flame out spy hole at all times from C/ 010 to C/ 9. Flame may be yellow/orange in body reduction. The flame out the spy holes is very important. Too yellow a back pressure flame will indicate too much reduction. Avoid this yellow flame. Too much blue flame will indicate going toward oxidation. An oxygen analyser would give you the means to get the reduction just right.

COOLING DOWN

Kilns may safely be cooled very quickly as far as technical problems are concerned in reference to body cracks, crazing, etc. They could be actually opened up and allowed to cool as fast as the kiln would go down to a dull red heat. But at dull red heat, **BEWARE** because as you get to the point where color is going from the kiln (around 600° C), you are also approaching quartz inversion when the beta quartz reverts back to alpha quartz with a 2% contraction. Too fast through this point (575° C) will cause dunting which is severe cracking in the clay body. Fast cooling below 600° C can also cause serious crazing. If you want to fast cool, it's safe to do so down to about 850° C. From then on, it is crucial to slow the cooling down or face major clay and glaze problems.

Fast cooling will also cause satin and matt glazes to appear more glossy by decreasing the time needed to grow micro crystals which are the cause of most satin and matt glazes. In a reduction firing, if the reduction is heavy at the end of the fire and not reoxidized, a fast cooled kiln could cause soot and a dull smuginess to

appear in the glazes. Everything could have a grey and dull surface. Some ceramists purposely cool fast, after reducing, to produce interesting grey colors in clays and glazes, even firing the kiln down in reduction as it cools, to produce unusual effects. Copper reds may benefit by fast cooling, which may help freeze in the red reduction color. But the general/normal practice is to cool slowly and gradually. Many kilns are cooled at the rate of about 1° **Fahrenheit** per minute taking around 20 - 22 hours before unstacking from a C/ 9 - 10 firing. Remember to slow down at 600° C at quartz inversion. An even greater danger exists at around 300° - 250° C when whatever **crystobalite** present contracts about 2% and is the cause of many clay body cracks. **Do not unstack** until you are below 200° C to be safe.

Individual kilns differ in how they fire and how they cool. It's difficult to make general statements that will apply to all kilns. But the cooling cycle that follows is the one I use on my soft brick ,65 cubic foot, down draft, inspirating burner, natural draft, natural gas fired kiln which has a 24 foot stack

VC Cooling Cycle: my C/ 9.5 firings usually end at 10:00 PM. At that time, I close all secondary air ports (around each burner) and close the damper all the way in. With this setting , the kiln will still have color (800° - 900° C) by about 7:00 AM the next morning when I open the damper about 2 inches. When color is gone, and the kiln is below 500° C, I open the damper to half way open - about 6.5 inches. I leave the kiln this way until below 200° C and then open the damper all the way and open the secondary air ports. This will happen about 24 hours later, or at about 10:00 PM the next day. I then let the kiln sit all night with all air open, damper open and the top door bricks removed. (I have a loose brick door.) I can then unstack the next morning. This is a very conservative and very safe cooling cycle. I will admit to having sometimes speeded up the cooling at the upper high temperature end so that the kiln can be unstacked the next night after 24 hours of cooling. But that only happens in a real time crunch and makes me uneasy the whole time.

The cooling system described above is more or less the same as that used by many other ceramists and is not mine alone. Many kinds of low fire and more porous ceramics can be cooled faster than I have indicated, with RAKU as the obvious end of the scale for fast cooling! But high fire ceramics present more problems than much low fire work due to things like crystalline changes, density and heat shock. Slow cooling for high fire is safer.