Kiln Firing – Understanding your Basic Controls

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Reduction is an atmospheric condition in a kiln firing when the kiln atmosphere has insufficient oxygen for complete combustion (more fuel than air to burn). At high temperatures, reduction produces carbon monoxide gas, which will steal loosely-bonded oxygen from materials in the kiln atmosphere, in ceramics this generally refers to compounds of iron and copper.

SAFETY NOTE:
Carbon monoxide is an odorless, colorless gas that can cause sudden illness and death. Do not remain in a closed kiln room during reduction.

Reduction in a kiln atmosphere changes the molecular structure of the material in the atmosphere and produces color changes. In oxidation, iron generally produces tan, brown, or rust colors. **In reduction, small amounts of iron give celadon colors: green, blue, olive, or grey-green colors.** Copper in oxidation is green or blue green. Small amounts of **copper** in the appropriate base glaze **in reduction atmosphere produces** copper **reds** in shades known as *sang-de-boeuf* (oxblood - red toward plum), peach bloom (pink-to-peach), or flambé (orang-red). Historical Chinese, Korean and Japanese ceramics is particularly famous for high temperature colors. While reduction can be done at other temperatures than high-fire (cones 8-11), it is held by many clay artists that high-fire reduction has the best color response, with richer tones, than reduction at lower temperatures.

Raw Glazing / Single Fire - Historically single fire or raw glazing was common practice before the 1930's. With the introduction of artist pottery studios and the post World War II ceramic education through university programs (usually housed in the Home Economics Departments) most work was single fired. As a return to what was common practice of the past, work may be raw-glazed or once-fired. This is currently, not the most common procedure because bone-dry greenware is fragile, may split or crack from being wetted by the wet glaze. Carbonaceous matter in the raw clay, during the single fire, burns out in firing and can possibly cause pin-holing in the glaze. Greenware is also prone to blowing up if fired too quickly past the point where water turns to steam (212°F), and pieces of exploded ware would be strewn throughout the kiln and become trapped in the developing glaze. Glazes for once-firing must be specifically balanced for shrinkage with the formed raw clay, and usually contain a much larger % of clay (over 30%) than glazes that are designed for bisque application.

Hotel & Restaurant (BONE) China - Bone China (whitewear) has a high mechanical strength and is chip resistance. Bone China is bisque-fired to maturity so that it may be supported during the firing (e.g. translucent porcelains). This vitrified ware is no longer porous. Special binders and special application methods must be used to apply the glaze before the second, lower glaze firing.
Both Spode's formulation of 6 parts bone ash, 4 parts feldspar and 3.5 parts kaolin remains the base for all bone china.

Standard Bisque - Studio potters usually bisque to a temperature below the maturing point of the clay, glaze is applied to the sturdier porous bisque wear and glaze-fired or second fired to maturity. Porosity test can be developed to determine the ideal porosity need for bisque fire. It is equally important to determine the ideal viscosity of a glaze that will be applied to the bisque wear. A Hydrometer is an instrument used to measure the specific gravity (viscosity) of liquids that is, the ratio of the density of the liquid to the density of water. Consistency of the porosity of clay and viscosity of glaze are standards for a successful glaze application. Porcelain bisque - 1945 °F /1063°C - cone 04, Stoneware bisque - 1828°F/998°C – cone 06, Earthenware bisque – 1657°F / 903°C - cone 010.

Pyrometers measure temperature, usually through a probe (thermocouple) inserted two inches (2") into the kiln. This indicates the temperature at the position of the probe and the time it was read. This may not indicate the temperature throughout the kiln or the way materials react to the time,

temperature and atmosphere of the kiln. Pyrometers are mechanical indicators of heat but never accurate. Ceramic sleeves should always be used to protect thermocouples from physical damage and corrosive atmospheres.

Pyrometric cones measure the actual working-heat (the effect of time and temperature and atmosphere on materials) and are considered a truer indicator of temperature. German ceramic scientist Herman Seger developed cones for firing. Orton manufactures cones in the United States. Cones are a combination of clay and glaze/raw materials, calibrated to melt at a specific temperature. The interval between cones is about 32 degrees Fahrenheit. Cones are made in large, small and bar formats. Melting temperature is somewhat different between large and small cones of the same number. Small cones are often used in electric kilns for visual cones because peeps are small and it's hard to see several large cones. Small cones and or bar cones are used in electric kiln kiln-sitters and generally register the same.

See Appendix 2 in "Hands In Clay" for color and temperature equivalents. Lower-firing cones are numbered with a "0" in front of the number, and read like a negative number (e.g. 022 is cooler than 010). There is no cone zero. Pyrometric Cone numbering goes from cone 01 to cone 1. Cones numbers w/o a "0" in front are hotter in ascending numerical order: cone 1 is cooler than cone 3. Some clays have a P.C.E. or (Pyrometric Cone Equivalent) have cone 42.

Cone packs are placed in front of both top and bottom peeps of the gas kilns. A wad of clay is used as a base to support a series of cones: In theory, a **guide cone** (tells you when you are getting close to the desired temperature), a **firing cone** (the desired temperature), and a **guard cone** (to gauge the limits of your firing).
Cones should be tilted at a slight (8 degree) angle (which matches the end cut of the cone) so that you will see them soften and bend before melting. The cone is at the desired temperature when it reaches the 3 o'clock or a horizontal position. Place cones close to each other so the group may be easily seen through the peep, flat number side facing the peep, the **cone that melts earlier are positioned first**

in the line (if cone order is reversed, the first cone to melt will nock the others over or worse, hold the others up). It is difficult to get 2 wide cone packs on a support in front of the peep, so balance the need to catch the drips with the logistics of placing 2 cone packs next to each other. Note that the cones in the left bisque illustration are unfired Bisque cones (08, 06). The cone pack to the right illustrates a high-fired melted cone pack. In a cone 10 reduction fire the following cones are used (010-04-01-3) note-lower cones are for body reduction (6-8-9-10) note-higher cones are for glaze reduction. Your cone 10R glaze firing will be firing way beyond the lower cone packs range. The lower cones will melt into a liquid and run. Protect your wear and the kiln shelves by placing all cone packs on a slice of I.F.B. (Insulating Fire Brick) or as a second choice make a sink or basin out of clay for the cone packs to rest. Make cone-packs ahead of time and dry them. Glaze or Glost kilns are usually heated faster than bisque (gas burners can be difficult to control at low temperatures without the forced air pressurizing the chamber), wet cone packs can blow up, scattering bits of clay debris throughout the kiln.
To increase the visibility of cones - place cone packs 6-10" from peep opening with an uncluttered background. A brick strategically placed 6-10" behind cones can help visibility. An accurate reading of the cones must be made.

SAFETY NOTE: Always use Protective Eyewear, Shade 3 or 4 or 5 IR Lens for long-term exposure to I.R. & U.V. is best.

For high-fire you will need 2 sets of high and low cone packs:
A. Lower cones for determining progression of temperature & when to begin **body reduction.** Usual low cones are 010, 04, 01 & cone 3.
B. Higher cone pack has your **Glaze temperature cones -** Glaze cone pack should contain 6, 8, 9, and 10. Cone 6 is the guide that should signal the start of damper adjustments for heat distribution top to bottom and the gradual progression (increase) of reduction. **Place cone packs on I.F.B slice** or make a boat for all of the CONE PACKs. The lower CONES WILL MELT down into a puddle and run WILD if not contained. An accurate accounting of all firings should be maintained. Kiln chart/ledgers noting the numbers of the cones in the cone packs will help you to know what you're looking at.

Placement of cone packs - Cone packs are placed in front of the peepholes, usually made with the body you are using in the ware. If two cone packs are needed (low and high temperature cones) Place the low temperature cones to the front (they will melt out of the way before the glaze cones –high temperature cones- are needed) facing in one direction, and the glaze cones in back facing the opposite way. Placing cones with a solid background using a large form or shelf support will help the cone visibility. Check position for cone visibility with the kiln door closed using a light source. Single event flashlights are flashlights that were misplaced and abandoned in the kiln during the loading and remain for the duration of fire. Cell phones and flashlights prefer temperatures under 200^{o}F.

Glazing - Most glazes benefit from even/uneven glaze application. This is most easily accomplished by dipping. A stronger bond of body to glaze is gleaned by dipping vs. spraying. See Information on glazing and high-fire glaze tendencies in Richard Burkett's "**HyperGlaze Software**.

Pot bottoms should be waxed (dry-footed, i.e. unglazed) to resist glaze application, as well as lid seats and lid edges if you plan to fire with the lid in place to reduce warping. High-fire glazes tend to move (run) during the firing, 1/4" should be left between the pot bottom and the beginning of the glazed area to prevent runs onto the kiln shelf. Your should consider this when making work, a deep bevel is made on the foot that catches the glaze and creates a shadow so the piece visually sits gracefully and also visually lifts the pot the 1/4" area needed above the kiln shelf w/o showing a ring of bare clay at the foot. If glaze sticks the piece to the kiln shelf, it may break the piece as it contracts in cooling. The work's owner will be asked to chisel/grind/remove (after a review of instruction in cleaning kiln furniture) the glaze from the kiln shelf and restore to the shelf to a working condition. In extreme cases of negligence students will be expected to replace kiln shelves. Thicker glaze applications tend to run more than thin ones. Combinations of glaze (e.g. double dips) may form a **eutectic** and produce runnier areas. **If you feel you are using a thick glaze application and/or doing**

experimental combinations of glaze, please make sure you work is loaded into the kiln on a **clay slab** or **I.F.B. slice** or **wad clay** or **a piece of broken kiln shelf** under it **to catch any runny glaze drips.**

Loading -Before you load, know your surrounding. Remove all combustibles form the kiln area, check to see that the kiln is free of debris around the ports and behind the bag wall. Check for shards, etc. Check to see that all the gas valves are closed. Check to see if the orifices and the burner's mixing chamber is clear and in working condition (a flashlight and mirror are needed for this operation). Check to see the working order of the blower system (Does the squirrel cage turn?). If you have any reason to suspect a problem with the kiln, test it before loading to make sure it is working properly. Use the silicon carbide shelves or the special Cordierite kiln shelves for the gas kilns. THESE SHELVES ARE HEAVY & EXPENSIVE. Please be careful and do not drop them, do not prop them against movable items. Find help if you have trouble lifting and placing shelves in the kiln. Check each shelf for proper kiln wash. This protects the shelf from glaze drips and makes it easier to chisel off any glaze runs. Kiln wash should be in a container in the kiln area. Apply a thin kiln wash application w/a brush or paint roller. Kiln wash should be the consistency of light cream. Several thinner layers stick better than one thick one. WASH ONLY THE TOP OF THE SHELF. Always keep kiln shelf sides and bottom clean and clear. Wash on the sides or underneath may pop off and fall into the work below. Kiln wash for low-fire and reduction firings is 50 silica + 50 EPK by weight. Substitutions in kiln wash for better quality wash (including soda salt and wood fires): alumina for silica, E.P.K. addition can be altered with 10-20% calcined E.P.K. for a better fit. A 10% addition of Epsom Salt to wash batch enhances the kiln washes corrosive resistance.

WARNING: Always **(Becky)** wear close-toed shoes when loading the kilns**.** If you are using the thin, **bonded silicon carbide shelves DO NOT EVER fire them wet or damp.** If they need to be kiln-washed, they must be completely dried before using them. If these shelves are heated wet, they may **EXPLODE.**

Post the first shelf with a H.F. Brick thickness off the kiln floor for adequate heat/air circulation. Each bottom shelve should have six points of support on each shelf and be level (front to back & side to side). Generally second level and up shelves are tri-posted while sharing end posts when possible. Shuttle or Car kilns should always share furniture post for the stability of the load. Posts supports are always placed above each other when loading subsequent levels so that the posts, not the shelves, bear the weight of the load. Our silicon carbide shelves are 200lb load limit per shelf.

Ware is grouped by height, and similar heights are loaded on the same shelf to use the space efficiently. Very tall pieces are often put on the top shelf so that multiple posts don't have to be used to achieve tall heights. The ware selected for the bottom shelf should be at least 6" high. A very low first shelf (say, plates or tiles) does not allow adequate heat circulation, and may result in under-fired or under-reduced works on the bottom. Avoid stacking shelves at the same level as the bag wall. This can cause the kiln to be hot in middle and cut flow to areas of the kiln. Check the bottoms of all ware and lids as you load to make sure there is no glaze. Always check to make sure the clay does NOT look like terracotta. If lowfire clay is accidentally fired to cone 10, it will melt and stick to the kiln shelf with the potential to ruin adjacent work and shelves. If anything looks like it may run too much, put it on a piece of I.F.B. or a broken kiln shelf or a brick or a layer of unfired 200 mesh alumina of silica to protect the kiln shelf. Glazed ware may be placed to the edge of the shelf, close together, but not touching. Each shelf course in the kiln should start by positioning shelves and shelf supports (and cone packs) before loading wear. **Full kiln loads** – are always to your advantage economically and esthetically and easier to maintain a consistent, even temperature and atmosphere in the firing. Kilns fire and cool more evenly; your glazes will be brighter & richer as crystal layers are allowed to form naturally in the cooling process.

Updraft & Downdraft loading –
Updraft kiln shelf placement should be center and equidistant from each side or center/center. The space between shelves should be consistent throughout the load. If kiln is dropping debris during

finish fire, you may choose to add blank top shelves to umbrella or shelter wear from falling debris during finish fire.
Downdraft shelf placement is extremely critical. The space between shelves should increase as they move from the exit flue opening. The increase in volume (size of space between shelves) helps to equal the exit flow or velocity of heat as you move away from the exit flue. Without the proper shelf placement, the kiln will develop and maintain HOT and cold spots. The staggering of shelves is dangerous in car/shuttle kilns in that it reduces the stability of the ware as the car is moved. Staggering shelves is most effective for walk-in kilns that do not move or electric kilns without envirovents. Backpressure with a forced air system that is measured at the bottom peep will yield even distribution of heat if shelves are placed properly. Kilns without a channel can be corrected by placing a shelf to contact the back wall above the flue opening. The row of shelves the follow should follow standard rule of increasing space between shelves as they move further from exit flue. All subsequent course levels can be started within two inches from back wall if the space increases as it moves further from the exit flue wall. Baffle bricks can be used on and under shelves to control the flow of exiting heat by adding bricks to baffle/control/direct the flow of exiting air.

Firing – When loading is complete, check the kiln ledger/chart and make sure the cones for the cone packs are noted. With the damper slightly open, approximately 3" open (less is better), all air/blowers on w/flaps closed, light the first burner. Adjust gas to the air (on with air flap closed). Generally candle/preheat the gas kiln with a strong blue cone heat overnight. With an early start you will finish your firing at a reasonable hour. Turning one or two burners on low /preheat setting overnight is a judgment call. Turning the air slightly higher on all unlit burners will strengthen the flame of the lit preheat burner. Generally, burners with retention tips on very low overnight are safe. You should frequently check your kiln/burner condition. Always evaluate the kiln and its condition before changing anything. Back burning yields a long bright yellow flame. The burner pipe will be too hot to touch. If burner is back burning turn burner off/allow time to cool burner pipe and relight with the proper air/ gas ratio. Blue cone should always show at early stages of firing.

Glazed ware holds less physical water than greenware, and the chemical water has already been fired off, so a glaze fire is less likely to explode from water turning into steam at 212° F than in the bisque. Be cautious if recently glazed pieces, especially thick ones that are still cold to the touch. They may be holding too much water and could cause layers of glaze to peel off of wear. Temperature should be increased gradually until the kiln is past red heat (about 1000° F), which is also quartz inversion, where silica changes shape. Remember clay expands then it contracts or shrinks 8-12% in bisque firing. Always fire slower than normal when re-firing any work that has been previously finish fired.

OXIDATION is complete combustion of fuel in the presence of adequate oxygen. Even with a complete efficient combustion you will still experience a normal 12% non-combustion of fuel (natural gas). The flame should appear blue, short and sharp, the kiln atmosphere will look clear, and the kiln makes a roaring rumbling sound. You should experience minimum backpressure of flames from damper or peeps. The gas should combust at the burner tips. The most efficient combustion (neutral flame) and will cause temperature to rise the fastest. Check for debris in firebox. The debris should be the brightest spot of light in firebox when the burners are combusting efficiently. Your kiln can be as **inefficient** in **oxidation** as it is in **reduction**. You can loose heat by oxidizing or reducing too much.

REDUCTION is incomplete combustion of fuel, caused by a shortage of oxygen, which produces carbon monoxide. Reducing flames will appear soft, licking, long, with orange/yellow tips. The kiln atmosphere will be murky. Backpressure or incomplete burned gasses will be seen as visible yellow, orange or blue flames at the damper and peeps. Black smoke indicates too much gas (wasted fuel), and can cause black-coring or glassifying clay bodies and dull glazes. It is not necessary to reduce this much. Inefficient combustion (oxidation or reduction) will slow the temperature climb. A kiln in reduction will help even out the kiln temperature. **You should do reduction at cone 010, and reduce for 20-40 minutes.** If you begin reducing later than 010, you have missed your window for body reduction. After body reduction, return to the setting that preceded the body reduction to clear

and clean the atmosphere with minimum gain of temperature. Match the time clearing atmosphere as was used to reduce the body. Minimum gain of temperature during body reduction will assure a good warm body color.

NEUTRAL or a **slightly reducing** atmosphere will produce a blue to greenish flames. After body reduction, it is common to leave the kiln in a neutral atmosphere to **slight** (NOT HEAVY) **pressure in reduction till cone 9 (slightly increasing reduction from cone 8 through 9**, then final glaze reduction from cone 9 almost down (4 o'clock position) through cone 10 tipping to 2 o'clock. Do not clear or oxidize the kiln at the conclusion of glaze reduction. The kiln will oxidize or clear naturally at turn off.

Kiln Control - Controls on the gas kiln consist of the **GAS** valve with a water column gauge that controls the amount of BTU available to the burner. The **PRIMARY AIR**, which is the blower on forced-air kilns, is the main control for the atmosphere. The **DAMPER** on the exit flue, controls the heat distribution from top to bottom. There are different combinations of these three primary controls that can assist but first one must understanding the three primary elements that control your kiln.

The primary controls work together to produce the desired effect. To produce an oxidizing flame, turn the gas to the desired heat level (B.T.U.). Adjust the primary or the forced air flap to adjust the air/gas ratio that produces a blue, sharp cone. You adjust the damper to distribute the desired heat from top to bottom. Creating turbulence with blowers and creating backpressure out the bottom peep assures even heat distribution.

To put the kiln into reduction, set the BTU with the gas, atmosphere through the blower (air to gas ratio) adjust the exit flow of the kiln with the damper to get a **backpressure** at the **bottom peep**. Make sure the **color** and flame velocity of bottom peep flame is controlled with the atmosphere (BURNER: air to gas ratio). Control peep flame with air and gas controls for flame color at the bottom peep. The amount or volume of backpressure is controlled with the damper. The pressure in the bottom peep should come out of the bottom peep (4-6 inches) and curl up two or three courses of brick. Notice the **velocity** & **color** of the flame exiting the bottom peep. The **bottom peep** is the best visual control of your kiln. Most people have difficulty viewing cloudy atmosphere or swirling gasses in the kiln. Rely on your understanding of this information, **not** the kiln gods.

The firing is oxidized from pre-heat to about cone 010. As cone 010 moves past 2 o'clock start body reduction. Reduced the kiln for 20-40 minutes, minimize any temperature gain in this critical stage. Checking the bottom peep should reveal a lazy flame exiting the peep and licks two to three courses of brick up the kiln. Color of flame is important to register as blue with a yellow tip is light to medium reduction and yellow with slight smoke is heavy reduction. When body reduction is complete (with no increase in B.T.U.) put the kiln into a neutral atmosphere for 20-40 minutes (open air flap and adjust damper if needed) to clear atmosphere. After clearing, proceed with firing by increasing the B.T.U. and adjust air/gas ratio to a light to medium reduction atmosphere until cone 6. The kiln is reduced with a medium reduction atmosphere from cone 6-8. From cone 8-9 increase reduction. Damper adjustments should be made (cone 6-8) to bring kiln to a more even distribution of heat. Damper adjustments are made while maintaining pressure at the bottom peep. Back Pressure or volume at the bottom peep remains the same but the flame color changes as you go through the cones while increasing reduction. As cone 9 falls, the kiln should be put into a final glaze reduction to finish the firing (usually the last 20-40 minutes). This will allow glaze materials to settle down. Once the kiln reaches the glaze maturity point between cone 10 standing tall to cone 10 @ 3oclock), turn off the kiln. **Turn the electrical blower switch off**, **close the each individual gas valves and the kiln master valve**. **Close the damper** to keep cold air from blowing through the kiln. Most glazes benefit from slow cooling (layers of crystal growth), and all need time in a molten state to allow bubbles to smooth out. Cold drafts can cause uneven cooling during quartz inversion or cristobalite inversion may cause **dunting**, or cracking though the body during cooling. After burner gas is off and blowers are turned off, close the damper and place the fiber squares in the burner ports. Make sure

the air flaps are wide open after turning the electricity to blower is off, this allows the burners to remain cool and extends the life of the burners retention tips. Retention tips must remain free & not in contact with any material when in use, outside contact will cause hot spots and premature deterioration. Note the time and adjustments on the kiln chart. Firing notes and observations are most important for a post firing review.

Safety
Please be cautious of loose clothing & tie hair back before checking the kiln. Remove and replace peep plugs from the side to avoid any backpressure. If you have trouble viewing the cones w/back pressure coming out the peeps, reduce the backpressure by opening the damper a bit. When viewing kilns above orange heat, **use protective dark green glasses intended for U.V & I.V. eye protection**.

TROUBLE-SHOOTING
You need to review the kiln conditions to make appropriate judgments for adjustments. Downdraft kilns react somewhat differently than updrafts, and each kiln had it's own personality. Differences in loading and weather may also affect firing. Generalizations below are for the updrafts.

If you have the damper wide open, you may be losing so much heat out the flue that the bottom will be cold in spite of an oxidizing flame. If the bottom seems cold (often the case early in the updraft firing as the kiln heats), close the damper a bit. Damper controls the distribution of heat.

Adjust air (blower) to control atmosphere, adjust the gas for BTU/ color flame (at the bottom peep) and the damper for proper velocity at damper and the backpressure at the bottom peep.

If you have the damper closed too much, you may find it difficult to get a clean, oxidizing atmosphere with excessive backpressure. Open the damper a bit and/or reduce the gas. You should always gain heat by opening the damper at the risk of losing reduction.

IF the kiln seems to stall toward the end of the firing, check the gas to air ratio. Make only single adjustments and wait twenty minutes before making additional changes. (1) Damper controls heat top to bottom (2) air controls atmosphere (3) gas controls the burner BTU. **REMEMBER that any change you make may take 15-20 minutes to show** an effect. Constantly changing the kiln settings may slow firing. Please note all changes and results on the kiln chart/ledger.

When the desired end temperature is reached, turn off the individual gas valves; turn off the blowers, and close master gas valve. Close the damper so that cool air does not continue to flow through the kiln. Note the time on the kiln chart after blocking secondary airports with fiber blanket squares and open-air flaps to allow burner/retention tips to cool.

Cooling/Unloading
Although it is possible to speed-cool a kiln by leaving the damper open from the end of firing through red heat, this is hard on the kiln structure and may not produce the best glaze surfaces, especially in crystal-surface glazes (the crystals form during cooling, and slow cooling promotes more crystals). Around red heat (1000^{o} F), flint (silica) goes through **QUARTZ INVERSION**, and the piece becomes about 2% smaller. This should happen slowly to avoid **dunting** (cooling cracks). Free silica in the clay can be converted to **cristobalite** when fired above about 1940^{o} F. This will invert and get about 3% smaller on cooling at 439^{o} F. This can also cause dunting if it happens quickly. A classic test for whether a kiln is cool enough to open is to put paper into a spy hole. When a paper no longer ignites (paper burns at 451^{o} F), you may open the damper a crack and remove the fiber from the burner ports. Please wear clean gloves to Unload when kiln is close to room temperature.
Persons unloading should note any unusual results from reduction or lack of while the kiln is still loaded and note positions of any un-reduced or under-fired work (note this on the back or bottom of the kiln chart for reference) even take photo's. Unload the work onto a cart. Remove shelves. Chip any glaze runs off with a chisel and hammer and/or rub off w/a black silicon carbide shelf scrubber.

To avoid cracking the shelf when chipping glaze off shelves, it is helpful to put the shelf on a resilient surface (e.g. wood), or lean against an immovable object at an angle and/or chip at an angle, not straight down. Re-apply kiln wash to the shelves. **WEAR SAFETY GLASSES and your M.S.A. respirator** during this process**.** Replace the shelves in the cabinet, stacking the shelves face-to face and back-to-back (to prevent wash chips on the backs of shelves that could fall into the work in stacking the kiln). Please take time to re-stack/re-organize kiln furniture, Sweep and vacuum in and around the kiln. Close damper and air flaps. Retrieve fiber squares from burner ports and store in the kiln shelf cabinet.

Bibliography - Clay and glaze discussions with Val Murat Cushing.

Hamer, Frank and Janet, *The Potter's Dictionary of Materials and Techniques,* 4th edition Univ. of PA Press, A & C Black, 1997.