RAKU 101

Practical Notes

Raku firing is like chess: you can learn the basics of the process in a day, but spend the rest of your life mastering all the possibilities. By the nature of the process, every piece you fire will be unique. You can influence the outcome for your fired pieces by manipulating some of the variables, but you can never truly control the process.

The central fact of raku firing is that it's FAST! Depending on your equipment and individual preferences, you can finish a complete firing cycle -- from lighting the burner to seeing the finished results -- in as little as one hour. Compare that to the seven-plus hours required for an electric lowfire glaze firing -- and that does not include cooling time! Everything you do in raku will be affected by the speed of the process.

Clays To Use -- You can raku just about any clay. Lowfire, midrange, stoneware, earthenware, white , red or brown: try any of them. I've successfully raku-fired porcelain. The different characteristics of the clay blends dictate how well they come through the firing process. To survive the process without breaking, the clay must be able to expand and contract with the changing temperature. It's the sudden, radical changes in temperarutre, and resulting fast expansion and contraciton (called "thermal shock"), that causes pieces to crack and break. The thermal shock can be ofset somewhat by slowing down your firing cycle and easing pieces through critical firing points.

1. Raku Clays - Specially formulated raku clays may include materials like Kyanite, which are intended to help them withstand thermal shock. Grog and sand in the clay add strength as well as texture. These materials help, but they'e not foolproof. You will lose some pieces in raku firing. There's simply no way around it.

2. Contruction - When making or choosing pieces for raku firing, uniform thickness is very important. Wheelthrown or handbuilt pieces sometimes have thick spots or heavy bases. It takes longer to heat these thicker areas, so they expand more slowly than thinner parts of the same piece. This stresses the clay, contributing to cracks and breaking. Slipcast pieces actually have an advantage over wheelthrown and handbuilt pieces because they are more likely to be all one thickness.

3. Bisque Firing - The temperature of the bisque firing makes a difference in the survival rate of your pieces. The most common bisque firing temperature is cone 04. In bisque firing, clay undergoes a process called vitrification: the particles soften and partially melt, moving closer to each other and bonding more tightly together. Vitrification is the process that causes pieces to shrink in firing. The smaller and more uniform the raw clay particles are, and the longer the piece is exposed to firing temperatures, the more the clay vitrifies as the particles bond together. Fine-grained clays like porcelain or white earthenware vitrify at cone 04 faster than large-particled, coarse or textured clays like stoneware or sculpture clays. The degree of vitrification directly affects the clay's ability to expand and contract under the heat: as the bond between particles gets tighter, the clay's flexibility -- its ability to expand and contract -- is decreased. I get the best results with bisque firing only to cone 08. This cooler bisque temperature leave the clay less vitiriied, so it has more flexibility. This also leaves more room between the clay particles for smoke to penetrate and blacken unglazed areas.

4. Slip Cast Questions - When firing slip cast figurines or other large hollow pieces with pour holes in the botttom, prop them at an angle on posts, brick pieces, shelf pieces, or stilts. This allows heat to flow over, around and under the piece, penetrating and soaking into the piece more evenly. Heat these pieces slowly. As the temperature rises in the kiln, the difference in temperature from the outside to the inside of the piece may be enough to shatter it. With handbuilt or slip cast pieces, mud-on parts or addition points are frequent spots for cracks and breaks.

When choosing slip cast pieces for raku, look for pieces that are no more than 1/8" thick. If slip cast pieces are too thick, they run a greater risk of cracking or breaking. Slip is a suspension of clay particles in water. The particles are very fine, and pieces made from slip are (or should be) very smooth, even satiny to the touch. There is no sand, grog, kyanite, or other material to lend strength to withstand the thermal shock process.

5. Loading the Kiln - When loading the kiln, try to keep pieces of similar size and mass together. If you mix large and small pieces, you're likely to overfire the small ones while waiting for the large ones to reach temperature. Also remember that surfaces toward the center of the kiln can shield each other: they'll be slower to heat and the glaze slower to mature.

Small pieces are harder to raku than large ones. Small pieces have less mass, cool more quickly, and don't hold as much

heat for as long a time when removed from the kilns. If you have multiple small pieces to fire like jewelry pieces, earrings or ornaments, you might try suspending them on pieces of high-temperature kanthal or nichrome wire stuck into a scrap o firebrick. This will give you a larger object to grab with your tongs when removing them from the kiln, and provide more mass to hold more heat to promote reduction.

The Firing - During the raku firing, you are balancing and juggling oxidation and reduction atmospheres in both the kiln and the reduction chamber to get the color effects you want. Oxidation and reduction are not really polar opposites; they represent more of a continuum, along which your glaze colors will change. Color results from any point of the spectrum can be desirable, depending on your own preferences.

1. Oxidation - "Oxidation" means that oxygen is present in the firing atmosphere. Copper oxides fired in oxidation atmospheres produce shades of green and blue. Think of a copper or bronze statue standing in the outdoors and weathered by the elements. What color is it? That is an oxidation color.

2. Reduction - Oxygen is not present in "reduction" atmospheres. Reduction atmospheres in raku are not often completely free of oxygen, but oxygen is present in lesser percentages than in the surrounding environmental air. Copper oxides fired in reduction produce darker shades, from tomato red through oxblood red to purple. The same copper oxides change color in reduction because sustaining the fire in either the kiln or the reduction chamber requires oxgen. If there is insufficient oxygen available in the air, the fire rips the oxygen it needs out of the copper oxide in the glaze. (This also applies to other oxides, like cobalt.) This leaves only the pure metal, thus changing the fired color result of the piece. In the case of copper oxide, when the oxygen is removed, it changes back to the bright, shiny metallic color of a new penny.

3. Lusters and Iridescence - Many people love the bright, flashy metallic splashes and streaks of color that can come from raku glazes. These lusters appear in a fairly narrow zone between the spectrum extremes of oxidation and reduction. To get lusters, you need some oxygen (oxidation) ... but not too much. You also need some reduction ... but not too much. Finding that right "zone" for your pieces is a process of trial and error experimentation. Hitting that zone consistently will mean learning about how to fire your pieces, how big they are, how they're made, the density of the clay, the size of the reduction chamber, density and type of combustibles, and even such seemingly "minor" variables as ambient humidity and barometric pressure. (Yes, they DO make a difference!)

The Firing Cycle - Raku firings are generally done in three stages, with the burner set on low for 10-15 minutes, medium for 10-15 minutes, and high for 5-10 minutes. There are many different kinds of raku kilns, home-built or commercially manufactured. Differently constructed kilns will have different working characteristics: some will go faster, some slower. The exact length of the firing cycles is also a matter of your preference: how hard are you willing to push your clays? You can vary the speed of firing as you fire different clays. The important part is not to stick to one firing schedule, but that the glazes melt and mature properly.

Time your firing by listening to the sound of the burner and watching the color and melt of the glaze. Raku firing just goes too fast for witness cones to be useful. (When a kiln reaches temperature, it may still take up to 15 minutes for witness cones to bend properly. By the time the cones bend, your raku glazes may be overfired.) Gloss glazes, especially White Crackle, are the most reliable timers. Gloss glazes will "flux" and boil up, so that the piece appears to be covered in soap foam, and then smooth down so that the piece appears glossy and wet. At full maturity, the pieces are actually covered in a thin layer of liquid glass. When the glaze looks shiny and wet, with a uniform glow and color, your pieces are ready to pull out of the kiln.

When the glazes melt and smooth down, you may notice streaks, light spots, or dark areas in the liquid glaze. This indicates that the pigments were unevenly distributed as glaze bubbles formed, rose and popped while the glaze fluxed. Wait for those streaks to disappear: then continue your firing for a couple more minutes. You will see the streaks and spots gradually disappear as the pigments are distributed more evenly.

If you fire at night, watch for the size of the flame plume rising from the kiln flue when the burner is set on high. The height of the plume indicates the amount of reduction in the kiln. Flame plumes more than 4" to 6" high indicate heavy reduction in the kiln. Heavy reduction may throw your glaze colors toward darker reds and purples. If you want less reduction in the kiln, turn down the gas PSI at your regulator. (This flame plume is almost invisible during the day, but it is there ... so be careful of it.)

Critical Firing Points - There are three temperature points where your piece is most likely to break while firing. These temperatures are roughly 212°F (the boiling point of water),

450°F (the steam flashpoint), and 1050°F (where quartz inversion occurs). These temperature critical points roughly correspond to when we turn the burner from low to medium to high.

Water boils at 212°F. When the heat builds up in your piece to this temperature, any remaining water on or in your piece literally boils. The steam has to go somewhere, and may crack, break, or blow apart your piece. For pieces that have already been bisque-fired, the most likely source of water is your preparation of the piece. To remove dirt or dust, use a brush or blow if off rather than rinsing the piece. Some of that water may soak in ... and it has to come out sometime, somehow in the kiln. If you have to rinse a piece to remove stubborn dirt or wash the gaze off to start over, set it aside to dry for a day. Come back to it later.

Glazing does not generally "wet" a piece enough to cause problems in the kiln. It's generally good enough to allow a piece to dry in the sun (or in a cooling kiln) for about an hour before firing.

This logic, that water flashing to steam has to escape the clay somehow, also applies to common everyday air that was trapped in the piece during forming. This sometimes happens with wheelthrown pieces, and is not uncommon at all with handbuilt pieces. When building pieces by hand, be *very* careful to avoid folding air pockets or bubbles into your clay. Sooner or later, whether in the bisque firing or the raku firing, that air will heat up, expand, and have to get out -- which means your piece may go "boom".

The second critical temperature point comes at roughly 450°F. At this point, any remaining chemical water -- not visible water, but water compounded into the glaze components -- burns out. Burning out the water in your glaze will change the color of the glaze on your piece. Glazes that are milk-chocolate brown when applied will turn dark-chocolate brown, or olive-green glazes will turn darker green or brown. Blue glazes may turn grey. This means that the water has burned out, and so have the organic gums that make the glaze brushable. When you see the glazes change color, it's time to turn the burner from low to medium.

The third critical temperature point comes at roughly 1050°F. It's the quartz inversion point. At this temperature, the crystalline structure of the quartz present in all clay ... shifts. It literally tweaks itself into a different form. This is a stress point for all clays, and particularly for handbuilt pieces where the clay particles are not compressed and line up (such as happens in wheelthrowing). Try to ease the clay through this temperature range with a steady, even, slow temperature increase. Allow more time with the burner at a "medium" flame setting. If you adjust the burner too high, too fast, you'll increase the change of this stress breaking your piece.

Note, too, that the quarts inversion point is reversible. As thepiece cools, the quartz crystalline structure un-tweaks and goes back to its original form. This is also a stress point for the clay.

When you see the glaze beginning to bubble along the edges, rims, corners or lips of a piece, it's a pretty safe bet you have successfully eased the piece through quartz inversion. When the glazes begin to bubble along edges or corners of the piece, the glazes have begun to melt. It's time to crank the flames up to "high" and finish the firing.

Post -Firing Reduction - The spectacular colors of raku are created in the post-firing reduction by the interaction of flames and smoke with the chemicals and metals in the melted glaze. The outcome is subject to the influence of many variables, including environmental conditions, time in transit, type and amount of combustibles used, position of the piece in the combustibles, and volume of the container used for reduction.

1. Environmental Conditions - It's hard to exactly quantify how, but raku results vary widely with the temperature and humidity at the time of firing. Many raku artists swear they get their best results on cool, damp days -- even when it's actively raining or snowing. I have observed that on hot, dry days (temperature over 90°F and low humidity), my raku results tend toward more and darker reds. This would appear to be caused by the relatively lower "weight" of the air: there is less oxygen present at the time of post-firing reductions. Experiment and see what works best for you.

2. Time in Transit - As soon as you open the kiln, the pieces begin cooling. Work on moving the pieces from the kiln to the reduction containers as fast as safely possible. The first 300 to 400 degrees are critcal to the glaze colors. The most common peak temperature for raku firing is cone 06, or roughly 1840°F. Glass -- the raku glaze -- melts at roughly 1450°F. You have a "zone" of about 400 degrees to work with before the melted glaze cools enough that it begins to solidify, forming the hard glossy shell. This "zone" is where the flames and smoke can most easily work on the glaze to create spectacular effects and colors. You want to ge the glazes in the smoke and fire before the termperatue drops below 1450°F. As soon as you shut off the gas and open the kiln, the timer is ticking as the glazes begin to cool. the exact amount of time you have to work with will vary with the size, density and mass of the fired piece.

Smaller pieces allow very little time to move them.

To give myself a little more working time, I sometimes leave the burner running while moving the pieces of of the kiln. THIS IS NOT RECOMMENDED FOR BEGINNERS! You can experiment with this technique as you get familiar with your kiln and working around the heat and flame.

Moving your pieces from the kiln to the reduction chamber is a good way to promote reduction effects, IF that is the color effect you want. If you want more oxidation colors, or if you find that the glazes are tending toward reduction color because of environmental factors, you might consider allowing your pieces to cool in the kiln before placing them in reduction. When I want more blues and greens or lots of luster flash, I may allow them to cool in the kiln (with the gas shut off) for up to 40 seconds before moving them into reduction. Again, the amount of cooling time wil vary with the size, density and mass of the piece.

3. Types of Combustibles - The chemical content of the materials you burn in the reduction chamber will make a difference in the color on your pieces. Some examples include banana peels (potassium, which yields greens and yellows), kelp (iodine and salt, for browns and oranges) and cedar shavings (complex aromatic oils for rainbow lusters). All these materials burn differently. It is not necessary for the materials (like banana peels) to be completely dry. In fact, you can get some interesting textural effects on the glaze by using fresh or damp materials, like setting a hot piece directly on fresh banana or orange peels. (Setting the peels on the piece doesn't work as well. The heat causes moisture in the peels to flash to steam, and the peel skates right off the piece.)

The best combustible materials are organics which have not been chemically processed. Chemically processed or chemically created materials often release toxic substances when burned. Never use any kind of plastic, styrofoam, or petrochemical product in reduction. Styrofoam is particularily dangerous: its oily black smoke contains cyanide in potentially lethal quantities. Petroleum products like motor oil and gaoline are dangerous for two reasons: One is their relatively low ignition points and their tendancy to explode into flames. Two, particularily in the case of used motor oil, is its toxicity. They are just loaded with heavy metals.

When choosing materials for your reduction, research their properties. Burning some materials, even organics, may hae consequences you did not intend. For example, many people like to use sage in the course of creating ritual vessels or objects. Burning sage has been identified as contributing to pregnancy miscarriages. There's a good reason that Native American sweat lodges were often for men only! Juniper gives interesting textural effects, with its clustes of very small needle-like leaves ... but juiper smoke is a harsh lung irritant. Know what you're burning!I work most often with a readily available, inexpensive combustible: newspaper. I prefer to tear the paper into strips by hand for two reasons: One is that mechanical or electrical shredders yield thin strips that are completely consumed very quickly. Strips about ½" to ¾" wide last longer. Not much longer, but enough to make a difference. Two, shredded paper has very sharp edges. When you put a hot piece down into the paper, those sharp edges last long enough to cut into the melted glaze. The marks last as the glaze cools. Some people find these "fire marks" desirable, and others do not. There are ways to avoid these marks. Experiment with using flat sheets of paper instead of torn or shredded paper.

Different colors of ink on newspaper really aren't "different" enough to change the raku outcome. Virtually all newspapers use soy-based ink for all their colors; the only difference is in the pigments added to the base. The chemical differences between the piments are insignificant.

Be careful, however, of using glossy paper such as coupon inserts added to the Sunday editions. The gloss comes from a coating on the paper which may be plastic-based ... and we already talked about burning plastics, right? Some artists say that the gloss coating adds color effects to the glaze as it burns, but I haven't seen it make enough difference to matter. Some inserts may also have a"scratch-off" surfaces for contests or sweepstakes. I don't know what this coating is composed of, but it seems like a bad idea to burn it.

4. Amount of Combustibles - There is no hard and fast rule for how much material to burn in your reduction chamber. I prefer working with 20-gallon or 30-gallon aluminum trash cans for post-firing reduction. When working with newspaper, I generally fill the can ⅓ to ½ - full with loosely packed and "fluffed" newspaper.

This is an area where the balance of oxidation and reduction comes into play again. In the reduction chamber is where the magic happens, as smoke, flame and glaze interact to create color effects. We want to allow some oxygen to get to the pieces ... but not too much. We want to starve the fire to achieve reduction ... but not too much. See the balancing act we're performing?

The presence or absence of oxygen varies not just from load to load, but also within the reduction chamber and around each individual piece. When we set hot pieces into a bed of newspaper, as the paper burns, the piece settles toward the bottom of the kiln with a layer of ash and partly burned paper around the sides and/or bottom of the piece. This settling

may create localized areas of heavy reduction on the piece, creating spots or a full ring of copper reduction colors. Working with either denser combustibles (like sawdust or cedar shavings) or packing the shredded paper more tightly contributes to creating a reduction (oxygen-free) atmosphere. The denser or tighter materials shield the piece from available oxygen. Not burying the piece in combustibles, or working with looser packed combustibles, allows oxygen access for as long as oxygen is available as the glaze cools, creating more oxidation effects -- the iredescent lusters and metallic flashes that make us go "ooooooohhhh!".

Troubleshooting the Results - Because raku is an unpredictable process, there will be times when the color results aren't what you hoped. There are no failures in raku, only pieces that you can learn from. Many of the undesirable results arise from misapplication of the glazes.

1. Matte Glazes Show "Riverbed" Cracks" - If your matte glazes (the formulas with dry, sandy finishes after firing) show networks of fine cracks that might be found at the bottom of a dry riverbed, the glaze was applied too thick. Matte glazes prefer thinner applications, meaning either one dipped coat or two brushed coats. When applied too thick, matte glazes may not show the oxidation flashes and results they would with thinner coats. On the other hand, for some kinds of sculptural work, the "riverbed" effect may be highly desirable.

2. "Sandy" Spots in Gloss Glazes - If you see spots where the glossy coating seems "thin" and allow the texture of the clay to poke through, that's a sure sign that the glaze was applied too thin. When gloss glazes are applied too thin, they won't yield much of any color because there simply isn't enough pigment. Unfired gloss glaze on a piece should be about half the thickness of a dime. Sometimes, depending on the glaze, it may take up to five or six brushed coats. Use the thickness of the applied glaze, not the number of brushed coats, as your guide.

3. "Crawl" or "Drip" Marks in Gloss Glazes - You may see this in particulaar when working with gloss glazes that flux extensively, like Copper Penny or Piepenburg Red-Bronze. ("Flux extensively" means they boil up a lot when beginning to melt.) There may be either of two cause for these marks: the first cause is that the pieces were pulled from the kiln too soon after the glaze finished melting. When glazes flux extensively, it may cause pigments to be unevenly distributed when the glazes finish melting. This causes a "splotchy" appearance in the final fired result. The second cause is that the glaze may have been applied too heavily. If, instead of having a splotchy, leopard-spotted appearance, the glaze has tended to congeal and pull itself together, leaving thin or bare spots on the clay,this is a sign the glaze was applied too thick. When the glaze finishes melting, it's basically a coating of molten liquid glass on the piece. Like any other liquid, it has surface tension. Liquid glass, on its own, tends toward a thickness of roughly ¼". It will pull itself together, or spread itself out, to achieve that thickness. It's the interaction of the surface tension with the (relatively) rough, porous surface of the clay that holds the melted glaze in a thin even coat over the piece. If there's enough glaze -- enough liquid glass -- present to overcome its surface tension "grip" on the clay, the glaze may try to pull itself together to reach that ¼" thickness. It will also run and flow under the influence of gravity.

4. Bubbles in Glaze - If you see unpopped bubbles in your glaze after firing, it's an indicator that the piece was either overfired or underfired. Underfiring is far more common.

5. Silvery-Grey Areas Under the Glaze - When you remove pieces with gloss glazes from the reduction chamber, you may see silvery-grey areas on top of or under the glaze. If it's on top, the silveriness is just a fine layer of soot that can be easily scrubbed off. Use a plastic kitchen scrubber and a gently non-abrasive soap like "Dial" liquid hand soap. Stay away from soaps and detergents with ammonia or chlorine! Also, be careful in how hard you scrub the pieces. The iridescent layers are very thin, and you could scrub them right off.

If the silver-grey areas appear to be under the glaze, there is no good way to remove them except to refire the piece. They will not scrub off. Most raku glazes crackle, craze and crack as they cool in the reduction chamber, even if you can't easily see the cracks. Sometimes as the glaze cools there is enough smoke pressure in the reduction chamber to drive the smoke under the glaze, and that creates these grey areas. It's more likey to happen when firing smooth-textured , fine-grained clays like slip cast pieces.

Refiring Your Work - Contrary to what you may have heard, raku pieces can sometimes be refired to get different, more desirable color effects. Evaluate each piece individually: if there are large cracks in the clay body, the piece should not be refired. Raku pieces will eventually crack or break when fired and refired; it's just a question of how many times you can get away with refiring, and the number varies for each piece. If you need to apply more glaze, one extra coat will generally be enough (except for pieces where the original glaze was too thin). If you need to increase the glaze "stickiness", mix 4 ounces of glaze in a separate jar with one or two teaspoons of honey or corn syrup.