

# the salt glaze surface



a guide to salt  
glazing and firing

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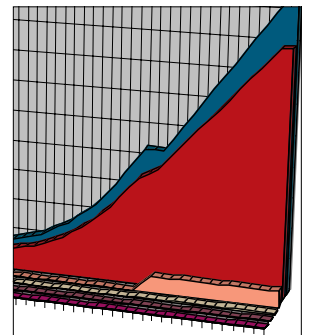
## A guide to salt glazing and firing

Salt firing and salt glazing have been common practice in ceramics for centuries, initially as an industrial glazing method, and then as an artistic treatment and technique in studio ceramics. Not only does salt glazing seal the ware, but it creates a distinctive orange-peel texture that has become a desirable decorative trait of salt glazed ware. We also use sodium in many of our glazes, but if you're going to fire with salt, it is best to use slip and glaze recipes designed to react with the salt in the kiln atmosphere. All of this and more is covered in the free download, ***The Salt Glaze Surface: A Guide to Salt Glazing and Firing.***

### Salt Firing, Science, and the Environment

by Gil Stengel

Many of us know that salt makes a glaze, and that sodium is a component of many of our glazes, but how this works exactly, and what the effects of the process are is difficult to measure without the right knowledge and equipment. Luckily, Gil Stengel and others have done the research and are willing to share their knowledge of salt firing with us.



### Salt Fuming: A Low-Temperature Salt Firing

by Paul Soldner

There is more than one way to salt a fire. The most common way to salt glaze is at high temperatures (around cone 10), but Paul Soldner has been salt fuming at low temperatures for several decades. He walks us through the entire salt fuming process, from loading the kiln to introducing the salt to a post-firing treatment of our work.



### Slip and Glaze Recipes for Salt Firing

Will Ruggles and Douglass Rankin have been admired for their wood-fired, salt-glazed work for years, and their slip and glaze recipes are trusted by many professionals.



# Salt Firing, Science, and the Environment

by Gil Stengel

**H**igh-temperature salt firing is a process by which salt (NaCl) is introduced into a fuel-burning kiln in solid form (table salt is often used) in order to vaporize the salt and spread that vapor throughout the kiln with the flame. The sodium in the vapor will react with the silica and alumina in the clay to create a glaze on the ware. Only a small percentage of introduced NaCl is used to form the glaze. Consider for a moment the amount of sodium present in any glaze. Amounts greater than a few percent are uncommon. Too much sodium, and most glazes become unworkable due to high thermal expansion and excessive fluidity. Given that the glaze resulting from the action of salt introduced into a kiln does fit most clays with some crazing and provides a normally durable surface, logic dictates that this glaze would be similar in makeup to other glazes, and the percentage of NaCl present in all the glaze resulting from a typical salt firing would not be a large number, even factoring in the glaze buildup on kiln walls and furniture. Yet stop and think for a moment—a typical salt firing normally introduces literally tens of pounds of fairly pure NaCl into the kiln. Where is all this Na<sub>2</sub>O going? Not into the ware, as a fairly normal clear glaze builds up there, and not into the kiln walls past the initial buildup, as further deposits are incremental. No, all this Na<sub>2</sub>O is heading right out the chimney of the kiln where either there or somewhere in the gas stream it quickly recombines back into NaCl.

John Neely, in an article in *Ceramic Art and Perception*, postulated that salt glaze itself is probably similar in makeup to nepheline syenite when combined with clay bodies composed of approximately a 1:4 ratio of alumina to silica. The glass buildup exhibited on ware of this kind is primarily made up of the clay constituents themselves, the end result of sodium reacting with the clay surface. Salt glaze is a glaze; however, what looks like a layer of thin glass on the surface of a given salt-glazed piece is that piece's clay body combining with small percentages of sodium. Close inspection under magnification will demonstrate a lack of a glaze/clay boundary, evidence that the glaze is coming from the clay components themselves rather than from a deposited glass layer. Different alumina/silica ratios will result in different percentages of sodium being incorporated into glaze. What is important here is an understanding that salt glaze is only composed of sodium in small percentages.

## Salt Firing and the Environment

Logic and the preponderance of data developed to date indicate that salt glazing is a safe technique, not the environmental danger that some have suggested in the past. The vehicle for the production of dangerous concentrations of hydrochloric acid or chlorine gas simply does not exist in ceramic art pottery kilns. This is not to say these toxins will not be produced in every situation, merely that to date the available data and common sense strongly indicate that this technique is not a health or environmental risk.

At the 1997 annual conference of the National Council on Education for the Ceramic Arts (NCECA), I moderated a panel discussion on environmental issues regarding salt and soda firing. My intention in proposing the panel "Sodium Vapor Glazing: A Measure of Pleasure, a Measure of Guilt" was to arrange a forum where the aesthetic and technical issues associated with vapor glazing could be discussed objectively and rationally, with a minimum of subjective material and, at least for the technical side, emotional content.

The panel title spoke of pleasure and guilt. In the last 40 years, salt firing has reemerged as a vital area of aesthetic research. At the same time, environmental concerns have emerged in all areas of our culture and life, and salt firing has unjustly developed a reputation for excessive pollution.

With the Internet and the attendant instant information access, misconceptions surrounding salt firing have been disseminated widely. For example, posts on one news group many years ago tried to give advice about salt firing this way: "Sodium coats everything and the chlorine gas will come off the kiln at temperatures about 1500°F. The gas is poisonous and is [bad] for the atmosphere. It's the equivalent of burning a huge pile of leaves and oily rags. Your downwind neighbors have a lot more to worry about than you do, so you have to consider where this smoke from your kiln is going to go. Not into someone's house across the street or up the hill or down the hill. Chlorine gas is heavier than air and sinks to the ground."

Another respondent claimed: "Additionally, the chlorine gas will combine with atmospheric moisture to produce hydrochloric acid, for a strong localized acid rain effect that will defoliate trees unfortunate enough to be downwind from you."

Despite the growing body of research demonstrating the benign nature of salt kilns, the volume of erroneous material on the Internet regarding salt emissions is substantial. However, I think it fair to point out as well that the majority of warnings I have read and heard were not given out with malice intended; quite the opposite. Most of the inaccuracies surrounding salt glazing have been stated with the intention of warning or helping another. Nevertheless, the lack of peer review and the liability lawsuit fear that is so prevalent in the United States are still shutting down salt kilns.

During our panel discussion in Las Vegas, Wil Shynkaruk from Utah State University presented the results of his research measuring salt kiln effluent. In the course of his testing, he determined that around 2% of NaCl introduced in a kiln combines with clay. This number corresponds to the results that Peter Meanley published in an article in Ceramic Review, where gas sampling from a salt kiln effluent produced numbers suggesting only a small percentage of salt was forming HCl effluent.

The test results these individuals have published are important because they demonstrate empirically that very little Na<sub>2</sub>O from NaCl reacts with aluminosilicate structures to form glaze. If little Na<sub>2</sub>O reacts in a kiln environment, then very little HCl can form in effluent gases from a given kiln. Most of the salt introduced into a salt kiln exits as salt, around 96% or more.

In Las Vegas, I compared the quantities of salt introduced into a typical fuel-fired kiln to the quantities of gas produced by a kiln's burner. While certainly not evidence of the relative danger of sodium emissions, as a small quantity of some substances can be quite dangerous, I think this comparison is interesting relative to the issue of risk in firings. The chart

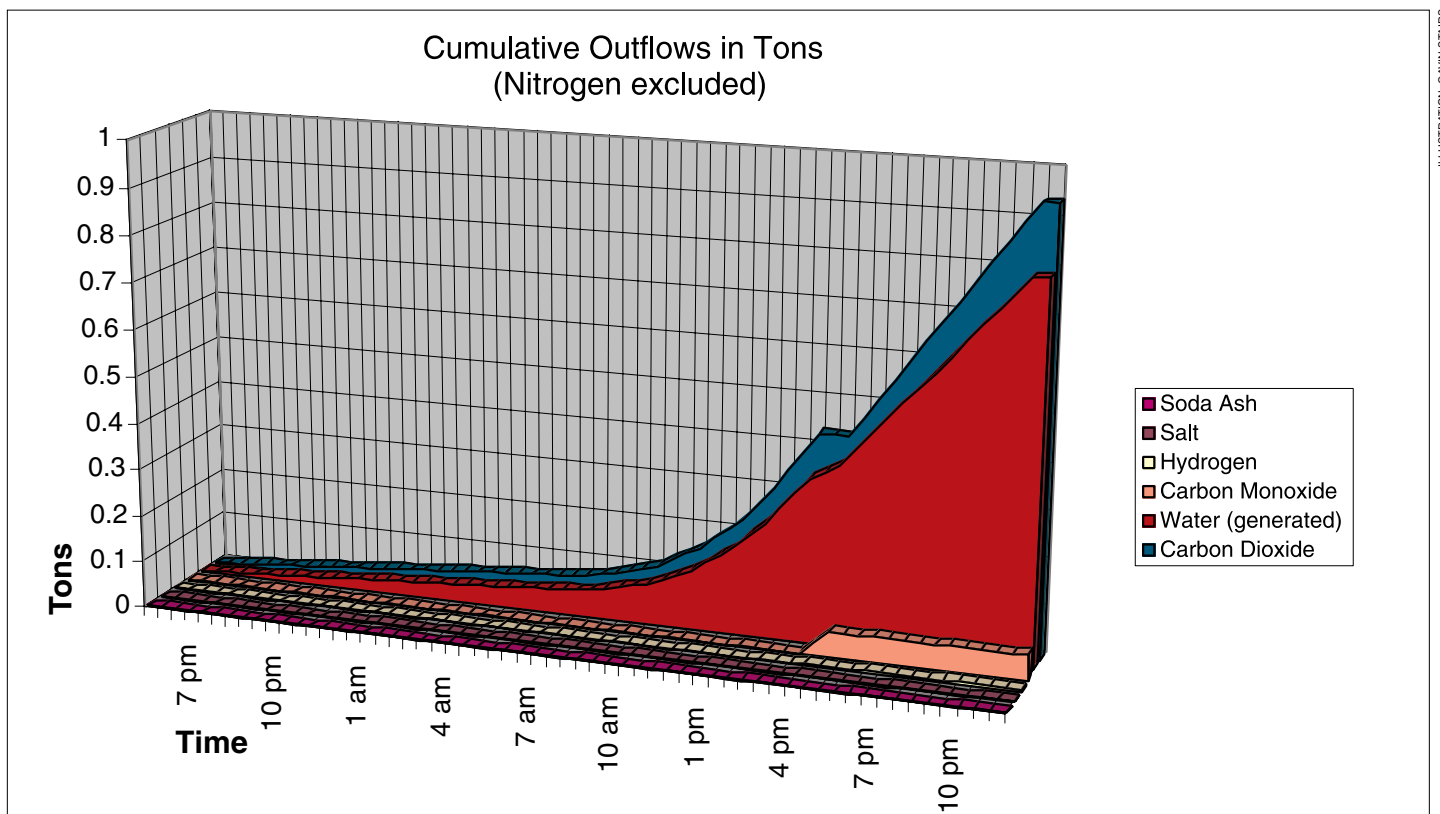
included here was prepared at my request by Gavin Stairs, an engineer and potter in Toronto, Canada.

Carbon monoxide is frequently present in reducing conditions. Carbon dioxide is produced in large quantities. These gases are colorless. Too often I have seen well-meaning teachers admonishing their students to put on respirators while salting a kiln, yet they are allowed to stand around unprotected while a typical reduction firing emits carbon and certainly carbon monoxide. Perception of risk is all too often driven by partial data or trend.

Prior to moderating the discussion in Las Vegas, I searched the American Ceramic Society's extensive library of ceramic technical material, looking for a study of kiln effluent from industrial salt kilns. The technique was widespread in North America and elsewhere for a considerable amount of time in the 20th century and I felt sure that somewhere someone had studied the gas composition from an industrial kiln, but my search at the society turned up no reports on such studies.

As part of this exercise, I combed through back issues of the Brick and Clay Record, an industrial trade magazine devoted to the sewer tile and brick industry. I quickly realized that sodium vapor glazing was abandoned by industry in the 1950s in favor of better-fitting, boron-based applied glazes. What I had thought to be a widespread industrial technique had simply been replaced by superior technology, and the impetus for emissions studies was removed.

This neither proves nor disproves theories about salt kiln emissions. It just means that because of the lack of data, we in the ceramic arts community will have to conduct our own scientific studies. Toward this end, Meanley and Shynkaruk have provided us with different methodologies that yield strikingly corresponding and very encouraging numbers.





# Salt Fuming: A Low-Temperature Salt Firing

by Paul Soldner

I am often asked why there isn't any written information on how to do low-fire-salt fuming. Despite the fact that it has been practiced for more than 20 years, I don't know of any books or articles giving specific directions. The following are concepts and methods I have learned mostly through trial and error.

In the beginning, it should be expected that there will be even more accidental effects from low-fire salting than ever found in raku. Perhaps this is the reason that so little information is available. Nevertheless, with experience accumulated from each firing, potters can discover what works best in their own kilns. And, yes, soda can also be fumed in the same way as salt.

## The Clay Body

Almost any clay can be used in low-fire-salt fuming, but if orange-flashing effects are desired, then the body should include some iron oxide. If slips, terra sigillata or stains are to be applied to the surface, the clay body can be any stoneware, porcelain or a raku blend.

My favorite low-fire-salt body is a mixture of equal parts plastic fireclay, Kentucky ball clay (OM 4), red clay, and sand (20 to 60 mesh). Note that there is an absence of flux; however, salt vapor fluxes the body, making it harder than regular bisqueware even at cone 010.



Low-fire-salt vase, 18 in. (46 cm) in height, thrown and altered, with slips and fumed copper.

## The Kiln

Either an updraft or downdraft fuel-burning kiln can be used. Excellent results can be obtained with hard-brick, softbrick, even fiber kilns, but the burner ports must enter horizontally. Kilns with bottom burners cannot be used because salt cannot be volatilized anywhere in the kiln except in the burner flame itself.

A salting port should be located directly above each burner so that salt can be dropped into the flame. Because it is important that salt fall into the flame, each burner port should be no higher than the kiln floor. If it is higher, build a salting platform level with each burner. The kiln also needs a peephole near the bottom of the door so that the quality of the atmosphere can be inspected during the firing. Finally, there must be a primary-air control on each burner.

## Stacking

Effects of low-fire salting can be compared to high-temperature wood firings. Variation is enhanced by the flame moving through the ware; there is also a flame-resist effect when work is tightly stacked and touching. In some ways, flame movement is similar to the beautiful patterns produced by a river flowing under, over, and through rocks. In this case, the flame is the river and the pots are the rocks.



Low-fire-soda, thrown-and-altered form, 27½ in (70 cm) in height.

Specific patterns can be achieved by masking surfaces with thin (approximately ⅛-inch-thick) pancakes of clay. Several layers of pages from glossy magazines or even thin slices of wood if placed under a clay pancake will produce dark gray patterns. Keep in mind that the shapes of the masking objects that touch the surfaces will have an effect on the patterns they leave.

Other patterns can be achieved by embedding rock salt into the clay pancake. A few large grains of salt will leave a beauty spot! Metal oxides or organic materials like seaweed can also be used.

The kiln, properly stacked for low-fire-salt fuming, will look like a disaster area to the unin-

formed observer. And it will necessarily be completely full. Shelves are not only unnecessary, but actually nonproductive, as glazes are not used and the temperature is so low.

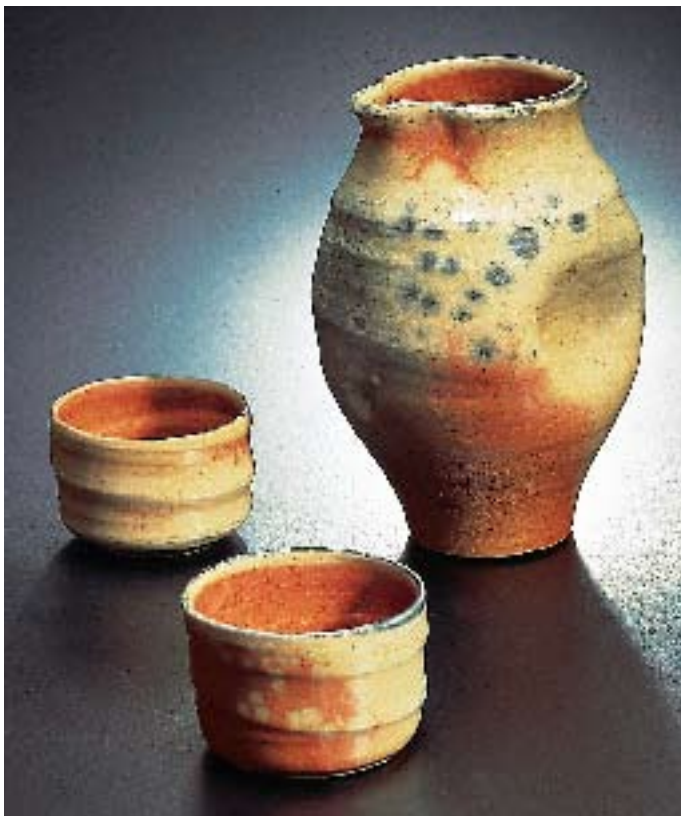
## Surface Preparation

If there is a small amount of iron in the clay body, spectacular oranges, yellows, and brown flashing can be expected. Raku slips will also have a positive reaction to the process. A raku white slip containing 1 part Gerstley borate, 2 parts flint, and 3 parts kaolin will often flash a beautiful pink from copper added to the salt or fumed off other copper-decorated ware. The same slip with





Wood-fired stoneware teapot, 8 in. (20 cm) in length, by Linda Christianson, Lindstrom, Minnesota.



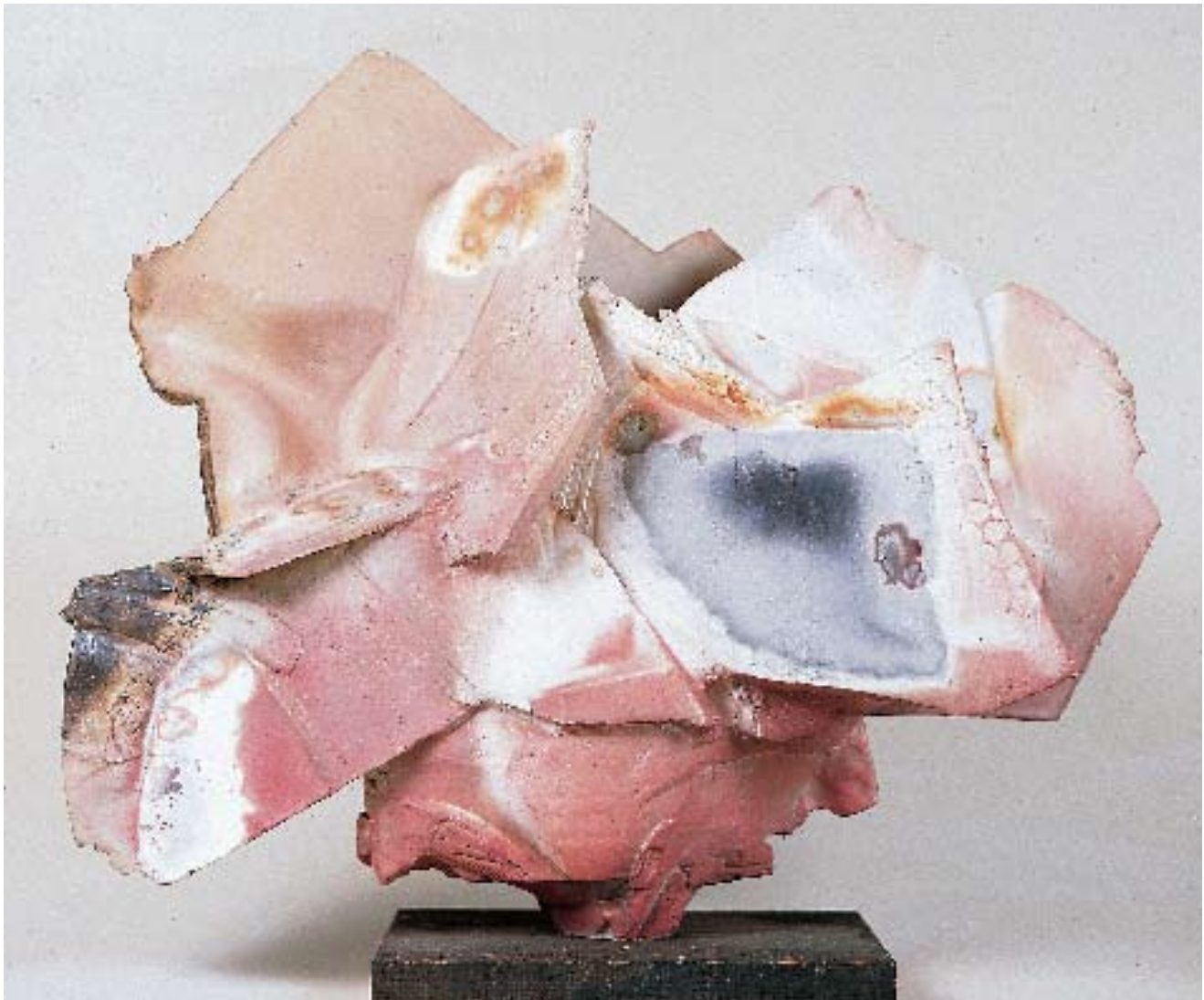
"Soy/Sake Set," to 4½ in. (11 cm) in height, porcelain with red shino glaze, by Malcolm Davis, Tallmansville, West Virginia.

3%–5% copper carbonate added will be even more reactive.

Colors (from copper in particular) are often quite varied because of the complex stacking, which results in reduction-oxidation and neutral flames licking over the object simultaneously. Similar variation in flashing can be anticipated from the use of terra sigillatas; however, the sigillata should be applied very thinly and/or fired to a higher temperature (possibly from cone 06 to cone 01) to prevent cracking. Applying the sigillata to damp bisqueware also seems to help. Remember, less planned decoration is better, and none is often good enough.

## Firing

The firing cycle is approximately the same length as a bisque firing. Although stacking, surface preparation and body composition are important, it is the quality and the quantity of the flame that make low-fire-salt fuming so different from other firings. To begin, the primary air on each burner is reduced to make a long, dirty, soft yellow flame for the entire firing.



Low-fire-salt vessel sculpture, 27 in. (69 cm) in height, thrown and slab built.

Oxidation and reduction cycles of glaze firings are of little significance in the low-fire salting; however, to pull the flame through the ware, dampers need to be open throughout the entire firing.

Of utmost importance is the need to fire the kiln with excess fuel. This is determined by observing the pressure at the bottom peephole. Above 1300°F (704°C), visible flames should be exiting constantly from the peephole. If this state cannot be maintained, increase the gas, add extra burners or drill out the burner orifices until flames are obtained.

Of course, this is a reducing atmosphere, except that it is achieved with the dampers opened and the kiln drawing. Curiously, cones will change

their melting point and are therefore not an exact indication of the actual temperature, but are close enough to warrant their use.

## Salting

Before loading the kiln, place salt in the flame path of each burner. A mound the size of a large orange is a good amount to start with.

When the kiln turns dull red, at about 1000°F (538°C), add more salt to each burner. For convenience, the salt can be wrapped in damp newspaper to form “burrito,” then pushed through the port into the flame. Additional salting every hour should be enough to achieve the desired effects.





Thrown-and-altered form with slips, 6 in. (15cm) in height, salt glazed in the firebox, by Paul Soldner, Aspen, Colorado.

A small amount of copper carbonate added to the salt may be helpful in encouraging a pink blush on the otherwise white slip surfaces. Many other oxides may be used to modify the fuming effects, but none as dramatically.

Oversalting may dull the surface color, so be conservative. Salting at the end of the firing is optional. Personal experience will determine its importance or not. Also, experiment with closing the dampers during the salting cycle, but only for a few minutes.

Work decorated with slips can be fired from cone 010 to cone 06. Terra-sigillata surfaces are better fired higher, from cone 08 to cone 3. Because there is no glaze to melt, precise temperature control is not a problem.

After the cones have melted and the last salt burrito has been added, the kiln can be shut off and cooled in the usual manner; no other treatment is needed or helpful. A good rule is to cool the kiln in the same amount of time it took to fire it.

## Postfiring

In order to protect the somewhat soft surfaces, apply one or two coats of acrylic floor wax (such as Futura) diluted about half and half with water to both the inside and out. If the result is too shiny when dry, dilute the wax a little more. The coating will preserve the colors and allow the work to be cleaned by washing with water from time to time.

# Slip and Glaze Recipes for Salt Firing



Will Ruggles and Douglass Rankin use salt cups in their firings. The ware is stacked in the kiln with salt cups filled at the outset, and as the temperature increases, the salt vaporizes and adds just the right amount of sheen to these plates. You can see what salt does to the shelves in this kiln (salt will find silica to react with anywhere it can), and this is why it is necessary to have a kiln and shelves dedicated only to salt firing. If these shelves were used in a kiln that had not been salted, the salt on the shelves would re-vaporize during the firing and salt that kiln and the ware in it.





**Napper, 10 in. (25 cm) in height, thrown and altered stoneware, salt fired to cone 10 in reduction, by Cathi Jefferson.**

## Recipes

### Ruggles/Rankin Green-Blue Slip

Cone 10, reduction

Borax . . . . .	4.27 %
Nepheline Syenite . . . . .	25.64
Bentonite . . . . .	1.71
EPK Kaolin . . . . .	17.10
Kentucky Ball Clay (OM 4) . . . . .	25.64
Silica . . . . .	25.64
	<u>100.00 %</u>

Add: Chrome Oxide . . . . .	3.42 %
Cobalt Carbonate . . . . .	2.56 %

### Ruggles and Rankin 6-Tile Slip

Cone 10, reduction

Nepheline Syenite . . . . .	9.90 %
6-Tile Clay . . . . .	69.31
Bentonite . . . . .	0.99
Grolleg Kaolin . . . . .	14.85
Silica . . . . .	4.95
	<u>100.00 %</u>

### Ruggles and Rankin #6 Slip

Cone 10, reduction

Custer Feldspar . . . . .	60 %
EPK Kaolin . . . . .	40
	<u>100 %</u>

Add: Cobalt Oxide . . . . .	5 %
Manganese Dioxide . . . . .	10 %
Red Iron Oxide . . . . .	15 %

For exterior use only; apply separately or over 6-Tile Slip.

Cathi Jefferson also prepares terra sigillata by mixing 4500 grams Cedar Heights Redart or Kentucky Ball Clay (OM 4) into 3 gallons water and 48 grams lye (or Calgon). After this mixture settles for at least 24 hours, she siphons off the top two-thirds for use. For a dark outlining slip, she adds 5 tablespoons of Mason Stain 6134 to 500 milliliters of the ball clay terra sigillata. For a rutile slip, she adds 20 grams rutile to 10 milliliters ball clay terra sigillata.

### Warren MacKenzie Shino Glaze

Cone 10, reduction

Soda Ash . . . . .	9.09 %
Spodumene (with iron) . . . . .	36.36
Custer Feldspar . . . . .	42.43
EPK Kaolin . . . . .	12.12
	<u>100.00 %</u>

Add: Bentonite . . . . .	2.02 %
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### Andrew Wong Luster

Cone 10, reduction

Lithium Carbonate . . . . .	5.26 %
Whiting . . . . .	2.11
Nepheline Syenite . . . . .	55.79
Kaolin . . . . .	26.32
Silica . . . . .	10.52
	<u>100.00 %</u>

Optional: add 5.26% soda ash.