

A small, semi-circular fragment of a ceramic plate, showing a blue and yellow glaze with a central decorative element.

HIGH-FIRE GLAZES

Edited by Sherman Hall

Ceramic
Arts
Handbook
Series



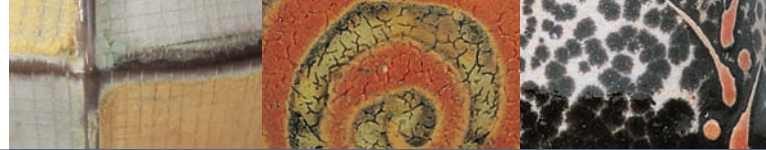


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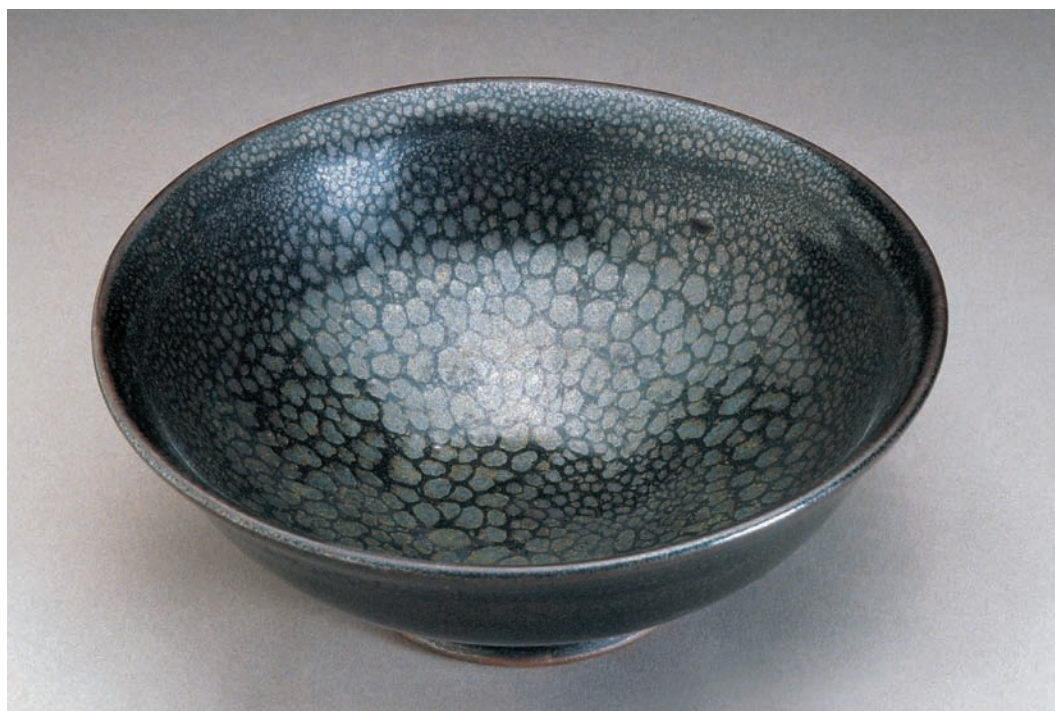
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1

Iron Glazes

OIL SPOT AND HARE'S FUR GLAZES

by John Britt



Oil Spot Bowl, approximately 6 inches (15 centimeters) in diameter, fired to Cone 10 in oxidation.

Oil-spot glazes are some of the most elegant and beautiful glazes ever discovered. At the same time, they are among the simplest glazes to achieve. They do not require the use of exotic materials or advanced analysis. In fact, oil-spot glazes can be mixed from the most common materials in a potter's studio. They work on a very simple chemical principle that, once understood, can result in many successful firings. As a category, oil spot glazes are sometimes called Black and Brown ceramics. They include a wide variety of iron glaze effects like black/brown tenmoku, oil spot, iridescent oil spot (Yohen), hare's fur (Yuteki), tortoiseshell, and partridge feathers. A complete discus-

sion of this category would be too lengthy for this article. I will discuss oil spot and hare's fur glazes, which operate in the same way.

Today, most potters are familiar with tenmoku glaze in a reduction firing. But to get oil spot effects, stiff tenmokus need to be fired in oxidation. This relies on a very simple chemical principle that, once understood, can lead to many successful firings. Red iron oxide (Fe_2O_3) acts as a refractory in oxidation but it can easily be changed to a flux in the form of black iron oxide (FeO), in reduction. Most potters are familiar with this property, but for oil spots we are interested in iron's ability to self-reduce. At approximately cone 7 (2250°F or



Porcelain with John's SG-12, then Hamada Rust over it, fired to cone 10 in oxidation, 2011. Variations in pattern can be achieved by adjusting the thickness of the undercoat (SG-12) and overcoat (Hamada Rust).

1232°C), ferric iron (Fe_2O_3) cannot maintain its trigonal crystalline structure and rearranges to a cubic structure, magnetite (Fe_3O_4), which further reduces to become ferrous (FeO). This is called thermal reduction, and what this means in layman's terms is that, when it is sufficiently heated, the red iron oxide used in the glaze recipe will naturally let go of an oxygen atom. As the liberated oxygen bubbles rise to the surface of the glaze, they drag a bit of the magnetite with them and deposit it on the surface. A rough black spot is left on the glaze surface that is a different color than the surrounding glaze, due to the larger concentration of iron oxide in that small area and its subsequent re-oxidization during cooling.

There are several glaze types used to achieve oil spots. Most are stiff feldspathic bases with 5–8% red iron oxide. This will produce brown-

on-brown oil spotting. Adding cobalt carbonate at approximately 2–5% produces a glazed surface with silver spots floating in a black field (see previous page).

Another popular option involves a multi-layered glaze approach. Oil spots can be achieved using an iron slip under a tenmoku glaze. This should be more accurately described as an “iron slip glaze” under a tenmoku glaze. John's SG-12, which is called a “slip glaze” because it contains a high quantity of slip clay (like Albany, Alberta, Redart, shale, etc.), is applied first. A cover glaze is then applied over it. In this case, the 215 Cover Glaze is used. The John's SG-12 is still applied thickly (three coats) and then the cover glaze is applied in one or two coats.

The two most important factors in the production of oil-spot glazes are the thickness of the glaze and a full oxidation firing. If the iron is reduced atmospherically early in the firing, as is typical in a standard reduction cycle, it will not be available to be reduced thermally at Cone 10. In a typical Cone 10 reduction firing, the kiln is put into reduction between Cone 012 and Cone 04, and reduction is maintained moderately throughout the firing. This causes most, if not all, of the iron to be unavailable to be reduced thermally. Consequently, there will be no bubbling from oxygen release at Cone 10 and no oil spotting.

Oil-spot glazes can be fired in any kiln that will oxidize—most often, in electric kilns, although it should be noted that electric kilns can produce a neutral or even reducing atmosphere. This runs counter to the common assumption that electric kilns always oxidize. Electric kiln atmospheres are often temporarily reducing or neutral due to the burning of carbonaceous matter, sulfur, the release of carbon dioxide from the many carbonates present in glazes, etc. Therefore, oil-spot results in electric kilns can be less than spectacular. A proper venting system should improve the results.

The glazes pictured here were fired in a 25-cubic-foot softbrick downdraft kiln equipped with natural-draft propane burners. Each firing took 10

to 12 hours and was allowed to cool naturally for 18 to 24 hours. There was a clean oxidizing atmosphere throughout the firing, although the heating cycle was slowed a bit between Cone 7 and Cone 10, because heating too fast during this segment does not allow sufficient time for the bubbles to heal over. To ensure an oxidizing atmosphere, an oxygen probe can be useful for the first few firings. Readings should be kept between 0.001 and 0.1, which is fully in the oxidizing area, well below a neutral atmosphere.

The second most important factor in successful oil-spot glazes is a very thick glaze application. This means approximately three coats of the glaze, totaling $\frac{1}{8}$ of an inch thick (the thickness of a dime and a nickel combined). One problem is that if you glaze the entire pot to that thickness, it will surely run off. Therefore, you must glaze it as you would a test tile, one dip all the way down, the next dip about halfway down and the final dip a third of the way down the pot. (Of course, you must vary this application procedure according to your pottery forms and firing temperature.) This will allow the glaze to run down the pot a bit without running onto the foot, while remaining thick enough to create oil spotting.

To assist in proper application, the glaze batch should first be run through a 100-mesh sieve, then mixed to a specific gravity of 180 (80 grams of glaze are contained in every 100 grams of water). As a counter example, runny glazes such as copper reds may be mixed to a specific gravity of 150. A glaze's specific gravity can be gauged either with a hydrometer or on a gram scale. This allows you to maintain a standard bisque temperature (Cone 06) and apply the maximum amount of glaze to the pot.

Although oil-spot glazes work on a very simple principle, the considerations involved in the firing can quickly become complex. Just as knowing how to apply the glaze requires some experience, so does knowing when to stop the firing, which is equally as critical to the result. As the oxygen is released from the iron crystal, the glaz-



This test tile shows the bubbling of an immature oil spot glaze. As CO₂ bubbles rise through the glaze, they deposit iron on the surface, which forms the spots after the bubble holes seal over.

es will often bubble up to a half inch above the surface of the pot. If the kiln is underfired, there will be visible craters and large, frothy bubbles left on the pots' surfaces.

The difficulty is in determining when the glaze has finished bubbling and the surfaces have sufficiently smoothed over. If too much time is allowed, the glaze will start to run off the pot. Pieces near the spy holes can be watched to determine when the bubbling has ceased, although draw rings are preferable. I generally fire to Cone 10, but this will vary due to information from the draw rings.

Surfaces of oil-spot glazes can be a bit rough, almost like sandpaper. To counteract this, I have tried refiring in the hope that this would smooth out the surface. Refiring in oxidation had no effect; however, refiring to Cone 10 in reduction was suc-

cessful. This produced a smooth surface over the oil spots and gave a variation in color, depending on both the atmosphere and the length and duration of the refiring. Sometimes the spots would have blue halos; other times they would become rust colored or contain silvery crystals. If refired to Cone 11, sometimes the spots disappear into silvery streaks. To avoid refiring, it is possible to put the kiln into reduction just after the bubbling has ceased and hold it for approximately 20 minutes.

The longer the pots are allowed to fire after the bubbling has ceased, the greater the hare's fur effect. This is not to say that running should be avoided, as it produces an equally beautiful surface. A hare's fur effect can also be produced if the pieces are refired to a higher temperature (perhaps Cone 11 or 12). This will create a beautiful streaked or mottled surface that has some evidence of running.

Variations in heating and cooling cycles appeared to have little impact on the production of oil-spot surfaces, but I believe that variations in the cooling and refiring atmospheres would be a fertile area for further research. Refiring in neutral, cycling in and out of reduction and oxidation, cooling in reduction or neutral, or even striking the kiln, may provide interesting surfaces as well, as iron is so susceptible to variations in atmospheric conditions.

It is possible, as some claim, that the original oil-spot glazes were actually Shinos (70% feldspar and 30% kaolin), with iron added and fired in oxidation. From a unity molecular perspective, oil spots and Shinos are very similar. Both are high in KNaO and very high in alumina. Oil spots differ in that they are also high in silica. Still, this theory is a possibility because the feldspar used during the Song dynasty in China was thought to have been higher in silica than our feldspars, something

more like Cornwall or rotten stone. Another theory is that oil spots were discovered while firing temmokus in reduction and occasionally finding an oil-spot effect on pots that were in oxidizing pockets of the kiln. That is how I "discovered" my interest in oil-spot glazes.

While working at Collin County Community College in Plano, Texas, I noticed that our studio black glaze, Candace Black, would occasionally produce small silver oil spots. It appeared that it only occurred when the glaze was in oxidizing pockets of our regular reduction kiln firings. After further investigation, I found that in full oxidation the glaze worked well as an oil-spot glaze, but I wanted to determine the factors that caused the spots to be better or worse.

I started by investigating the clay body. Much of the literature on oil spots talks about the interaction of the clay body with the glaze, about the need for a high-iron body or slip that would release iron at the clay-glaze interface and yield oil spots. I experimented with many types of both light and dark stoneware, domestic as well as English porcelains, and found porcelains to be the best clay body for oil spots.

Considering the effect of iron slips in the production of oil spots, I made a slip from the clay body and added 5–9% iron from a variety of sources. These included crocus martis; Barnard, Albany and Alberta slips; Cedar Heights Redart; red, black and yellow iron; yellow ochre; iron chromate; etc. Neither the iron in the clay body nor the addition of iron to a slip appeared to have any beneficial effect on the production of oil spots. But, just as some of the historic Chinese Jian wares had a dark body with oil-spot glazes, I produced a dark body with my porcelain by adding 8% yellow ochre. This proved successful, although refiring to Cone 11 or 12 in reduction caused some bloating.



Detail of a vase, porcelain with Nuka Glaze over Hamada Rust, fired to cone 10 oxidation. While this is not a true oil spot hare's fur glaze, it produces a similar pattern, and is often referred to as hare's fur for this reason.

Hare's Fur

Hare's fur is named because it is said to resemble the fur of a hare. It is a specific type of oil spot glaze that is black with delicate brown streaks. Another form has silvery streaks floating in a black/brown base (also called Yuteki). An even more difficult form to achieve has iridescent streaks, which is why it is highly prized and commands a high price. (Also called Yohen, which means color-changeable.)

One way to achieve the hare's fur effect is to fire the glazes very hot and have a long soak to allow the glaze to run down the side of the pot, causing the oil spots to run and melt together on vertical surfaces, but an easier way is to use a more fluid cover glaze, like Hamada Rust, over the slip based glaze (John's SG-12). This causes the oil spots to run down the pot forming delicate streaks rather than stiffly holding the oil spotting. This running

and streaking can be varied by using different cover coat glazes. You can use a kaki cover glaze to achieve more orange colors, or an iron saturate to give more iron spangles.

There is some confusion in describing hare's fur glazes because some potters refer to all streaky, milky, runny glazes as hare's fur (e.g., blue hare's fur). Technically this is incorrect. Streaky, milky, runny glazes could be caused by rutile or a nuka glaze over another glaze, creating an effect similar to oxidation oil spot streaking. One example is a Nuka Glaze over Hamada Rust.

Oil spots can also be achieved at cone 6 but since the process starts somewhere around (2250° F) the spots may be small. To improve the look you can soak the kiln beginning at cone 6, until cone 7 drops.

High-Fire Glazes

CANDACE BLACK

Cone 10

Dolomite.	5 %
Whiting	5
F-4 Soda Feldspar	65
Kaolin	5
Silica	20
	100 %
Add: Red Iron Oxide	8 %
Cobalt Carbonate	2 %

JOHN'S SG-12

Cone 10/11 Oxidation

Bone Ash	2.06 %
Dolomite.	5.53
Talc.	3.08
Whiting	1.73
Custer Feldspar	38.03
Red Art Clay	40.12
Kentucky Ball Clay	9.46
	100.00 %
Add: Red Iron Oxide	4.50 %
Rutile	1.00 %
215 Cover Glaze	

Cone 10/11 Oxidation

Whiting	13 %
Custer Feldspar	45
EPK Kaolin	11
Silica	28
	100 %
Add: Red Iron Oxide	8 %

HAMADA RUST

Cone 10

Gerstley Borate	12.40 %
Whiting	6.20
Custer Feldspar	77.00
EPK Kaolin	4.20
Silica	0.20
	100.00 %
Add: Synthetic Red Iron Oxide	8.70 %

Porcelain with a hare's fur combination glaze composed of two coats of John's SG-12, one coat Candace Black, and one coat of Hamada Rust, fired to cone 10 in oxidation.

NUKA

Cone 10

Bone Ash	2 %
Talc.	2
Whiting	22
Wood Ash (unwashed) or Frit 3134	3
Custer Feldspar	36
OM-4 Ball clay	6
Silica	30
	100 %

OIL-SPOT GLAZE #29

Cone 10/11

Dolomite.	3.93 %
Whiting	3.93
Kona F-4 Feldspar	51.10
Kaolin	4.79
Silica	36.25
	100.00 %
Add: Cobalt Carbonate	5.00 %
Red Iron Oxide	8.00 %

This glaze can produce large oil spots that will run if too thick.

GROLLEG PORCELAIN BODY

Cone 10/11

Custer Feldspar	25 lb
Bentonite	2
Grolleg	55
Silica	25
	107 lb

For a dark body, add 8 pounds yellow ochre.



Iron Glazes

IRON RECIPES

PORCELAIN BODY

Cone 10

Custer Feldspar	24.76 %
6 Tile Clay.	17.82
EPK Kaolin	17.82
Tennessee Ball Clay (#10)	17.82
Pyrax.	1.98
Silica.	19.80
	100.00 %

For a casting slip, mix the dry clay body with a solution of 39.60% water, 0.25% Darvan and 0.08% soda ash.

OLIVE GREEN TO BLACK GLAZE

Cone 10

Gerstley Borate	10.00 %
Pearl Ash	6.30
Whiting	16.20
Custer Feldspar.	4.50
Nepheline Syenite	34.20
Grolleg Kaolin.	20.70
Silica.	8.10
	100.00 %
Add: Chrome Oxide	0.13 %
Cobalt Carbonate.	0.13 %
Red Iron Oxide	5.00 %

Ewer, 12 inches (30 centimeters) in height, thrown porcelain, slip-cast handle and spout, with Olive Green to Black Glaze, by Pete Sherzer.





PORCELAIN BODY

Cone 10

Custer Feldspar	24.76 %
6 Tile Clay	17.82
EPK Kaolin	17.82
Tennessee Ball Clay (#10)	17.82
Pyrax	1.98
Silica	19.80
	100.00 %

For a casting slip, mix the dry clay body with a solution of 39.60% water, 0.25% Darvan and 0.08% soda ash.

IRON RED GLAZE

Cone 10

Bone Ash	2.91 %
Pearl Ash (Potassium Carbonate)	10.68
Whiting	25.24
Custer Feldspar	6.80
Grolleg Kaolin	35.92
Silica	18.45
	100.00 %

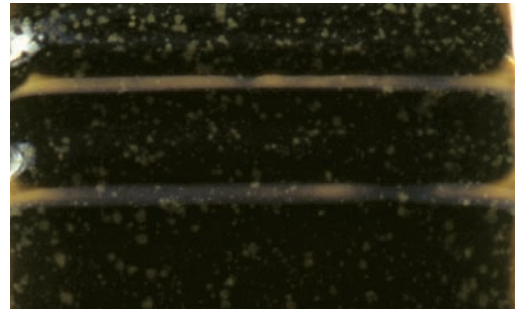
Add: Red Iron Oxide (Spanish) 9.71 %

Vase, 14 inches (36 centimeters) in height, porcelain, with Iron Red Glaze, by Pete Sherzer.

COLEMAN TEADUST TENMOKU

Cone 10

Talc.	7 %
Whiting	16
Custer Feldspar	40
Ball Clay	12
Silica	25
	100 %
Add: Red Iron Oxide	10 %



L6E

Cone 11

Bone Ash	7.5 %
Dolomite.	5.4
Whiting	9.1
G-200 Feldspar	39.3
EPK Kaolin	23.6
Silica	15.1
	100.0 %

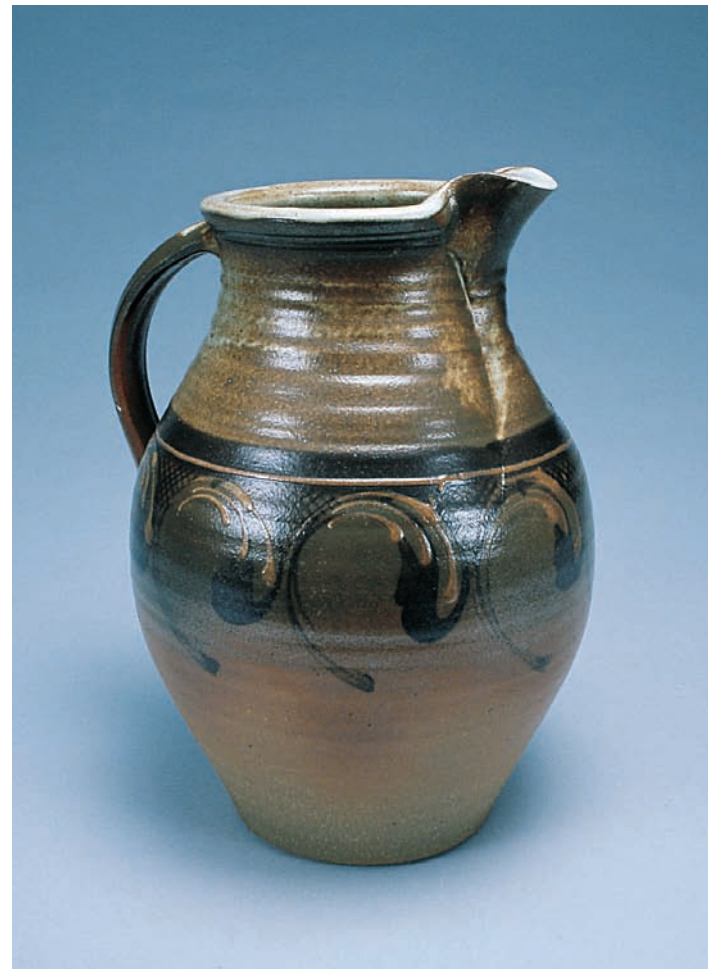
Add: Red Iron Oxide 0.9 %

L6E is Beige to Brown—when applied thin, it's dark brown; when applied thick, it's a creamy, oatmeal beige.

BLUE SLIP

Cone 11

Nepheline Syenite	18 %
Kentucky Ball Clay (OM 4).	73
Cobalt Oxide.	9
	100 %



Pitcher, 11½ in. (29 cm) in height, stoneware, with L6E Glaze, brushed cobalt slip and slip-trailed porcelain, by Lynn Lais.

High-Fire Glazes

Platter, 14 inches (36 centimeters) in diameter, wheel-thrown stoneware, with Iron Red and Transparent Feldspar Ash glazes over brushed and combed white slip, fired to Cone 10, by Chris Nielsen.



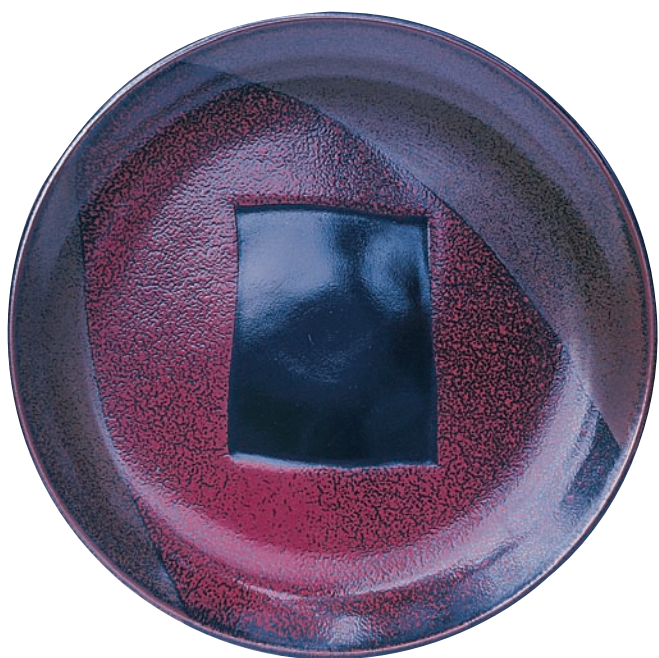
IRON RED

Cone 10

Red Iron Oxide	11.0 %
Whiting	11.9
Unispar	40.4
Silica	36.7
	100.0 %

Add: Bentonite	1.8 %
Calcium Chloride	0.3 %

In heavy reduction, the surface varies from glossy to crystalline, and the color varies from red/violet to tan (black where thick or oxidized). I usually apply this glaze over white slip work. I then overlap it with Transparent Feldspar-Ash Glaze. The slip will show through as transparent olive green.



OSBLOOD GLAZE

Cone 9, reduction

Dolomite	3.01 %
Whiting	10.23
Borax Frit	16.55
Potash Feldspar	44.38
Kaolin	1.25
Silica	24.58
	100.00 %

Add: Tin Oxide	0.80 %
Copper Carbonate	1.00 %

TEMMOKU GLAZE

Cone 9, reduction

Whiting	13.68 %
Potash Feldspar	46.32
Kaolin	13.68
Silica	26.32
	100.00 %

Add: Red Iron Oxide	8.42 %
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Plate, 45 centimeters (18 inches) in diameter, stoneware, with Temmoku Glaze, fired to 1280°C (2236°F) in reduction, then warmed and glazed with Oxblood Glaze and fired again to 1280°C in reduction, by Vincent Beague.



Cannister set, to 12 in. (30 cm) in height, thrown white stoneware with Rutile B-1 Glaze, wood/salt fired to Cone 10.

RUTILE B-1
Cone 10

Dolomite	15.1	%
Whiting	11.3	
G-200 Feldspar	30.7	
EPK Kaolin	16.0	
Silica	26.9	
	100.0	%
Add: Bentonite	2.0	%
Yellow Iron Oxide	2.0	%
Zircopax	1.0	%



Mihari Tower—Winter Series, 13½ inches (34 centimeters) in height, handbuilt from wheel-thrown and textured stoneware slabs, double glazed.

WINTER SERIES GLAZE (TEMAMOKU)

Cone 10

Whiting	20 %
Custer Feldspar	33
EPK Kaolin	15
Silica	32
	100 %

Add: Red Iron Oxide 9 %

The Winter Series is actually double glazed or poured over the piece. Then the Desert Series Glaze is applied on top. This highlights the texture and adds an interesting visual texture to smooth surfaces such as the lips.

Iron Glazes

TEMMOKU

Cone 10

Barium Carbonate	2.82 %
Whiting	14.69
Custer Feldspar	61.02
Bentonite	11.30
Georgia Kaolin	10.17
	<u>100.00 %</u>

Add: Red Iron Oxide	8.48 %
Zinc Oxide	2.83 %

BLACK CLAY MATT

Cone 10

Whiting	14.8 %
Wood Ash (mixed)	9.9
Custer Feldspar	31.7
Kaolin	23.8
Silica	19.8
	<u>100.0 %</u>

Add: Bentonite	2.9 %
Red Iron Oxide	4.9 %

In reduction, this is richly textured dark olive to black, breaking to iron red where thin at higher temperatures. It goes charcoal gray with more oxygen. Without ash, it turns an uninteresting flat brown.

IRON SATURATE #1

Red Iron Oxide	8.0 %
Whiting (325 mesh)	16.0
Custer Feldspar	36.0
EPK Kaolin	16.0
Silica (200 mesh)	24.0
	<u>100.0 %</u>

IRON SATURATE #2

Red Iron Oxide	11.0 %
Whiting (325 mesh)	15.0
Custer Feldspar	30.0
EPK Kaolin	8.0
Silica (200 mesh)	36.0
	<u>100.0 %</u>

IRON SATURATE #3

Dolomite	4.5 %
Red Iron Oxide	9.1
Whiting (325 mesh)	5.5
Custer Feldspar	60.9
EPK Kaolin	4.5
Silica (200 mesh)	15.5
	<u>100.0 %</u>

IRON SATURATE #4

Red Iron Oxide	10.0 %
Whiting (325 mesh)	17.0
Custer Feldspar	23.0
EPK Kaolin	25.0
Silica (200 mesh)	25.0
	<u>100.0 %</u>

IRON SATURATE #5

Red Iron Oxide	9.4 %
Whiting (325 mesh)	15.1
Custer Feldspar	40.3
EPK Kaolin	9.4
Kentucky OM 4 Ball Clay	5.6
Silica (200 mesh)	20.2
	<u>100.0 %</u>

IRON SATURATE #6

Red Iron Oxide	19.0 %
Whiting (325 mesh)	12.0
Nepheline Syenite	21.0
EPK Kaolin	24.0
Silica (200 mesh)	24.0
	<u>100.0 %</u>

IRON SATURATE #7

Red Iron Oxide	15.0 %
Whiting (325 mesh)	15.0
Nepheline Syenite	20.0
EPK Kaolin	25.0
Silica (200 mesh)	25.0
	<u>100.0 %</u>

IRON SATURATE #8

Red Iron Oxide	14.0 %
Whiting (325 mesh)	19.0
Cornwall Stone	19.0
EPK Kaolin	24.0
Silica (200 mesh)	24.0
	<u>100.0 %</u>

IRON SATURATE #9

Red Iron Oxide	13.0 %
Whiting (325 mesh)	21.0
Custer Feldspar	17.0
EPK Kaolin	28.0
Silica (200 mesh)	21.0
	<u>100.0 %</u>

2

Copper Glazes

COPPER AS A GLAZE COLORANT

by John Britt

Copper oxide is an active metal that combines easily with oxygen, which means that it is very sensitive to oxidation and reduction atmospheres. It produces a wide range of colors in glazes, from greens (delicate light greens to turquoise to deep emerald green), to red, pink, blue, black, yellow, and copper luster.

Sourcing Copper

Copper was one of the first metals worked by humans (6000–4000 BCE). It shows up in glass as early as 2000 BCE and in glazes of the Han Dynasty (200–25 BCE).

Some of the most famous copper green glazes are known as Oribe, which comes from Furuta Oribe, a general and tea master during the Japanese Keicho period (1596–1615 CE). Another popular copper glaze is a copper red. It most likely came about from the accidental reduction of copper green glazes fired in a wood-burning kiln. Some of the early sources of copper in glazes are believed to be from spraying water onto hot bronze. This produces a black flaky substance composed of copper oxide and tin oxide (the metals in bronze), which was then finely ground and used to produce copper reds. Copper red colors include strawberry, oxblood, flambé, black-red, peach bloom, apple red, rose carmin, etc.

There are four major sources of copper in glazes: Black copper oxide (CuO); red copper oxide (Cu_2O); copper carbonate (CuCO_3); and copper

sulfate (CuSO_4), which dissolves in water. Each has different properties that can make a significant difference in the outcome of the glaze. Copper carbonate is the most commonly used form. It disperses well in a glaze slop and melts well in glazes to give uniform color. Black copper oxide has a larger particle size that doesn't melt well and can cause specking in glazes. Red copper oxide is the strongest form and has a hydrophobic coating (oleic acid surfactant) that keeps it from reoxidizing in the air. Because of this coating, it won't mix with water and simply floats on the surface. This can be corrected by adding several drops of liquid soap, which breaks the surface tension and allows it to disperse.

Copper Glaze Tips

Oribe pieces are decorated on one side with an iron oxide design over a transparent glaze while the other side is decorated with a transparent copper green glaze. Then they are fired in oxidation. Oribes can get a scummed layer on top that dulls the color. The traditional method for getting a clearer copper Oribe is to soak chestnut husks in water and then soak the pots in this acidic solution. But today potters just use a weak muriatic acid (hydrochloric acid) solution. (This is toxic so use in a well-ventilated area with safety glasses and a mask.)

Copper volatilizes above 1877°F (1025°C) and becomes increasingly volatile, making it a fume



V.C.A.A. COPPER

Cone 10 Reduction

Cornwall Stone	46 %
Whiting	34
Silica	20
	100 %

Add: Tin Oxide	4 %
Copper Carbonate	4 %

Apply thin for a speckled green or thicker for a mottled black. Both applications shown here on porcelain.



PATSY'S GREEN (ORIBE)

Cone 10 Oxidation

Gerstley Borate	13.4 %
Dolomite	5.9
Whiting	8.3
Zinc Oxide	4.0
F-4 Feldspar	46.2
EPK Kaolin	2.4
Silica	19.8
	100.0 %

Add: Black Copper Oxide	4.0 %
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hazard. The volatilization can affect adjacent pots, particularly those with tin whites or celadons, resulting in a pink blush. This property can also be used to decorate a pot. Glazing the inside of a saggar with an Oribe glaze and then placing a tin white glazed tea bowl in the saggar will give a delicately blushed pink tea bowl.

Copper glazes are often used in soda and salt firings because the introduction of volatile sodium during the firing turns copper glazes various shades of blue/turquoise/green. Sometimes potters use high amounts of copper (10%) in a green salt glaze, which turns black, but when the salt fumes hit that part of the pot, the area turns deep green on one side with the other side of the pot fading to black.

Raku: With sufficient post-firing reduction, the copper oxide/carbonate can be reduced to metallic copper finishes. These copper lusters are only microns thick so they can reoxidize to produce green colors (much like a penny oxidizes) if the pots aren't coated with a polyurethane sealant.

Copper is also used in Islamic luster firing techniques as well as Egyptian Paste (ancient Faience), which is a self-glazing, low-fire clay body that goes back 7000 years. It was probably discovered by firing sand, clay, and salt or soda ash. Then colorants were added to make colorful beads and ornaments.

Toxicity

While there is no legal limit set for safe leaching of copper in glazes, potters should be aware that the legal level of allowable copper deemed safe for drinking water is 1.3 mg/L (based more on its effects on taste than toxicity). Levels of above 5% can create black metallic surfaces and should not be used in functional ware (Digitalfire Reference Database, <http://digitalfire.com>).

Excessive amounts in a glaze can be leached with prolonged or repeated contact with acidic foods or beverages. The extremely basic conditions in dishwashers can attack a glaze surface, causing erosion of the surface and resulting in increased leaching over time.

Defining the Tests

Copper Oxide—Black Copper Oxide (Cupric) CuO ; melts at 2419°F (1326°C). Red Copper Oxide (Cuprous) Cu_2O ; melts at 2255°F (1235°C). Cupric oxide decomposes at 1847°F (1008°C) to cuprous oxide and oxygen. It is an active flux, so adding it to a glaze may cause the glaze to run. Its high coefficient of expansion/contraction may increase crazing in larger amounts. It is toxic, volatile (fume hazard), and can leach into food. It can migrate through a clay body, and almost any copper glaze with a matte black surface leaches copper in the presence of acidic liquids. It can also cause pinholing.

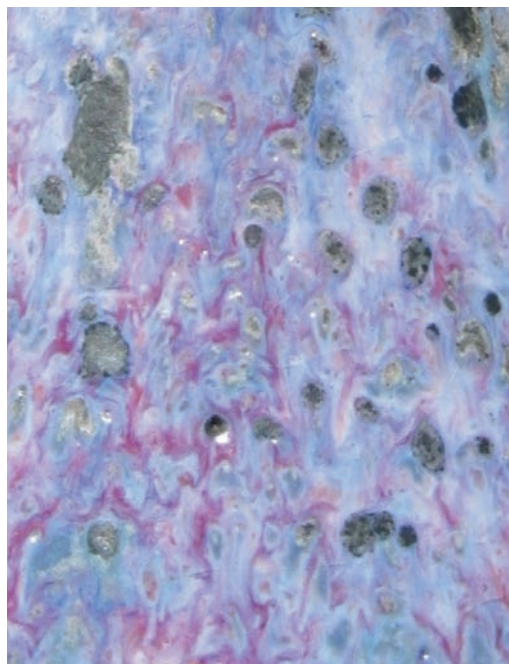
Copper Carbonate—The idealized formula for this green powder is CuCO_3 , but the material may come as a variety of compounds and may contain impurities. $\text{Cu}_2(\text{OH})_2\text{CO}_3$ (Malachite) may be a more accurate formula representation. Since it is reactive chemically, it disperses better in a glaze thus giving more even results than copper oxide. It off gasses and can cause pinholes or blisters in a glaze. At approximately 572°–608°F (300°–320°C) copper

carbonate releases carbon dioxide and water, and then at 1922°F (1050°C) it loses more oxygen as it restructures. Copper carbonate makes greens in amounts of 5% or less, blacks above 5%, and at 0.3–0.8% it makes blues in oxidation and copper reds in reduction. Approximate conversion: 5% copper carbonate = 3.6% black copper oxide = 3.24% red copper oxide.

Copper Sulfate—This blue crystal is an agricultural fungicide. It is soluble in water, starts decomposing at 302°F (150°C), loses four water molecules by 392°F (200°C), then changes to copper oxide and sulfur trioxide by 1202°F (650°C). Often used in pit and low-temperature saggar firings. Produces grays in soluble salt firings as well as pinks and reds in heavy reduction.

Copper Chloride—Often used in water soluble metal salt firing (aka *water coloring* on porcelain). Produces burgundy colors in pit and saggar firings.

Copper Filings—Chips of copper metal. Copper filings are sometimes sprinkled in or on a wet glaze to give black spots with flashes of red on the perimeter.



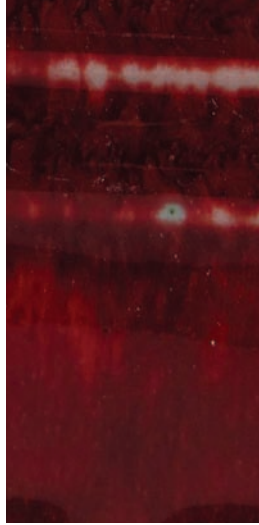
JEFF'S RED (UNDER ORIBE GLAZE)

Cone 10 Reduction

Barium Carbonate	4.4 %
Dolomite	8.7
Whiting	8.4
Ferro Frit 3134	8.7
Custer Feldspar	41.9
Zinc Oxide	1.7
Silica	26.2
	100.0 %
Add: Bentonite	1.0 %
Copper Carbonate	0.5 %
Tin Oxide	2.6 %

Jeff's Red is fired once, then reglazed with an Oribe glaze and fired again.

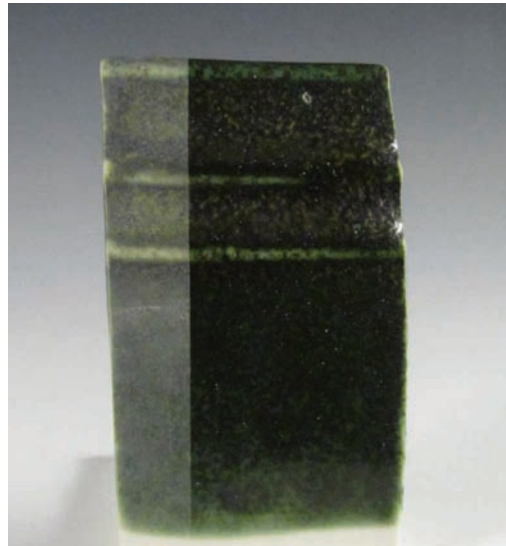
High-Fire Glazes



JOHN'S RED

Cone 10 Oxidation

Talc.	3.64 %
Whiting	13.64
Zinc Oxide.	4.55
Ferro Frit 3134	9.09
Custer Feldspar	48.18
EPK Kaolin	5.45
Silica	15.45
	100.00 %
Add: Tin Oxide	1.20 %
Copper Carbonate	0.80 %



PINNELL CELADON

Cone 10 Reduction

Barium Carbonate.	1.9 %
Whiting	19.6
Custer Feldspar	24.5
Grolleg Porcelain.	19.6
Silica.	34.3
	100.0 %
Add: Tin Oxide	1.0 %
Yellow Iron Oxide	0.5 %

Celadon glaze with tin oxide, pink flashing of copper from Oribe glazed pieces next to it in the kiln.

WILLIE HELIX

Cone 10 Oxidation or Reduction

Nepheline Syenite	40.0 %
Whiting	19.0
Kaolin.	11.0
Silica.	30.0
	100.0 %
Add: Copper Carbonate	1.2 %
Black Copper Oxide	5.0 %

3

Crystalline Glazes MAKING CRYSTALS CLEAR

by Sumi von Dassow

The most fascinating and exacting glaze family of all may be the crystalline glazes. Achieving and controlling the growth of crystals in molten glaze is as close to pure science as pottery gets. To most of us, it remains an obscure and mysterious science with rules we don't really understand but results we admire mightily.

The Challenges

Crystalline glazes are difficult to work with for two major reasons: First, crystals grow only in a glaze that is very low in alumina, which makes these glazes very fluid when they melt. Thus, a major challenge for users of crystalline glazes is controlling the glaze flow so it doesn't get all over the kiln shelves. This is usually done by firing each pot on its own pedestal with a built-in catch basin for the overflow of glaze.

The second challenging aspect of working with crystalline glazes is that, to grow crystals, the glaze must be fired to its melting temperature, partially cooled, then held at the optimum crystal-growing temperature for several hours. The firing schedule can be varied in a number of ways to achieve different results, but firing crystalline glazes requires a pyrometer and constant attention to the temperature inside the kiln or a computer-controlled kiln with a pyrometer.



The blue crystals on this blue jar are formed from cobalt oxide while the blue background results from the cobalt carbonate.

A Hardy Soul

These hurdles mean relatively few potters venture into crystalline territory. Carla Thorpe is one of those hardy souls. Carla, formerly a jeweler, since taking up pottery has been attracted to time-consuming techniques that allow her to lose herself for hours in the process of making a pot. She has eagerly embraced the challenge of crystalline glazes, both because she enjoys the process and because in growing crystals on a pot she is literally mimicking the process that created many of the gemstones she used to work with. Though the loss rate can be high, and preparing and finishing the pots can be tedious, she is endlessly fascinated by the results.

Carla's Technique: The Barrier

During a recent visit to her studio, Carla demonstrated the processes of preparing a pot for glazing and applying a glaze, and of separating fired pots from their catch-basin pedestals and grinding the foot smooth. Preparing a pot for glazing simply requires gluing the pot to its pedestal with a mixture of white glue and alumina hydrate, preferably the day before glazing so the glue can dry. The glue keeps the pot precisely placed on the pedestal during glazing and loading so that the runny glaze won't seep under the pot in the firing and adhere it permanently to the pedestal. The alumina hydrate forms a barrier between the pot and pedestal after the glue burns away, so they can be separated easily along the seam between the two pieces.

Firing Schedule

SEGMENT	RAMP	SET POINT	HOLD
1	200°F / hour	800°F	0
2	150°F/ hour	1250°F	0
3	300°F / hour	2100°F	0
4	108°F/ hour	2330°F	0
5	999°F/ hour	2050°F	3 hours

Carla often varies this schedule by dropping the temperature to 2000°F degrees three times, then immediately increasing it to 2050°F and holding it for an hour each time. This schedule promotes the formation of "growth rings" in the crystals..

Firing Schedule Variation

SEGMENT	RAMP	SET POINT	HOLD
1	200°F / hour	800°F	0
2	150°F/ hour	1250°F	0
3	300°F / hour	2100°F	0
4	108°F/ hour	2330°F	0
5	999°F/ hour	2000°F	0
6	999°F/ hour	2050°F	1 hour
7	999°F/ hour	2000°F	0
8	999°F/ hour	2050°F	1 hour
9	999°F/ hour	2000°F	0

* "999°" refers to full-on or full-off power. This setting varies among different controllers so check your owners manual.

Glaze Application

Carla applies glaze by brushing it on liberally with a large soft Japanese “hake” brush. Crystalline glazes can be difficult to apply, since they can’t contain any clay. In most glazes, clay is used not only to provide needed minerals but also to keep glazes from settling quickly and to facilitate application of a smooth even coat either by brushing or dipping. Unfortunately, clay contains alumina and so can’t be used in crystalline glazes. Fortunately, the extremely fluid nature of the glaze means that the glaze can be “slopped on,” as Carla puts it, in a messy and uneven coat and it will smooth out in the firing. She also notes that these glazes change consistency over time and many potters only mix up enough for one day’s work. To most potters this would represent another tedious aspect to crystalline glazing, but to Carla it presents an opportunity to experiment with many different combinations of glaze colorants.

Firing

The firing process is exacting but fairly simple if you have a computer-controlled kiln. She uses the schedule recommended by the kiln manufacturer (Skutt) for crystalline glazes.

Cleaning the Bases

After the pots are cool, the next tedious part of the process is separating the pots from their pedestals and grinding the bottom smooth. Carla per-

forms the separating operation with a hammer and chisel; other potters use a Dremel tool with a grinding bit. For grinding the bottom smooth, Carla uses a bench grinder left over from her jewelry days, which is equipped with an exhaust fan, a very nice feature. She uses a fine-textured grinding disk manufactured specifically for the purpose of grinding glaze drips. Carla explains that some potters finish their crystalline glazed pots by gluing them onto wooden pedestals to cover up the imperfect foot, but she prefers to grind the bottom as smooth as possible and leave it bare. If the pot was fired on a carefully fitted pedestal, this is not too difficult.

A Star Performance

Those pots that survive all this stressful treatment come out with beautiful glossy coats embellished with crystals of varying colors, like captured snowflakes. They are stunning, particularly when seen in bright sunlight. At first one’s eye takes in the sparkling effect of the pot as a whole, then it begins to see the galaxy-like swirl of crystals within the glaze. Gradually the eye is drawn deeper into the glaze, eventually examining and marveling at the structure of the individual crystals. It is this irresistible attraction that makes these glazes star performers.

SNAIR CRYSTALLINE GLAZE VARIATION Cone 9

Ferro Frit 3110	49.3 %
Zinc oxide	24.8
Kaolin	1.5
Silica	18.3
Titanium dioxide	6.1
	100.0 %

Add: Bentonite

1.0 %

Cream colors

Add: Red iron oxide	1.0 %
Manganese dioxide	0.5 %

Blues

Add: Cobalt oxide	2.0 %
Cobalt carbonate	2.0 %
Manganese dioxide	3.0 %