PHYSICAL CHARACTERISTICS OF CLAY AND GLAZES

Paul Nash, Professor of Ceramic Art / Studio Ceramic Artist
paulnashceramics.com

Table of Contents

PART 1

INTRODUCTION, CLAY TYPES

The earth's surface composition is made up of minerals.

<u>Five minerals make up 90% of the earth's surface:</u>

1. **Feldspars**
   a. **Orthoclase K_2O**
   b. **Albite Na_20**
   c. **Anorthite Ca0**
   d. **Spodumene Li_20 (Mineral/Feldspar)**
2. **Amphibole Pyroxenes - Calcium-Magnesium Silicate**
3. **Quartz**
4. **Mica**
5. **Titanium materials**

<u>Feldspar:</u> Any group of crystalline minerals that consists of aluminum silicates with an alkaline (potassium, sodium, calcium, or lithium).

Seventy-five percent of the earth's crust is silica and alumina. Silica and alumina were originally in the form of feldspar. Feldspar rock is broken down primarily by water, but also by wind and the expansion and contraction of earthquakes, and the melting of glaciers. When alumina and silica are combined with two parts chemical water, this becomes clay.

<u>Clay:</u> can be defined as <u>an earth mineral substance composed mostly of hydrous silicate of alumina</u> - plastic when wet; hard and rock-like when fired.

[Hydrous: containing water, usually chemically.] Chemical water leaves the clay between 650 to 900 degrees Fahrenheit. Clay starts to become a bisque-like material above 900 degrees F. We bisque fire at 1,830 degrees F. Cone 06.

<u>Clay Formula</u>: $Al_20_3 \bullet 2Si0_2 \bullet 2H_20$ (Kaolin clay is a very pure white clay)

Physical Characteristics:

Quality of plasticity: The amount of organic matter present in clay determines the plastic quality. The more organic matter in the clay, the more plastic the clay becomes. This organic matter is usually in the form of carbon.

Particle size and shape: Clay particles are elongated and plate-like in two-dimensions, and thin in the third dimension. The smaller the particle size, the more plastic the clay.

P = Primary (non-plastic)(short)
S = Secondary (plastic)(fat)

Classification of Clay: Clay can be divided into two groups:

1. **Primary Clay (residual clay):**
   Clay which is found where it was formed. This clay is called Kaolin or Fire Clay. If natural fire clay is workable, then it is called it a natural stoneware clay. The following physical characteristics are present in these clays:
   - **a. Purity**
   - **b. Whiteness**
   - **c. Freedom from objectionable mineral or organic contamination**
   - **d. Large particles**

2. **Secondary Clay:**
   Clay that has been carried by water, glaciers and wind from its original site.
   Physical Characteristics:
   - **a. Impurities, organic matter**
   - **b. Fine-grained and plastic**

The largest deposits of Secondary Clays in this country are found in Tennessee and Kentucky. Kaolin Clays (primary) are found in Florida and Georgia. The purest Kaolin Clay is found in North

Carolina.

The following clays are found throughout the world in varying colors:

(P) 1. <u>KAOLIN</u> (China Clay)

Melts above 1800 C. 3272 F. Ceramic Industry uses porcelain and Bone China slip casting for most of its commercial pottery. There are only small deposits of China Clay. As Primary Clay, it is relatively pure and is used chiefly in glazes and the making of porcelain clays. Porcelain Clay can have shrinkage of 16% - 20%.

Porcelain Clays initial development occurred during the Shang Dynasty 1400B.C. (1700B.C. to 1027B.C.), the Han Dynasty (206B.C. to 220A.D.), and the Song (Sung) Dynasty (960A.D.to 1279A.D.). The highest development of porcelain occurred in the Sung and Ming Dynasties (1364A.D. to 1644A.D.). Their porcelain clay matures at 1300 degrees C., 2372 F. Cone/8,9,10,11. The Chinese culture developed the high fire process of stoneware and porcelain by inventing the down draft kiln between 2000 B.C. to 1500 B. C. Prior to the down draft kiln all cultures fired with updraft kilns. These kilns were unable to fire above 2,000 F. Cone/03-01

Europe (France, Germany and England) discovered Kaolin in the early 1700's A.D. but did not create a true porcelain until about 1770 A.D.

(S) 2. <u>BALL CLAY</u>

Melts into a glass at 1,300 C., 2,372 F. Cone/8,9,10,11. Maturing temperature is around Cone 06 - 04. Shrinkage is about 20%. It is very plastic and contains carbon. Ball Clay is a Earthenware Clay, but is too plastic to be use by itself. It is used in the making of clay bodies to improve plasticity. The largest deposits are found in Tennessee and Kentucky. Natural earthenware clay is found mostly along riverbanks, and was utilized by most cultures.

(P) 3. <u>FIRE CLAY</u>

Melts at 1500 C., 2759 F. Cone 17,18,19. Fire clay is a non-plastic clay mainly used in the making of Stoneware Clays. Fire Clay has shrinkage of 12% - 16%. When used by itself for making pottery, it is called natural stoneware clay. If fire clay is non-plastic to use as stoneware clay, it is then called Sagger <u>Clay</u> and is used in the making of kiln furniture.

(P) 4. <u>SAGGER CLAY</u>

Sagger clay is very non-plastic and makes a dense tough body when fired. It is rough and refractory, making it resistant to thermal shock and fatigue. Sagger clay is used for flue liners, fireplace brick, the making of kiln furniture and firebrick. (Firebrick is used for building a kiln, not to be confused with fireplace brick)

(S) 5. <u>STONEWARE CLAY</u>

Matures at 1200 to 1300 C., 2210 to 2390 F. Cone 8,9,10,11,12. It is a plastic Secondary Fire clay. Stoneware clay that can be used by itself directly from the clay deposit is called a Natural Stoneware clay. (<u>Do not confuse this natural stoneware clay with stoneware clay bodies that are made up of different primary and secondary clays.)</u>

(S) 6. <u>EARTHENWARE CLAY</u>

Matures from 950 to 1100 C., 1733 to 2030 F. Cone 08,07,06,05,04. Ceramic Industry fires to Cone 02, 01, which is low fire earthenware. Natural Earthenware Clay can be used by itself directly from the clay deposit; it is also called surface clay. This is the most common form of clay and is found everywhere on earth. It is used for common red brick and was the first clay used historically in pottery making. There is also high fire earthenware, C/4,5,6. One can fire in an electric kiln and the clay and glaze has a

look that is somewhat stoneware looking in nature.

7. MISCELLANEOUS CLAYS:

Adobe (S) / Terra Cotta (S) / Flint (P) / Shale (P) / High Alumina clays (P), / Gumbo (S) / and Bentonite (S) (Bentonite is a volcanic clay used in glazes to keep the liquid glaze in suspension, so it does not settle to the bottom of the bucket.)

COLORED CLAYS AND MINERALS:

Alberhill Clay – dark red
Kaolin - white
Kentucky Ball #4 clay – buff brown
Fire Clay - buff
Goldart Clay - tan
XX Sagger Clay – bone white
Barnard Clay - black
Silica - white
Red Iron Oxide – dark brown
Feldspars - white

WORKING STAGES OF CLAY:

1. **Plastic: Wet or Soft (Plastic or Plasticity is the pliability of the clay. How nicely the clay moves without cracking or falling apart.**

2. **Leather Hard: The clay is stiff but there is still water in the clay. This is an important stage. (You can add clay on or carve away the clay.) There are several stages of leather hard. Soft Leather Hard, Leather Hard, and Stiff Leather Hard. Soft Leather Hard and True Leather Hard are the best stages for attaching clay together.**

3. **Bone Dry: (The clay is completely dry and ready for the bisque firing.) The bisque firing turns the clay back to a rock like material, making it ready for the glazing process.**

4. **Greenware: (Clay pottery before it is fired.) All the above stages plastic (Soft), leather hard and bone dry) is Greenware.**

<u>TEMPERATURE</u>: Temperature is read in Fahrenheit or Celsius (centigrade). Most countries read temperature in Celsius. One uses pyrometric cones to read the temperature inside a kiln firing. The pyrometric cone was invented in the 19^{th} century in Germany.

Temperature for Bisque Firing

<u>BISQUE FIRING</u>:

Bisque firings are fired in an oxidation atmosphere, between C/09 to C/04. I bisque fire at C/06, 1,830 F. Bisque kiln firings, fire above 1,650 degrees Fahrenheit to drives off all organic matter; dead plants, animals, humans, etc., that has turned into carbon impurities in the clay. Blotting occurs to the clayy when firing to the higher temperatures if not bisque above 1,700 degree F.

<u>FIRING A BISQUE KILN</u>:

1. **Pre-heat, drives off any remaining physical water. 100 to 200 F.**
2. **Fires out the Chemical Water. 650 to 900 degrees Fahrenheit.**
3. **Quarts Inversion. 1000 to 1100 degrees Fahrenheit.**
4. **Fires out the Organic Matter in the clay. 1,600 to 1,700 degrees Fahrenheit.**
5. **Bisque Kilns should fire from 1,700 and above. Cone 09 to 04.**
6. **I fire at Cone 06, 1,830 degrees Fahrenheit.**

The thicker the clay wall structure, the longer the firing needs to be. I pre-heat for 72 hours and fire another 72 hours to bisque objects that are 3 inches in thickness for a bisque firing.

Burnishing and Slips

<u>BURNISHING BISQUE</u>:

Is usually bisque fired below 1,600 degrees Fahrenheit. Cone 016 to 012. The organic matter can diminish the burnished surface if fired above 1,650 degrees. The best way to burnish is to let the pot or engobe become bone dry, then burnish with cooking oil. Brush on the cooking oil and let it soak in and then burnish.

<u>SLIPS</u>: There are different kinds of slip.

There is slip for casting, pouring into a mold, there are decorating slips with color added to the slip and there is slip for attaching clay pieces together. Slip is a liquid clay. Clay becomes slip by adding and mixing water and or vinegar into the clay.

<u>Decorating Slips:</u> Decorating slips are called engobes. In the ceramic industry engobes are called underglaze colors. There are low fire and high fire underglaze colors. Duncan Concepts or Amaco Velets are two brands that have low fire, C/06 and high fire underglazes, C/5. C/06 underglaze colors turn into a slip glaze at C/10. Bright Red, Orange, Yellow colors all come out at C/10. C/5 underglaze colors fires matt at C/10. Underglaze colors can be applied onto the pottery in the wet, leather hard, bone dry or

bisque stages. One can get underglaze colors in liquid, chalk, pencil and in powder form.

<u>Casting slip:</u> Casting Slips are another type of slip used in casting pieces from plaster molds. There are deflocculants in the slip that make the slip very fluid for pouring into the mold.

There are different kinds of slip mixtures. I use clay and vinegar, no water to make my slip for connecting. Just Vinegar alone works well, or clay and water, or clay, water and vinegar.

Bone Dry Clay and Vinegar makes a good slip for attaching and repair. One can repair broken bone-dry pieces by soaking in vinegar until the clay starts to soften, then attaching with the bone-dry clay slip. Or take the piece back to leather hard and then repair.

Below is a slip formula that some clay artists like, which is a mixture of clay, vinegar, karo syrup and hydrogen peroxide.

<u>SLIP BONDING FORMULA</u>:

Vinegar	**1 cup**
Karo Syrup	**1 cup**
Clay body that you are working with	**1 cup**
Hydrogen Peroxide	**one teaspoon**

Depending on the size of a project, one may want to double or even triple the quantities of the formula before starting.

Mix thoroughly, if slip appears to be too soupy, gradually add more clay until slip becomes thicker.

<u>Wet Work:</u> <u>This formula works best in the wet working stages</u>. Apply liberally to scored areas and allow it to dry slowly. Clean surrounding surfaces of any excess clay or slip.

Important: Make sure your work area is always protected with newspaper or any material that you do not want to keep. Slip will dry like concrete, so clean up any spills immediately. Never allow slip to dry on your tools or your brushes. Always keep tools and brushes submerged in water while working. Wash with soap and water when finished. Never leave container with slip open while working, always keep closed between applications.

Bisque Ware: Successful repairs have also been made with bisque ware. However additional bisque firing is recommended to secure the repair. Avoid touching the repaired area, delicate care should be taken when handling the entire piece until after the glaze firing.

Storage: The slip will store well as long as the container is properly sealed. If it appears to be too thick after storage, gradually add vinegar until it becomes more consistent. Note: Smells like dead fish in the drying process.

Weathering Process to make Clay

CLAY BODIES

All clays come from feldspar through the weathering process: rain, wind, earthquakes, glaciers, expansion and contraction of the earths crust. 60% of all mountains are made up of feldspar. A mountain breaks down into pieces of rock, rock breaks down into dirt, and then dirt breaks down and combines with water. The physical water bonds with the molecular structure of the dirt to create clay. This is an on-going process on our planet.

Feldspathic Mountain: Na_20
K_20 $4A1_20$ $6Si0_2$
$Ca0$

Sodium, Potassium and Calcium, plus 4 alumina and 4 silica, are lost from the rock and dirt during the weathering process, thus the chemical composition of clay becomes $A1_20_3$ $2Si0_2$ plus the addition of $2H_20$ (chemical water).

Primary Clay (Koalin and Fire Clay) is clay that is found at the site or near the site of feldspathic mountain. It is white or light in color, not too plastic,

fires white and to a high temperature. This clay has a coarse grain.

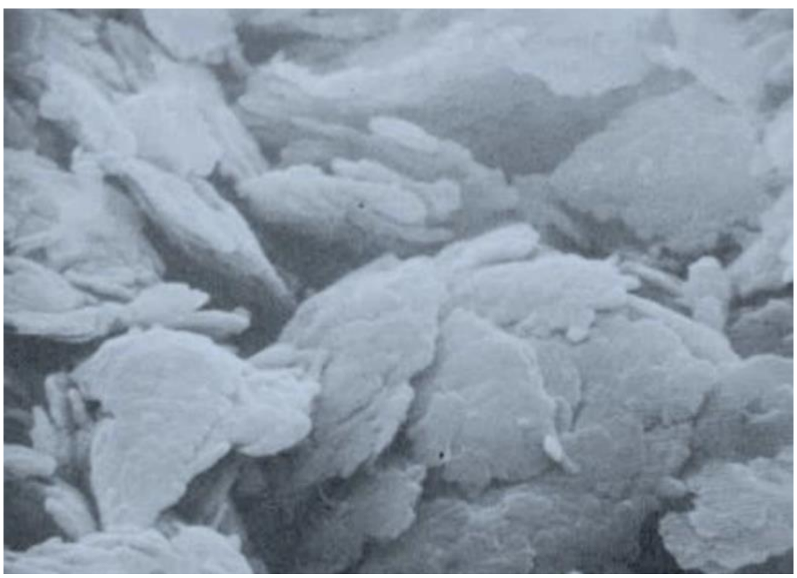
Secondary Clay (Earthenware Clay) is clay that has been moved from the primary site, and is dark, mostly plastic, and fine-grained and burns white. Secondary Clay is called Ball Clay when it is too plastic to use by itself.

Surface Clay is natural Earthenware Clay used in pottery making. It is plastic, gray or dark, and fires light. It is low-fire clay, firing at about 1900ºF.

*** A good working clay body is a combination of Primary and Secondary Clays, Feldspar and Silica.**

Clay Particles

*** Clay particles are elongated plate-like shapes. (Think of a deck of playing cards with the edges cut off at diagonals).**



C/10 STONEWARE CLAY

	Brown	Gray	White	porcelain
Kaolin Clay (E.P.K.)				**2.5**
Goldart (stoneware)	**1**	**2**		
Red Clay (earthenware)	**1**			
Kentucky Ball #4 (earthenware)	**2**	**2**	**2**	**2.5**
Lincoln Fire Clay #60	**4**	**4**		
XX Sagger Fire Clay			**6**	
Potash Feldspar (Custer)	**1**	**1**	**1**	**2.5**
Silica	**1**	**1**	**1**	**2.5**
	10.0	**10.0**	**10.0**	**10.0**

Add 10% Grog or Silica Sand to all clays for throwing, and 20 to 30% for hand building. (Do not confuse Silica with Silica Sand). They are two completely different minerals.

Clay bodies are formulated in percentages adding up to 10. Stoneware clay bodies are 80% clay, 20% fillers (feldspar and silica). Percentages are the equivalent of grams, ounces and/or pounds.

Grog and Silica Sand are additives and are not part of the total percentage of the clay body. Grog is made in ceramic industry by bisquing clay and grinding it into sand.

Nash White and Nash Red Sculpture Stoneware has approximately 18% Grog.
I started experimenting with Red Iron Oxide, 1.7% added to the total weight

of the Nash White Stoneware, to make the Nash Red Stoneware C/10 which fires to a light brown to medium brown.
Only use Red Iron Oxide # 521. Do not use a high yielding Red Iron Oxide #4284, dunting will occur. After many years of fine tuning the iron oxide in the Nash Red, I would still get shivering every now and then from some of the matt glazes. So, I decided to eliminate the red iron oxide from the Nash Red clay body and use a natural red clay as the source of Iron.

I have substituted Red Horse Clay for the Red Iron Oxide#521 in the Nash Red Clay Bodies which is a natural red clay. Changing to the Red Horse Clay has given a nicer plasticity to the Nash Red Clay Body and I am not having the dunting problem anymore. Dunting is when pottery cracks in the cooling of a glaze kiln after a glaze firing.

Do not confuse Silica Sand with Silica. Silica is glass. Grog and Silica Sand are added to clay bodies to create strength to the clay. We call this strength the tooth of the clay. I use 200-mesh silica, if you're going to work low fire glazes then use the 400-mesh silica.

Old Hickory Ball#5 is a good replacement for Kentucky Ball#4 if need be.

The Chouinard White Stoneware is a very good white stoneware, but the Nash White works better. Clay deposits do change over time (decades). If dunting or cracking starts to occur in the future, just drop the feldspar by half or add back the fire clay. The Nash bodies are a tight body, only absorbing .2% water after doing the boiling test from Daniel Rhodes book. That testing was done in the year 2004.

Nash White Stoneware Clay

Kty. Ball #4	2.1=2.0	100	300
XX Sagger	5.7=6.0	267	800
Custer	1.1=1.0	50	150
Silica	1.1=1.0	50	150
	10.0	467	1400
Grog – Mulcoa 325 Fine		84	250 (18%)
		551	1650

Chouinard White Stoneware Clay

Kty. Ball #4	300
XX Sagger	900
Custer	150
Silica	150
	1500
Grog –Mulcoa 48	150 (10%)
	1650

NASH WHITE SCULPTURE STONEWARE C/10 – change Grog – Mulcoa 325, powder grog to Mulcoa 35, medium grog. This is a very good clay body for hand building and wheel throwing. There's a nice tooth to the clay.

CLAY BODIES: STONEWARE

Nash White Stoneware C/10 (For beginning students, wheel throws like porcelain, wheel throws and hand builds very well).

Kty. Ball#4	**100.0**
XX Sagger	**267.0**
Custer Feldspar	**50.0**
Silica 200 Mesh	**50.0**
Mulcoa 325 Grog (Fine)	**84.0**
	551.0

NASH WHITE SCULPTURE STONEWARE C/10 This has a normal amount of grog for a stoneware clay body. Very Good. Salt fires very well.

Kty. Ball#4	**300.0**
XX Sagger	**800.0**
Custer Feldspar	**150.0**
Silica 200 Mesh	**150.0**
Mulcoa 35 Grog Medium	**250.0**
	1650.0 Total

Nash Red Stoneware Clay C/10 (For beginners and intermediate students). Wheel throws very good and hand builds very well). Salt fires very well.

Kty. Ball#4	**50.0**
Red Horse Clay	**17.0**
XX Sagger	**267.0**
Custer Feldspar	**50.0**
Silica	**50.0**
Mulcoa 325 Grog (Fine)	**84.0**
518.0	

Nash Red Stoneware Clay C/10 (tripled)

Kty. Ball#4	**250.0**
Red Horse Clay	**51.0**
XX Sagger	**800.0**
Custer Feldspar	**150.0**
Silica	**150.0**
Mulcoa 325 Grog (Fine)	**250.0**
1651.0 Total	

<u>Nash Red Sculpture Stoneware C/10</u>

Kty. Ball#4	**250.0**
Red Horse Clay	**51.0**
XX Sagger	**800.0**
Custer Feldspar	**150.0**
Silica 200	**150.0**
Mulcoa 35 Medium Grog	**125.0**
Mulcoa 20 Coarse Grog	**125.0**
	1651.0 Total

The Nash Red and Nash Red Big Sculpture are outstanding brown stoneware clay body for wheel throwing and hand building. Salt fires very well. The Nash Red fires smooth and the Red Sculpture fires course in texture.

<u>Joe-S (Soldate) Clay C/10</u>

Lincoln Fire #60	**200**
Kty. Ball #4	**100**
Custer Feldspar	**40**
Silica Sand (60 mesh)	**40**
	380

For a Brown Stoneware, 2 cups (16 ounces) Red Iron Oxide added to the clay body.

<u>Chouinard Brown Stoneware Clay C/10 (Windward)</u>

Lincoln Fire #60	**200**
Red Clay	**50**
Kty. Ball #4	**100**
Goldart Stoneware	**50**
Custer Feldspar	**50**
Silica	**50**
Grog (medium)	**50**
550	

The Chouinard Stoneware is a very good working clay body. I used it as a student at Chouinard Art School. You can substitute grog for silica sand.
This is a good idea for salt firings, creating an orange peel texture.

<u>John Mason Sculpture Clay C/10</u>

Kty. Ball #4	**100**
Lincoln Fire #60	**100**
Silica Sand	**30**
230	

Never tried the John Mason Clay.

HIGH FIRE EARTHENWARE
Chouinard Red High Fire Earthenware Clay C/5

Red Clay 300
Kty. Ball #4 60
Lincoln Fire #60 150
Custer Feldspar 60
Silica 30
Grog 60
660
*** If scumming occurs after bisque (White Film) add One cup Barium Carbonate to the clay body to stop the scumming to the C/5 Red Clay.**

Chuck Baxter C/5 (buff colored)

Lincoln Fire #60 175
Kty. Ball #4 100
Goldart Stoneware 125
Talc 25
Nepheline Syenite 50
Silica 25
500
***Earthenware clay bodies are usually fired in an oxidation atmosphere. Whether they are low fire earthenware or high fire earthenware clay bodies.**
LOW FIRE EARTHENWARE
Chouinard Brown Earthenware Clay C/04

Goldart Stoneware 50
Kty. Ball #4 50
Red Clay 150
Nepheline Syenite 75
Talc 150
Silica 25
500
Chouinard White Earthenware Clay C/04

Goldart Stoneware 150
Kty. Ball #4 150
Nepheline Syenite 90
Talc 180
Silica 30
600

To Change Color:
2% Manganese Dioxide, Light Brown
4% Manganese Dioxide, Dark Brown

1% Barnard, Dark Gray
10% Red Clay, Red
2.5% Iron Chromate, Gray

If a clay body at C/04 is not vitrified, use this remedy:
The clay absorbs less than 5% water, take out 5 Nepheline Syenite and add 5 Ferro Frit 3124.   If the clay absorbs more than 5%, take away 10 Nepheline Syenite and add 10 Ferro Frit 3124. Water absorption for all clay bodies should be 2% or less.

RAKU

Raku (pleasure, happiness, oneness) is an earthenware process that fires to around 1,700 to 1,800 degrees Fahrenheit. The glowing orange pottery is transferred from the kiln to a cold environment. There is also a cone 5 high temperature Raku that the Japanese potters also do. Traditional Raku is fired in oxidation. Western Raku is fired in an oxidation atmosphere and then by using combustibles, a reduction atmosphere is created.

Chojiro (1515-1592 A.D.) created the raku process. Zen Buddhist priests honored Chojiro and his mother for creating this firing process and the Emperor of Japan renamed Chojiro, Raku.

One can produce various effects and colors by reducing in the kiln at the end of the Raku firing and then putting the pottery into a can of combustibles: newspaper, saw dust, wood chips, leaves, etc.

<u>Norm Schulman White Raku Clay Body</u>

Groleg Kaolin	**10**
Bonding Clay (Natural Stoneware)	**5**
Kty. Ball #4	**2**
Grog	**5**
Talc	**5**
	25 lbs.

<u>Nash Raku Clay Body for Glass</u>

Spodumene	**33**
Groleg Kaolin	**24**
Bonding Clay (Natural Stoneware)	**12**
Kty. Ball #4	**6**
Grog	**12**
Talc	**12**
	99

In the above Raku Clays, Groleg Kaolin can be changed to XX Sagger Fire Clay or Lincoln Fire Clay. The clay bodies will then probably work better. Any Stoneware Clay will work as a Raku Clay Body if the free Silica is eliminated from the clay body.

<u>Raku 1-2-3 Glaze (Clear Crackle)</u>
This clear crackle glaze fires to a higher temperature then most raku glazes.

1 cup Flint (Silica)
2 cups E.P.K.
3 cups Colemanite (Gerstley Borate)

<u>Raku 1-2-3 Slip White</u>

1 part Colemanite
2 parts E.P.K.
3 parts Silica
Can add 3% Copper Oxide

80% Colemanite and 20% Nepheline Syenite will create a nice clear Raku Glaze at a lower temperature. One can change Nepheline Syenite with other feldspars that will create nice variation to a base Raku Glaze.

PORCELAIN CLAY BODIES

<u>Porcelain Clay C/10</u> – This is the original porcelain clay body from China, dating back to the Tang, Song (Sung) and Ming Dynasties.

Kty. Ball #4	**100**
E.P.K.	**100**
Silica	**100**
Custer	**100**
	400

If E.P.K. is replaced with English Grolleg Kaolin one will get a better working porcelain body.

<u>Porcelain Clay C/10-11</u>

Grolleg Kaolin	**57**
Custer Feldspar	**16**
Priax Pyrophyllite	**6**
Spodumene	**5**
Flint	**15**
	99

Porcelain Clay C/10-11 – This is a very good porcelain clay body; I worked with this clay at Rhode Island School of Design.

Grolleg Kaolin	**57**
Custer Feldspar	**16**
Priax Pyrophyllite	**11**
Flint	**16**
	100

Porcelain Clay C/10

E.P.K. or Grolley	**42**
G-200	**12**
Spodumene	**8**
Kty. Ball #4	**23**
Flint	**15**
	100

Porcelain Clay C/9-12

G-200	**22.0**
E.P.K.	**43.5**
Silica	**21.5**
Nepheline Syenite	**6.7**
Kty. Ball #4	**3.3**
Bentonite	**3.0**
	100.0

Porcelain Clay

E.P.K.	**42**
G-200	**12**
Nepheline Syenite	**8**
Kty. Ball #4	**23**
Flint	**15**
	100

Nash Porcelain Clay

E.P.K.	**42**
Kty. Ball #4	**23**
Flint	**15**
G-200	**20**
	100

Shrinkage of Nash Porcelain - 7% Green ware, 10% Bisque, 18% Glaze.
By changing E.P.K. to English Grolleg Kaolin, one will have a better working porcelain clay body.

2% Bentonite can be used for increased plasticity in porcelain clays. Clay will become rubbery from the bentonite after a month or two.
Kentucky Ball #4 is usually used instead of bentonite for plasticity.

A substitute for Priax Pyrophyllite is Spodumene. There is a .02 molecular weight difference between Priax Pyrophyllite and Spodumene.

SLIP APPLICATIONS - ENGOBES

Decorating Slips: Decorating slips are called engobes. In the ceramic industry engobes are called underglaze colors. There are low fire and high fire underglaze colors. Duncan Concepts or Amaco Velets are two brands that have low fire, C/06 and high fire underglazes, C/5. C/06 underglaze colors turn into a slip glaze at C/10. Bright Red, Orange, Yellow colors all come out at C/10. C/5 underglaze colors fires matt at C/10

Underglaze colors can be applied onto the pottery in the wet (plastic stage), leather hard, bone dry or bisque stages. One can get underglaze colors in liquid, chalk, pencil and in powder form.

Types of Historical Slip Treatments:

1. **Sgraffitto - Brush the surface completely, and then scratch away the slip.**

2. **Slip trailing - Using a slip trailing tool, squeeze onto the pot.**

3. **Inlay – Incise the surface, fill with slip, let dry to leather-hard, then scrape away.**

4. **Mishima - Incise, then brush slip on surface**

5. **Brush - Just brush the slip onto the surface.**

6. **Wax Resist - Apply wax, let dry, then apply the slip.**

7. **Pouring – Pour the slip over the surface.**

8. **Dipping – Dip the surface into the slip.**

9. **Hakima – Wide brush, made out of cotton. Dip in slip and brush on.**

10. **Haki brush - Made out of rice sticks. Dip it in the slip and brush it onto the pot. Put the slip on heavy, so it is thick.**

HISTORICAL/USE OF TEXTURE

Texture is created on pottery through either subtractions or additions to the surface. Textures can be created on a natural clay surface, or with a slip or glaze.

Texture may be applied in the following ways:

1. **Pressed - The texture is pressed into the pot by means of a natural form or an implement, which has been carved. (An example of a natural form is a rope pressed into the clay.) This technique is formal in nature. This type of texture is found on pottery of the Tang Dynasty. It is usually covered with a glaze. Slip may or may not be used over the design.**

2. **Incised - This process usually creates a more refined and narrow line. Slip is frequently used in this line, creating an inlay effect.**

3. **Carved and Relief - This technique is most often formal. It takes the form of animals or floral patterns.**

4. **Applied Relief -**

   a. Clay is pressed into a mold to make the form and then attached to the pot. Wedgewood pottery from England is the most famous example.
   b. The addition is usually a coil or ball of clay, which is then sculpted. This method usually gives the effect of the relief growing out of the pot or being part of the original surface, rather than being attached. Very early pottery used this method.

5. **Punctured – This punctured texture is applied by a natural implement, such as with the fingers or a stick. This technique is the freest of all the methods.**

The above textures can make the following historical designs:

1. **Floral**
2. **Animal**
3. **Curved lines - either short lines or continuous lines**
4. **Human forms, usually in stick figures**
5. **All-over pattern**

GLAZES

A glaze is a form of glass. Glazes are formulated in molecular weight, not in percentages. Pure glass is called Silica, Quarts, and/or Flint. Pure glass melts at 3,119 to 3,140 degrees Fahrenheit. Cone 32-33.

Oxidation/Reduction

All gas kilns fire in an oxidation atmosphere in the beginning. <u>Oxidation is a clean firing, which means all combustible materials are being burned. Reduction is creating smoke, which is carbon.</u> In the high fire process in a reduction atmosphere, beautiful Celadons, Copper Reds, Iron Blues, etc., are created. Electric kilns fire in an oxidation atmosphere. Gas kilns fire in an oxidation and/or reduction atmosphere. A Neutral atmosphere is between oxidation and reduction.

The mineral we use to create the reds and blues in Chun Red Blue glazes is Gerstley Borate. Gerstley Borate is also known as Colemanite. Gerstley Borate is a source of Boron and has been mined out around the year 2000 and was recreated in ceramic industry for us to use. I use the Laguna Gerstley Borate from Laguna Clay Company in the City of Industry, California.

There are three types of glass — glass, enamel and glaze:

1. **Glass – glass creates its own form, as in glass blowing.**
2. **Enamel - glass is melted onto metal.**
3. **Glaze – glass is melted onto clay.**

50% of all glazes contain Silica. Silica, Quarts and/or Flint are all the same mineral.

A glaze is a glass-like substance on the surface of the pot, used to cover and line ceramics. A glaze is fused by the action of heat.

A glaze can be shiny or dull. If it appears dull, it is a matt glaze. If it is shiny, it is a gloss glaze. If it is in between, it is a semi–matt glaze.

The treatment of Glazes

1. **A glaze can be used by itself or with other glazes. <u>The four methods of applying glazes are pouring, dipping, brushing and spraying.</u>**

2. **Over-slip – a glaze can be used over a decorative slip. Slips are usually applied before the first firing.**

3. **Majolica – Majolica is an opaque white glaze. Oxides are brushed on the bisque ware first and then the pot is glazed with the Majolica glaze, (under-glaze decorating). Or the reverse, the Majolica glaze can be glazed on the bisque ware first and then decorated with oxides (over-glaze decorating). Historical pottery used cobalt to create the different values of blue. This is early Italian ceramics.**

<u>BASIC GLAZES CAN BE CHANGED BY ADDING:</u>

1. **<u>Oppassifiers</u> - Tin ($Sn0_2$), Titanium ($Ti0_2$) (Rutile), Zircon (Zircopax) ($ZrSi0_4$). These minerals opaque a glaze, usually creating a white color.**

2. **<u>Colorants</u> -**

   A. <u>Underglaze colors</u> – Oxides or carbonates that have been fired and stabilized. The underglaze colors are usually consistent before and after firing. In the ceramic industry engobes are called underglaze colors. There are low fire and high fire underglaze colors. Duncan Concepts or Amaco Velets are two brands. Refer to page 8

   B. <u>Oxides</u> - oxides are usually black before firing. Oxides for color are called metallic oxides. Oxides used for color are <u>Copper Oxide</u> (Cu0) – green; <u>Cobalt Oxide</u> (Co_30_4) – blue; <u>Red Iron Oxide</u> (Fe_20_3) - brown to yellow; <u>Rutile Oxide</u>, TiO, yellows and tans; <u>Chrome Oxide,</u> CrO, green; <u>Nickel Oxide</u> ($Ni0_2$) - moss green or gray; and <u>Manganese Dioxide</u> ($Mn0_2$) - purple to scarlet.

   When calculating the molecular structure of a glaze, there are three RO columns. (R is an element, O is an oxide.) Refer to page 351, <u>THE ART AND CRAFT OF CLAY</u> by Susan Peterson or <u>CLAY AND GLAZES FOR THE POTTER</u>, by Daniel Rhodes, Revised Edition, page 124 or 3rd Edition, page 177.

POTTER'S USEFUL INFORMATION

Pottery Wheel

The potter's wheel was invented between 4,000 to 3,000 B.C. in Africa (Egypt) and the Middle East (Iran and Iraq). The modern kick wheel was developed around 3,000 B.C.

Silica, Quarts, and/or Flint are the same mineral. Pure silica melts at 3,140 degrees Fahrenheit. C/32-33

Packing Clay

PACKING CLAY: 90% E.P.K. 10% Kentucky Ball#4 (I use this one for stacking.)
PACKING CLAY: 50% E.P.K. (Kaolin Clay) 50% Silica
PACKING CLAY: 50% E.P.K. 50% Alumina Hydrated

Brick & Kiln Information

Kiln Wash

KILN WASH: 50% E.P.K. 50% Alumina Hydrate, (one can substitute Silica for Alumina Hydrate) Add Bentonite and Gum, If the kiln wash settles too much, then add 1 ounce at a time of Magnesium Sulfate (Epsom Salt) to help keep it in suspension.

KILN WASH: 50% E.P.K. 50% Silica / add Bentonite and Gum

28 grams is equal to one ounce
454 grams is equal to one pound

ITC 100HT is a ceramic coating for the walls of kilns. It reflects heat back into the kiln and not into the firebrick and is a Zirchromium-based material. It works very well in salt kilns. One can build a kiln with soft brick and coat it with the ITC 100HT. Salt will not absorb and eat away the soft brick.

Geil Kilns: Soft Fire Brick: B&Z Firebrick 26/60. Is 60% alumina and rated for 2,600 Degree Fahrenheit. Geil Kiln Company uses this brick for their kilns.

Burner Systems: Eclipse Inc which is a division of Honeywell. Industrial Burners. Eclipsenet.com.

Electrical Control Panels: Johnson Controls. Call North American Parts Center and Techical, 800-482-2278. York Unitary Products Group, 877-874-7378.

Big Kilns: Donovan Palmquist. kilnbuilders.com / all types of high fire kilns. Phone: 612-250-6208. Will build on site at your studio.

All glazes, both high fire and low fire must have 1% to 3% Bentonite that is put into the glaze in the dry mixing stage. We use 3%. Bentonite keeps the glaze in suspension when it is in liquid form. <u>If a glaze still settles, then add 1 ounce of Magnesium Sulfate to the liquid glaze. (Epson Salt)</u>

All glazes must have liquid gum, one to three ounces. Gum holds the glaze coating on the bisque ware. Liquid gum is added into the glaze after the glaze is in a liquid form. Refer to pages 39,40.

Do not confuse the word Magnesium with the word Manganese. They are two completely different earth minerals.

Eutectic

The two types of Eutectic:

a. <u>In Science</u>: Two elements with different melting temperatures combined together to create a third temperature melt at a new temperature, is called a Eutectic.

Example: Pb0 C/014
Temperature Melt C/01
$Si0_2$ C/32

b. <u>In glazing</u>, a Eutectic is the application of a glaze, then over-lapping another glaze on top of the first glaze, to create a third color value.

<u>SILICA</u>:

Silica is added to the clay (1) to prevent shrinkage between the glaze and the clay, which prevents crazing. (2) To better fuse the glaze to the clay. Using too much silica in a glaze will devitrify the glaze, causing the glaze to look very dry and possible causing shivering.

<u>SALT KILN</u>: (ORANGE PEEL)

In a high fire salt glaze kiln firing, adding silica sand into a clay body creates the most successful orange peel effect. One can also use engobes with silica sand. About 10% Silica Sand instead of grog works best. The Nash clay bodies salt really well without silica sand. Best salting starts at Cone 8 to Cone 11.

<u>CONE 4,5,6 HIGH FIRE EARTHENWARE GLAZES FROM CHOUINARD ART SCHOOL</u>:

Cone 5 glazes are fired in an oxidation atmosphere, usually fired in an electric kiln. Fleck glaze at C/5 (2230ºF, 1221ºC) with zircopax over red slip is effective. This glaze creates white and brown colors. Fleck glaze also works well over black and dark blue slips. Fleck glaze with 1% copper is successful over barrard clay, red, black, and dark blue slips (Engobes).

C/5 Satin matt creates excellent color effects except with cobalt.

C/5 June glaze is an excellent high fire Earthenware Glaze.

Percentages

<u>Satin Matt (Eggshell) C/5</u>

Zinc Oxide	**7.5**
Silica	**55.5**
E.P.K.	**26.4**
G-200	**152.1**
Whiting	**58.5**
	300.0

Additives:

- **2% Copper Carbonate**
- **4% Manganese Dioxide**
- **7% Tin Oxide**
- **2.5% Iron Oxide**
- **2.5% Copper Oxide**
- **1% Cobalt**

White Lead is very dangerous and the proper resperatetor should always be used. The fleck glaze formula should be tested for lead leaching if going to be used for utilitarian pottery. Any chemical lab can test a piece of pottery without breaking it.

June Glaze C/5

G-200	**88.0**
Colemanite	**34.8**
Barium Carbonate	**37.0**
Whiting	**14.4**
E.P.K.	**4.8**
Silica	**21.0**
	200.0

Additives: 2% Copper Oxide or 3% Copper Oxide

Fleck Glaze C/5

White Lead	**361.2**
Ferro Frit 3195	**143.2**
G-200 Feldspar	**106.6**
E.P.K.	**67.1**
Tin Oxide	**54.0**
	732.1

Additives to the C/5 Fleck Glaze: Only need to use ½% to 1% to get a medium to strong color value. These combinations will work at Raku

Temperatures & C/10 Stoneware Temperatures.

3% Copper Oxide = Dark Green
2% Copper Oxide = Light Green
2% Manganese Dioxide = Purple
1% Rutile = Buff White
2% Red Iron Oxide = Red Brown
1% Cobalt Oxide = Blue
10% Zircopax = Opaque White
1/2% Nickel = Tan
1% Ilmanite = Brown Speckles
Chrome and tin oxide = pinks
Chrome and zinc = brown tan
Chrome and magnesium = brown tan
Barium with cobalt = purples

Glazes usually take 1/8% to 5% of oxides or carbonates to create color. These are percentages down to 1/32 of a percent.

Percentages:

1% = .01
1/2% = .005
1/4% = .0025
1/8% = .00125
1/16% = .000625
1/32% = .0003125

Different types of Glazes:

Gloss (Transparent) and or Oxides/Carbonates to change color.
Matt
Semi-Matt
Opaque
Semi-Opaque
Wood Ash
Salt (Orange Peel Texture) Cone 8 to 11
Texture (Shino Glazes is one example of texture crawling)
Crystalline (Looks like snowflakes)
Raku

Egyptian Paste (Alkaline) (soda blues, turquoise 1800 to 1900ºF)
Lusters Cone 019 to 016
China Paint or Over Glaze Enamel Cone 019 to 016

Color of Space Inside A Kiln

The space inside a kiln will start to become colored light around 1,200F to 1,400F. (<u>Dark Red</u>)

Pit Fire: C/016 to 012, (<u>Red to Orange light in kiln</u>) 1,407F to 1,623F (No Glaze).

Lusters and China Paint: C/019 to C/014, (<u>Dark Red light in kiln</u>). 1,234F to 1,540F

Low Fire Earthenware: C/010, (<u>Red to Red Orange light in kiln</u> 1,641F to 1,686F. Low fire earthenware is where you can get very Bright red, Bright orange and Bright yellow glazes.

Low Fire Earthenware: C/06 to C/03, 1,873F to 2,068F (<u>Orange to Orange Yellow light in kiln</u>).

High Fire Earthenware: C/4 to C/6, (<u>Yellow Orange to Yellow light in kiln</u>) 2,167F to 2,291F.

High Fire Stoneware: C/9 to C/12, (<u>Yellow-Yellow White light in kiln</u>) 2,300F to 2,419F.

High Fire Porcelain: C/9 to C/15, (<u>Yellow – Yellow White light in kiln</u>) 2,300F to 2,608F.

White Light and Yellow Light is dangerous to our eyes, you need to ware proper welding glasses or glasses that remove ultraviolet light when looking into the kiln at the stoneware temperatures.

PART 2: THE ART OF HIGH FIRE GLAZES

INTRODUCTION

I have been teaching high fire reduction ceramic art for over forty years and have been working in ceramics for over fifty years. The one question that keeps coming up from students, whether they are beginners or advanced students, is why does a glaze do this or that after the pot comes out of the kiln? After all these years, I have seen a pattern from most of my students. It takes anywhere from one year to three years to explain the relationship of an application of a glaze or glazes in the high fire reduction process. So, I thought if I put the examples in an easy to understand format for the students, it would make my life easier as an educator, teaching the art of the high fire process. The purpose of this book is to show the wide variety of colors and textures from high fire stoneware glazes. There are many stable varieties and combinations of glazes. The earth minerals are easily accessible throughout the United States. With basic changes, one can expand one's palette of colors and textures, using just a few basic glazes.

I recommend four great books in the ceramic field. All ceramic students should have these books. Clay and Glazes for the Potter, Revised Edition by Daniel Rhodes, Hands in Clay by Charlotte F. Speight, and The Art and Craft of Clay by Susan Peterson and A Potter's Handbook by Glenn Nelson and Richard Burkett. Before you use this book, you should have studied and memorized the information in these books. My book will give the ceramic artist a solid foundation in creating their own studio, so you will not be wasting time and money. There are a few more excellent books out there, but any good ceramic teacher would agree that the books I have mentioned above, are the books that a new student or advanced student to ceramics should have.

There are three good high fire base glazes that almost make up all the other glazes, with only a few exceptions. These glazes are cheap to make, are made up of minerals that are easily accessible, and are reliable in a stoneware or porcelain firing. These glazes can make a wide variety of glaze color: the Celadon base glaze, the Semi Matt base glaze, and the Stony Matt base glaze. There are examples in the studio and at my website: paulnashceramics.com The glazes with the addition of metallic oxides and/or carbonates, you will get an endless variety of colors and textures.

Even though you will have a very good starting point for high fire glazes, the kiln you use and the way you fire the kiln will also change the glaze color and texture. Over the years I have fired several updraft kilns: the old West Coast Kilns and Fred Olsen Kilns. Both of these updraft kilns fire quite well. You can get good clay color and nice Celadons, Copper Reds, Iron Blues, and Chun Red Blues (Chun glazes are boron base glazes).

I have also fired downdraft kilns. The downdraft kilns do take longer to fire and the results are pretty close to being the same as an updraft kiln. The kind of kilns that I would recommend for this day and age are the Paul Geil Kilns or Donovan Palmquest Kilns. Paul Geil has taken the updraft design of a kiln and added the downdraft damper flue design to it. Normally the damper of an updraft kiln is at the top of the ceiling roof. He has put the damper at the bottom, like a downdraft kiln. The uniqueness of this is that you don't need a big chimneystack at the back of the kiln, like the standard downdraft kiln.

The Geil Kiln doesn't fit any of the concepts of kiln building. The kiln fires great. The clay color is richer and the glaze colors has a depth and beauty that the old design kilns can't achieve.

If you can't afford a Geil Kiln, I would recommend the Fred Olsen Kiln Kit. If you have experience in building kilns, I would take the Olsen Kiln Kit and modify it to the Paul Geil design. That's just me.

There is no doubt that Paul Geil Kilns will replace all the old standard updraft kilns and downdraft kilns of the past. I first fired one of Paul's kiln in the mid 1970's, early in my studio and teaching career. This was when Paul had just started a business of building kilns. Initially I thought that this was a very strange but interesting concept, to use an updraft burner assembly with a downdraft damper, and to have the flue ending at the top of the kiln. I realized, don't judge a kiln by its look. It fired great, excellent, and outstanding.

Before I start introducing the glaze formulas and applications of a glaze, you need to understand the firing atmosphere of a kiln. There are oxidation, reduction and neutral atmospheres in firing a kiln. All gas kilns fire in oxidation in the beginning of the firing. Body reduction starts around 1,500 to 1,600-degree Fahrenheit. By 1,900, glaze reduction is starting right after the body reduction, one moving into the other so you don't lose the body color,

and ending in a neutral, and then back to a short oxidation at the end. You need to understand these processes and be able to experiment in firing a glaze kiln, to get an even temperature top and bottom, you need to know how much of a reduction atmosphere to obtain to get good results, and to know how much of an oxidation soak is necessary at the end of the firing. When I was learning how to fire a kiln, I would put into the kiln 4,5,6, cone packs with a clay pool catch, to catch the cones as they melt into a liquid glass during the firing of the kiln. The 4,5,6 cones would be in front of the 9,10,11 cones. If the kiln is uneven in temperature at the time the 4,5,6 cones melt, this will give you enough time to play with the damper and/or the burners to even out the kiln before you start to get to the maturing temperature of cone 9,10,11. If the kiln is even top and bottom when the temperature is at cone 4,5,6, the kiln will be even at cone 9,10,11. It is always best to work and watch an experienced kiln expert fire a kiln before you start firing kilns. There is the stress and responsibility of safely firing all the pottery that is in the kiln. I will go into more detail later about firing a reduction kiln.

Clay bodies are important. I have used the commercial stoneware clays and I have seen many students use all kinds of commercial stoneware clays from different companies. None of them are that good. My new students get very frustrated because of the grog or silica sand in the clay that cuts their fingers and hands. My advance students get frustrated because of the poor working quality of the stoneware clays. Some of these qualities are short plasticity, bad color, and poor fit of a glaze. These problems were my problems early in my career in the 1970's, so I had Aardvark Clay and Supply Company in Santa Ana, California start making my clay body for me. This was a clay body which I had used at the Chouinard Art School, when I attended there as an undergraduate student in the late 1960's.

Sometime in the 1990's I got the idea to put fine grog in the clay so my beginning students would have an easier time learning the potter's wheel. The idea worked, but the clay didn't stand that well for advanced students or for me when I was throwing large forms. So, I started experimenting with grogs and silica sands to create more tooth in the clay body. It took about four years of research. I have developed a great wheel throwing and hand building clay bodies. The Nash White is an excellent wheel throwing and hand building clay for beginners. The Nash Clay Bodies are great clay bodies for wheel throwing and hand building on a larger scale.

The Nash Red Sculpture is a brown stoneware and the Nash White Sculpture is a bone white stoneware.
Porcelain clays are very important too. You want to be very competent with stoneware clay first before moving to porcelain clay. Porcelain doesn't stand up that well and the body in general has a short plasticity. You need to wedge porcelain clay three to five times longer than stoneware clay and you need to dry porcelain clay slower during the greenware stage.

There are three important areas of ceramics: the clay body, the glaze, and the kiln. I will give you glaze and clay formulas in percentage form, which means it can be weighed out in grams, ounces, or pounds. If you want the molecular weight formula, you'll need to research this information yourself. Use <u>Clay and Glazes for the Potter</u> by Daniel Rhodes, chapter 14, page 156, if you have no experience. This book best explains the molecular structure and weight of a glaze formula. If you can't find Daniel Rhodes book, then use the book <u>The Art and Craft of Clay</u> by Susan Peterson, chapter 10, page 361.

The test pots that are next to each glaze formula displayed in the studio are glazed with three different applications by dipping them in a glaze: a thick glaze application at the top, a medium application in the middle, and a thin application at the bottom. You will see that the glaze will have a different color and texture with each area of application. The only problem you might have if you apply the glaze too thick, is that it might peel away from the pot in the raw stage, or run off or crawl off the pot during the firing. You can touch up and re-fire it, if the glaze crawls. Sometimes that will correct the problem. You should be able to re-fire a pot six to eight times before the clay will fatigue and break. The Celadon glazes, if applied too thick, will craze.

All the glazes I am using work really well. You will not get crazing or shivering from these glazes. You can combine all these glazes together by overlapping one glaze over the other to create patterns. This is how you will start to get beautiful combinations of colors and textures. You will need to experiment with how you overlap a glaze, to dip the pot and/or pour the glaze over the pot, and dip the pot again into a different glaze, and/or pour another glaze over the pot. This will create endless variations of color. This process is called a Eutectic, to create a tertiary color by overlapping different glazes over each other.

An easy way to understand the general thickness of a glaze application: if it's thinner than your finger nail, that's a normal application, if it's the thickness

of your thumb nail, that's medium to thick, and if it's the thickness of your big toe nail, that's too thick. The best way to see the thickness of a glaze in the raw stage is to scratch the surface with a needle tool. Just scratch a line about an inch long and you will see the depth of the raw glaze. Then rub that area with your finger and the line will usually disappear. If the line does not disappear, just add a little glaze, let the glaze dry, and smooth it down with a tool of your choice.

Before I start giving the glaze formulas, I think you should know how the formulas came to me. Most of these glazes are from Chouinard Art School, which is now California Institute of the Arts, in Valencia, California, when I was studying at Chouianrd for my undergraduate degree.

Some of these formulas are the original glaze formulas from China. These glaze formulas traveled from China, to Korea, then to Japan, then to England, and then to the United States in the early 1900's.

Alfred University, Alfred, New York is a ceramic university, founded in 1836 with ceramic science, ceramic art, and ceramic engineering degrees, they analyzed the glazes from China and Japan to create the formulas we have today. From Alfred, the glazes started their journey to University of Southern California (USC) and Chouinard Art School, both in Los Angeles, California.

GLAZE FORMULAS/BRINGING A BATCH FORMULA TO 100

To bring down or up the total percentages of any glaze or clay formula to 1, 10 or 100. Just divide the percentage into the total weight.

Chouinard Celadon Glaze Base:

80.0	**divided by**	**417.8= .191=**	**19**
144.0	**divided by**	**417.8= .344=**	**34**
81.5	**divided by**	**417.8= .195=**	**20**

112.3 divided by 417.8= .268= 27
0.998= 100

CONE / 9,10,11 STONEWARE GLAZES:

8,000 Grams makes a full 5 gallon buck of glaze.

The Chouinard Celadon Glaze-Base:

Whiting	**80.0**	**800.0**	**1600.0**
Silica	**144.0**	**1444.0**	**2888.0**
E.P.K. (Kaolin)	**81.5**	**815.0**	**1630.0**
G-200 Feldspar	**112.3**	**1123.0**	**2246.0**
Total	**417.8**	**4,182.0**	**8,364.0**

Celadon Glaze Base:

Custer Feldspar	**260.0**	**1300.0**	**2340.0**
Whiting	**250.0**	**1250.0**	**2250.0**
E.P.K.	**190.0**	**950.0**	**1710.0**
Silica	**360.0**	**1800.0**	**3240.0**
Total	**1060.0**	**5300.0**	**9540.0**

You can bring any formula to a total of 100 by dividing the percentage by the total batch. 80.0 divided by 417.8 = .191=19

The Chouinard Celadon formula gives a nice clear glass on white stoneware and porcelain. Applied on brown stoneware clay, it will be a clear gray glass. If you add 1 to 3% Red Iron Oxide to the base, you will get a traditional Pool Green Celadon. If you add one half of one percent .005 of Black Stain F-3786 from Laguna Clay Company, City of Industry, California, you will get a Pool Apple Green Celadon, which is quite beautiful.

The Celadon glazes make nice Iron Blue Glazes.
To make an Iron Blue glaze: add: 6% Rutile - 2%Tin Oxide - 2% red Iron Oxide. Another variation is: 5% Rutile - 2% Tin Oxide - 4% Red Iron Oxide. Both will make a nice Iron Blue Glaze.
A Rusty Iron Blue: 4% Rutile - 2% Tin Oxide - 4% Red Iron Oxide.
A nice Celadon Black Glaze: 8% Red Iron Oxide - 1% Chrome Oxide - 3% Manganese Dioxide.

Bentonite and Gums are used in all glazes, no matter if you are making high fire glazes or low fire glazes. Bentonite needs to be put into the dry earth minerals and mixed by hand before adding water. If you don't do this, the bentonite will become gel-like and it will be very difficult to dilute. Always use 3% Bentonite for suspending the glaze in a liquid form.
If the glaze continues to settle or having pin holing, then add one ounce, 28 grams of Magnesium Sulfate to 8,000 to 10,000 grams of glaze. Adding 1% Lithium Oxide can also help in control pin holing.

Lithium absorbs heat shock, which is used in flameware pottery. The fire is directly touching the pottery. Spodumene is the main source of Lithium Oxide.

GUMS

<u>GUM TRAGACANTH AND GUM ARABIC ARE THE BEST GUMS:</u>

The gums are used for adhesion. Gum Tragacanth works a little better than Gum Arabic. Add 40 grams to two-third cup Ethyl alcohol or a denatured alcohol to dissolve the gum. Then add water to make a gallon of the liquid gum. Use one ounce of liquid Gum Tragacanth to every 1000 grams of glaze batch. Gum Tragacanth is expensive. The next best gum is Gum Arabic. If you use the Gum Arabic, use two ounces of liquid gum to every 1000 grams of glaze batch. Dissolve the same way for all gums. Always add liquid gum to the glazes that are also in a liquid form. You can always add more gum to a glaze if the glaze coating is not sticking to the pot.

C.M.C. also works well as an adhesive and is the cheapest gum you can buy. C.M.C. is a man-made gum in the science industry. If you use the C.M.C., weigh out 30 grams and dissolve the same way as the other gums. You only need to add two to three ounces to 8,000 grams of a glaze batch. C.M.C. will have a tendency to thicken the glaze if you use too much. If that happens, just add more water to thin the consistency of the glaze. You won't have this problem with the natural gums. The C.M.C. mineral does go bad over a period of time.

<u>Semi Matt Glaze Base:</u>

G-200 Feldspar	**2570.0**
Tennessee Ball#1	**454.0**
Colemanite	**722.0**
Dolomite	**460.0**
Talc	**884.0**
Whiting	**280.0**
Silica	**<u>1198.0</u>**
Total:	**6568.0**

This base glaze makes a very nice semi-clear glaze. It looks good by itself. If you start adding percentages of different oxides or carbonates, you will get endless beautiful variations of colors. Some of the most popular ones are:

Semi Matt Gold: 5% Rutile - 1%Tin Oxide, and 1%Lithium Oxide to control pin holing. One ounce of Magnesium Sulphate to 8,000-gram batch also helps to prevent pin holing.
Semi Matt Blue: 1% Cobalt Carbonate.
Semi Matt Chrome: 1% Chrome Oxide.
Semi Matt Green: 2% Chrome Oxide.
Semi Matt Blue Green: 1% Cobalt Carbonate - 1/2% Chrome Oxide. Semi Matt Green Blue: 1% Chrome Oxide - 1/2% Cobalt Carbonate. Semi Matt Gray: 2% Copper Oxide.
Semi Matt Gray Blue: 2% Copper Oxide - 1% Cobalt Carbonate.
Semi Matt Blue Green with flecks: 1/2% Cobalt Carbonate-
1/2 %Chrome Oxide - 1/2% Copper Oxide.

You can go on and on with percentage variations on your own and continue to get beautiful subtle colors.

If you take out the whiting from the Semi Matt Glaze formula, you will get a blue lavender color from the Cobalt. Made sure you re-add the total batch of the glaze, if you remove the whiting.

If you use Kona F4 Feldspar in the formula instead of G-200, you will get a nice texture change in the glaze. You can eliminate the whiting in the formula and get nice color variations with the addition of Oxides and Carbonates.

Oxides and Carbonates are always calculated to the batch weight. An example: for 1% of Cobalt Carbonate to the batch weight of the Semi Matt

Glaze, 6,566.0 you would add 65.66 grams of cobalt, 65.7 because you would round it off.

10,000 grams of dry glaze will usually fill a 5-gallon bucket, so you might want to go a little under the 10,000-gram mark.

Most glazes call for 1/4% to 5% of an oxide or carbonate to be added.
I have given you percentage figures up to 1/32 of a percent:

1%: .01
1/2%: .005
1/4%: .0025
1/8%: .00125
1/16%: .000625
1/32%: .0003125

<u>Stony Matt Glaze Base:</u>

Whiting	**440.0**
Dolomite	**884.0**
Talc	**904.0**
Cornwall Stone Feldspar	**1600.0**
Nepheline Syenite	**1108.0**
E.P.K.	**<u>2000.0</u>**
Total:	**6936.0**

Cornwall Stone comes from England, so it will be more expensive than the other feldspars, but it is worth it. Cornwall Stone will leave hard rocks in the sieve when screening the glaze. Throw out whatever rocks are left in the 80-mesh sieve or dissolve in hot water. Cornwall Stone Feldspar and some other minerals have large impurities that will not pass through an 80-mesh screen. Throw these impurities out. You do not want them in the glaze.

I was experiencing a little shivering if there was a sharp edge on a piece of pottery made from the Nash Red Clay body. I divided the total percentages by

5 to work with a smaller total Batch. I increased the whiting by 5 % each time until the shivering stopped. If you don't understand shivering and crazing you should look it up in one of your ceramic books. The shivering was coming from over reducing the kiln during glaze firing. I open the damper an additional half of an inch to three and three-quarter inch opening to the damper; there is still a medium reduction atmosphere. It takes a few firings of a new gas kiln to get a feel for the firing process. Each kiln is different.

The Stony Matt Base is a beautiful off-white Matt glaze.
1% Copper Oxide: Oatmeal Matt
1% Manganese Dioxide: Light to toasty Oatmeal Matt
3% Vanadium Oxide: Soft Yellow Rust Matt
1/2% Cobalt Carbonate: Stony Blue Matt
4% Rutile - 2% Red Iron Oxide – 1% Tin Oxide – 1/2% Lithium Carbonate: Goldbrown Green Matt. This combination is very unpredictable, but fun because it's never the same.

As you can see with these three base glazes and the colorants, you will have a solid base of very good glazes to work with.

Here are some other base glazes that are very reliable:

Heavy Iron Glaze (Tenmoku)

G-200	**3160.0**	
Silica	**2040.0**	
E.P.K.	**750.0**	
Whiting	**1330.0**	
Red Iron Oxide	**710.0**	
Total:	**7990.0**	**Add 3% Bentonite**

You can double the E.P.K. you will get a nice Kaki glaze from the Heavy Iron Glaze. If you remove the Red Iron Oxide, you will have a clear base glaze with the Heavy Iron and the Kaki glazes.

Red Kaki Glaze

G-200	**3120.0**
Silica	**1620.0**
Bone Ash	**720.0**
Whiting	**480.0**
Talc	**420.0**

E.P.K.	**360.0**	
Red Iron Oxide	**720.0**	
	7440.0	**Add 3% Bentonite**

You can add Red Kaki and Copper Reds together to make nice combinations.

Far Out Copper Red Glaze by Paul Nash

Kona F4 Feldspar	**4262.0**
E.P.K.	**104.0**
Silica	**1872.0**
Colemanite	**824.0**
Whiting	**500.0**
Zinc Oxide	**344.0**
	7906.0
2% Copper Oxide	**159.0**
3% Bentonite	**238.0**

You can get nice variations from the Far Out Red glaze by using 1/2% to 3% Copper Oxide and adding Cobalt Oxide from 1/4% to 1/2% with the Copper Oxide. 1% to 3% Tin Oxide will help stimulate color. Add 1/2% Cobalt Carbonate, 3% Tin Oxide and 2% Copper Oxide to the base Far Out Red glaze, and you will get a different beautiful red blue glaze. You will find a slight difference in color when using copper oxide or copper carbonate. I don't see any difference with cobalt oxide or cobalt carbonate.

Chun Turquoise Glaze from Chouinard Art School

Fritt (Pemco) P 54 (Ferro) F 3134 or F 3116	**1800.0**
G 200 Feldspar	**2840.0**
Whiting	**200.0**
Colemanite	**360.0**
Kentucky Ball #4	**530.0**
Silica	**2000.0**
	7730.0
4% Copper Carbonate	**308.8**
3% Bentonite	**231.6**

Chun Red Glaze

Colemanite	**1062.0**
Whiting	**837.0**
Custer Feldspar	**734.0**
Nepheline Syenite	**3388.0**
E.P.K.	**163.0**
Silica	**1816.0**
	8000.0
1.7% Tin Oxide	**136.0**
3% Copper Carbonate	**240.0**
3% Bentonite	**240.0**

The mineral we use to create the reds and blues in Chun Red Blue glazes is Gersley Borate. Gersley Borate also has the name Colemanite. Gersley Borate is a source of Boron and has been mined out around the year 2000 and was recreated in ceramic industry for us to use. I use the Laguna Gersley Borate from Laguna Clay Company in the City of Industry, California.

Copper Grape Red Chun Glaze

Zinc Oxide	**200.0**
Barium Carbonate	**408.0**
Dolomite	**408.0**
Colemanite	**408.0**
Whiting	**656.0**
Custer Feldspar	**4080.0**
Silica	**2040.0**
	8200.0
2% Copper Carbonate	**164.0**
1/4% Cobalt Carbonate	**20.5**
1% Tin Oxide	**82.0**
3% Bentonite	**246.0**

Rusty Shino Glaze

Nepheline Syenite	**3200.0**
Kona F4 Feldspar	**1040.0**
Spodumene	**720.0**

Kentucky Ball#4	**1200.0**
E.P.K.	**640.0**
Redart Clay	**240.0**
Soda Ash (Need to dissolve in hot water)	**960.0**
	8000.0
3% Bontonite	**240.0**

Shino White Glaze

Soda Ash	**200.0**
Kona F4	**550.0**
Nepheline Syenite	**2250.0**
Spodumene	**750.0**
E.P.K.	**500.0**
Kentucky Ball #4	**750.0**
	5000.0
3% Bentonite	**150.0**

Shino Glazes are supposed to go on thick to get crawling. After glazing let the pottery set for a few days so the sodium carbonate can come to the surface of the raw glaze. The glaze also looks good applied thin if you don't want crawling.

Spodumene White Tan

EPK	**2000.0**
Dolomite	**1760.0**
Whiting	**320.0**
Spodumene	**1600.0**
Custer Feldspar	**2400.0**
	8080.0
Tin Oxide 5%	**404.0**
Bentonite 3%	**242.4**

Adding 1 oz. of Magnesium Sulfate helps the suspension of a glaze. If you have a glaze that has a tendency to settle and harden at the bottom of the bucket then add the Magnesium Sulfate and remix the glaze.

Toshiko Orange Highlight Glaze

Nephine Syenite	**360.0**
Silica	**270.0**
Kentucky Ball #4	**135.0**
Zinc Oxide	**90.0**
Whiting	**270.0**
Colemanite	**31.0**
Zircopax	**90.0**
Rutile	**288.0**
Bentonite	**36.0**
	1570.0

All the glazes mentioned above work really well and you would have a great foundation of base glazes to work with. It will be up to you to determine how many glazes you want as a color palette for your ceramic artwork. As a poor artist just starting out, I strongly recommend that you work with the Pool Green Celadon, Semi Matt's and Stony Matt's, adding some oxide for color. Firing oxidation or reduction to cone 10 will save you time and money, however the reductions process can create some beautiful colors.
If you want the exact same glaze color every time, then you should fire the kiln oxidation.

FIRING A HIGH FIRE REDUCTION KILN

I start body and glaze reduction at around 1600 degrees Fahrenheit. I was taught to start body reduction at around 1500 degrees F. which works well with copper red glazes (Chun). But after many years of firing, I have found that one can still get a good body reduction starting at the higher temperature, 1,800 degrees F. which cuts down a little on the time to reach Cone 10.

The kiln fires in oxidation up to 1, 500 to 1,600 degrees Fahrenheit, then it goes into a medium reduction atmosphere. The earth mineral in the brown clay body start reducing at the lower temperature then a glaze. A C10 glaze will start to flux around 1,900 - 2,000 degrees. I like to have at least a 5 inch flame at the top peephole and about a 2-inch flame at the bottom peep hole. The kiln fires this way until we get to cone 8, about 12 hours. When cone 8 just starts to drop I put the kiln into a heavy reduction, so there is some smoke licking out at the end of the flames from the peelholes. The temperature will drop about fifty to one hundred degrees or so and then settle into a soak. I soak for 45 minutes and then I go to an oxidation atmosphere flame, having a neutral flame at the top peephole and no fame at the bottom peephole. The kiln is in an oxidation neutral atmosphere until it gets to cone 10. Shut down the kiln and close the damper. I like to have Cone 11 tipping a little bit. Any combination of Cone 9,10,11 on top and bottom is considered an even firing.

All gas kilns start with the damper 1/2 open, firing in an oxidation atmosphere. Adjust the damper when you start to get a nice orange color in the kiln. At 1,600 degrees, the inside of the kiln is an red orange color and I close the damper to 1/3 open to start a medium reduction, which is about three and half to four inch opening to the damper. Always check your peephole flames.

Get to know the neutral flame atmospheres, from an oxidation neutral flame to a reduction neutral flame.

Body reduction for brown stoneware clay can start anywhere from 1,500 degrees Fahrenheit to 1,600 degrees. I start body reduction at about 1,600 degrees and it seems to work fine. Again, all gas kilns fire differently.

PLASTER OF PARIS

Always use U S. Pottery Plaster #1. It will give a strong but absorbent plaster for making plaster bats, tops for wedging tables, drying slabs, etc. It will take a few practice tries before you get the mixing process down.

WATER-PLASTER RATIO -- 1 to 1 3/8 by weight

Water		Plaster				Water		Plaster			
½	pint			11	oz.	6	quarts	16	lb.	8	oz.
1	pints	1	lb.	6	oz.	7	quarts	19	lb.	4	oz.
1 ½	pints	2	lb.	4	oz.	8	quarts	22	lb.		
1	quart	2	lb.	12	oz.	9	quarts	24	lb.	12	oz.
1 ½	quarts	4	lb.	8	oz.	10	quarts	27	lb.	8	oz.
2	quarts	5	lb.	8	oz.	11	quarts	30	lb.	4	oz.
2 ½	quarts	6	lb.	14	oz.	12	quarts	33	lb.		
3	quarts	8	lb.	4	oz.	13	quarts	35	lb.	12	oz.
3 ½	quarts	9	lb.	10	oz.	14	quarts	38	lb.	8	oz.
4	quarts	11	lb.			15	quarts	41	lb.	4	oz.
4 ½	quarts	12	lb.	6	oz.	For each additional quart of water beyond 15, add 2 lb. 12 oz. plaster					
5	quarts	13	lb.	12	oz.						
5 ½	quarts	15	lb.	2	oz.						

Plaster comes in the form of a white powder. When mixed with water, it recovers the water it had, prior to being treated by heat, and ends up with the same composition as the original gypsum.

Add salt to the water if you want to slow the action of the setting time (5 to 10% Salt). Use hot water to speed the action of the setting time.

2 3/4 lbs. plaster and 1 qt. water makes a 6" wheel-throwing bat.

Volume of a cylinder --when figuring formula in cubic inches.

$$V = \pi r^2 h$$

(V = volume; π= 3.14; r = radius h = height)

Volume of a cube --when figuring useage in cubic inches.

$$V = L \times W \times H$$

(V = volume; L = length; W = width; H = height)

Cubic inches to quarts—use formula below when converting

cu in. ÷ 80 = number of quarts water

(cubic inches from above volume calculation divided by 80 equals number of quarts of water)

After conversion to quarts, use table.

<u>General Information</u>

1 qt. water + 2 ¾ lb. plaster will make about 80 cubic inches of solid plaster.

Sculpture artists use Ultracal 30 plaster for casting. Ultracal 30 is stronger then Pottery Plaster #1 because it's a form of cement. Because of this it doesn't want to absorb water. A 50/50 mix works pretty well.

21 pounds of Ultracal 30 needs 2 gallons of water for the mix.

PLASTER OF PARIS INFORMATION

HYDRATED CALCIUM SULPHATE
$2CaSO^4$ .0. $5H^20$ Plaster (Gypsum)

Calcine-dry fire to 325°F-375°F, (163°C-170°C) . Drives off 75% of the chemical water to form 2CaS04.2H20 ----- 2CaS04.0.5H20+3H20 (released as steam) after heating. This is known as plaster of Paris. From the heating we lose 3 molecules of H20, which leaves the plaster in the above formula.

Plaster is caustic to our skin, so apply Vaseline to your hands and arms to protect them. Do not use green soap on hands. The plaster will not set up. Grease your mold with green soap, mold soap, or hospital soap. All are the same. A good liquid dish soap or shampoo will work. Vaseline works very good well.

1. **Sift plaster into the water.**

2. **Keep your hand flat at the bottom of the bucket and undulate slowly, trying not to create air bubbles. Air bubbles that come up to the surface can be skimmed off with your other hand and/or a spoon.**

3. **Try to pour just before it starts to thicken, but don't pour too soon.**

4. **You can pour the plaster through a 20 or 30 mesh screen to break up air bubbles when pouring into a mold.**

5. **After pouring, shake the mold with your hands. Air bubbles will come up to the surface. Blow on the air bubbles and they will disappear.**

6. **When the plaster gets to its hottest point, it is ready to be released from the mold. That is the easiest way to release it, then to let it cool and then release it.**

7. **It is best to let the plaster cure for two weeks, drying slowly, but you can force dry it at about 100°F or 35°C. U.S. Pottery plaster #1 is the best gypsum for making molds, bats, and slabs.**

Ceramic Companies

There are a couple of companies that carry high quality plaster bats that fit directly onto the wheel head of your pottery wheel. They are expansive.

Pure and Simple Molds; pspottery.com Phone: 707-459-1483.

The Ceramic Shop; theceramicshop.com Phone: 215-427-9665.

Aardvark Clay Supply; aardvarkclay.com Phone: 714-541-4157

Laguna Clay Company; lagunaclay.com Phone: 800-452-4862

Laguna carries good standard plaster bats at different sizes. You need to use some soft clay and water on the wheel head to create a slip that secures the bat to the wheel head. If the plaster bat is too dry or too wet, it will not hold the suction and the bat will come off the wheel head.

Seattle Pottery Supply; seatlepotterysupply.com Phone: 800-522-1975

GLOSSARY TERMS

Amphibole: Any group of rocks forming minerals containing calcium, magnesium, iron, aluminum and sodium combined with silica.

Amphibole Pyroxene: Any of a group of igneous rock forming silicate minerals that contain calcium, magnesium, iron, or aluminum.

Aeolian: Wind blown.

Alkaline: Having properties of an alkali, having oxides of barium, strontium, and sometimes magnesium.

Alkali: A compound of hydrogen and oxygen with any one of the elements lithium, sodium, potassium, rubidium, and cesium. Solubility in water and capability of neutralizing acids. A mixture of salts in the soil; carbonate of sodium.

Ammonium: The chemical ion NH4.

Ammonium Chloride: White crystalline compound NH4 Cl.

Amorphous: Shapeless, formless.

Attenuate: To make or become thin.

Basalt: A fine to dense igneous rock calcium or sodium in its composition.

Biotite: A brown or dark green form of mica, with silicate of iron, magnesium, potassium, and aluminum.

Bismuth: A heavy brittle grayish white metallic chemical element used in making luster's.

Borates: A salt or ester.

Burette: A graduated glass tube with a small aperture for measuring fluids.
Calcite: Calcium carbonate crystalline form; a major constituent of limestone, marble and chalk.

Carbonate: A salt or ester of carbonic acid.

Carbonate Acid: Formed when carbon dioxide dissolves in water.

Carbon Dioxide: Incombustible gas.

Chloride: A compound of chlorine with another element or a radical.

Chlorine: Irritating gas used as an oxidizing agent.

Colloidal: Resembling liquid gelatin.

Cristobalite: A silica calcined at 1500°C, 2732°F for investment casting.

Ester Acid: Compound formed by the reaction of an acid and an alcohol.

Ferro: Latin word meaning iron; ferrous iron.

Ferro-Magnesian: Group of Amphibole Pyroxenes.

Hydrochloric Acid: A strong corrosive irritating acid.

Kaolin: Hydrous aluminum silicate used in making porcelain.

Limestone: Stone formed by organic remains of shells.

Metamorphic: A change in the structure of rock.

Mica: Any class of silicates.

Muriadic Acid: Hydrochloric acid.

Nitrate: A salt or ester of nitric acid.

Nitric Acid: A corrosive liquid.

Nitrogen: Tasteless, odorless, gaseous chemical; 78% of the earth's atmosphere by volume.

Props: Post supports.

Pin Holing: Add 1% (80 grams) Lithium Carbonate and 1 ounce or 28 grams of Magnesium Sulphate to an 8,000 batch of glaze to eliminate pin holing. You can add more Magnesium Sulphate but start with one ounce.

Resin: A substance obtained from the gum or sap of some trees used in varnishes and plastics.

Shale: A rock formed by clay.

Silica: Crystalline silicon dioxide.

Silicon: Non-metallic element.

Slag: Waste left after the melting of ores and the separation of metal from them.

Theta: Measurement of any given angle.

Volatile: Vaporizing.

Volt: The speed of the ohm; electrical potential.

ARTIST CLOSING STATEMENT:

In closing, ceramics is an endless process. The information in this book is from 40 plus years of working with clay and fire. There is always some loss factor in ceramics. Ceramic industry after more then 400 years of modern ceramic technology still looses 20% of its ceramic products from pots cracking, glazes pin holing, crawling and so forth. As a studio potter, my loss factor has been about 10%. As a ceramic sculpture artist, my loss factor is about 30%. The important thing is that you are having fun and enjoying the miracles of clay and fire.

There are additional glaze formulas on my website: paulnashceramics.com

Good Luck and May The Force Be With You.
Paul Nash
Professor of Ceramic Art
Studio Ceramic Artist