FUSIBLE ENGOBE FORMULATED FOR LARGE CERAMIC SCULPTURE

PROBLEM IN LIEU OF THESIS

Presented to the graduate Council of the North Texas State University in Partial Fulfillment of the Requirements

For the Degree of

MASTER OF FINE ARTS

By

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Denton, Texas

August, 1986

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ABBREVIATIONS IN RESULTS CHARTS

SURFACES:

G	Gloss Surface
S	Satin Surface
SM	Satin-Matt Surface
SW	Satin-Waxy Surface
W	Waxy Surface
SG	Satin-Gloss Surface
MD	Matt-Dry Surface
DP	Dry Pitted Surface
P	Pitted Surface

SURFACE DEFECTS:

B	Blistered
C	Crawled
Po	Pooled
P	Pitted
F	Flaked

CHAPTER I

INTRODUCTION

I was introduced to ceramics during the last years of my undergraduate studies. My previous concentration had been in two dimensional art forms. Therefore, the idea of creating three dimensional art work was fairly new. Starting first with the functional side of ceramics, I soon discovered an interest in large sculpture and vessel forms. The technical challenges of constructing large forms intrigued me. It was at this stage that I concentrated my efforts on large ceramic art forms. Later only kiln size and studio space limited me and surface decoration became a stronger consideration. Scale and imagery evolved into a personal way of dealing with clay.

My surface methodology changed drastically when I switched from conventional pottery to sculpture, especially large sculptural forms. My surfaces were a result of constant underglaze formulation, pit firing with reductive agents, and further exploration into slip glazes and single firing glazes. The majority of my surfaces were either black or of textured earth-toned engobes. In most cases I felt my forms worked stronger than the surface treatment. While in graduate school, I concentrated equally on the content and structure of my work thus defining imagery and scale. I resolved surface quality and color by the non-traditional methods of painting and drawing on clay. I saw myself as a sculptor, not a functional vessel maker where glazing is necessary.

The possibility of a more practical method of color decoration gave me incentive to further explore ceramic chemistry. My large ceramic sculpture required a coloration that offered durability, problem free application, and a suitable range of color. These qualities were best achieved through the fusible engobe. Previously, my application of color was primarily restricted to spray painting and oil stick drawing on a highly reduced and highly vitrified terra cotta surface. My sculptures were basically outdoor pieces which required a warranty of permanence. The larger the sculpture, the more the need for a colorant that fused to the body surface.

Traditionally, glazing has been the primary source for coloration in sealing ceramic surfaces. This was best illustrated mainly in the vessel making process. Sources for ceramic coloration extended beyond glazes to the following: underglazes, terra sigillata, Egyptain paste, single firing glazes, slip glazes, and vitreous slips & engobes. While reviewing these alternatives I explored the necessary questions needed to formulate a fusible engobe from a traditional engobe base. My research and past testing pointed to the engobe as a logical area for further calculation. In the past, engobes had produced the closest desirable results. Through examining certain properties of the basic engobes, I formulated an engobe to my specifications.

The problem I proposed and solved was to produce a fusible engobe that met the necessary criteria and produced a surface and coloration necessary for my large ceramic forms. These criteria were as follows:

1) Produced results through single firing method.
2) Fired to range of cone 04 - 2 (1940°fahrenheit - 2130° fahrenheit).
3) Adhered to greenware.
4) Showed a resistance to scratching, rubbing-off, chipping, and be durable.
5) Simulated wet ware surface effect.

CHAPTER II

DISCRIPTION OF PROCESS

The first of my testing started with three given formulas. These formulas were labeled tests A, B and C. I wanted to set up the least amount of variables so I tested through the following methods:

1) Five per cent iron oxide was added to insure that oxides did not alter the results. Oxides have properties that can react as fluxing agents and therefore produce a glassed surface.
2) After mixing, the mix (engobe) was sifted through a twenty mesh screen to insure consistency.
3) The engobes were allowed to settle overnight to insure accurate application.

Charts were designed for easy formulation and evaluation. The charts were labeled: Formulation Chart, Results Chart, Color Test Formulation Chart, and Color Test Results Chart.

The Formulation Chart consisted of a breakdown of chemical classification. The basic breakdown of the engobe was extended from clay, flux, and colorant to include filler, opacifier, hardener, and deflocculant. These additional categories enabled me to test and locate specific problems for reformulation. The engobe was further subdivided into the following: clay, flux, filler, opacifier, hardener, and deflocculant plus five per cent colorant.

The Results Chart evaluated the engobe bases on three separate temperature levels: 2035°fahrenheit, 2090°fahrenheit, and 2130°fahrenheit. This chart evaluated the catagories for settling, greenware adherence, greenware hardness, fired ware hardness, fired ware adherence, and surface quality.

The first of the tests were fired in a burn-out kiln, used for jewelry, and fired to 2000°fahrenheit. The reason for using this test kiln was because of its' rapid firing cycle which enabled me to have immediate results. The first tests were conclusive enough but soon the test kiln proved inadequate. The tests at 2000°fahrenheit, labeled B-4 - B-7, resulted in uneven temperatures. All testing was continued in a regular electric kiln. In this kiln the previous tests and the remaining tests were fired at 2090°fahrenheit. The results of the retesting were consistent with the results of the previous tests at 2000°fahrenheit. To confirm results a temperature range test was conducted at 2035°fahrenheit, 2090° fahrenheit, and 2130°fahrenheit.

The first tests were tests A, A-1, B, B-1, C, and C-1. The formulations and results were logged on the Formulation Charts and Result Charts. My main concerns were with the clay content and flux percentages. Calcined kaolin replaced the clays. This was done because problems with greenware adherence were anticipated. Next, the flux was increased to fuse the engobe onto the clay surface. My results with tests

C and C-1 were poor in all categories. From this , test C was discontinued and the more promising test series A and B were concentrated on.

Tests A and A-1 were formulated with higher percentages of flux in hopes of vitrifing the traditional chalky surface. The results proved much like a glaze. Frit P-133 and ultrox were added to A-1 to encourage a direction for further formulation. The results showed no difference in surface, and defects occured in the fired adherence category. Tests B and B-1 showed a marked difference in the fired surface. Test B looked like an over-fired engobe, the surface looked chalky and crumbled when touched. The amount of flux was twenty per cent and consisted of the frit P-133 and talc. In test B-1, talc was omitted and the frit was increased to forty-five per cent therefore fluxing the engobe to a glassy surface. The surface became harder but the engobe still adhered poorly. In test B-1 gerstley borate was used as an opacifier. This was done because it could double as an auxillary flux. Opacifiers were not important at this time because the color tests were conducted after the engobe base was established. Gerstley borate, at a much higher percentage, was used as a flux in the A test series.

In test A-2 the opacifier, ultrox, was omitted and the filler, flint was reduced. From this the percentages were carried into the flux hoping to make the surface more fluid thus eliminating the previous crawling defect. The results were a highly fluxed surface that pooled. The surface changed from a semi-matt to a glossed surface, where it pooled. Test A-3 reacted much the same even though ten per cent borax was kept as a hardener and flint was reduced by ten per cent. It was evident the flux had to be reduced and the clay slightly increased. At this stage it was necessary to introduce new organic chemicals to broaden the scope of the results.

In tests B-2 and B-3 the patina was successful, although the fired surface still pooled. The next step was to decrease the flux five per cent and slightly increase the clay content. Test B-2 had the most favorable results thus far; therefore, only slight alteration in the B series was necessary. The shortcomings to work on were greenware application and hardness.

Tests A-4 through A-7 were experimentation with sugar and calgon. Sugar, an organic binder, was used as a hardener and calgon, a dishwashing detergent, as a deflocculant. The sugar was supposed to harden the surface and the calgon was supposed to keep the solution from settling. The tests were not satisfactory with either additives but the solution settling and greenware adherence slightly improved. The greenware hardness and surface effect still remained a problem. The solution settling was solved but not to satisfaction. The hopeful solution to this problem was with soda ash in my next tests. Soda ash in small percentages acts as a hardener.

Tests B-6 through B-7 involved a slight change in percentages of the clay and flux to improve surface characteristics. Calcon was also introduced as a deflocculant, as with the adjoining A tests series. Calgon did not yield any noticeable change. The surface and fired ware adherence never seemed to get better in the B test series. The clay percentages might have contributed to this, therefore in B-7 the calcined kaolin was lowered to twenty per cent and the flux to forty-five per cent. The results were that the surface got too glossy. From this, the logical step was to lower the filler and add borax as a hardener.

Tests A-8 through A-10 introduced soda ash and experimental auxillary fluxing with salt. In tests A-8 and A-10 five per cent soda ash was introduced as a deflocculant, and as an auxillary flux. Tests A-9 and A-10 were sprayed then let dry, and then the engobe solution was applied. The salt crystals were expected to migrate, to the surface, dry, and then react as an auxillary flux to promote a different surface. In A-10 the salt was used more as a flux than in A-9. Unexpectedly, test A-9's fired surface crawled. No reason for this was found. The A-8 test showed the most desired surface thus far. It was satin smooth and simulated a wet surface quality. Therefore, the clay and flux percentages were from then on to remain constant. At this point greenware hardness was satisfactory but the settling remained a problem. At this stage only one more test series was anticipated for conclusive results. A greenware surface hardener was needed.

Tests B-8 through B-12 introduced borax as a hardener, soda ash as a deflocculant, and salt as an auxillary flux. Tests B-11 and B-12 introduced salt in the same way as in test A-9 and A-10. In B-11 the salt appeared to have pitted the surface and because of the increased clay content, became chalky. In B-11 salt was tested to see if it would react as a flux. The surface quality of B-21 was very favorable but not because of the salt. The salt was eliminated from then on. Tests A-8, B-7, and B-12 were to be used for bases for the final engobe base tests.

In tests B-13 through B-15 and A-12, C.M.C. gum, an organic binder, was introduced as a hardener and deflocculant. Ball clay was also introduced as a hardener. The results proved favorable with the C.M.C. gum. C.M.C. gum jelled the solutions which benefited greenware application, greenware hardness, and solution settling. The problem with the C.M.C. gum was that it hindered the mixing process. Five per cent was too high a percentage and therefore two per cent was the last change for the final engobe base, B-16. Test B-16 produced the best results in all categories and was therefore selected for the final color tests. The formula for B-16 is as follows:

Calcined kaolin........................	20%
Frit P-133.............................	45%
Flint..................................	15%
Gerstley borate........................	2%
Soda ash...............................	5%

CHAPTER III

COLOR TESTS

The color tests were the final part of the thesis project. Two charts were designed to formulate and catalogue the results. The color tests were conducted in both a gas kiln with a reducing atmosphere and an electric kiln with an oxidizing atmosphere. The color tests were formulated from fourteen single mixes, at five per cent and ten per cent each (except cobalt carbonate). There were twenty-five combinations, from a color blend chart, totaling fifty-three oxidation tests and fifty-three reduction tests. The results of these tests were yellows, tans, browns, blues, greens, and blacks. The tiles were then tested to see if the application was extended from dry ware to leather hard ware. Tests showed that one coat was successful but two coats caused the engobe to flake and crawl. A particular problem occured, in the mixing stage, due to the C.M.C. gum. The C.M.C. gum jelled and therefore did not dissolve into the formula solution. The result was a white dotted surface. One week later another attempt was made with the colored fusible engobes. The results were very favorable because the formula solution smoothed out and therefore the jelled globs were dissolved. For best results one must: 1) apply the fusible engobe to a dust free surface, 2) after mixing let set for approximately one week to allow the C.M.C. gum to dissolve, and 3) apply one coat only. The color charts and tiles formed the last part of the thesis project.

CHAPTER IV

CONCLUSION

Through my research and testing a practical surface treatment was achieved for large ceramic sculpture. An engobe was successfully formulated that reached a fired range of cone 04 to cone 2 (1940° fahrenheit to 2130° fahrenheit), fused to the clay surface to create a permanent hard bond, showed a durability in unfired ware, and simulated a wet ware surface effect. My success solved an important technical problem and can help other ceramic sculptors with similar problems.

FORMULATION CHART

+ 5% FeOx	CLAY	FLUX	FILLER	OPACIFIER	HARDENER	DEFLOCCULANT
A	30% calcined kaolin	40% gerstley borate	30% flint			
A-1	20% calcined kaolin	20% gerstley borate 30% frit	20% flint	5% ultrox		
A-2	20% calcined kaolin	20% gerstley borate 40% frit	20% flint			
A-3	20% calcined kaolin	20% gerstley borate 40% frit	10% flint		10% borax	
A-4	25% calcined kaolin	30% frit 20% gerstley borate	20% flint		5% sugar	
A-5	25% calcined kaolin	20% frit 5% salt solution 20% gerstley borate	20% flint		5% sugar	2% calgon
A-6	20% calcined kaolin	35% gerstley borate 10% frit	20% flint			2% calgon
A-7	20% calcined kaolin	30% gerstley borate	20% flint		10% wollastonite 5% sugar	

frit: P-133

FORMULATION CHART

+ 5% FeOx	CLAY	FLUX	FILLER	OPACIFIER	HARDENER	DEFLOCCULANT
A-8	20% calcined kaolin	40% frit 20% gerstley borate	15% flint			5% soda ash
A-9	25% calcined kaolin	40% frit 20% gerstley borate	20% flint	← spray with salt solution		
A-10	30% calcined kaolin	30% gerstley borate	20% flint	← spray with salt solution	10% borax	5% soda ash
A-11	20% calcined kaolin	40% frit 20% gerstley borate	15% flint		10% C.M.C. gum	5% soda ash
A-12	20% calcined kaolin	35% gerstley borate 10% flint			5% ball clay 5% C.M.C. gum	5% soda ash

FORMULATION CHART

+ 5% FeOx	CLAY	FLUX	FILLER	OPACIFIER	HARDENER	DEFLOCCULANT
B	35% calcined kaolin 15% ball clay	15% frit 5% talc	20% talc	5% ultrox	5% borax	
B-1	25% calcined kaolin	45% frit	20% flint	5% gerstley borate	5% borax	
B-2	20% calcined kaolin	50% frit	10% flint	10% gerstley borate	10% borax	
B-3	20% calcined kaolin	40% frit	25% flint	10% gerstley borate		
B-4	25% calcined kaolin	45% frit	10% flint	10% gerstley borate		
B-5	30% calcined kaolin	35% frit	10% flint	10% gerstley borate		
B-6	35% calcined kaolin	45% frit	25% flint	10% gerstley borate		2% calgon
B-7	20% calcined kaolin	45% frit	20% flint	10% gerstley borate	5% borax	5% soda ash

FORMULATION CHART

+ 5% FeOx	CLAY	FLUX	FILLER	OPACIFIER	HARDENER	DEFLOCCULANT
B-8	20% calcined kaolin	45% frit	10% flint	10% gerstley borate	5% borax	5% soda ash
B-9	20% calcined kaolin	45% frit	20% flint	10% gerstley borate		5% soda ash
B-10	25% calcined kaolin	45% soda ash	10% flint	20% gerstley borate	10% borax	
B-11	30% calcined kaolin	45% soda ash spray with salt solution	10% flint	10% gerstley borate	5% borax	
B-12	20% calcined kaolin	45% frit spray with salt solution	10% flint	10% gerstley borate	5% borax	
B-13	30% calcined kaolin	45% frit	10% flint	5% gerstley borate	5% C.M.C. gum	5% soda ash
B-14	30% calcined kaolin	45% frit	10% flint	5% gerstley borate	10% ball clay	5% soda ash
B-15	20% calcined kaolin	45% frit	15% flint	5% gerstley borate	5% C.M.C. gum	5% soda ash

FORMULATION CHART

+ 5% FeOx	CLAY	FLUX	FILLER	OPACIFIER	HARDENER	DEFLOCCULANT
B-16	20% calcined kaolin	45% frit	15% flint	5% gerstley borate	2% C.M.C. gum	5% soda ash

FORMULATION CHART

+ 5% FeOx	CLAY	FLUX	FILLER	OPACIFIER	HARDENER	DEFLOCCULANT
C	9½% fire ball 18½% ball clay 22% calcined kaolin	20% soda feldspar	20% flint	5% ultrox	2½% borax	
C-1	20% calcined kaolin	50% soda feldspar	20% flint	5% ultrox	5% borax	
	DISCONTINUED C TEST SERIES					

RESULTS CHART

@ 2000° f	SETTLING	GREENWARE ADHERENCE	GREENWARE HARDNESS	FIRED WARE HARDNESS	FIRED WARE ADHERENCE	SURFACE
C	ok	poor	poor	poor	poor, F	chalky, F
C-1	ok	poor	poor	poor	poor, F	chalky, F
	DISCONTINUED C TEST SERIES					

RESULTS CHART

@ 2000° f	SETTLING	GREENWARE ADHERENCE	GREENWARE HARDNESS	FIRED WARE HARDNESS	FIRED WARE ADHERENCE	SURFACE
A	ok	poor	poor	good	poor, B, C	vitrified, G, C, B
A-2	ok	poor	poor	good	poor, C	vitrified, SG, C
A-3	good	poor	poor	good	good	vitrified, G, Po
A-4	good	poor	poor	good	good	vitrified, S, Po
A-5	good	good	poor	good	good	vitrified, S, Po
A-6	IMPROPER FIRING ______					
A-7	IMPROPER FIRING ______					
A-8	ok	poor	poor	poor	poor, F	chalky

RESULTS CHART

@ 2000° f	SETTLING	GREENWARE ADHERENCE	GREENWARE HARDNESS	FIRED WARE HARDNESS	FIRED WARE ADHERENCE	SURFACE
B	ok	poor	poor	good	poor, B, C	vitrified, G, C, B
B-1	ok	poor	poor	good	poor, C, B	vitrified, S, C, B
B-2	poor	poor	good	good	good	vitrified, G, S
B-3	good	poor	poor	good	poor, C	vitrified, S, C
B-4	IMPROPER FIRING					
B-5	IMPROPER FIRING					
B-6	IMPROPER FIRING					
B-7	IMPROPER FIRING					

RESULTS CHART

*	SETTLING	GREENWARE ADHERENCE	GREENWARE HARDNESS	FIRED WARE HARDNESS	FIRED WARE ADHERENCE	SURFACE
A-2	good	good	poor	good	good	vitrified, G
A-3	poor	good	poor	good	good	vitrified, G
A-4	good	poor	poor	good	poor, C	vitrified, SG, C
A-5	good	good	poor	good	good	MD
A-6	good	good	poor	good	good	vitrified, G
A-7	good	good	poor	good	good	vitrified, G
A-8	good	good	poor	good	good	vitrified, G
A-9	good	good	poor	good	poor, C	vitrified, GS, C

* Results fired at 2035° fahrenheit, 2090° fahrenheit, and 2130° fahrenheit with the same results.

RESULTS CHART

*	SETTLING	GREENWARE ADHERENCE	GREENWARE HARDNESS	FIRED WARE HARDNESS	FIRED WARE ADHERENCE	SURFACE
A-10	good	good	poor	good	good	vitrified, S
A-11	good, jelled alittle	very good	very good	ok	ok	DP
A-12	very good	very good	very good	ok	ok	DP

* Results fired at 2035° fahrenheit, 2090° fahrenheit, and 2130° fahrenheit with the same results.

RESULTS CHART

*	SETTLING	GREENWARE ADHERENCE	GREENWARE HARDNESS	FIRED WARE HARDNESS	FIRED WARE ADHERENCE	SURFACE
B-2	poor	good	poor	good	good	vitrified, G
B-3	good	poor, F	poor	good	poor, C	vitrified, S,C
B-4	good	good	poor	good	poor, C	vitrified, S,C
B-5	good	good	poor	ok, C	poor, F	F, looked burned off
B-6	good	good	poor	good	poor, C	vitrified, S,C
B-7	good	good	poor	good	poor, C	vitrified, G,C
B-8	good	good	poor	good	good	vitrified, G
B-9	good	good	poor	good	ok, began to C	vitrified, S

* Results fired at 2035° fahrenheit, 2090° fahrenheit, and 2130° fahrenheit with the same results.

RESULTS CHART

*	SETTLING	GREENWARE ADHERENCE	GREENWARE HARDNESS	FIRED WARE HARDNESS	FIRED WARE ADHERENCE	SURFACE
B-10	good	good	poor	ok, C	poor, P	C
B-11	good	good	poor	poor, C	poor, P	C,P
B-12	poor	good	poor	good	good	vitrified, SW
B-13	good	ok, C	ok	good	good	vitrified
B-14	good	poor	poor	good	good	vitrified, D
B-15	good	good	good	good	good	vitrified, SW

* Results fired at 2035° fahrenheit, 2090° fahrenheit, and 2130° fahrenheit with the same results.

COLOR TESTS FORMULATION BLEND CHART

	illmenite Il-3	cobalt carbonate CoC-2	chrome oxide Ch-3	iron hydroxide FeH-3	lithium carbonate Lc-3
NICKEL OXIDE N-3	Il-3 N-3	CoC-2 N-3	Ch-3 N-3	FeH-3 N-3	Lc-3 N-3
MANGANESE CARBONATE MangC-3	Il-3 MangC-3	CoC-2 MangC-3	Ch-3 MangC-3	FeH-3 MangC-3	Lc-3 MangC-3
RED IRON OXIDE RFe-4	Il-3 RFe-4	CoC-2 RFe-4	Ch-3 RFe-4	FeH-3 RFe-4	Lc-3 RFe-4
YELLOW OCHRE Yo-4	Il-3 Yo-4	CoC-2 Yo-4	Ch-3 Yo-4	FeH-3 Yo-4	Lc-3 Yo-4
COPPER CARBONATE CuC-4	Il-3 CuC-4	CoC-2 CuC-4	Ch-3 CuC-4	FeH-3 CuC-4	Lc-3 CuC-4

COLOR TEST FORMULATION & RESULTS CHART

COLORANT	EMBLEM	COLOR oxidation	COLOR reduction
5% copper carbonate	CuC-5	light green, shiney	medium green, satin-waxy
10% copper carbonate	CuC-10	brown-green, shiney	dark green, satin-waxy
5% black stain	Bk-5	black, satin-gloss	black, satin
10% black stain	Bk-10	black, satin-gloss	black, satin
5% chrome oxide	Ch-5	army green, satin	army green, satin-matt
10% chrome Oxide	Ch-10	army green, satin	army green, satin-matt
½% cobalt carbonate	CoC-½	medium blue, satin	medium blue, waxy
2% cobalt carbonate	CoC-2	dark blue, satin	dark blue, waxy

COLOR TEST FORMULATION & RESULTS CHART

COLORANT	EMBLEM	COLOR oxidation	COLOR reduction
5% manganese dioxide	MangD-5	light brown, satin	tan, waxy
10% manganese dioxide	MangD-10	medium brown, satin	brown, waxy
5% ilmenite	Il-5	creamy with black dots, satin-waxy	medium cream with black dots, waxy
10% ilmenite	Il-10	creamy with black dots, satin-waxy	light cream with black dots, waxy
5% nickel oxide	N-5	medium green, satin	brown-green, satin-matt
10% nickel oxide	N-10	medium green, satin	army green, satin-matt
5% red iron oxide	RFe-5	light tan- red, waxy	maroon, satin-matt
10% red iron oxide	RFe-10	dark red- tan, waxy	dark maroon, satin-matt

COLOR TEST FORMULATION & RESULTS CHART

COLORANT	EMBLEM	COLOR oxidation	COLOR reduction
5% yellow iron oxide	YFe-5	maroon, satin	tan, waxy
10% yellow iron oxide	YFe-10	maroon, satin-gloss	brown, waxy
5% yellow ochre	Yo-5	medium maroon, satin	dark maroon, waxy
10% yellow ochre	Yo-10	medium maroon, satin	maroon, satin-matt
5% yellow stain	Y-5	bright yellow, satin-matt	bright yellow, waxy
10% yellow stain	Y-10	bright yellow, satin-matt	bright yellow, waxy
5% green nickel oxide	GN-5	grey-green, satin-matt	army green, matt-satin
10% green nickel oxide	GN-10	grey-green, satin-matt	army green, matt-satin

COLOR TEST FORMULATION & RESULTS CHART

COLORANT	EMBLEM	COLOR oxidation	COLOR reduction
5% manganese carbonate	MangC-5	medium brown, satin-matt	brown-green, waxy
10% manganese carbonate	MangC-10	medium tan, satin-matt	army green, waxy
5% pink stain	P-5	light pink, satin-matt	light pink, waxy
10% pink stain	P-10	medium pink, satin-matt	medium pink, waxy
3% ilmenite 3% nickel oxide	Il-3 N-3	light green-grey with dots, satin-waxy	light brown, waxy
2% cobalt carbonate 3% nickel oxide	CoC-2 N-3	brown-green, satin	medium brown, waxy
3% chrome oxide 3% nickel oxide	Ch-3 N-3	medium brown, satin	medium brown, waxy
3% iron hydroxide 3% nickel oxide	FeH-3 N-3	medium brown, satin-waxy	dark brown, satin

COLOR TEST FORMULATION & RESULTS CHART

COLORANT	EMBLEM	COLOR oxidation	COLOR reduction
3% lithium carbonate 3% nickel oxide	Lc-3 N-3	light green-brown, satin-waxy	medium brown, waxy
3% ilmenite 3% manganese carbonate	Il-3 MangC-3	medium brown with dots, satin-waxy	light brown, waxy
2% cobalt carbonate 3% manganese carbonate	CoC-2 MangC-3	medium tan, satin	light brown, waxy
3% chrome oxide 3% manganese carbonate	Ch-3 MangC-3	medium tan, satin-waxy	grey-brown, waxy
3% iron hydroxide 3% manganese carbonate	FeH-3 MangC-3	maroon-brown, satin	dark maroon, satin
3% lithium carbonate 3% manganese carbonate	Lc-3 MangC-3	medium tan, satin-waxy	medium brown, waxy
3% ilmenite 4% red iron oxide	Il-3 RFe-4	light brown-tan, satin-waxy	medium grey-brown, waxy
2% cobalt carbonate 4% red iron oxide	CoC-2 RFe-4	light brown-tan, satin-waxy	medium grey-brown, waxy

COLOR TEST FORMULATION & RESULTS CHART

COLORANT	EMBLEM	COLOR oxidation	COLOR reduction
3% chrome oxide 4% red iron oxide	Ch-3 RFe-4	light tan-green, satin-waxy	grey-brown, waxy
3% iron hydroxide 4% red iron oxide	FeH-3 RFe-4	medium tan-green, satin-waxy	dark grey-brown, waxy
3% lithium carbonate 4% red iron oxide	Lc-3 RFe-4	light green-tan, waxy	light grey-green, waxy
3% ilmenite 4% yellow ochre	Il-3 Yo-4	tan modeled with rust, waxy	medium tan, with dots, waxy
2% cobalt carbonate 4% yellow ochre	CoC-2 Yo-4	black, satin-gloss	black, waxy
3% chrome oxide 4% yellow ochre	Ch-3 Yo-4	dark maroon, satin	dark maroon, waxy
3% iron hydroxide 4% yellow ochre	FeH-3 Yo-4	rust, satin-waxy	dark maroon, waxy
3% lithium carbonate 4% yellow ochre	Lc-3 Yo-4	tan-yellow with rust, waxy	tan, waxy

COLOR TEST FORMULATION & RESULTS CHART

COLORANT	EMBLEM	COLOR oxidation	COLOR reduction
3% ilmenite 4% copper carbonate	Il-3 CuC-4	blue-green, satin	light green
2% cobalt carbonate 4% copper carbonate	CoC-2 CuC-4	blue-green, satin-gloss	dark green-blue, satin-gloss
3% chrome oxide 4% copper carbonate	Ch-3 CuC-4	dark blue-green, waxy-satin	dark green, satin-matt
3% iron hydroxide 4% copper carbonate	FeH-3 CuC-4	brown-green, waxy-satin	dark brown, satin
3% lithium carbonate 4% copper carbonate	Lc-3 CuC-4	light green, gloss-satin	light green, gloss-satin

GLOSSARY

EARTHENWARE: Low-fire pottery (below cone 03), usually red-tan in color with an absorbency of from 5% to 6%.

EGYPTAIN PASTE: A clay body that has glaze-forming ingredients and colorants incorported into the body in a soluable form. The body is nonplastic and fires to between cones 08 and 05. First developed by the Egyptains before 5,000 B.C., this paste was the earliest form of glaze known.

ENGOBE or SLIP: A suspension of slurry of finely divided ceramic materials in a liquid. This underglaze can be applied to wet ware, green ware, and bisque ware. Generally, the difference between and engobe and a slip is that engobes are applied to larger surface areas.

FLUX: A substance that even in small quantities, lowers the fusion point of material in which it is naturally present. e.g. borax added to glaze.

FRIT: A commercially prepared combination of silica and soluable fluxes melted together and ground to powder to render the flux insoluable. Frits render toxic effects of lead and melt such compounds as borax or soda ash.

GLAZE: A liquid suspension of finely ground minerals that is applied by brushing, pouring, or spraying on the surface of bisque fired ceramic ware. After drying the ware is fired to the temperature at which the glaze ingredients will melt together to form a glassy surface coating.

SLIP GLAZE: A glaze consisting primarily of readily fusible clay or silt and other ingredients blended to a creamy consistency in water.

TERRA COTTA: An earthenware body, generally red in color and containing grog. It is the common body type used for ceramic sculpture.

TERRA SIGILLATA: The red slip glaze used by the Romans, similar to the Etruscan bucchero and Greek black varnish ware and made of fine decanted particles of red clay.

UNDERGLAZE, UNDERGLAZE DECORATION: A finely milled ceramic color decoration, or ther coating applied directly to the unfired or bisque fired surface of ceramic ware and subsequently covered with a transparent glaze and then fired concurrently with a glaze.

VITREOUS or VITRIFICATION: The progressive partial fusion of a clay as a result of a firing process. Vitrification is the point where the clay is at its hardest state.

VITREOUS ENGOBE or SLIP: An engobe or slip that is fritted to flux much like a glaze. A traditional use is where potters use it to replace a glaze where trimming is to tedious.

BIBLIOGRAPHY

Chappell, James. The Potter's Complete Book Of Clay And Glazes. New York: Watson-Guptill Publications, 1977.

Dawalt, Kent. "Notes From Glaze Calculation Class." Indiana University, Bloomington, Indiana, 1982.

Nelson, Glenn C. Ceramics: A Potter's Handbook. 4th ed. New York, Chicago, San Francisco, Atlanta, Dallas, Montreal, Toronto, London, Sydney: Holt, Rinehart and Wilson, 1978.

Rhodes, Daniel. Clay And Glazes For The Potter. Revised ed. Radnor: Chilton Book Company, 1973.