SCREEN PRINTING TECHNIQUES IN POTTERY DECORATION

BY

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DECLARATION

I solemnly declare that this is an original work of mine and that it has not been submitted elsewhere for the award of any degree. All references are duly acknowledged in "Bibliography".

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CERTIFICATION

This thesis entitled SCREEN PRINTING TECHNIQUES in POTTERY DECORATION by Akinbogun, Lawrence Tolulope, meets the regulations governing the award of the degree of Master of Arts (Industrial Design) of Ahmadu Bello University, Zaria and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This thesis is dedicated to my granny Madam Elizabeth Oyebo Akinbogun who departed this world as I was rounding up this programme.

ABSTRACT

The study is concerned with highlighting and initiating the techniques of screen printing in pottery decoration among the Studio Potters in Nigeria. There are 83 pages, 8 tables and 13 plates.

Three major purposes were outlined for the study:

1. To identify the procedures involved in screen printing.
2. To identify the suitable materials for screen printing on pottery.
3. To demonstrate the aesthetic quality of screen printing on pottery.

Two basic assumptions were made:

1. That the materials for screen printing can be obtained in the country.
2. That variations and instability of kiln atmosphere during firing may affect the result of the study.

The following constitutes the entire population for the study: screen mesh, stencils, adhesive, transfer paper, lacquer varnish, oil vehicles, ceramic inks. Rational sampling was adopted in drawing samples for the study due to inavailability and inaccessibility of some of the materials.

Based on the analysis of data for this study, the following inference were drawn:

1. That generalisation cannot be made of the materials used in the study.

2. It is more economical to use engobe in under-glaze printing than using stain.

3. That the cheap and common silk scarf specially made for sifting flour is very good for screening ceramic inks.

4. Prints do not register on dusty ceramic surfaces

5. That engine oil and petroleum jelly pomade are not suitable as oil mixers for screen printing.

6. That local corn starch, soft newsnrint and filter paper are potential materials for making ceramic decal.

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DEFINITION OF SPECIAL TERMS

There are some special terms used which are peculiar to the study. Their meanings are explained as follows:

Ball Mill-	A grinding mill used for the fine grinding of glaze and colour minerals.
Bichromates-	Chemicals used as glue hardeners
Bisquit -	Fired but unglazed wares
Blisters -	Bubbles formed either in the body or glaze of pots during firing due to rapid liberation of gases.
Calcinate -	To purify a material by the action of heat
Colloid -	Material in a form so finely divided that when dispersed in a liquid, it does not settle out unless floculated by a suitable electrolyte.
Colour bleedings-	The blotting of edges of design during printing.
Colour scumming-	Appearance of light coloured marks along edges of a printed ceramic surface.
Crawling -	A glaze defect characterised by the way the glaze parts and rolls back on itself leaving a bald patch of body.
Dacron -	A synthetic fibre
Decal -	A printed design on a specially prepared paper which is later applied as transfer.
Decalcomania-	Art of printing design or picture on a specially prepared transfer paper.
Emulsion -	Light - sensitive coating
Engobe -	A prepared slip that is halfway between a glaze and a clay.

Filler	-	A non-plastic addition to a clay or body to enhance texture, workability, glaze fit or whiteness.
Firing	-	The heating process of converting clay to pot.
Fluorspar	-	Also called calcium fluoride (CaF_2). It fluxes at a lower temperature than do other calcium compounds.
Flux	-	Low melting compound in a glaze
Frit	-	Part of a glaze recipe that has been melted and re-ground prior to its inclusion in the glaze slop.
Glaze	-	A layer of glass which is fused into a place on a pottery body.
Glycerine	-	A heavy colourless, odourless and sweetish taste liquid which has oily properties but is miscible with water and alcohol.
Greenware	-	Unfired pottery.
Gum arabic	-	Natural gum used in glazes as binder to promote better glaze adherence to the body.
Halftone	-	Breaking up photographic image into black and white dots of varying sizes.
Hardening-on	-	The fixing of under-glaze decoration prior to glazing by firing in the region of 700°C to 800°C to burn out oils and varnishes used as carrying media.
Jaw-Crush	-	Process of crushing materials in a jaw crushing machine.
Lacquer	-	Coating varnish.
Muffle	-	The fireclay chamber or box within a kiln which protect certain wares from the direct action of the kiln gases.
Opacifier	-	A material added to a glaze or enamel to render it opaque.
Porcelain	-	A vitrified white translucent ware

Sgraffito - Scratched decoration especially when the scratched line reveals a different colour.

Silkscreen- Silk fibre stencil support

Squeegee - A rubber-bladded tool, that is used to draw ink across the silkscreen stencil.

Stain - Metallic oxides heated to a sufficient high temperature to make them into a crystal resistant to the action of the minerals in glazes. They are later introduced as colourant.

Stencil - A blocked out area on a screen

Spinel - A kind of stain used as colourant in place of the metallic oxides because of its greater resistance to change by either the fluxing action of the glaze or the effects of high temperature.

Terrasigilata- Type of pottery with a slip of very fine particle-size which gives smooth impermeable surface after firing.

Transparency- Photographic film.

Turpentine - (a) The brownish yellow sticky, semi-fluid oleoresin exuding from terebinth tree.

(b) A light coloured volatile oil distilled from such oleoresin used in paints and varnishes.

Varnish - A liquid which dries to transparent film of varying degrees when coated over a solid surface.

Vehicle - Any medium used to assist in applying colour or glaze.

Viscosity - The stiffness of a liquid created by the friction amongst its particles and molecules.

CHAPTER ONE

INTRODUCTION

1.1. Introduction

Surface decoration has remained an important aspect of ceramics since time immemorial. However, screen printing technique is a recent development in surface treatment of pottery, though it has been used extensively in the areas of graphic and textile design.

Screen printing process as explained by Ragan, (1956) is essentially a stencilling process in which the stencil is supported by an open-mesh fabric (such as silk bolting cloth) and the print made by drawing a rubber squeegee across the stencil with a charge of colour ahead of the blade. The colour is forced through the open parts of the stencil and deposited on the surface on which the print is to be made. Ragan notes that the origin of screen printing process is lost in antiquity and that as it is known today, it dates from about 1900 A. D.

Conrad, (1979) states that the printing of ceramic pigments on ceramic surface has been developed extensively since the 1930s.

And that silkscreen is the most versatile of all printing methods since it is efficient in printing delicate, sharp details including photographs. He remarks that although the ceramics industry has used this decorating technique extensively, studio potters have not.

As rightly remarked by Conrad, (1979) studio potters rarely use screen printing technique in decorating their pots. Rather, they use some other less complex methods like sgraffito, overglaze and underglaze painting, terrasigilata, slip traling, wax resist and emborsement to beautify their pots. Though the later techniques are simple and require direct approach, the materials are readily available with no rigorous exercise or formula, but they are by no means a substitute for screen printing.

Similarly, Thames and Hudson, (1978) remark that it is quite possible to devote a lifetime to ceramics and never use a printing process for surface decoration. However, where a long production run is involved or where the image requires a degree of standardization, printed imagery is essential. Also if any kind of photographic quality is sought a printing process is the only way it may be achieved.

In the developing countries, Nigeria for example, the art of decorating pots with screen printing process is yet to be embraced by the potters, save for very few ceramics industries who make use of screen printed ceramic transfers. The most conspicuous of them is the Richware Ceramic Industry Ilupeju Lagos. A majority of the ceramic transfers are imported. Potters tend to shy away from this art perhaps due to the general belief that screen printing does not fall under the scope of pottery making. Although the process of screen printing in ceramics is demanding, the outcome justifies the extra effort required.

It will be necessary to remark on the tremendous influence of contemporary pottery in our society. Today the people have been entangled by the taste of imported wares. They want floral design or even their pictures on the wares to commemorate one ocassion or the other. We will remain at the mercy of the developed countries where such orders are made if we fail to try our hand on the simple process.

Screen printing does not end with decoration. According to Ragan, (1956) two general classifications are evidence of any kind of screen printing; firstly, decorative uses, wherein the print is a means of embellishing the piece in order to improve its appearance and to add to its value.

Secondly, industrial uses which involve the use of screen process to provide a protective coating to serve as a temporary support. To provide an acid resist and to label.

Since no studies have been directed to screen printing technique in ceramics within the country, the need has come to examine the area with a view to initiate the idea from a practical perspective. This study therefore is directed towards a simple approach to screen printing techniques in decorating pottery wares, preparation of ceramic inks and the firing of the printed cerami surfaces.

1.2. Statement of the Problem

The problem of this study is highlighting and initiating the techniques of screen printing in pottery decoration among the studio potters in Nigeria.

1.3. Purposes and Objectives of the Study

The purposes and objectives of the study are:

1. To identify the procedures involved in screen printing.
2. To identify the suitable materials for screen printing on pottery.
3. To determine the degree of suitability of the materials.

4. To demonstrate the aesthetic quality of screen printing on studio pottery.

1.4. Research Questions

The following research questions are formulated from the purposes and objectives:

(1) Are the materials for screen printing process in ceramics available in the country?

(2) To what extent are they available?

(3) To what extent will the characteristics of the materials affect their suitability?

(4) To what degree will findings from this study be appreciated?

1.5. Scope and Delimitation of the Study

The study covers the preparation of the materials needed for screen printing on ceramic surfaces like; screens, stencils, ceramic inks and glazes. It also covers the printing and firing of printed ceramic surfaces. The study is delimited to Nigeria. Coating varnish and transfer paper were obtained from Lagos. The rest of the materials were obtained in Kaduna State.

1.6. Limitation of the Study

Inavailability of the electric kiln and muffled kiln affected the colour result of the ceramic inks.

Totally oxidised atmosphere could not be achieved in the gas kiln used for the study.

1.7. Basic Assumptions

1. It is assumed that the materials for screen printing can be obtained in the country.

2. It is assumed that variations and instability of kiln atmosphere during firing may affect the result of the study.

1.8. Background and Significance of the Study

Contemporary pottery is taking a spectacular position in the country today. Research is being conducted on aspects of glaze making, kiln building, wheel construction and other aspects of production. However, the aspect of screen printing in finishing pottery wares has remained an untouched area. Nigeria in the 20th century has widely used commemorative products during celeberations. The boom in printed plastic and metal containers is evidence of this. But when it comes to having designs printed on ceramic wares people have to look elsewhere.

In the light of the above, this study will be significant in that it will create the awareness and orient the techniques of screen printing as a means of decorating pottery among the studio potters in the country.

It will serve as information source on the materials that are used in screen printing process on ceramic surfaces as well as encouraging further studies into the area of standardizing them. Also, it will highlight the importance of screen process decoration over the monotonous bare surface pottery wares currently being practised by the studio potters in the country.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

The purpose of the review is to examine the existing literature on the following aspects of ceramic screen printing:

1. Historical background of screen printing
2. Equipment for screen printing
3. Ceramic inks
4. Application of ceramic printing inks
5. Firing of printed surfaces.

2.1. Historical Background of Screen Printing

The origin of screen printing has been lost in antiquity. Ragan, (1956) believes that it may have been the first method of printing used by man. He refers to the evidence found that the Egyptians used a crude form of the art in which stencils were fastened to crude papyrus fabrics. And the human hair used by the Japanese as stencil supporting material for printing textiles hundreds of years ago.

Roger and Marsh, (1975) however trace the origin of screen printing to the Japanese who came up with the idea of using threads to hold a delicate stencil together. The evidence may often be seen in their old stencil prints.

The Europeans, however developed the idea by using an open mesh fabric on a frame and attached the delicate stenci onto this frame. This principle later formed the foundation upon which screen printing is based.

The invention of modern silk screening, according to Ragan, (1956) and Conrad, (1979) began in the early 1900s. Ragan notes that much of the pioneer work was done in California, particularly in San Francisco.

The printing of ceramic pigments on ceramic surfaces as remarked by Conrad, (1979) has been developed extensively since the 1930s.

2.2. Equipments for Screen Printing

Conrad, (1979) lists the basic equipment for screen process thus:

a) Wood or mètal frame
b) Screen fabric
c) Squeegee
d) Printing base
e) Stencil
f) Exposure lamp
g) Miscellaneous materials; knife, rags, masking tape.

2.2.1. <u>Screens</u>

Most authors recommend the use of silk fabric for screen process, but other screens can be used. Ragan, (1956) notes that wire material is quite useful in the ceramic field because of its superior abrasion resistance, its free printing properties and the relatively heavy deposit of ink provided. The blocked out areas can also be removed from the screen by burning them over a gas flame an advantage which is not present in the other screen materials. While this is done, care must be taken that no ceramics colour remains in the mesh before burning, otherwise it will fuse permanently into the mesh. Ragan recomends fine wire up to 325 mesh being used for fine detail and 60 to 100 mesh for coarse detail with heavy deposits of colour.

Parmelee, (1973) observes that the abrasiveness of the ceramic powders used in the printing necessitated frequent changes of silk fibres screen, which made screen printer to adapt synthetic fibres of nylon, dacron and other polyesters to his use.

While Ragan, (1956) also notes the use of synthetic for ceramic screen printing, he however highlights the disadvantages thus:

a) Some synthetic fibres can be dissolved or softened by strong solvents.

b) Some will stretch after being mounted on the frame and some will not accept certain kinds of stencils.

Conrad, (1979) favours the use of silk fibre. He stresses the advantages as its high strength and uniform weave. He recommends the following meshes for different uses thus: 109 to 157 mesh range for half tones and other fine details. 79 to 109 mesh range for paper stencil or direct - to - wet clay printing because it allows the heavy glaze, engobe, or stain particles to pass through the screen.

For best result and long lasting screen, Conrad, (1979) and Bartels, (1973) recommend 124 and 125 mesh nylon silk respectively. The frame size according to them is determined by the dimensions of the image to be transferred. They give a comfortable average size as 16 by 20 inches.

2.2.2. <u>Stencils</u>

Conrad, (1979) describes stencils as a blocked out areas on a screen.

Ragan, (1956) classifies stencils for screen printing thus:

a) Hand cut stencils which include paper stencils, water soluble film, lacquer film and lacquer proof film. These are used for a design which do not contain a fine detail. The stencil is cut with a knife.

b) Photographic stencils which include transfer films and direct photographic stencils. The art work is developed in a light-sensitive plastic support and etched in hot water to create the open areas in stencil. The film is then placed in contact with the screen and allow to dry. The plastic film can then be peeled off having the stencil in place on the screen, while in direct photographic stencils, a solution of polyvinyl alcohol is sensitized with a bichromate and coated directly on the screen where it is dried, exposed, etched and dried again. Ragan remarks that this is probably the most durable photographic screen known in ceramic applications. Though not as sharp as transfer films but cheaper.

c) Emulsions. This combine the light - sensitivity of the colloids with resinous emulsion which is coated on a screen in the same manner of Direct Photographic Stencil.

Kaplan, (1975) describes a direct method of stencil preparation in a clearer form.

Both sides of the silk are coated with a light sensitive emulsion and subsequently exposed in direct contact to a film positive. The emulsion hardens in areas struck by light and remains soft where light is blocked out by the dark portions of the film positive. The screen is then rinsed or washed out with warm water to remove soft emulsion. The hardened area remaining in the pores of the silk comprises the negative stencil.

2.3. Ceramic Ink

According to Antreasian and Adams, (1971) all lithographic inks are composed of three basic parts:

(a) The varnish or carrying vehicle. (b) The pigment or colouring matter (c) Various modifying agents that impart special properties.

While this principle is applicable to ceramic screen printing process, Conrad, (1979) notes that only a ceramic based ink can be used for permanent images on a ceramic surface that is to be fired. He defines ceramic inks as ceramic compound suspended in a liquid medium known as vehicle. These compounds may be stains, engobes, clays, glazes or enamels.

2.3.1. Ceramic Compounds for Ceramic Inks

(a) Engobe: Rhodes, (1957) defines an engobe as a layer of coloured clay applied to the surface of piece of pottery to change its colour or to add some decorative accent. The compositions must be designed that it will;

i. Cling to the ware during the shrinkage which accompanies drying and firing.

ii. Vitrify or harden at a temperature similar to the maturing temperature of the clay on which they will be used.

iii. Survive under the glaze coating without being dissolved into the glaze and without checking or peeling.

Rhodes divides the materials which go into engobe in groups consisting of clays, fluxes, fillers, hardeners, opacifiers and colourants. Kaolin and ball clays are chosen for whiteness and for their relative shrinkage. The fluxes used will vary with the maturing temperatures. For a filler, flint is used. For hardening, a little borax may be used, organic binders such as sugar or gums may be used for this purpose but they have the disadvantage of spoiling with age.

For opacity, zirconium oxide or tin oxide may be added to the engobe. This is not necessary for the darker colours.

Some typical engobe compositions are shown in the chart below as contained in Rhodes, (1957).

TABLE: 2.1. TYPICAL ENGOBE COMPOSITIONS

Temperature Cone Range	Cone 08 - 1			Cone 1 - 6			Cone 6 - 11		
State of ware to which engobe is applied.	Damp	Dry	Bisquit	Damp	Dry	Bisquit	Damp	Dry	Bisquit
Kaolin	25	15	5	25	15	5	25	15	15
Ball clay	25	15	15	25	15	15	25	15	5
Calcined Kaolin		20	20		20	20		20	20
Leadless frit	15	15	15			5			5
Nepheline syenite				15	15	20			5
Feldspar							20	20	20
Talc	5	5	15	5	5	5			
Flint	20	20	20	20	20	20	20	20	20
Zircopax	5	5	5	5	5	5	5	5	5
Borax	5	5	5	5	5	5	5	5	5
Total	100	100	100	100	100	100	100	100	100

Rhodes gives the following list as the typical amount of colouring oxides which are added to engobes and the probable resulting colour when fired in oxidised atmosphere:

2%	Iron oxide	- light tan
4%	Iron oxide	- Brown
6%	Iron oxide	- Dark brown
1%	Iron chromate	- Light grey
2%	Iron chromate	- Medium grey
1%	Cobalt oxide	- Medium blue
1%	Cobalt oxide)	
2%	Iron oxide)	- Grey blue
3%	Copper oxide	- Medium green
10%	Vanadium Statin	- Yellow
6%	Manganese dioxide	- Purple brown
3%	Granular Manganese	- Speckle brown
6%	Rutile	- Creamy tan
2%	Cobalt oxide)	
2%	Manganese dioxide)	- Black.

Conrad, (1979) states that to make the engobe printing ink, engobe and colourant are weighed, dry mixed and screened through a 200 mesh screen. Vehicle is then added until the mixture is thoroughly blended to a paste consistency.

(b) Stains: Conrad, (1979) describes stains as certain metallic oxides and spinels. Spinels in ceramic are synthesizer minerals made by firing a mixture of the constituent oxides at sufficient temperatures to calcinate them into a crystal resistant to the actions of the minerals in glazes.

The chemicals for stain are weighed and fired in a crucible to the temperature of 1260°C. The hot crucible is removed from the kiln, the content dumped in water. It is then wet-ground until it will pass through a 60 mesh. It is washed in water and ground continously until it will pass through a 200 mesh screen, it is then dried. Vehicle is added to make consistent paste for printing.

Stains are composed as under-glaze or over-glaze colours. According to Parmelee, (1973) the terms over-glaze and under-glaze colours clearly indicate the different uses made of them for decoration. The reagents are the same to a considerable degree, but the preparation, application, and conditions of firing differ notably.

Under-glaze colours are applied directly to the bisque body and must produce the desired effects at the maximum temperature required to develop the covering glaze. Parmelee notes that the successful use of under-glaze colours depends on the following critical variables:

(i) Maturing temperature of the cover glaze; the more brilliant colours are to be had at temperature below cone 6.

(ii) The composition and thickness of the glaze; A fritted glaze lessens the potential attack on the colours and the degree of colour migration will largely be controlled by diffusion. Thick applications of glaze contribute to smudging and the solvent action of glazes is much diminished in thin glazes.

(iii) The composition and temperature of preparation of the stain or colour base; in many instances the higher the temperature of the calcination the richer and more durable the colour. Fine grinding of the calcined colour base, its thorough purification of soluble salts by washing and recalcination is the practice commonly employed in order to insure purity of colour and freedom from harmful soluble salts. To insure good results, the condition of the atmosphere during the calcining process must be controlled.

The insoluble under-glaze colour body consists of a pigmentry oxide, a flux to bind the colour to the surface, accessory materials to serve as diluents modifiers of the colour and refractory to control the fusibility as may be needed.

The amounts of fluxing in diluting agents added varies, possibly 20% to 30%. Alumina and Kaolin are the reagents mostly used as diluents and refractories. Finely ground bisquit can also be used. The fluxing agents may include feldspar and frit used in the cover-glaze or specially compounded boric oxide, zinc oxide.

Parmelee states further that to prepare under-glaze colour stain, the materials are thoroughly mixed and finely ground, calcined, carefully levigated, washed and again calcined and ground. The cycle of calcining, grinding and washing may be repeated several times. The composites should be mixed with suitable medium to permit their application to the ceramic body.

Rhodes, (1957) recommends that the materials for under-glaze colours be calcined until they sinter into a hard but unmelted mass. He indicates the following recipes as typical ingredients by ratio in some under-glaze stains:

Brown

Iron oxide	-	30
Green chrome oxide	-	28.5
Zinc oxide	-	72

Black

Red iron oxide	-	10
Chrome oxide	-	76

Black cobalt oxide	-	20
Manganese dioxide	-	12

Blue

Black cobalt oxide	-	26
Zinc oxide	-	104
Flint	-	70

Pink

Tin oxide	-	100
Whiting	-	40
Flint	-	40
Fluorspar	-	15
Lead chromate	-	6

They yield the result when fired in oxidised atmosphere. Rhodes notes that reducing atmospheres in the kiln change many colours and prevent the development of others.

Over-glaze colours on the other hand are also called enamel. According to Rhodes, (1957) over-glaze colours are low-fired enamels applied to the finished glazed ware and fired on in a separate firing. In fusing they attach themselves to the surface of the glaze on the ware and become reasonably parmanent after firing. Rhodes however remarks that the use of strong detergents and mechanical dish washing may gradually remove them from the ware.

Parmelee, (1973) states the requirements that must be met by over-glaze stains in order for them to be of practical use thus:

a) The colour bodies on all the ware subjected to any single firing should mature uniformly and satisfactorily at the same temperature of the operation.

b) The colour bodies must have approximately the same or, up to 10% lower thermal expansion characteristics on the surface on which they are fired.

c) The flux used should develop a firm, fused bond between the colour and the surface on which the colour is applied.

d) There should be adequate resistance to abrasion, chemical attack by food acids and alkaline detergents and hot water.

As contain in Parmelee, (1973) the over-glaze colour body consists of the flux, diluents possibly of refractory nature if required. Few oxides such as lead oxide, boric acid or borax, soda, potash are used as flux to facilitate optimum conditions. Silica and alumina are used in a rare case.

Below is a table of batches for the preparation of fluxes for over-glaze colours as contained in Parmelee, (1973):

TABLE 2.2: FLUXES FOR OVER-GLAZE ENAMELS

Materials	No.1	No.2	No.3	No.4	No.5	No.6
Flint	25-20	16	70-73	34	15	35
Red lead	75-80	61	10-18	12	38	
Borax				58		
Boric acid		23	20-9		50	65

They are recommended for the following colours;

No.1. Useful for the cobalt blues and certain reds prepared from iron oxide.

No.2. Useful for a variety of colours, particularly yellows, pale brown, red colours from iron oxide and grays.

No.3. For green colours prepared with chromium compounds and with mixtures of cobalt and chrome yellows.

No.4. This flux is suitable for the carmine and light purple obtained by the use of gold.

No.5. This flux is recommended for dark purple prepared with gold.

No.6. For very delicate water green, very pale bottle green and a torquoise bluish green.

NOTE: The batches are not capable of producing colours on their own, they only serve as base for colouring oxides.

Over-glaze decoration as remarked by Parmelee has the advantages of much wider selection of bright colours and much sharper detail than that of under-glaze. However, over-glaze is vulnerable to chemical and physical damage being directly exposed to this agencies.

2.3.2. Vehicles

Antreasian and Adams, (1971) describe vehicle as a heat treated linseed oil varnish that contributes the fatty qualities necessary for the ink to perform lithographically. It also provides viscosity and binding properties that enable the ink to flow properly and to bind the pigment particles to the surface on which the ink is printed.

Dale, (1964) notes that linseed oil and turpentine appear to have emerged as the most favoured traditional media for application of oil based ceramic colours. They have two properties in common. Both undergo oxidation (or polymerisation) on exposure to air and as this process proceeds viscosity increases. He stresses further that linseed could be polymerised or thickened by boiling because of its low volatility.

Dales, (ibid) remarks that the analysis of the physical and chemical properties associated with linseed oil and turpentine based mixes, points the way for the selection of modern synthetic resins and solvents used in particular decoration.

Some of the synthetic resins are:- Drying oil modified alkyds, oil soluble, chlorinated diphenyls, fully synthetics - the polymetha - crylates, and perspex type which volatilize without carbonising on heating.

According to Conrad, (1979) various liquids can be used as vehicle, but should have the following qualities, viscosity, safe to handle, dry without crawling, smudging, bubbling and developing pinholes and should not clog the screen or leave any carbon residue when fired. Although Conrad recommends commercial squeegee vehicles, he however remarks that other vehicles work satisfactorily, these vehicles include :

a) Screening varnish - A mixture of one third each of varnish, turpentine and boiled linseed oil,this forms a tough film.

b) Decal lacquer - Best used on lacquer-proof film, dries fast, forming a hard film.

c) Water-Soluble Silkscreen Extender. It's major advantage is that it will clean up with water. It forms a tough film when dry, but it is not as satisfactory as the oil base.

He also recommends the use of the following household items:- Baby oil, liquid soap (such as ivory), vaseline and wax emulsion.

But notes that they cannot be used for extensive printing project because they will clog the screen and form a film on the ink while printing is in progress.

According to Parmelee, (1973) 25% solution of gum arabic in water with a little glycerine can be used as vehicle, however the use of a medium containing too much gum may result in formation of blisters.

In preparing custom made ceramic ink, Conrad, (1979) suggests that the vehicle and the ceramic compound must be hand-mixed using either spatula on a glass plate or a mortar and pestle. He suggests a ball mill for large batches and that grinding and mixing are important with thorough blending, wetting the ceramic compound and thickening the mixture to make a better printing ink. Ragan, (1956) does not agree with the idea of mixing a printing ink in the ball mill which he considered impractical because of the high viscosity of the printing material.

Bartel, (1973)'s approach to mixing of ceramic ink with vehicle is very simple. In mixing of engobe for screen printing, he recommends that the slip ingredients be dry mixed and added to a small amount of water so that the resultant mixture is about the consistency of tooth-paste.. He prefers soft margarine tubs as ideal for mixing and storing small batches of coloured slip and a rubber spatular as a good mixing tool.

2.4. Application of Ceramic Printing Ink

Printing can be done on damp and dry green-wares, bisqued wares, and glazed wares depending on the kind of ceramic ink to be used.

2.4.1. Printing with Engobe

According to Bartel, (1973) using the silk screen to transfer image on moist green-ware with slip gives a more interesting and subtle effect than photographic silk screen decals, he notes that the decoration can be completed while one is still strongly involved with a piece. This permits modification of the clay from that relate to the decoration.

Bartel favours a slightly textured clay surface for the printing, this allows a thicker deposit of slip in the depressions. Clay can be rolled between two sheets of cotton canvas to acheive this. For the clay surface to contrast well with most coloured slips the porcelain body is suitable. If the piece is made of a dark stone-ware clay, white slip of porcelain body may be used to coat the area to be printed.

To print the image, Bartel (ibid) stresses that the silk screen is placed flat on the prepared clay slab. A bead of heavy slip is laid across one edge of the screen where the screen is not opened.

A rubber squeegee is pulled rapidly back and forth several times. If this is done slowly, the slip tends to dry and will clog the screen. After printing about three or four slabs, it becomes necessary to wash out the screen. The screen must be dried thoroughly before it is used again. A wet screen causes the slip to bleed and the image will lose clarity.

The printed slab may now be formed into a pot, a piece of sculpture, or any slab built configuration. To screen image on a thrown piece, Bartel notes that an additional step is required because of the roundness of the form and its fragile nature which makes direct screening not possible. To do this, image should be screened onto a piece of ordinary paper toweling in an upside down position in order to get a mirror image. The toweling should be laid face up on the surface of water to get it saturated.

After a very few moments, the saturated toweling should be lifted out of the water and the coated side placed on the leather hard thrown pot. The wet toweling being slightly stretchy conforms to the convex surface. A smooth wooden tool is used to rub the toweling to help transfer the slip to the pot.

Conrad, (1979) notes that image can be screened on tissue paper and transferred directly on moist pottery surfaces.

2.4.2. Printing with Under-glaze Colours

According to Rhodes, (1957) under-glaze colours can be applied either directly on the raw or bisqued ware by silk screen printing. And also by direct transfer printing where the designs are printed onto thin transfer paper. The transfer paper, with the fresh printing on it is placed face down on the ware and rubbed. The design is registered on the surface of the ware in the process. Under-glaze colour is mixed with a suitable vehicle before the application.

Thames and Hudson, (1978) remark that decal transfers may be applied to bisquit, but the risk of faults is increased. It is more difficult to achieve a perfect contact between the print and the absorbent clay surface, particularly if the clay has anything other than a very smooth surface.

Most authors favour a thinly applied transparent glaze in covering the design, this is done after 'harden-on firing'.

Parmelee, (1973) lists the major problems in printing with under-glaze colours thus:

(a) Colour bleeding (b) Imperfect transference to the ware (c) Poor transference to the paper. (d) Colour workability less than optimum, and (e) Colour scumming.

2.4.3. Printing with Over-glaze Colours or Enamel

According to Rhodes, (1957) over-glaze prints can be applied as decalcomania, can also be printed directly on to the glazed ware. Decals have the advantage of th numerous colours which can be applied to the ware in on operation.

Kaplan, (1975) describes decal fabrication as simp the silk screening of a low-fire glaze onto a special paper. A coating of clear-burning ceramic varnish is next applied to provide a flexible film for transferrin the image onto the ware. When soaked in water, the pap releases the image and varnish so that the decal may be positioned on the surface of a previously glaze-fired piece. During a subsequent low-temperature firing, the varnish film burns off while the image fuses with the glaze and becomes an integral part of the surface.

In a similar but clearer form, Parmelee, (1973) defines decal as the printing of designs, pictures, or type on a specially prepared surface such as gummed pap This printing is subsequently transferred to a surface which is often difficult to decorate directly due to curvature or complexity of contour. The decal being flexible conforms to the surface applied to.

The most likely defects characteristic of overglaze decal process as contain in Parmelee are: (a) specks (b) blisters (c) colour rolling and (d) colour scumming.

Chandler, (1967) notes another method of overglaze colour application. Varnish is screened on transfer paper instead of the normal printing ink. Ceramic colours in powder form are then dusted on the paper and adhere only where there is varnish, such transfer are commonly wetted and then pressed or rubbed onto the ware by hand with a roller, the paper being peeled off.

On direct printing on to the glazed ware, particularly for polychrome printing, Singer and Singer (1963) note that new thermoplastic media make rapid printing possible. The media are waxes or resins that are solid at room temperature but can easily be melted at moderately elevated temperatures 50°C - 100°C. The colourant is mixed in when the vehicle is liquid and kept in thermostat - controlled bath. The screen is heated either by using a stainless steel screen as a resistance heater as well as a printing screen, or by infra red lamps or a combination of these. The hot liquid ink can then be squeezed through the screen on to the cold ware surface and it immediately solidifies.

Singer and Singer stress further that thermoplastic media were first developed for the polychrome printing on bottles and other cylindrical shapes where most trouble had been experienced with traditional squeegee oils. All these objects having a curved surface always have a brief contact with the printing screen. In applying the technique to flat surfaces there may be difficulties due to the screen and surface being in contact for a longer period so that the screen becomes cold. The screen should be placed at about 3mm above the ware, and a fast squeegee stroke be used on a taut mesh, so that there is instant release of the screen after passage of the squeegee.

2.5. Firing of Printed Surfaces

Thames and Hudson, (1978) recommend an absolutely clean kiln for firing printed decoration. Any dust within the kiln atmosphere if deposited upon the printed image will soften it to some degree during firing and can also produce a series of raised spots upon the finished image.

Bartel, (1973) notes that green-wares printed with water base engobe ink are bisque fired in the normal way. For glaze firing he advises that selected cover glazes be transparent enough to allow the image to show through and be applied thinner than normally used.

The application of glaze should be uniform in order to obtain a satisfactorily consistent image.

According to Chandler, (1967) bisquit wares carrying a pattern formed by an oily ink will repel the watery cover glaze slip. For this reason bisquit wares carrying under-glaze decoration sometimes have to undergo a preliminary firing at a temperature of about 600°C to burn out all the organic substances. This is called 'hardening-on'.

Choosing covering glaze for under-glaze pattern. Parmelee, (1973) favours a glaze which comes to maturity quickly and therefore requires a gloss fire of only short duration. Prolonged heat treatment may cause the glaze coating to flow on inclined surfaces and thereby distort the decoration. He suggests that thermal expansion conduct of the under-glaze and the cover-glaze should not differ greatly.

Rhodes, (1957) remarks that the firing temperature influences under-glaze colours. The higher glaze firing will dull the colour of some under colours or make them disappear altogether. Some colours however such as the blues resulting from cobalt oxide, are stable at all temperatures. Reducing atmosphere in the kiln also changes many colours and prevents the development of others.

According to Chandler, (1967) when over-glaze colours are applied, the already glazed ware has only to undergo a subsequent firing called 'enamel firing' at a much lower temperature commonly in the region of 750°C. This is usually done in an electrical kiln and takes only a few hours.

Similarly, Parmelee, (1973) notes that the firing temperature of over-glaze patterns is quite low about cone 015 to cone 017 and the time is of short duration. If heated beyond the limits for the decoration, sharpness of the pattern will be lost by boundary diffusion. He recommends a special furnace of the muffle type with excellent ventillation for firing over-glaze colours.

Kaplan, (1975) similarly recommends oxidation firing for all oil based ceramic inks. The kiln should be fired with the lid vented so that fumes from the burning varnish in the ink can escape. But unlike Chandler, (1973) Kaplan favours gradual firing to allow a slow combustion of organic matter present in the ink.

CHAPTER THREE

RESEARCH PROCEDURE

3.1. Introduction

The research procedure stresses from the procurement, beneficiation and pilot study of the selected raw materials to the preparation of different ceramic inks, screens, stencils and the printing and firing of the printed surfaces.

The design of this study falls under Product Development Research. According to Adetoro, (1986) Product Development Research is often in environmental studies where researchers tend to develop alternative or new products as well as translate the research findings into usable items. In doing this he lists the following as the steps involved: Studying of prior research, Establishing goals and objectives, developing the product, field testing it, retesting it, evaluating it in relation to terminal objectives and disseminating it by using the finding to asses the product.

3.2. Population

The following constitutes the entire population for the study. Screen mesh, stencils, adhesive, transfer paper, lacquer varnish, oil vehicles, ceramic inks, clay bodies.

3.3. Sampling

Rational sampling was used in drawing samples for the study due to the inavailability and inaccessibility of some of the materials.

Silk mesh was used as representative of screen mesh. Photographic film and lacquer film were used as representatives of stencils. Engobe, under-glaze stains and over-glaze enamel were used as representatives of ceramic ink. Petroleum Jelly Oil, Linseed Oil and Engine Oil were used as representatives of oil vehicles. Ceramic Clear Coat varnish was used as representative of lacquer. Corn-starch and 'Robin' starch were used as coating gum for decal paper. Cardboard paper, typing sheet, catridge paper, Newsprint and filter paper were sampled as decal paper.

3.4. Procurement of Raw Materials

Fine silk mesh, emulsion and sensitizer were bought at an Art Material Shop in Zaria. Coarse mesh, Petroleum jelly and Corn starch, were obtained at Zaria market. Linseed oil, Ceramic Clear Coat Varnish, decal paper, were procured in Lagos.

Clays, glaze materials were obtained from Zaria. Oxides were used from the store of the Ceramic Section of the University.

3.5. Treatment and Processing of Raw Materials

Colouring oxides were obtained in processed form. Other materials that were obtained in their raw states and beneficiated are listed below with the stages they underwent.

Bomo Clay:	Soaked for two days, sifted, and dried.
Kankara Clay:	Soaked for two days, sifted and dried
Feldspar:	Calcined to 960°C, crushed, ball-milled for 18 hours, dried sifted.
Quartz:	Calcined to 960°C, crushed, ball-milled for 24 hours, dried and sifted.

3.6. Pilot Study

The purpose of the pilot study was to establish the viabilities of the samples for further study. It was carried out to establish the following:

A) To determine the degree of shrinkage between engobe base ink and the clay bodies

B) To determine the adhesive quality of the binders in the engobe slip.

C) To identify the oil mixers that burn off without leaving out any residue or hampering the ceramic ink.

D) To ascertain the optical quality of engobe under transparent glaze.

E) To identify the thermal expansion characteristics of clay bodies, engobe and transparent cover glaze.

F) To identify papers with high rate of water absorption.

The following tests were carried out in the pilot study:

3.6.1. Test for Shrinkage and Thermal Expansion of Engobe-base on Clay Bodies

Three different slip bases were prepared for different application at high temperature range as recommended by Rhodes, (1957). Each comprises different percentages of fluxes, modifiers and stabilizers as listed later in this chapter. Though each of them is recommended for different application - damp application, bone dry application and bisque application, for the purpose of this study, each of them was used at the three states.

They were applied on test tiles of stoneware and porcelain bodies to determine their adhesive and shrinkage qualities at the three states of application. They were bisque fired to determine the degree of thermal expansion and contraction on the two different bodies.

3.6.2. Test for Viscosity and Clear Burning of Oil Mixers

Three different oils namely Linseed oil, Petroleum jelly and Engine oil were tested for viscosity and clear burning. Each of them was mixed with ceramic pigments to determine the viscous extent. The mixtures were applied on test tiles and subjected to hardening-on firing temperature (750°C) to see which of the oil mixers burns off without leaving any carbon residues or interfering with the optical quality of the colour.

3.6.3. Test for Suitable Paper and Starch for Ceramic Transfer

The following papers, cardboard, typing sheets, duplicating paper, catridge paper, newsprint and filter paper were tested for water absorbency. Each was coated with local starch made from corn and industrially processed starch under the trade name 'Robin'. After allowing the paper to dry for about 12 hours, the starched surface was coated with ceramic clear coat varnish and dried for another 12 hours. They were soaked in water and brought out periodically to assess their absorbent time and the ability to release the thin film of the coated lacquer varnish.

3.7. Preparation of Screen

Frames of different sizes were constructed for the screens according to the sizes of designs. Silk mesh was nailed on to frame from two sides. Mesh was stretched and pulled at the other two edges which had been coated with glue. It was pressed onto the glued surface and stapled. Fine and coarse silk mesh were used.

3.8. Preparation of Stencils

Photographic stencils and lacquer stencil were prepared for the study. A black and white photograph was developed into halftone positive or transparency at the darkroom of the Camera Department of Faculty of Education. As stated by Conrad, (1979) the halftone positive method renders gray values by breaking up the photographic areas into black and white dots of varying sizes. The multitude of dots determines the gradual tonal change of light to dark in the halftone. Also a picture of a bird and Ahmadu Bello University logo were developed into photo-line positive transparency in which case the photographed images were translated into solid black or white areas, no gray areas.

PLATE 1: 'A' HALFTONE POSITIVE
'B' PHOTOLINE POSITIVE
'C' IMPROVISED HALFTONE POSITIVE

The positive transparency were transferred onto the screens at the darkroom of the Graphic Design Section. The procedures for exposing the film are stated below:

1. Emulsion was mixed with sensitizer in ratio 5 to 1 respectively. The solution was allowed to settle for 30 minutes under a dim red light.

2. The solution was applied on the screens from inside with the aid of a plastic ruler. The screens were dried under an electric fan.

3. The positive transparency was placed on the screen in a very close contact. A glass was placed on the transparency also in a close contact. A sizeable foam was placed under the screen to press it against the glass.

4. The exposing light was switched on and focussed on the screen for 7 minutes.

5. The screen was washed in cold water under a subdued light. The part exposed to light was hard while the emulsion on the part shielded by the positive image was weak, thereby making the area to be washed away by water.

6. After the washing, the image appeared on the screen in negative form. The screen was dried. Paper tape was used in masking the angles where the screen and the frame meet.

Lacquer stencil was prepared for tiles decoration using an abstract design. The design was drawn on paper and placed under the screen. The design being visible from the other side was traced on the screen, the white areas were coated with lacquer varnish. The varnish dried up after about 12 hours and sealed up the coated areas thereby forming a negative for the design.

PLATE II: SCREENS: 'A' Photographic Stencil
'B' Lacquer Film Stencil.

3.9. Preparation of Ceramic Ink

Three different kinds of ceramic ink were prepared namely; engobe, under-glaze stain, and over-glaze enamel. The preparation procedure and recipes are presented below:

(a) Engobe Ink: Rhodes, (1957) engobe composition formular was applied in the preparation of engobe base ceramic ink. Three different engobes were prepared for different application thus;

Engobe No. 1

Brown colour for damp wares application.

Kaolin	-	25%
Ball clay	-	25%
Feldspar	-	20%
Flint	-	20%
Zirconium	-	5%
Borax	-	5%
Black iron oxide	-	4%
Total	-	104%

Engobe No.2

Blue colour for dry wares application

Kaolin	-	15%
Ball clay	-	15%
Calcined kaolin	-	20%
Feldspar	-	20%
Flint	-	20%
Zirconium	-	5%
Borax	-	5%
Cobalt oxide	-	2%
Total	-	102%

Engobe No.3

Green colour for bisque application

Kaolin	-	15%
Ball clay	-	15%
Calcined kaolin	-	20%
Leadless frit	-	5%
Nepheline syenite	-	5%
Feldspar	-	20%

Flint	-	20%
Zirconium	-	5%
Borax	-	5%
Chrome green	-	4%
Total	-	104%

Each composition was ball milled in wet state for five hours to achieve the fineness that could pass through printing mesh. They were sun dried.

TABLE 3.1: PRINCIPAL MATERIALS USED FOR ENGOBE COMPOSITION AND THEIR FUNCTION.

Materials	Function
Kaolin	For whiteness and low shrinkage rate
Ball clay	For plasticity
Feldspar	Used as flux
Flint	Used as filler
Zirconium	Used as opacifier
Borax	Used as flux
Iron oxide	Colourant for browns
Cobalt oxide	Colourant for blue
Chrome green	Colourant for green

(b) Under-glaze Stains: The procedure for preparing under-glaze stain is different from that of engobe. While engobe was composed and used in raw state, under-glaze materials were weighed out, dry mixed and subjected to high temperature for calcination. The first two under-glaze stains were composed as recommended by Nelson, (1966).

i. Pink Stain

Zirconium	-	54%
Whiting	-	23%
Flint	-	16%
Borax	-	4%
Potassium Dichromate	-	3%
Total	-	100%

54% zirconium was used in place of 50% tin oxide recommended by Nelson, (ibid) thereby changing the percentages of the other oxides.

ii. Black Stain

Green chrome	-	65%
Red iron oxide	-	35%
Total	-	100%

6% Zirconium oxide was added to opacify the composition.

iii. Yellow ivory

Zinc Oxide	-	30%
Iron Oxide	-	5%
Alumina Oxide	-	15%
Titanium	-	10%
Antimony	-	30%
Chrome	-	10%
Total	-	100%

The materials for this batch were selected as recommended by Parmelee, (1973) for enamel temperature. The percentage was however speculated to suit high temperatures.

Each composition was kept in a crucible and fired to cone 9 (1280°C) in a gas kiln. They were brought out of the kiln after cooling down. They were crushed and ground into fine particles.

TABLE 3.2: PRINCIPAL MATERIALS USED FOR UNDER-GLAZE STAIN COMPOSITION AND THEIR FUNCTION.

Materials	Function
Zirconium	Opacifying agent also used in place of tin oxide.
Flint	Diluent agent
Borax	Used as flux
Potassium dichromate	Often used with tin oxide to obtain pinkish effect.
Green chrome	Colourant for green, used with red iron oxide to produce black.
Antimony Oxide	Colourant for yellow hue

(c) Over-glaze Enamel: The procedure for preparing enamel is somehow similar to that of under-glaze stain in that they are both heated up before use. The difference is that while under-glaze stain were calcined at high temperature and allowed to cool down before grinding, enamel were melted at less temperature and brought out of the kiln in the hot state, poured into cold water, jaw crushed and fine ground.

Over-glaze enamel 'i' and 'ii' below were prepared as recommended by Nelson, (1966) while 'iii' -'v' were compounded using the fluxes recommended by Parmelee, (1973) while the percentage were guess work.

i. Yellow Enamel

Antimony oxide	-	33.3%
Red lead	-	50%
Zirconium	-	16.7%

Zirconium was substituted for Tin Oxide.

ii. Orange Enamel

Antimony oxide	-	29.8%
Zirconium	-	12.8%
Brown iron oxide	-	14.9%
Red lead	-	42.5%
		100%

Zirconium was used in place of Tin oxide.

iii. Blue Enamel

Flint	-	25%
Read lead	-	75%
		100%

10% of cobalt oxide was added to the batch to give the bluish effect.

iv. White Enamel

Flint - 16%

Red lead - 61%

Boric acid - 23%

37.5% of Zirconium was added to this batch.

v. Green Enamel

Flint - 16%

Red lead - 61%

Boric acid - 23%

19% of Chrome and 10% of Zirconium were added to make an opaque green.

TABLE 3.3: PRINCIPAL MATERIALS USED FOR ENAMEL COMPOSITION AND THEIR FUNCTION.

Materials	Function
Zirconium	Opacifying agent also used in place of tin oxide for opaque white.
Red lead	Used as flux
Boric acid	Used as flux
Flint	Diluent agent
Antimony oxide	Colourant for yellow hue
Cobalt	Colourant for blue hue
Chrome	Colourant for green hue

The process of heating enamel is a little bit of task. The kiln should have a door that can be opened and closed with ease. It should also be able to withstand thermal shock.

The crucible should also be strong enough to withstand thermal shock when brought out of the kiln in a hot state.

For the purpose of this study the recipe below was used in a speculated percentage in composing a crucible body.

Ball clay	-	27%
Kaolin	-	55%
Calcined kaolin	-	9%
Silica sand	-	9%

The crucibles were thrown on the throwing wheel to a conical cup size shape. They were first fired at about 1000°C temperature before used.

PLATE III: CRUCIBLES; 'A' Used for Melting Enamel
'B' Used for Melting Under-glaze Stain.

3.10.1. Printing with Engobe Based Ink

Printing with engobe was done directly onto clay surface and onto tissue paper which were subsequently transferred onto curved surfaces. Stone-ware body and porcelain body were formulated for the printing base. The stone-ware was formulated mixing ball clay with kaolin in ratio 2 to 1 respectively.

Bartle's (1973) recommendation for porcelain body was adopted in formulating the porcelain body thus:

Kaolin	-	34%
Ball clay	-	15%
Flint	-	21%
Feldspar	-	12%
Nepheline syenite	-	15%
Bentonite	-	3%
Total	-	100%

The two bodies were made into slabs. Bartel, (ibid) favours a slightly textured surface for a good deposition of ink. Some of the slabs were slightly textured using fertilizer bag while some were left plain. Printing was done in three states - damp, bone-dry and bisque states. Also direct paper transfer method was used.

This is a process whereby the image is first screened on tissue paper and subsequently pressed against a curved surface with the aid of a soft sponge. The image is registered in a reverse position. (See plate VI)

Due to the plastic nature of the engobe components, water was used as the printing vehicle. Water was added until the engobe was about the consistency of tooth paste. They were thoroughly mixed. The screen was placed on the printing slab, the ink was applied with a stroke of the rubber squeegee. The printed slabs were bisque fired and coated with transparent glaze.

PLATE - IV: Unglazed Prints

Below are the recipes of the transparent glazes used. Recipes 1 and 2 are recommended by Bartel, (ibid) for stone-ware and porcelain bodies respectively.

1. Stoneware transparent (cone 9)

potassium feldspar	-	4%
Ball clay	-	25%
Dolomite	-	22.5%
Whiting	-	3.5%
Total	-	100%

2. Porcelain transparent (cone 9)

Nepheline syenite	-	114.8 parts
Dolomite	-	36.9
Whiting	-	24.9
Barium carbonate	-	19.6
Kaolin	-	6.4
Flint	-	108.0

3. Transparent ash glaze (cone 8 and 9)

Wood ash	-	20%
Talc	-	3%
Bomo clay	-	20%
Feldspar	-	57%
Total	-	100%

Below are the recipes of the transparent glazes used. Recipes 1 and 2 are recommended by Bartel, (ibid) for stone-ware and porcelain bodies respectively.

1. Stoneware transparent (cone 9)

potassium feldspar	-	4%
Ball clay	-	25%
Dolomite	-	22.5%
Whiting	-	3.5%
Total	-	100%

2. Porcelain transparent (cone 9)

Nepheline syenite	-	114.8 parts
Dolomite	-	36.9
Whiting	-	24.9
Barium carbonate	-	19.6
Kaolin	-	6.4
Flint	-	108.0

3. Transparent ash glaze (cone 8 and 9)

Wood ash	-	20%
Talc	-	3%
Bomo clay	-	20%
Feldspar	-	57%
Total	-	100%

The wares were gloss fired in oxidised and reduced atmosphere in a gas kiln.

3.10.2. Printing with Under-glaze Stain

Printing with underglaze stain is similar to printing with engobe except that under-glaze stain requires more viscous vehicle. Also while water is used as vehicle in engobe printing, oil is used in mixing under-glaze stain because it is less plastic than engobe ink having gone through a high temperature calcination.

Two different oils that had been pre-tested for clear burning were used. They are linseed oil and engine oil. Each oil was added to the pigment in a separate container, the addition was done gradually until they formed a consistence of tooth paste. The solutions were mixed vigorously before application. The screen was placed directly on the bisque fired ceramic surface as did with engobe. The stain was applied onto the screen and with a stroke of the rubber squeegee the image was printed on the ceramic surface.

Printing was done on stoneware and porcelain body. Printing was also done on tissue paper which were subsequently transferred to curved surfaces. (See plate VI). Printed wares were subjected to hardening - on firing to burn out the oil vehicle before the application of transparent cover glaze. They were gloss fired in oxidised and reduced atmosphere in a gas fired kiln.

3.10.5. Printing with Over-glaze Enamel

Unlike the engobe and underglaze stain, printing with over-glaze enamel takes totally different steps. Printing was done on glazed wares and also on specially prepared transfer paper. The enamel pigment was mixed with linseed oil to a suitable consistency. It was applied on the screen and printed onto the decal paper. The prints were allowed to dry for about twelve hours before coated with ceramic clear coat varnish. Soft brush was used in applying the varnish onto the design. The papers were allowed to dry completely before transferring the design onto the ceramic surfaces. The designs were transferred onto the wares by soaking the printed paper in water for about thirty seconds. The paper were placed on the ceramic surface, the back paper was slided off under the design leaving the design adhering to the thin film of the varnish on the glazed ceramic surface. The wares were fired in a gas kiln to enamel temperature ($600^{o}C$ - $750^{o}C$).

PLATE V: Application of Ceramic Decal (Transfer) By 'Slide-Off' Method

CHAPTER FOUR

ANALYSIS OF RESULTS

4.1. Introduction

Various tests were conducted on the materials needed for screen printing on ceramic surfaces. Different methods of application were experimented on. The analysis of the tests are presented in this chapter.

4.2. Result of Pilot Study

Materials with good result were selected while those found unsuitable were rejected. The results are analysed below:

4.2.1. Shrinkage and Thermal Expansion Results of Engobe Bases

Nelson, (1966) notes that engobes are essentially clay slips, with the significant difference that some engobes are intended for use on either dry or bisque ware, thus necessitating variations in composition in order to adjust the varying shrinkage rates. The three engobe bases numbered engobe 1, 2 and 3 in chapter three recommended for damp, dry, and bisquit application respectively have good shrinkage rate with the stoneware and porcelain bodies used.

However, there was no significant difference in the shrinkage rate when the engobe bases were interchanged in application. Each base conformed with the bodies at the three different states of application without flaking off.

The thermal expansion of the bases correspond. The result of the test tiles fired showed no cracking nor peeling of the engobe bases.

4.2.2. Determining the Viscosity and the Clear Burning of Oil Mixers

Viscosity implies the stiffness character of the oil mixers. Of the three oils tested - linseed oil, petroleum jelly and engine oil - linseed oil has the highest viscosity when mixed with the pigment. However, attempt to increase the viscosity by heating as recommended by Conrad, (1979) yielded no positive result. The oil tended to volatilise instead of getting thicker. The reason could be due to the refined state of the oil when it was purchased. Though the petroleum jelly was in pasty form, this did not make it to be viscous when mixed with the pigment. The mixture broke up easily during application. Also the oil dried off the surface which it was applied leaving a chalky pigment behind. Engine oil however, mixed well with the pigment but it contracted and also broke up into patches after application onto the clay surfaces. All the oil mixers burned off without leaving carbon when tested for clear burning, there was no damage to the optical quality of the colour.

4.2.3. Identifying Suitable Paper and Starch for Ceramic Transfer

According to Conrad, (1979) any water absorbent paper is required for custom made transfer or decal paper. The result of the test carried out showed that cardboard paper, catridge paper and duplicating paper have a very low water absorbent rate. They could not release the thin film of the coated lacquer when soaked in water for more than one hour. However, newsprint and filter paper have a higher water absorbent rate than the formers. They performed fairly well. They have the tendency of releasing the thin film of the coated lacquer varnish when soaked in water. This was achieved by soaking them in water for more than thirty minutes, a time which is much longer than that required of a standard ceramic transfer.

Local corn starch proved to be successful as coating gum for transfer paper. Newsprint and filter paper coated with local corn starch released a thin film of coated lacquer varnish without reacting with the film. The other starch used which was industrially made under the trade name 'Robin' was not suitable as coating gum for transfer paper. It reacted chemically with the lacquer film. When soaked in water, the film swelled up, this led to the disintegration of the film when sliding it off the backing paper.

4.3. Behaviour of the Screens and the Stencils

Two different screen were used thus; fine and coarse mesh. The pores of the fine mesh are too small to allow the passage of ceramic pigment. It deposited a very faint image. This mesh is very expensive. Silk scarf designed for sifting liquid flour worked well as coarse mesh. It is readily available at a cheaper price. The hole is wide enough to deposit sufficient ceramic ink during printing, though it lacks the fine details of the fine mesh.

Of the stencils used, halftone photographic stencil posed some difficulties. Most of the printing press around could only develop halftone positive of small dots. When such half-tone was transferred onto coarse screen, the dots joined together in the dark areas of the image. And where there should be grey tones the dots could not register on the screen because they were too fine to stand individually on the coarse mesh. Most of the dots disappeared into the pores of the mesh.

The portrait was then drawn on transparent paper and shaded with big juxtaposed dots for the purpose of this study. 0.8 type of drawing pen was used in making the dots. The transparent paper was improvised to represent half-tone positive needed in exposing the image on the screen. (See plate I). The screen was able to retain the grey areas because the dots were big enough to cover the holes in the coarse mesh.

When it was used for printing, the photographic quality of screen printing manifested.

The photoline positive transparency posed no difficulty in image registration during printing. It printed black and white with no tonal gradations, that is, flat images.

4.4. Characteristics of the Ceramic Inks

4.4.1. Engobe

Of the three different batches of engobe prepared, two yielded the required colours after firing. (See table 4.1.). Engobe No.1 yielded brown, No.2 yielded light blue while No.3 turned out brown or black in some ocassions instead of the intended green colour. This must have been due to two facts thus; the substitution of chrome green for copper which was not at the disposal of the researcher and the reaction of the engobe with the direct burning gases and flame in the gas fired kiln.

TABLE 4.1: COLOUR RESULT OF ENGOBE INK AFTER FIRING

	Intended Colour	Resulted Colour(s)
Engobe No.1	Brown	Brown or dark brown
No.2	Light blue	Light blue
No.3	Green	i. Green under porcelain glaze. ii. Black under stoneware glaze.

The batches were plastic and fine enough for application after ball-milling for six hours in wet state. As to this adhesive material was not needed as binding agent. Although engobe No.1 which contained 4% of iron oxide settled quickly at the base of the container leaving the suspending water above. Constant stiring is needed before use. Permelee, (1976) notes that colloidally dispersed portion has an important role in determining the duration and the completeness of the suspension of the slip and the dispersoids are responsible for the adhesion of the slip to the surface of the ware prior to and during the firing.

4.4.2. Under-glaze Stains

The result of the high calcination of under-glaze stains exposed the difficulty that is typical of colour attainment in stone-ware and porcelain temperatures Nelson, (1966) remarks that since under-glaze colours are fired at the same temperature as the glaze, the variety of colours available is less than for over-glaze colours. Most of the delicate hues available in over-glaze colours will burn completely at hard porcelain range of cone 14 (1366°C). This leaves the blues, browns, grays, gold-pinks, reduction reds and celadon hues available for use at these higher temperatures

Under-glaze stain No. '1' turned light green instead of the intended pink colour (see table 4.2.). It sintered into a solid mass with large particle size. The resulted green colour must have been due to the fact that zirconium oxide was substituted for tin oxide and also the atmospheric condition of the gas fired kiln. Parmelee, (1973) remarks that the atmospheric condition during calcining process contributes one of the critical variables in preparation of under-glaze. To ensure good results the atmosphere must be controlled.

Under-glaze stain No.2 sintered and turned black at 1280°C. This was the intended colour. Under-glaze stain No.3 had about 40% of its contents volatilized. This is as a result of low melting materials such as antimony oxide and zinc oxide which constituted a reasonable percentage of the batch. According to Parmelee, (1973) stain prepared by calcining the mixtures of the oxides used in stain No.3 are entirely stable through and well above decorating temperatures. The mixture was however, composed by making the materials that can withstand high temperature 70% of the batch. The residues from the batch sintered patially with a light brown hue. Parmelee, (ibid) states further that a light yellow brown may be had by the addition of antimony oxide to a chrome - iron - alumina-zinc mixture with a portion of lightly fired porcelain body and calcined to cone 10.

TABLE 4.2: COLOUR RESULT OF UNDER-GLAZE STAIN AFTER CALCINATION.

	Intended Colour	Resulted Colour
Under-glaze Stain No.1	Pink	Green
No.2	Black	Black
No.3	Yellow/Ivory	Light brown

4.4.3. Over-glaze Enamels

The result of the fritted over-glaze enamels indicated a tremendous success in terms of colour achievement and brilliancy. (See table 4.3.). Enamel No.1 gave a brilliant yellow hue when melted and ground. Enamel No.2 turned dark brown when melted into solid mass but gave a brilliant soldier green when ground instead of the intended orange colour. This may be due to the effect of brown iron oxide which was substituted for red iron oxide.

Enamel No.3 turned to torquise green when melted, light blue when ground and light green when applied onto ceramic surfaces or transfer paper. Enamel No.4 gave a cream colour when fritted instead of the intended white colour. This is obviously due to zirconium oxide that was substituted for tin oxide which was not at the disposal of the researcher.

Enamel No.5 appeared leaf green when melted but turned deep green when ground and applied.

TABLE 4.3: COLOUR RESULT OF FRITTED OVER-GLAZE ENAMELS.

	Intended Colour	Resulted Colour
Enamel No.1	Yellow	Yellow
No.2	Orange	Soldier green
No.3	Blue	Light green
No.4	White	Cream
No.5	Green	Green

4.5. Result of the Different Methods of Application

4.5.1. Printing with Engobe

For damp printing, leather-hard slab is the best. Prints would not register on too soft or wet slab, the screen absorbs water from the wet surface thereby making subsequent printing to appear faintly. The mixing consistence of the engobe itself should be a little bit less than that of tooth paste but should not be too fluid, when a too fluid engobe was used, it ran underneath the screen and since the rate of water absorbent of damp clay is low, it smeared the surface and soaked the screen.

This made subsequent printing impossible until the screen was cleaned and dried.

When printing on damp clay, the ink should be wiped clean off the open part of the mesh with the squeegee before the screen is lifted, otherwise the print would smear and subsequent printing would not be good. Only a little pressure just to allow the passage of the engobe is required when pulling the ink across the screen with the squeegee. Too much pressure leaves no ink on the damp clay since it has low water absorbent capacity, the ink will rub off the damp surface, the print result will be a faint or ghost image.

When printing on bone dry clay surface, the paste should be a little bit thicker than on a damp clay surface because the rate of water absorbent in the former is higher. It absorbed too much ink during printing, the ink spread and lessened the sharpness of the design. Oil mixer worked better than water as a vehicle when used on bone dry clay surface, the prints were sharper. This is because the rate at which oil percolated into clay body was less than that of water.

Printing on bisqued surface was however the simplest, be it with oil based or water based.

The rate of water absorbent was moderate, not too slow and not too fast. The prints done on bisqued slabs were consistently good.

Printing on plain surface yielded a better result than printing on slightly textured surface. It gave a sharper image. The fine details were lost on the textured surface, the ink settled in the pores thereby distorting the image. All printing surfaces must be free of dust. Dust deposit prevented the registration of the print, instead the dust clung on to the mesh and clogged the screen.

4.5.2. Printing with Under-glaze Stain

Printing with under-glaze stain posed some difficulties which were not experienced when printing with engobe. Because of the high calcination of the materials, it took a long process grinding the sintered grain into fine particles, and no matter how fine they were ground, they were not plastic when mixed with water unless when mixed with oil.

In the first printing where the particles size was not very fine, the oil vehicle moved out of the screen.

Subsequent movement of the squeegee to one direction helped in wiping the particles off the screen, but then, too much of ink was deposited and the more the coarse particles were moved on the screen the more they wore out the stencil. In the subsequent printing where the particles were ground finer, this problem was alleviated.

Direct transfer whereby the image was printed on tissue paper and subsequently transferred on to curved surfaces was effective particularly when the pigment particles were ground into very fine powder and mixed with a highly viscous linseed oil. The adhesiveness of the oil mixer need to be very strong for the print to transfer from the tissue paper to a ceramic surface.

PLATE VI: DIRECT TRANSFER METHOD:
'A' TISSUE PAPERS FROM WHICH IMAGES WERE TRANSFERRED TO CURVE SURFACES.

'B' CURVED SURFACES SHOWING FIRED PRINTS.

4.5.3. Printing with Over-glaze Enamels

Over-glaze enamels behaved the same way like the under-glaze stains during printing process. The enamels were fine ground and mixed with viscous linseed oil. The prints made on decal paper were very sharp and accurate.

PLATE VII: PRINTED CERAMIC DECAL (TRANSFERS).

4.6. Optical Qualities of Fired Prints

The engobe prints with low percentage of colouring oxides and lots of glaze materials dissappeared in some cases and appeared faintly in other cases. The composition being close to that of glaze made the engobe to melt and diffused into the transparent cover glaze. The colour appeared faintly because of the low percentage in which they were introduced. These problems were further enhanced by the thin deposit of ink which is typical of screen printing. In some cases where the image survived firing it has a subtle photographic effect.

The half-tone dots and the mesh strips merged during partial diffusion.

PLATE VIII: FIRED ENGOBE PRINTS SHOWING THE DIFFUSION OF THE INK INTO THE TRANSPARENT COVER GLAZE.

Attempts to improve on the optical quality of the image were made by increasing the percentages of the kaolin in the batches by 100% of the initial constitute. This was to make the engobes refractory enough from being diffused into the transparent cover glaze. Also the percentages of the colouring oxides were increased by 500% of the initial amount to increase the colour intensity of the prints. This development yielded a successful result, the prints made after, remained sharp and strong in colour intensity after firing.

PLATE IX: FIRED ENGOBE PRINTS AFTER BEEN STABLIZED.

The optical clarity of under-glaze stain was sharper and stronger than that of engobe before they were improved on. Every little detail was clearly seen after firing. In some prints where the ink deposit was too much the tonal gradation was lost to harsh smeared image.

The colours of both engobe and under-glaze stain were highly influenced by the transparent cover glaze and the firing atmosphere.

PLATE X: FIRED PRINTS OF UNDER-GLAZE STAIN

Over-glaze enamels however did not undergo significant colour transition from the printing state to the firing state. The colour intensity became slightly brighter when prints were fired. Most glazes that contrast well with each enamel and mature at higher temperature can be used as transfer surface for enamel. The white stoneware glaze recipe below contrasted well with the enamels prepared except the cream one.

Cone 9 White Glaze

Feldspar	-	55%
Whiting	-	10%
Kaolin	-	15%
Flint	-	10%
Zinc oxide	-	5%
Zirconium	-	5%
Total	-	100%

The problem with the enamels prepared is that they only sintered at very low temperature required for enamel. They became very glassy at about 1000°C. This could be due to the influence of high temperature material that is, Zicronium which was introduced to opacify the enamels and also as a substitute for tin oxide in some cases.

PLATE XI: FIRED PRINTS OF OVER-GLAZE ENAMELS.

CHAPTER FIVE

FINDINGS, CONCLUSION AND RECOMMENDATION

5.1. Findings

The following findings were made in the course of study:

i. It is more economical to use engobe in under-glaze printing than using stain for two obvious reasons. Firstly, it requires a greater amount of colourant to prepare stains than needed in engobe preparation. Secondly, while water can be used as vehicle in engobe ink due to the plastic nature of the materials, it is only oil that can be used as vehicle in stain application because it is less plastic having been subjected to high temperature calcination. It is quite expensive to purchase good oil mixer like linseed oil.

ii. The cheap and common silk scarf mesh specially made for sifting flour is very good for screening ceramic inks. The pores are wide enough to allow the passage of pigment particles. Though this mesh is coarser than the fine mesh used for the usual screen printing, the sharpness of the printed image is averagely okay.

iii. That ceramic pigment ground and sifted through a mesh finer than the one that will subsequently be used in the printing makes a better flowing ink.

iv. Mixing an oil based printing ink that is just enough for a printing session is better than mixing a large batch that would be kept for a longer period, otherwise, the particles will cling together and roll off the screen instead of flowing onto the ceramic surface. This is not so in the case of water based ceramic ink. The longer the ink is allowed to age in the water carrier the more plastic it becomes.

v. That the quantity of colourants required in each batch of engobe for screen printing should be higher than the amount used in the normal engobe applications due to the less amount of engobe that is deposited in screen printing application.

vi. The percentage of stabilizers such as kaolin and ball clay should be high enough to keep the fluxes in control and prevent engobe ink from diffusing into transparent cover glaze.

vii. Prints do not register on dusty ceramic surfaces. Instead the dust cling on to the screen thereby preventing the ink from flowing out.

viii. That engine oil and petroleum jelly broke into patches when used as vehicle thereby distorting or defacing the prints.

ix. That some of the linseed oil sold in gallons are thicker than the more refined ones sold under the trade names 'Talens' and 'Yagi'. An attempt to make all the linseed oils from different sources thicker by heating was not successful. They rather volatilized instead of getting more viscous.

x. Generalisation cannot be made of the linseed oils available in the country. Linseed oils from different sources behave differently. The thick ones are good as oil mixer for ceramic ink while the lighter ones perform below average.

xi. That local corn starch performed better than the industrially prepared starch with the trade name 'Robin' when applied as coating gums for decal paper.

xii. Soft newsprint and filter paper coated with corn starch release a thin film of subsequently coated ceramic clear coat varnish. Though their performance is very low compared to that required of standard decal paper. For example, it takes about forty minutes of soaking in water before the thin film is released and by this time the film is not very strong to hold the print in a perfect state.

xiii. Enamel in their crystal form after fritting are darker and duller in colour intensity than when ground.

xiv. A simple combination of kaolin, ball clay, calcined kaolin and silica sand in ratio 55; 27; 9; 9 respectively performed execellently when used as crucible body. The crucibles have a very high resistance to thermal shock when used in enamel fritting.

xv. Over-glaze enamels fired under an oxidised atmosphere give more consistent colour stability.

xvi. The grades of some of the materials used like the silk meshes and the halftone dots are not standardized.

5.2. Conclusion

Screen printing techniques in pottery decoration is a vast area that cannot be exhausted in a research of this duration. One of the objectives of the study was to create the awareness and orient the techniques of screen printing among the studio potters in the country through a simple approach to the procedures involved and the identification of the suitable materials needed for the process.

In the course of study, a lot of problems were encountered which indicate that the art of printing on ceramic surfaces should be looked into in a wider perspective. For instance, the materials and the process fall under two areas of art; ceramics and graphics. This however brought about some distractions in the study. The study would have been less cumbersome if it has been narrowed down into making ceramic inks, developing suitable materials for ceramic transfer or the techniques involved in ceramic screen printing. However, this can only be possible when the art of screen printing has been widely used.

The findings and correction to the problems encountered during the study should be seen as foundation in screen printing process in pottery decoration.

There is room to develop this art to higher appreciable level, for example, multicolour printing which involves colour separation and creating some special effects with colours will be a step forward in this area.

Pre-tests were carried out to assure the researcher about the posibility of the problem area. The result of the tests formed the basis upon which materials were selected for further test while those that were found unsuitable were rejected. Generalisation cannot be made of the materials used in the study. The viability of the materials depends on the source, environment, stock or the batch from which they are obtained. For example, of the different newsprints used for transfer paper only the one from 'National Concord' newspaper gave a desirable result being the softest.

5.3. Recommendation for Further Research

Based on the experience acquired from the study, the following recommendations are made:

i. Research should be conducted to identify more suitable materials for decal fabrication.

ii. There should be further studies into composition of more stable ceramic inks of various colours.

iii. Future study should go into photosensitizing ceramic surfaces for the real photographic qualities.

iv. Interested potters should pick up the idea of making decal in large quantity for the purchase of interested industrial and studio potters, by so doing the technique will become popular in our environment.

v. Screen printing process as regard to pottery should be taught as a course in ceramics in our schools.

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APPENDIX I

PLATE XII: Fired Prints of Tiles Decoration

PLATE XIII: Materials for Printing Decals.

APPENDIX II

Specimen of a Suitable Mesh for Screening Ceramic Inks.