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A GUIDE AND VISUAL AID TO THE PROCESS OF CERAMICS

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A thesis

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ABSTRACT

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A GUIDE AND VISUAL AID

TO THE PROCESS OF CERAMICS

"A Guide and Visual Aid to the Process of Ceramics" is a thesis intended to provide the teacher who has little experience with ceramics a comprehensive yet easy-to-follow summation of the basic processes and chemistry in studio ceramics. The thesis could also be used by the student or by the enthusiast who would like to broaden his basic knowledge in this area.

The thesis will assist in the organization of studio space, in the selection and use of equipment, and in the initiation and development of skills necessary for the production of ceramics. It contains notes on clays, mining of clays, glazing, and glaze calculations. A set of 35 M.M. slides and instructions are included in this thesis that explains step-by-step hand building and wheel throwing techniques.

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INTRODUCTION

As an artistic medium clay is unique. Few other media have such versatility. For example, clay can be shaped and pushed into designs and constructions that range from elaborate murals and huge relief sculptures to tiny sculpted forms. It can be fired to change its chemical state, and be glazed an infinite number of colours. In short, there is a great deal of information that must be known about the substance clay and the whole field of ceramics by anyone proposing to teach ceramics to students.

Books are available on every aspect of ceramics but they are not tailored to the needs of teachers. They are either too simple and vague, too technical or too specific in their approach. In each case they provide little practical information for the teacher who needs or wants to set up a ceramics programme in the classroom. What has been needed is a text that deals specifically with how to approach a ceramics programme for the classroom.

This thesis, "A Guide and Visual Aid to the Process of Ceramics," is a summation of basic facts pertaining to ceramics and is designed for the classroom teacher who has had little or no experience with clay. It takes into consideration that many teachers who have not been trained to teach ceramics must undertake these programmes. Thus, for these teachers this thesis is a reference book that covers all aspects of ceramics that would be necessary to conduct a programme at either the elementary or secondary level.

As a guide this thesis is divided into two sections. Part I contains the technical information. It outlines (a) types and properties of primary and secondary clays, (b) glaze chemistry and basic glaze calculation, (c) lists and discusses various kinds of studio equipment both on a major and minor scale and finally, (d) gives hints on how to set up a studio situation.

Part II outlines all the steps in teaching a ceramics programme. It explains how to discover and process their own source of clay and how to set up an efficient reclaiming process within the studio. Part II demonstrates both hand and wheel building techniques that include pinch, coil, and slab building as well as methods of wheel centering, shaping, making bowls shapes, removing wash from the wheel, turning, pulling handles and making lids.

The second part also includes the natural drying of clay and the chemical changes that occur within clay during firing and finally, contains information on bisque, glaze, and raku firings.

This manual is assisted by sixty-nine 35 mm colour slides which graphically show the techniques and various steps in hand and wheel building.

PART I

A. CLAYS

Clay is found in the igneous rock of the earth's crust. Chemically, igneous rock contains approximately 60 percent silica and 15 percent alumina--the two chief ingredients in clay--plus other materials in lesser proportions. Pure clay, known as kaolinite, is written as follows:

Al_2O_3	$2SiO_2$	$2H_2O$
Alumina	Silica	Water

As the igneous rock of the earth's crust is attacked by the rain, wind, freezing temperatures and heat, the rock is broken down, ground, and worn away into smaller particles. This erosion transforms the rock from a solid state to smaller particles which in turn become a plastic clay. The plastic quality of the clay refers to the ability of clay to retain a given shape when moulded.

Generally the smaller the particles become, the more plastic the clay itself becomes. Clay as it is found in nature, is designated as either primary or secondary, depending on the manner in which it was eroded. Each type of clay has its own distinct physical properties.

Primary Clay is formed by the decomposition of a rock bed which is slowly broken down by the action of ground water seeping through the rock. As the particle sizes become smaller, a clay is formed. Few impurities are found in primary clay because of the manner in which it is formed. However, the lack of any grinding action usually results in irregular or large particles. Thus primary clay is usually very pure, but is coarse grained, and has poor plasticity.

Secondary clays result from the transportation of small fine-grained particles of clay suspended in water, blown by the wind, or carried by glaciers to new locations. Silt or rock suspended in water is the largest source of <u>secondary clays</u>. The silt-laden water settles in low estuaries, forming stratified layers of clay. As a result of this type of formation, secondary clays often contain carbonaceous material such as leaves or twigs. These impurities form a gel as they decompose and contribute to the clay's plasticity. The advantage of secondary clays is their relative abundance, fine-grain texture, and plasticity.

Among primary and secondary clays there are many varities. A clay's individual physical properties depends upon the geological conditions that led to its formation.

Each clay body is unique and can be used to correct or alter the physical properties of any existing clay body. The following is a summary of the more useful clays and their properties.

<u>Kaolin</u> is a primary clay that is usually found in pockets rather than stratified layers. If often contains rock fragments of feldspar and quartz which must be removed before it can be used. It is instrumentalin the composition of porcelain, high fire, and white clay bodies. It is relatively free of iron and fires to a white or buff colour.

Kaolin by itself has poor plasticity and has to be combined with other ingredients before the mixture can be worked.

Ball Clay is a secondary clay found in stratified layers. It is highly plastic but cannot be used by itself as shrinkage is often as much as 20 percent. Ball clays are primarily used in combination with other clay bodies to increase plasticity.

Fire Clays resist fusion or deformation up to 1500°C. Clays with this property are said to be refractory. Fire clays vary in plasticity. There can also be a difference in the colour of the various fire clay bodies after firing. In industry refractories or fire clays are used primarily for manufacturing fire brick, while in pottery they are added to stoneware bodies to increase resistance to sagging and warping during firing. Fire clays are rough in texture and can be used in clay bodies to increase their "tooth" or coarseness.

Saggar Clays are high refractory clays that resist fatigue and thermal shock which result when clay undergoes repeated firings. Because of its special nature this clay is used to make saggar boxes in which green ware is placed to screen and protect it from the direct flames during firing. Saggar clays must be plastic enough to be moulded if they are to be considered useful.

Stoneware Clays are secondary or sedimentary clays that display a wide range of plasticity. These clays vitrify or loose their absorbent quality between 1200°C and 1300°C. May clays are acceptable as stoneware and may be suitable to work with in their natural state without additions to the clay body.

Earthenware Clays are low fire clays that contain iron and other minerals, and fire between 950°C and 1100°C. When raw or unfired, they appear red, brown, greenish or grey and are often located on the earth's surface. Much of this surface clay cannot be used because of the presence of soluble salts that form a scum on the surface of the clays when they are fired.

Adobe is a surface clay that is sun-dried rather than fired. It is non-plastic and contains a high percentage of sand.

Bentonite, a highly plastic clay, cannot be used alone due to excessive shrinkage, but when added to other clays, it improves their plasticity.

Gumbo is a surface soil clay that contains a high degree of organic material, and as a result, is extremely plastic and sticky. It is usually not suitable for classroom needs.

B. GLAZES

Glazing is the most important and the most difficult area in ceramics to master. It is important because, without glaze, many clay pieces would remain porous and impractical as containers of liquid; and difficult because some basic chemistry is required for experimentation with glaze types.

Glaze experimentation can be very complex as it involves a full knowledge and use of chemical weights and elements, and requires the manipulation of complex chemical formulae. The task would seem difficult for the average student at the high school level, but this does not rule out the possibility of experimentation on a limited basis.

1. The Chemistry of Glazing

Glazes are a form of glass. They have the same physical properties as glass such as hardness, resistance to corrosion, and durability. In its natural state glass is pure silica sand and melts at a very high temperature--approximately 1720°C. However, if a pot was glazed with pure silica and fired to its melting point of 1720°C, the pot would melt because the clay could not withstand the high temperature. Thus it is necessary to add agents that decrease the melting temperature of the glaze.

A glaze then is a form of glass that when heated melts around the pot in a tough, shiny coating. The ingredients that promote the melting process of a glaze are derived from the raw materials of the earth's crust. Glaze chemistry is a search for the correct balance of ingredients designed to produce a specific effect.

The raw materials used in glazes are natural products that are quite common and inexpensive to purchase. In all, there are approximately twenty-one different materials that may be used but only twelve are used extensively and warrant consideration as supplies for glaze experimentation. These twelve raw materials are outlined in Table I.

The melting agents that are to be found within the raw materials are known as fluxes. These are the ingredients that lower the melting temperature of every glaze so that it melts around the pot before the pot melts. The fluxes are chemically found in glazes as oxides. As the kiln heats and the glaze increases in temperature, the non-oxide substances in the raw materials are driven off while the oxide and the

TABLE I
A Table of Glaze Materials

Name	Formula	Property (or whatever)
Flint	SiO_2	Main source of silica in glazes.
Clay	$Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$	Source of alumina oxide.
Feldspar		Used in most glazes, usually providing the principal melting agents. I contains alumina, silica, and sometimes, depending on where it was mined, potassium, sodium, calcium, lithium.
Whiting or Calcium Carbonate	$CaCO_3$	Provides calcium oxide.
Magnesium Carbonate	$MgCO_3$	The basis of magnesium carbonate.
Dolomite	$CaCO_3 \cdot MgCO_3$	Contains calcium and magnesium carbonates.
Barium Carbonate	$BaCO_3$	Supplies the barium oxide.
Talc	$3MgO \cdot 4SiO_2 \cdot H_2O$	Useful when both magnesia and silica are desired.
Colemanite	$2CaO \cdot 3B_2O_3 \cdot 5H_2O$	Only source of boric oxide. Can be used alone as a melting agent for very low fired glazes.
White Lead	$2PbCO_3 \cdot Pb(OH)_2$	Pure source of lead oxide.
Zinc Oxide	ZnO	Provides the only source of zinc.
Lepidolite	$(HO_2F)_2\ KLiAl_2Si_3O_{10}$	Makes most glazes shiny and is sometimes used as a source of lithium. It has a lower fusion or melting point than most feldspar.

silica melt together to form a glaze. Each oxide has different physical properties. When engaged in experimentation it is necessary to have the raw materials on hand that provide the necessary oxides.

The more important oxides and their physical properties are listed below in Table II.

2. Glaze Calculation

Most glazes consist of three separate oxide groupings that perform specific functions during the firing. The first group, known as the RO oxides, act as fluxes and promote the melting of the glaze. The second group, known as the R_2O_3 oxides, are the refractory elements in glazes which affect the hardness, durability and extent of glaze melting. The last group, known as the RO_2 oxides, function as the glass makers within the glaze.

The more common of these oxides are shown below in Table III.

Glaze formulae that have been separated into their respective oxide groupings are known as Empirical formulae. These chemical formulae are sometimes known as unity formulae because the sum of the oxides in the RO column always total one molecule. It is not necessary, however, that the R_2O_3 and the RO_2 group total one molecule. The molecular value of the RO group must remain in unity or balance at all times to ensure flux content within the glaze. If the sum of the RO column totals 1.3 for example, the sum of the individual groupings should be divided by 1.3 to bring the formula into unity.

TABLE II

Glaze Forming Oxides and Their Physical Properties

Name	Formula	Physical Properties
Silica	SiO_2	The chief ingredient in most glazes. It is durable, hard, and resists chemical change.
Lead Oxide	PbO	Used primarily as a flux because of its low melting point. It does not craze or form cracks readily and the glazes it forms can vary from clear to textured to satin or matt. The disadvantages are that lead oxide in glazes tends to turn black in oxygen starved or reduction firings, and, if used above cone 6, it becomes volatile. CAUTION: lead is poisonous. Care must be used in the classroom so that students do not breathe the fumes of lead oxide or get any of it on food, etc. Lead glazed articles are dangerous if they are repeatedly used as food containers.
Calcium Oxide	CaO	Used as a flux to give hardness and durability to glazes. It has a high melting point, 2572°C.
Barium Oxide	BaO	Has similar qualities to calcium oxide, except it produces a soft, satin, or matt surface.
Magnesium Oxide	MgO	Used principally as a high fire flux producing a smooth creamy surface.
Zinc Oxide	ZnO	Used in moderation, acts as a flux in the middle and high temperature range.
Barium Oxide	B_2O_3	Has a low melting substance that reduces the expansion of glazes.
Alumina	Al_2O_3	Important for correcting glazes that tend to run. It also adds to the hardness and durability of glazes.
Sodium Oxide	Na_2O	Produces a very brilliant colour. It is a strong fluxing agent. It is, however, not too durable. Glazes with soda content tend to craze and form tiny cracks on the surface of the pot.

TABLE III

A Grouping of the More Common Ceramic Oxides

into the RO, R_2O_3 and RO_2 System[3]

RO	R_2O_3	RO_2
PbO	Al_2O_3	SiO_2
Na_2O	B_2O_3	TiO_2
K_2O	Fe_2O_3	ZrO_2
ZnO	Sb_2O_3	
CaO	Cr_2O_3	
MgO		
BaO		
FeO		
Li_2O		
CdO		

[1] Glenn C. Nelson, Ceramics (New York: Holt, Rinehart and Winston, 1960), p. 119.

An uncomplicated glaze formula consisting of a lead oxide and a silica oxide would be written as:

$$PbO - 1 \qquad SiO_2 - 1$$

The formula does not show how much or even what materials must be used. It states that in this formula there is one molecule of lead oxide and one molecule of silica. It is only when the formula is converted to a batch recipe that the quantities of raw material are determined. The raw materials that would be used in this case are litharge (PbO), and flint (SiO_2). To determine the exact weight of these ingredients, multiply the number of molecules required--in this case, one molecule each--by the total molecular weight of the molecule. For example,

Molecular weight of lead, Pb	=	207
Molecular weight of oxygen, O	=	16
Total		223 x 1 = 223
Molecular weight of silica	=	28
Molecular weight of oxygen	=	32 (16 x 2)
Total		60 x 1[4]

From the converted formula it is shown that 223 weight units of litharge and 60 weight units of flint are required to achieve a glaze that is made up of one molecule of both litharge and flint.

From any formula a recipe can be calculated in the above manner. The more complicated the molecular formula, the more involved the calculating becomes. For complex glaze calculation see Appendix.

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[2] Daniel Rhodes, Clay and Glazes for the Potter (Philadelphia and New York: Chilton Books, 1957), p. 82.

Sometimes it is convenient to convert the batch recipe to a percentage batch so that colouring oxides can be easily added as a small percentage in excess of the 100 percent of the glaze. To calculate this percentage divide the weight of the individual ingredients by the sum of the total weights and multiply by 100. For example,

Lead	207 ÷ 223 x 100 =	92.8
Oxygen	16 ÷ 223 x 100 =	7.2
	Total	100

After the desired glaze has been calculated, make a small quantity of glaze. All that remains is to fire, retest and adjust the formula until successful results are attained.

Potters may use frits to eliminate some of the guess work in glaze experimentation. A frit is a type of glass that has been fired and ground to a powder, and is ready to use as a glaze ingredient. Frits contain only the glass making oxides. A list of their physical properties is available from the manufacturer. All extraneous raw materials have been burned out during a previous firing. By using a frit, for example, the toxic effect of lead glazes can be eliminated.

Colour brilliance is achieved by adding metallic oxides to the basic glaze. A glaze percentage batch contains raw materials that total one hundred percent. The colouring oxide is added in excess of the one hundred parts of the glaze. For example, if a glaze contains .5 of red iron oxide, the sum of the percentages of raw materials would total 100.5. Adding too much metallic oxide to the glaze will cause it to fire dull and metallic looking, while too little colouring oxide will show little appreciable difference in the glaze colour.

'Discovering which oxides create which colours and what results various combinations of oxides will produce can be part of the glaze experimentation in the classroom. The following table lists some oxides, the resultant colours and the approximate percentages that are used in glazes. All suggested quantities are in excess of the one hundred percent glaze batch.

For the elementary school or for the school that does not have the facilities for experimentation with oxides, frits, and/or raw materials, commercially produced under glazes are recommended. They are reliable, producing a variety of colours and are easy to use.

C. EQUIPMENT

The craft of pottery is dependent upon equipment. Without it the task of transforming raw clay into glazed ware would be difficult.

1. The Potters' Wheel

There are three types of potters' wheels commonly used by western potters: the kick, the electric, and the treddle wheel. For the beginning student, the kick wheel with a 50-75 pound flywheel is perhaps best. A heavier flywheel is harder to set in motion, however, once up to speed, it can be used longer without loosing its momentum because of its greater mass. Lighter flywheels are suitable for young students but require frequent kicking which can be exhausting. Kick wheels are easy to operate and allow the student to control the speed of the wheel.

TABLE IV

Colouring Oxides

Oxide	Percent	Colour
Iron Oxide	1 to 10%	It results in a tan, brown, reddish brown or yellow. It can be used with other oxides to produce warmer, earthy colours.
Cobalt Oxide or Cobalt Carbonate	1/2 to 1%	Cobalt is a reliable oxide. It produces a blue which is similar in all glazing and firing circumstances. When used alone it produces a harsh colour. This can be eliminated with the addition of other oxides such as iron or manganese.
Copper Oxide	2 to 5%	It produces blue and green colours but in strong alkaline glazes it produces a turquoise. When used in lead glazes it produces various shades of green. In reduction firings, copper is noted for its copper-red colour.
Manganese Oxide	2 to 6%	It produces a purple or brown colour in glazes.
Chromium Oxide	2 to 5%	It yields a great variety of colours; yellow, pink, brown, green and red. The colour depends largely upon the ingredients of the base glaze and the firing conditions.
Nickel Oxide	1/2 to 3%	Again, depending upon the basic glaze, nickel may produce a variety of colours; blue, tan, brown and green--none of which are too brilliant. It is often used with other harsher oxides to soften the colour.
Rutile	2 to 10%	It is an ore containing titanium oxide and iron oxide. It gives a tan or brown colour to glazes. When used with other oxides it produces a mottled colour which creates a rich surface.

continued . . .

TABLE IV - continued

Oxide	Percent	Colour
Illmenite	1 to 5%	It is similar to rutile but has more iron oxide in it. In a coarse granular state it produces dark specks in a glaze.
Vanadium Oxide	4 to 10%	It is used as a stain to achieve yellow.

This is important for the beginner who must learn to gauge the movements of his hands to the speed of the wheel before successful throwing can be done. With an electric wheel students have a tendency to misjudge its speed. Once the movement of the hands and speed of the wheel have been gauged the thrower can work without his legs tiring.

Electric wheels are more expensive than kick wheels. A low cost electric wheel can be made by attaching an electric motor to a kick wheel. The spindle of the electric motor can be fitted with a rubber wheel that rests on the flywheel and provides the driving power. If throwing is done a great deal of the time or young students are involved who will have difficulty keeping the flywheel of a kick wheel in motion, then the electric wheel would be most suitable. When choosing either an electric wheel or a kick wheel it is essential to see that the seat has some adjustment mechanism. Kick wheels without seat adjustments make it difficult for young people to reach the flywheel and are dangerous if the child should lose his balance and fall.

The treddle wheel is not as common in North America as the kick and electric wheels. To use the treddle or side kick wheel, the potter keeps his foot resting on a lever at the side where the wheel plate is situated and pumps to produce motion. This pumping action, although easy for the accomplished potter to master, is very difficult for the student to grasp. Often while working, his whole body will lurch forward as he pumps which gives him little control of the clay.

2. Kilns

A kiln is the most essential piece of equipment in the potters' studio. Without it, his pottery remains in a porous and extremely fragile state. A kiln can be as humble as a bonfire or as elaborate as a commercial manufacturer's tunnel kiln. Their various names are determined by the energy source that fires them; for example, electric, wood, or oil. Kilns are one of the most expensive items to purchase for the studio. When considering the size and style of kiln, the needs of the class should be carefully evaluated.

For the classroom, a kiln should be large enough to accommodate the work of the students as a group, but not too large that firing is done only once or twice during the year. On the other hand, if the kiln is too small, it causes tedious delay before pieces are fired. The ideal size would be a kiln that allows students to make frequent firings so that they have an opportunity to benefit from glaze testing and to correct problems such as poorly fluxed glazes that may occur during firing. A minimum size for the inside firing chamber should be approximately 18 x 18 x 15 inches. When considering a kiln the advantages and disadvantages of the electric kiln and full burning kiln should be compared.

Electric kilns are easy to operate and have simple control and safety devices. In these kilns the heat is confined to the chamber and they do not require elaborate exhaust and ventilation controls. For classroom use these kilns are excellent since they can be used in spaces where full burning kilns cannot. If cost is a factor in choosing a kiln, a top loading electric kiln would be least expensive.

In this kiln, the top lifts up and ware is placed into the firing chamber. Since elements are situated on the four walls, the circuitry is relatively uncomplicated and inexpensive. If, however, an electric kiln requires installation, it should be handled by an electrician.

Some models of electric kilns are extremely portable and can be moved from one room to another without difficulty. These usually are equipped with castors. Also, some smaller kilns come in sections which contain their own electrical 110 volt circuitry and use a conventional wall plug and socket. The size of the inside firing chamber is determined by the number of sections stacked on top of one another.

There is also a front loading electric kiln. This type of electric kiln requires an elaborate metal hinge, and extra elements and circuitry for the door which opens on the front. These kilns do hold the heat better than the top loader, especially if the latter has a loose-fitting lid. However, because of the extra electrical connections, it is more expensive than the top loader.

Electric kilns fire uniformly and consistently due to their neutral inactive atmosphere. This, however, is the one disadvantage of electric kilns. The neutral atmosphere inside the firing chamber makes most glazes appear flat and drab when compared to the glazes produced from fuel burning kilns. An electric kiln should reach firing temperature within eight hours. If it takes longer, it is not economical for classroom use.

Fuel Burning Kilns can be fired with a variety of materials including wood, coal, oil, charcoal or gas. For college and advanced classes or the serious potter, a fuel fired kiln is essential because its atmosphere which is highly charged with gasses ensures a wide variety of effects on glazes. Clay bodies and glaze colours tend to be warmer and richer, and textures more lively on ware fired in electric kilns.

The most practical fuel burning kiln is the gas kiln. It does not require either the fuel storage space or the manual labour involved in firing a wood kiln. A gas kiln consists of burners which supply the heat, air ducts that allow oxygen to enter the kiln ensuring combustion, and a chimney to draw the hot gasses away from the kiln.

Small gas kilns are classified as up-draught because the heat travels up through the kiln. In larger gas kilns, instead of the heat rising out the top of the kiln, it is redirected by means of a baffle wall--over the roof of the kiln, down over the ware, up through a flue at the back of the kiln and then up the chimney (see Figure 1). During the firing, the flame does not come in contact with the ware. Instead, it is directed around the inner chamber by muffle walls. In this way hot spots are eliminated on the ware. If there is danger of the flame coming in direct contact with the ware the potter may wish to use saggars in which to protect his pieces (see page 3).

If enough oxygen is allowed into the kiln during firing to allow complete combustion of the gases before they enter the firing chamber, it is called an oxidation firing. During oxidation the kiln will burn clear without flame or smoke. When the oxygen is reduced or starved in the kiln during firing, it is known as a reduction firing. These different types of firing have an important effect on glaze colours and textures. For example, reduction firing creates an excess of unburned carbon in the kiln which seeks oxygen present in the clay and glazes and subtly changes the colours of glazes and clay bodies.

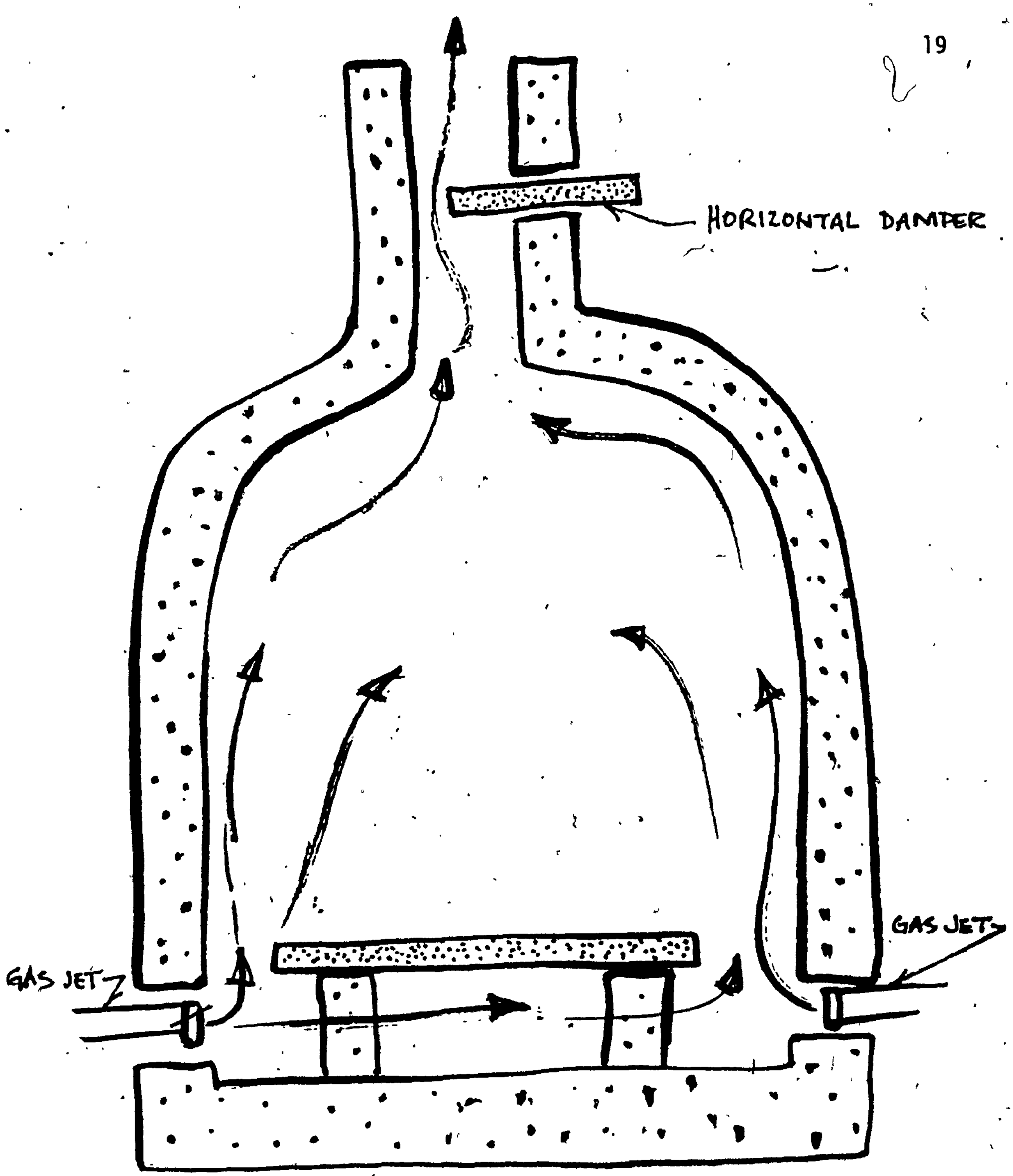

Figure 1. Diagram of up-draught kiln showing direction of air flow

Fuel burning kilns demand a great deal of attention when being fired. They require the careful manipulation of dampers and burners to insure the proper atmosphere that will bring out the colours of the glazes. Because of this difficulty, fuel burning kilns are not always advisable if the ceramics programme is designed for young children.

There is little chance of mishap involved in firing kilns when handled properly, but care must be taken to provide proper ventilation in the way of fans, blowers, or an open window. Exhaust fumes may carry harmful gasses that are discharged during firing. Firing also throws an excess amount of heat into the classroom which can make it uncomfortable. Flammable material should never be stored near the kiln; there is always the danger of fire. The flashings around the chimney should be properly constructed with the masonry of the chimney being at least eight inches away from any wood rafters. There should be twelve inches between the kiln itself and any walls and the walls should be faced with asbestos for proper safety.

Since the temperatures at which the kilns are fired are much too high for ordinary thermometers, other pyrometric or heating measuring devices must be used. The most popular of these is the pyrometric cone (see Figure 2).

These cones are small triangular pyramids of clay that are designed to bend and melt at a specific temperature. There are cones available for a wide variety of temperatures. For kilns that do not have automatic shut off controls, the cones can indicate temperature within the kiln. If, for example, it is desirable to fire at cone 04,

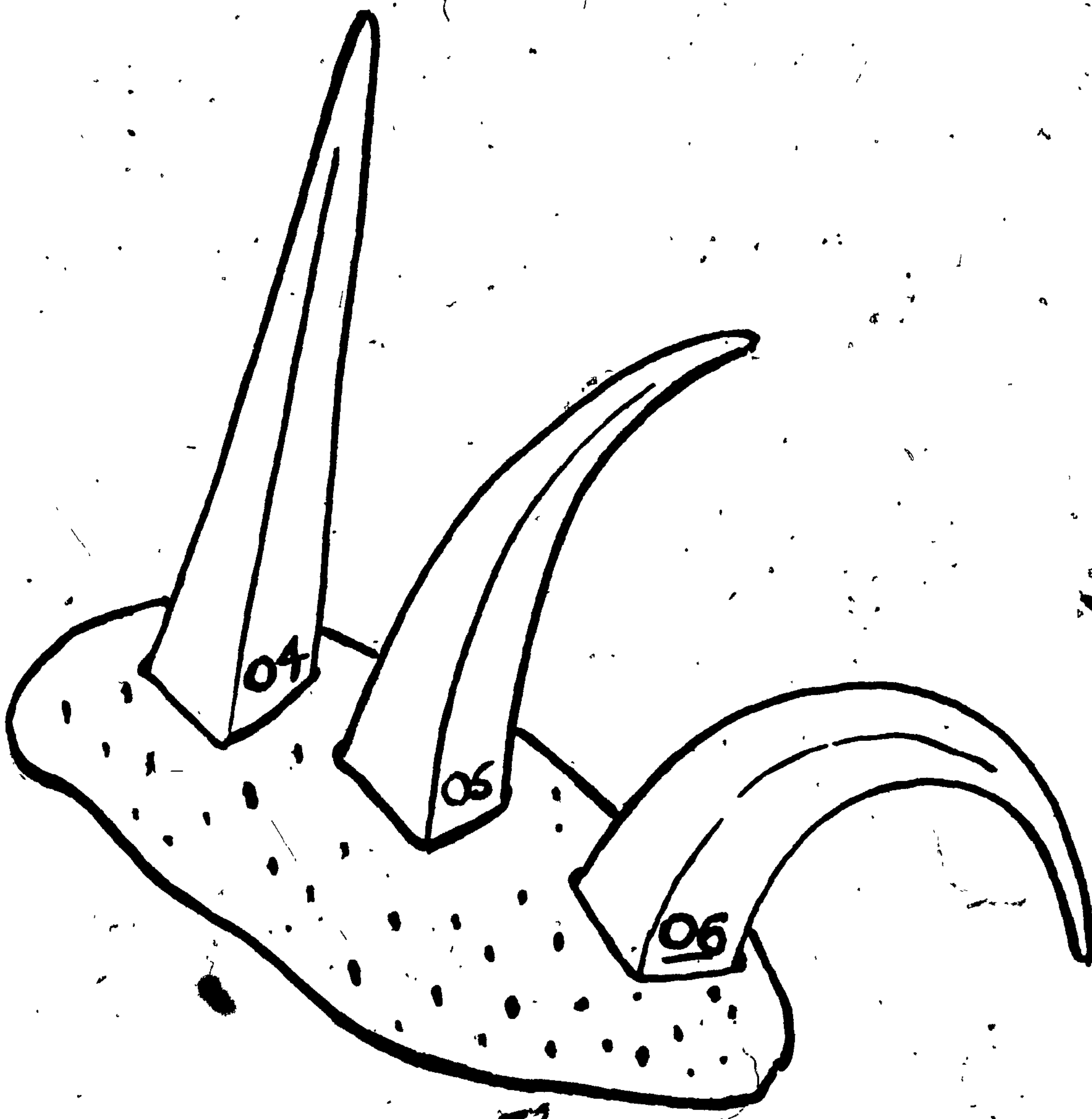

Figure 2. Pyrometric Cones

place three cones, reading 03, 04, 05 in a small wet lump of clay in front of a peephole, which is a small hole about 1" in diameter in the wall of the kiln. When the cone 05 melts prepare to shut off the kiln for the heat is approaching cone 04.

For most schools, a kiln that fires up to cone 04 should be adequate. However, for advanced classes, a kiln capable of firing to stoneware temperatures, cone 8, would be desirable.

In an electric kiln, when the cones go down the top elements should be turned to medium or off while the bottom elements of the kiln remain on until temperature is reached. Often in an electric kiln the temperature at the bottom of the kiln remains cooler that at the top. In gas kilns after the gas has been shut off and the draught closed, the temperature will sometimes rise because of the extra heat in the fire box flowing into the firing chamber.

A much less accurate way of estimating the temperature of the kiln is to notice the colour within the firing chamber during the firing. As the temperature in the kiln rises the colour changes from a very low red colour to a dazzling white colour. Each colour value is associated with a specific temperature as follows:

TABLE V

Colour of Inside Firing Chamber of

Kiln and Equivalent Temperature Range[5]

Colour	Degrees Fahrenheit
Lowest visible red	885
Lowest visible red to dark red	885 - 1200
Dark red to cherry red	1200 - 1380
Cherry red to bright cherry red	1380 - 1500
Bright cherry red to orange	1500 - 1650
Orange to yellow	1650 - 2000
Yellow to light yellow	2000 - 2400
Light yellow to white	2400 - 2800
White to dazzling white	2800 - and higher

[3]Glenn C. Nelson, Ceramics (New York: Rinehart and Winston, 1960), p. 198.

3. Pug Mill

One piece of equipment very useful in the pottery studio is the spirol screw pug mill. A pug mill simply works on the same principle of a meat grinder. It is fed a variety of clay types and textures and it extrudes a homogeneous clay mass. Pug mills are particularly useful for mixing clay. They can be used to mix clay from the dry powder and/or the leather hard state to a workable consistency, or they can be used to reclaim used clay. However, to produce a good consistency in pugged clay, it is important to use only a little dry clay or a little wet clay in the pug mill. Also, dried clay pieces should never be used. They should be slaked down, otherwise the dry clay pieces cause lumps in the clay body when they are fed through the pug mill.

4. Minor Studio Equipment

Any well equipped pottery studio will usually include some kind of damp cupboard which is designed to retard the drying of the newly formed clay piece. If a piece of pottery is set out in the open, the rapid drying will likely split or seriously warp the clay. A damp cupboard keeps the clay moist longer and allows it to dry slowly and evenly.

Damp cupboards can be simple in design and need not be elaborate expensive devices. A damp cupboard can simply consist of shelves with plastic sheeting draped in front, or metal-lined cupboards with doors and water trays to ensure that a high degree of humidity is maintained. Burlap sacking can be dipped in water and tacked to the walls of the cupboard which would act like a taper in providing additional humidity. When considering the location of a damp cupboard, it is important to remember that a damp, cool place is needed. Do not build this cupboard near a hot air register or near the kiln. The measures that are necessary to maintain dampness will depend on where the studio is located within a building and the local climate. When space does not allow for a proper damp cupboard, a plastic bag can be used as a substitute. It will sufficiently retard the drying and keep the clay moist up to a week or more.

An electric grinding wheel, although not an essential piece of equipment, is very useful in a studio. For example, when ware is removed from the wheel sharp, jagged glaze spurs which can sometimes occur can be easily ground off. Safety goggles should always be worn to protect the eyes when grinding.

All power tools that are used should have safety guards. The wiring should be insulated and contain a ground wire. Every student should be properly instructed and familiar with safe operation of equipment.

Some of the smaller equipment used in the studio is expensive to purchase from a commercial dealer but costs can be reduced if ceramic tools are made at the school. There is a great variety of commercially produced products available but many of these can be easily made out of scrap materials. Equipment such as turning tools, looped tools, knives, storage units, are necessary but simple tools to make. For example, the following can be easily made.

A cut off wire for cutting pots off the wheel head is made by joining two large buttons and two pieces of thin wire. Tie the wire to the buttons and press one button into a lump of clay on the wheel.

Kick the wheel and hold the other button firmly in the hand letting the wires twist together. When the two wires are completely twisted together an excellent inexpensive cut-off wire has been produced.

A simple turning tool can be made by taking a stiff piece of thin wire or a piece of metal strapping and fixing it in a loop with tape or string on the end of a handle. The edges of the wire and/or strapping can be sharpened with a file to give a better cutting edge.

An old kitchen knife will work well for trimming excess clay off pots. If this is not available a sharpened stick is adequate.

Ribs, which are used for making a pot's walls even, can be made from tin which is cut into a kidney shape. Old rubber spatula blades or half bottoms from plastic bleach bottles also make excellent throwing ribs.

For throwing larger pots a bat or disc is affixed to the wheel head with clay and the pot thrown on top of the bat. Round flat plaster bats or plywood discs are excellent but equally as efficient are old 78 R.P.M. records. The cut-off wire can be slipped underneath both the pot and the bat and both removed from the wheel together. When the clay has dried slightly it can be separated from the bat without it warping.

A needle point to cut rims off thrown lop-sided pots can be made from old dentist tools, crochet hooks or any metal object filed to a long, sharp point.

A wedging board can be made from plaster poured into a mould approximately two feet square and four inches thick. When the plaster is dry stretch canvas over the top and tack it to the sides.

A cutting wire stretched tightly at a 45° angle between two points near the wedging board works well when cutting up large blocks of clay or for checking crop-sections of newly wedged clay for air bubbles.

Storage bins for clay can be constructed from wood and lined with plastic. Lids should be tight to keep the clay moist. Plastic garbage cans with lids are inexpensive and work well for storing clay as well as mixed glazes.

5. Student Equipment

For the student potter very little equipment is needed. Much of the equipment can be easily hand made or substituted by other inexpensive items. A basic list of equipment for the student should include:

- plastic bags to wrap the pottery in if no damp cupboard is available;
- calipers for measuring;
- a ruler;
- an apron or old shirt to protect clothing;
- sharp pointed instrument for trimming tops;
- rubber soled shoes for kicking the kick wheel;
- a sharpened stick for carving and trimming;
- an old knife for slab work;
- a piece of canvas for rolling slabs out on;
- a sponge;
- a looped tool for turning;

- a twisted cut-off wire;
- a small tool box in which to keep the items above.

Other small equipment that should be available in the studio for general use includes slats and pastry rollers for slab work, plastic bowls for water, large, lidded containers for glazes, scoops for measuring chemicals, mortar and pestle for grinding glaze ingredients, a triple beam balance for weighing glaze materials, turn tables for glazing, hot plate for heating waxes, and brushes.

6. Hints on Setting up a Studio

The availability of space and the amount and size of equipment will determine the physical nature of the studio. Here are a few basic common sense ideas to follow when setting up a studio.

1. Whenever possible try to consider traffic problems within the room. If pots waiting to be fired are shelved in heavy traffic areas they could easily be knocked and broken.

2. The damp cupboard should be located near the wheel to eliminate walking long distances with greenware.

3. If possible, there should be separate areas for the storage of raw materials, glazing, glaze mixing, firing and reclaiming clay.

4. Large, solid tables should be used for hand building.

5. Pottery wheels should be located near water, if possible, to minimize the amount of spilled water on floors.

6. Heavy textured rubber mats should be used in the studio to prevent slipping in potentially wet areas.

7. Proper ventilation should be provided if spray glazing is undertaken. Unfrited glazes can be poisonous if inhaled while spraying.

8. Do not eat in the glazing area. Harmful ingredients could be eaten or inhaled.

9. All potentially toxic ingredients should be clearly labelled in excess of the manufacturer's labelling.

10. Proper ventilation should be provided if a gas kiln is used to eliminate the dangers of explosion due to the build up of gas fumes.

11. Sinks should have a special clay trap that allows water through but traps clay particles. If this is not available a garbage can, barrel, or large container will be sufficient as a clean up sink. The clay will settle to the bottom of the container and the water can be skimmed off. The sloppy solution of clay can be dried and reused.

12. Organize an efficient clay reclaiming procedure.

PART II

A. CLAY FOR THE CLASSROOM

Clay may be purchased from a commercial dealer in either a dry powder form or in a moist ready-to-use condition. Whether dry or moist clay is purchased will depend on the facilities available for mixing clay. Mixing from the dry state is less expensive but more work for the teacher, especially if younger students are involved. For the average class, buying moist ready-to-use clay will suffice. Commercially produced clay is safe, reliable, and needs no adjustments unless a desired quality such as a "tooth" or rough texture, is required. Also, its source for classroom purposes is inexhaustible. A low fire clay or earthenware clay should be purchased if the kiln does not fire beyond 1100°C and a stoneware clay if the kiln fires beyond 1200°C. Red earthenware clays are refined fire clays that have sand and ball clay added to them and are usually poor throwable clays. Some buff earthenware clays and stoneware bodies are not suitable and can vary in throwing qualities. White clay bodies with the exception of porcelain are poor throwing clays.

Commercially produced clay in powdered form is excellent for advanced classes who are concerned with achieving a specific clay type. Any clay as well as various raw materials may be added to the clay powder to produce new physical properties within the clay. The ingredients can be mixed in plastic bags, on the floor with a shovel, in an old bathtub, or in a spirol screw pug mill. One of the better machines for mixing clay is a second-hand dough mixer from a bakery. Finding a mixer is difficult and it should not be considered as part of the necessary studio equipment. No matter what kind of mixer is used, however, the clay that is produced must be properly covered to prevent drying.

1. Discover Your Own Source of Clay

One of the most satisfying aspects of clay work is preparing, and using clay that has been discovered from a local source. A clay deposit is one of the most inexpensive sources of clay. It is also an excellent way to learn about the various properties of clay.

The procedure for preparing clay is quite simple. However, first, the clay must be located. Stratified layers of secondary clay can be seen in buildings, excavations, roadways, railway cuts, and creek and river banks. Natural clays which vary in colour may appear white, tan, yellow, grey, red-brown, grey-green, blue-green and nearly black. When several suspected sources of clay have been located one should prepare for the testing and eventual mining of the clay. It is advisable to take along the following equipment.

- a shovel
- a pick axe
- boxes or plastic bags for transporting clays
- a map of the area
- a jar of water

- a medicine bottle containing a dilute solution (10 percent) of hydrochlorine (muriatic) acid
- a dropper to apply acid

There are four simple tests that can be conducted on the clay site to see if the material can be used for ceramics work.

1. Wet the material. If it becomes wet and sticky then it contains clay of some sort.

2. Roll a small amount of the clay into a coil about the thickness of a pencil and form a circle about one inch in diameter. If it forms the circle without splitting, then the plasticity of the clay is suitable.

Clay that splits and breaks is not plastic enough. If, however, the clay becomes sticky it indicates the clay is too plastic. In both cases, alterations to the clay body can easily correct the plasticity of the clay so that it can be used.

3. Pour a drop of 10 percent solution of hydrochloric acid on the clay. If bubbling occurs, an insoluble lime is present in the clay. This clay body would not be suitable for the potter. Lime absorbs water and during firing it expands and will cause the pot to explode or to have pieces of it flake off.

4. Carefully look at the surface of the clay. If it appears to have a white scum or white staining on it, this indicates the presence of alkalies which make the clay unsuitable for use.

If the clay passes these four preliminary tests, then dig up a sizeable amount of the clay and take it back to the studio for processing and further testing. At the studio break the clay into small pieces and place it in a barrel of water which will allow the clay to slake or break down into a creamy solution. When it is thoroughly slaked, pour it through a 60 mesh screen to remove all foreign matter, such as rock fragments, sand, twigs, leaves, etc.

Allow the clay to settle to the bottom of the barrel and siphon off the water that settles to the top. To bring the clay to a plastic workable state, pour the clay solution into either a plaster vat and let it dry until the correct plasticity is reached, or dry it in a canvas bag hung from the ceiling which allows excess water to drip out and leave the plastic clay behind.

Slaking the clay moistens all the particles in the clay body which in turn ages the clay and improves its plasticity. If possible, cover the clay with old mouldy bacteria laden rags that have been used for this purpose before. The bacteria promotes the growth of additional bacteria and mould in the clay. The mould produces an acid residue which forms a type of gel around the clay particles and promotes further aging and improvement of plasticity. Storing the clay in a warm, damp area also encourages the growth of bacteria. Aging the clay takes about one week; aging it beyond that time does little to improve the plastic quality of the clay.

2. Wedging

Wedging is a process that rids the clay of air bubbles, lumps, hard spots, and foreign objects, and leaves the clay with an even consistency and plasticity throughout. If a clay piece containing air bubbles is fired, the air bubble could expand and create a bulge or explode. If lumpy clay is used when throwing on the wheel it is more difficult to keep walls even in height and thickness. Usually the pot will collapse.

Wedging should be done on a canvas covered plaster of paris block. The plaster will absorb any excess moisture within the clay while the cloth prevents the clay from sticking. If the clay is dry or stiff try wedging the clay on a non-absorbent surface such as a wooden table and sprinkling it with water from time to time to increase its wetness and plasticity. A simple method of wedging clay is to cut the clay in half and slam one half into the other. Repeat this until the clay has a consistent texture. A second method known as a spirol kneading method is explained in the below slides. It is a skill that must be learned, but once acquired it is perhaps the easiest and most effective way of wedging clay.

a) Wedging - Slides 1-5

Slide 1. Shape the clay into a ball shpae. Push down into the clay with the palms and heel of your right hand.

Slide 2. Grasp the clay with your left hand letting it act as a guide preventing the clay from spreading out. At the bottom of the downward thrust exert a slight pressure forward. Too much thrust will result in folding which will create air pockets.

Slide 3. Lift the clay and rotate it slightly to the beginning of the motion again.

Slide 4. Repeat the pushing and rotating motion until the clay forms a spirol shape.

Slide 5. To insure that the clay is properly wedged, cut the clay in half with a wire. If air pockets are visible in the cross section continue wedging.

Next, consider total percentage of shrinkage between the wet state and the glaze-fired state. To find the total percentage of shrinkage, measure a slab of clay three centimeters wide, ten centimeters long and one centimeter thick. Carefully measure the length of the clay wet and again after firing has been completed. Calculate the total percentage of shrinkage from this formula.

$$\text{Percent Linear Shrinkage} = \frac{\text{Plastic Length-Fired length}}{\text{Plastic length}}$$ [6]

Percent of linear shrinkage can also be calculated for dry clay and bisqued clay by substituting the measurement of the ten centimeter bar when dry or bisqued into the above formula where it says "fired length."

Clay that shrinks overall more than eight percent cannot be used alone but may be useful when combined with other clay bodies. Plastic clay usually shrinks about five percent while some very plastic clays shrink as much as eight percent. If the clay shrinks too much, the resulting cracking and splitting will make it diffiuclt to complete a project.

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[4] Rhodes, Clay and Glazes for the Potter, p. 200.

Grog refers to clay that has been fired and finely ground. This substance decreases the plasticity and shrinkage of most clays to which it is added. Stiff grog-laden clay may not be suitable to the potter but it is particularly good for sculpture because of its ability to resist sagging when shaped. Silica sand or flint can also be added, performing the same task as grog.

Naturally dried clay will still contain moisture depending on the relative humidity of the available atmosphere. It only really becomes dry when heated beyond the boiling point of water and the chemically uncombined water has completely evaporated.

On days when the sun is hot it is safe to speed up the drying time of clay by placing the greenware in the direct sunlight. [illegible] makes it possible to form the pots and a few hours later turn [illegible] apply handles, or add the finishing touches. The work should be rotated periodically, otherwise uneven drying and warping will result. The same quick drying method can be followed if the newly formed clay pieces are placed near a hot air register or near a kiln that is being fired.

3. Slops and Pugmills

An effective way to cut expenses and reduce the consumption of clay is to set up a "slops" system for reclaiming clay. The system consists of two large garbage cans, barrels, or containers, a sieve, a siphon and plaster of paris vats that are about two inches deep. Fill the two containers about 1/2 full of water. All clay trimmings, dried clay, or scraps of any sort should be thrown into the first container. The water slakes down the clay into a sloppy solution known as slops. When slaking is complete, scoop the slops through the sieve into the second container. By using a sieve all lumps and any foreign material are removed from the clay that may have been picked up in the studio. The sieved, sloppy solution is now the source of new clay. Let the slops settle and skim off the excess water. Take the sieved slops and pour them into a plaster vat and allow the plaster to absorb the moisture out of the clay. This usually takes two days, depending on the depth of the slops. When the slops dry to a suitable plastic state, the resultant clay is ready to be wedged for use. By setting up an effective slops system the cost of purchasing new clay can be reduced to a minimum.

If the studio is equipped with a pugmill, then the slops can be used with leather hard pieces of discarded clay or powdered commercial clay to make new batches of clay. (Caution: Do not use bone dry pieces of clay in a pugmill, they will cause lumps in the clay. Bone dry clay should be slaked.) It is advisable not to pour slops into the pugmill unless they have been sieved. This avoids foreign objects in the clay, and damage to the pugmill.

B. CREATING WITH CLAY

1. Function and Design

Good ceramic design is a combination of visual beauty and ulitarian function. The two qualities should be inseparable. A cup, for example, should be light weight, comfortable to drink out of, have an easily gripped handle and still be pleasing to look at. Similarly a pot that does not sit properly without rocking and a tea pot that does not pour are poorly designed. A soup bowl is designed to hold a liquid. The inside should be free of bumps, ridges, holes, grooves, so that a spoon can reach the bottom of the bowl and retrieve that last drop of soup. If the bowl was cut in half, the profile should be a smooth, gentle, uninterrupted curve. The outside shape can be left up to the imagination of the artist because its function is that of decoration. Lids of pots should lift off the pots without sticking and they should be constructed with lugs or grips so that they can be easily handled without fear of dropping. Function is an integral part of design in ceramics and as such it should not be ignored.

2. Hand-Building

Hand-building is done by simply using the hands to mould, press, squeeze, push and form the clay to a desired shape. It can be a satisfying experience to feel the clay respond to the touch of the hands. Hand-building is very suitable for large ceramics classes and particularly good for young children because it does not demand elaborate equipment and the child has few skills to learn before he can be creating. The young child has little difficulty making shpes that to him are real, identifiable objects. At first students are unfamiliar and sometimes timid of clay. However, they soon discover one of the most exciting physical properties of clay--it can be easily shaped and moulded. Even the most delicate touch of a finger can be recorded on the surface of the clay. The child will discover that, unlike flat paper, a clay surface can have holes poked in it and be built into a three dimensional form. Shaping requires very little skill and often teaches the student to have a better understanding of clay as a medium for expression.

a) <u>The Pinch Method of Building - Slides 6-10</u>

The pinch method is a way to build shapes or form simple pots by using only the hands. The clay should be quite plastic and properly wedged for this method.

<u>Slide 6</u>. Shape some plastic clay into a ball. The size of the ball will determine the size of the pot. Press the thumb into the middle of the clay.

<u>Slide 7</u>. Pinch or squeeze the clay between the thumb and fingers and gradually rotate it in the hand.

<u>Slide 8</u>. Continue this motion until the walls become thin and a basic bowl shape has been formed.

<u>Slide 9</u>. To keep the pot upright a foot or base made from a coil of clay can be attached. This however, is optional depending on design.

<u>Slide 10</u>. The completed pot is able to stand by itself.

b) <u>Coil Method of Building - Slides 11-17</u>

<u>Slide 11</u>. Once the clay has been wedged roll the clay with the hands on a table until it becomes a long snake-like coil.

<u>Slide 12</u>. For the bottom or base roll out a slab of clay and cut out a base to the desired size and shape.

<u>Slide 13</u>. Take a knife and criss-cross the two pieces at the point where they are to be joined. Then apply water to both surfaces by gently running wet fingers over the scoring. This

creates a slip or watery solution of clay which will help bind both clay surfaces together. If plastic clay is used the criss-crossing can be eliminated. Simply push one surface into the other--to form a strong join.

<u>Slide 14</u>. The sides can now be built by joining the coil onto the base and layering coil upon coil.

<u>Slide 15</u>. When the desired height has been reached smooth the inside and outside of the pot with the thumb. Some potters use a wooden paddle to achieve the desired shape and thus eliminate the coil design. This is optional.

<u>Slide 16</u>. Coils can also be used to add design to clay surfaces. Roll a series of coils and form them into patterns or designs. Then, press them into the surface of another piece of wash.

<u>Slide 17</u>. Coil building can be a very rapid way of building large pots if large coils are used. Roll out a large coil, squash it and use it for building. One variation is achieved using large pieces of flattened clay rather than coils and joining them together by pressing them into one another.

c) <u>Slab Building - Slides 18-23</u>

Building with clay slabs is a quick way to construct shapes and to create imaginative pots. The clay should not be too plastic, otherwise it will collapse. As mentioned before "grog" can be added to the clay to increase its strength.

Making slabs requires very simple equipment.

- two slats about 3/8 - 1/2 inches thick and about two feet long. The thickness of the slats determines the thickness of the slab.

- a rolling pin or dowel for rolling out the clay.
- a canvas cloth on which to roll the clay. The cloth prevents the clay from sticking to the surface of the table.
- a knife or sharp stick for cutting.

Slide 18. After the clay has been wedged roll it out on the cloth between the slats until it is an even thickness.

Slide 19. With a knife cut out the shape you wish to use.

Slide 20. A simple pot can be made by folding the slab of clay into a cylinder, pinching the two ends together and adding another slab for the bottom.

Slide 21. To ensure that slabs remain intact criss-cross the edges that are to come in contact with each other and lightly brush them with water or slip.

Slide 22. You can further increase the strength of the join by adding or "welding" small coils of soft clay into the seam.

Slide 23 Slab pieces are excellent for creating carved designs because their walls are usually thick.

3. Working With the Potters' Wheel

Watching a potter throw on a wheel is like watching a magician at work. The clay seems to grow as if it were alive. Throwing, however, is not a trick to learn; it is a skill that has to be acquired through practice. However, it can be simplified by observing a few basic rules.

1) The clay should be properly wedged and free of all lumps, air pockets, and foreign matter.
2) Rubber soled shoes should be worn if using a kick wheel since they are less likely to slip.

3) The potter should be able to assume a comfortable, well-balanced position on the wheel and have the following basic equipment within reach.

a) a bowl of water

b) a small sponge

c) a sharp stick or knife used for trimming

d) a needle-like device that is used to cut off tops of uneven walls

e) a cut-off wire.

a) Centering - Slides 24-32

Centering the clay on the wheel head is the first skill to acquire. If the clay is not properly centered before "pulling" or forming is attempted, the pot is likely to collapse before completion.

There are two basic centering techniques practiced by potters. These are explained in the following slides.

Slide 24. Shape the wedged clay into a ball and throw it sharply onto a wheel head that has been dampened.

Slide 25. Slowly rotate the wheel and pat the clay into an even shape in the center of the wheel.

Slide 26. Kick the wheel with the right foot and make it go as fast as possible. Then wet the clay so its entire surface is covered with water. Set both hands on the turning clay. The action between the water on the clay and the hands produces a wet, sloppy solution of clay known as slip. This is the critical material that prevents the clay from developing any spots and allows the clay to pass smoothly through the hands.

It is important to keep the clay well-lubricated at all times. However, too much water will increase the plasticity of the clay until it becomes difficult to work with. On the other hand, if the clay feels dry as it passes through the hands, more lubrication is required.

Slide 27. Squeeze the clay with the hands and force it up into a cone shape.

Slide 28. With the left hand at a diagonal across the center, press down on the clay until a beehive shape is attained. The right hand is held at the side of the clay and acts as a guide to hold the clay in check.

Slide 29. When the clay revolves without wobbling then the clay can be considered centered. Some potters use a second method of centering which is much faster than the first method.

Slide 30. Kick the wheel as fast as possible, wet the clay, and place the left hand diagonally across the center of the clay. Grasp the fingers of the left hand with the right hand. Brace yourself by resting your elbows on your thighs and spread your legs into a wide stance.

Slide 31. Apply downward pressure. At the same time pull the clay toward your lap. At this point the edge of the left hand will act as a lathe to shape the clay.

Slide 32. When there is no wobbling motion in the clay and it rotates evenly in the hands, slowly release the pressure. The clay should now be centered.

B) The Cylinder - Slides 33-38

The next stage after centering is to "pull" or shape the clay into the basic cylinder shape.

Slide 33. When the wheel is revolving, rest both hands on the clay. Place both thumbs in the center and press down to make a small depression within the clay body. Keep the depression well-lubricated.

Slide 34. Gradually enlarge the depression to within 1/4 inch of the top of the wheel head. This depth will establish the thickness of the bottom.

Slide 35. With the left hand on the inside and the right hand held at the right hand side, square off the bottom by running the fingers of the left hand flat along the bottom to the right hand side. The right hand keeps the clay in check. The clay is actually pushed against the right hand which forces the clay upward.

Slide 36. This upward motion of the clay is the basic principle behind "pulling" the clay. A force is exerted on the clay and its direction is determined by the attitude of the hands.

Slide 37. "Pulling" is achieved as follows: squeeze the clay between the finger tips of the left hand and the side of the bent index finger of the right hand and draw the hands up with even pressure through the height of the wall. Continue pinching and pulling until the desired thinness of the wall is established.

Slide 38. After pulling is completed, cut the cylinder in half and examine the cross-section. Can areas be improved? The bottom of the cylinder should be flat and the walls should be of even thickness with a slight thickening at the top. This thickening will prevent the rim from splitting. It is a good practice to cut several cylinders in half until quality is consistently satisfactory.

c) Shaping - Slides 39-40

There is a great variety of pot shapes that can be created from the basic cylinder by simply bending or shaping the cylinder walls inward or outward.

Slide 39. The simplest shape is a bulging shape. Place the left hand inside the pot and push out with the finger tips.

Slide 40. To narrow the opening of a cylinder rest both hands on the outside of the wall near the top and "choke" the pot slowly. The opening will gradually narrow.

d) The Bowl Shape - Slides 41-45

The bowl is a natural extension of the cylinder shape. It is a wide-mouthed cylinder with a rounded bottom. The method for throwing a bowl varies slightly from the cylinder.

Slide 41. To begin a bowl center the clay into a doughnut shape, as shown in the slide. Leave a thickness of about one inch at the center of the doughnut. It is this thickness that will provide the foot at a later date.

Slide 42. The flat part of the thumb is used for smoothing the bottom of the bowl.

Slide 43. Pull from the right hand side at a diagonal, not straight up as done when throwing cylinders. Retain a slight thickness at the rim to prevent the rim from splitting.

Slide 44. As the height of the walls increase, the speed of the wheel should decrease otherwise the centrifugal force could collapse the bowl. If possible maintain a slight curved shape to a bowl. This will help to offset the effect of the centrifugal force. The rim of the bowl is finished by holding a wet piece of leather or paper towel against it.

Slide 45. A cross-section of the inside shape should reveal a gently curved bottom with no corners leading to the rim. The bottom of the bowl is left intentionally thick so that a foot can be turned later

e) Removing Work from the Wheel - Slides 46-48

When throwing is finished the work must be removed from the wheel and allowed to dry. The procedure is quite simple.

Slide 46. Trim all scraps and excess clay from the bottom, outside of the pot. Be certain there is no water left on the inside.

Slide 47. Hold a cut-off wire tightly and draw it flush along the wheel head underneath the pot.

Slide 48. Dry the hands. Gently pick up and place the pot on a wooden bat and set it aside to dry. If the pot does not readily lift up after undercutting, wet the wheel and draw the wire underneath the pot several times. The pot will then slide off the wheel onto the bat.

When making large pots the bat is first affixed to the wheel by using soft clay as a mortar and pressing the bat into the clay. The pot is then thrown on the bat. When the pot is finished, the pot and bat are both undercut, removed together and set aside to dry.

Shapes such as bowls, casseroles or such with a wide opening are usually thrown on a bat because the wide openings are susceptible to warping when handled at the greenware stage.

f) Turning - Slides 49-56

After a pot has been thrown and cut off the wheel, it requires some attention to complete and finish the bottom. The excess clay is carved away. This is known as turning. Pots are turned either on the wheel or off the wheel.

Slide 49. Turning a pot off the wheel is very simple. Hold the pot, tilt it on an angle and roll the pot in a circle along its edge.

Slide 50. When the edge is gently rounded, tap the flat bottom of the pot with the heel of the hand to cause a slight depression. The depression on the bottom of the pot forms a rim on which the pot sits. This method of finishing is particularly suitable to mugs, jugs, jars or any pot that does not require a turning tool to form the foot or base. If the design of the pot calls for a tooled foot, the clay must be moist enough to be easily cut by the turning tool but not too moist or it will loose its shape. Similarly, it must not be allowed to dry to a point where it can no longer be turned.

Slide 51. The first step is to recenter the pot upside down on the wheel, then secure it in place with pieces of soft clay which are pressed against the pot and secured to the wheel head. Be careful not to dent the pot at this point.

Slide 52. Shapes such as thin-necked bottles cannot be placed on the wheel upside-down without the aid of a chuck or fired ceramic hour glass shape. The pot is centered inside the chuck which is in turn centered and secured to the wheel head.

Slide 53. Kick the wheel and slowly bring the edge of the turning tool to the top edge and begin stripping off the excess clay. Some people prefer a looped turning tool, while others prefer a small sharpened blade. There is a great variety available.

Slide 54. After the sides are trimmed attention should be given to carving a foot. Begin at the center and work out to the inside edge of the proposed foot.

Slide 55. The final stage is to work on the outside edge to cut it back and form the actual foot upon which the pot will sit.

Slide 56. In the slide the pot on the left shows a cross-section of a bottom that has been rolled while the pot on the right has had its bottom turned. Notice that both pots have a rim on which to sit.

There is a simple test to gauge the thickness of a bottom to avoid cutting through it with a turning tool. Tap the bottom with your finger. A thin bottom will give a light tapping or hollow sound while a thick bottom sounds firm and solid.

g) <u>Handles - Slides 57-62</u>

Handles for both thrown and hand-built pieces of work can be made in a variety of ways. A simple, yet functional, handle is formed by rolling a coil of clay, shaping it and attaching it to the pot. This, however, often produces an uneven or rough hand-built appearance that is inconsistent with the evenness of thrown pieces. For coil handles do not look out of place for hand-built pieces, a handle is usually pulled for thrown pieces.

<u>Slide 57</u>. Begin with a well-wedged piece of clay and begin shaping to a taper. A taper can be made by wetting the clay and drawing the hands down the clay several times. Squeeze gently and evenly until a short taper is produced.

<u>Slide 58</u>. Break off the taper.

<u>Slide 59</u>. Attach it to the side of the pot by pressing the taper against the side.

<u>Slide 60</u>. Hold the pot in one hand so that the taper hangs straight down and continue pulling the clay and elongating the taper.

<u>Slide 61</u>. When the taper has reached the desired length and thickness slip the index finger under the taper and slowly right the pot, shaping the handle as you go. Attach the handle to the bottom and trim off any excess clay.

<u>Slide 62</u>. Another method of making handles is to cut them out of a lump of wedged clay with a shaped loop tool. The thickness of the handle will remain constant as will the design depending on the bend of the loop tool. For the inexperienced potter

who finds pulling handles difficult—this is a very easy method of producing several look-alike handles at once.

Handles must be attached to greenware. If the clay has been allowed to dry to leather hard, any handle that is attached will crack and fall off as it dries. Once a handle is successfully attached to a pot, it should be wrapped in moist towels to retard its drying. The pot is then placed in a damp cupboard or sealed plastic bag to dry slowly.

h) <u>Lids - Slides 63-69</u>

There are two ways to make lids on the potters' wheel; the upside down and the right side up methods.

The upside down method is very much like making a bowl that is to sit on the rim of a pot. The basic inside curve of the lid is established first and then, when the clay has dried to the state where it can be turned, the lid is inverted and trimmed like a bowl. A handle can then be added to the lid.

<u>Slide 63</u>. It is a good idea to measure the opening of the pot. As the pot shrinks so will the size of the opening. If measurements of the lid and pot opening are taken when wet both will shrink at the same rate. The lid should fit the pot well.

<u>Slide 64</u>. Center the clay and begin to press down about one half inch from center. This forms a button which will be the knob for the lid.

<u>Slide 65</u>. Dig in from the side and pinch off a piece of clay.

<u>Slide 66</u>. Pull the clay that has been pinched off straight out, horizontal to the wheel. This will establish the width of the lid. Finally,smooth and finish the edge of the lid.

<u>Slide 67</u>. Measure the width of the lid to insure that it fits the opening of the pot.

<u>Slide 68</u>. Cut the lid off the wheel with the cut-off wire and set it aside to dry.

<u>Slide 69</u>. The cross-section of the lidded pot shows how the lid should fit on the rim of the pot.

C. GREENWARE TO GLAZEWARE

1. <u>Natural Drying</u>

As clay dries it goes through two stages before it is ready for its first firing.

<u>Greenware</u> is work that has just been finished. It is still extremely plastic and as it dries, the water in the raw clay leaves a vapour. When the surface is just dry, capillary action draws out the water from the moist interior of the mass of clay. The clay now begins to shrink as the particles draw closer together.

<u>Leather hard</u> refers to clay that has been allowed to dry to a point where the moisture between the particles has evaporated. If the particle size in the clay is large, less shrinkage will occur, but if the particle size is small, then there will ge a greater percentage of shrinkage because of the presence of additional moisture in the

clay. When natural drying has been completed, the pieces can be handled without any danger of changing the shape, but the clay is still extremely fragile at this stage and has to be fired before it changes its physical properties again.

When clay dries, it is subject to splitting, warping, and cracking because different thicknesses of the clay in a particular part of the work will dry at different rates. For example, a thin handle will dry much quicker than the mass to which it is attached. For that reason, every attempt should be made to allow work that has surfaces of varying thickness to dry as slowly and as evenly as possible. To retard the drying of thinner areas wrap them in moist paper towels and cover the whole pot with plastic or place in a damp cupboard. For thicker sections, the addition of non-plastic particles such as grog during wedging aids in drying the clay.

2. Chemical Changes that Occur during Firing

Clay articles in their dry state are not usually functional. For example, if liquid was placed in an unfired pot, the ware would absorb moisture and eventually return to a plastic state. Thus in order for the pottery to be functional, it must be fired in a kiln. Anyone firing a kiln must be aware of the important physical and chemical changes that take place in the clay body as the temperature of the kiln rises.

0°-100°C - In this temperature range drying is completed as the water and moisture are driven off by the heat. If the advance in temperature is too rapid, steam is formed within the clay body and causes the clay to burst or explode. Special care must be given to large pieces with thick walls which are particularly susceptible to steam explosions.

350°C - The chemically combined water in the clay starts to be driven off. The rise of the kiln temperature should be slowed to prevent steam and to avoid breakage.

500°C - Dehydration takes place. At this temperature the clay loses its plasticity and an irreversible chemical change takes place. The clay can no longer be returned to a plastic state. Clay that has been fired past this point is said to be bisqued.

573°C - Quartz inversion occurs in all clays. The quartz crystals rearrange themselves which results in a slight 2 percent decrease in volume when cooling.

900°C - Oxidation occurs. All ingredients in the clay body that are not in oxide form (e.g. organic material) decompose or burn off.

Note: In fuel fired kilns if the atmosphere in the kiln is "reduced" or starved of oxygen or the firing advances too rapidly, carbon may remain in the clay body and cause it to fire darker or to swell.

As the temperature of the firing increases, the clay goes through a series of physical changes that alter the clay from a chalk-like substance to a dense, impervious, glass-like substance. When the clay makes this change, it is said to have vitrified. Each clay type vitrifies at a different temperature depending on its ingredients. During vitrification the clay particles fuse together into a glossy state.

The firing of a kiln is an exacting task. In a fuel fired kiln the final temperature must be slowly approached and care must be taken to avoid overfiring, which may cause melting or sagging. When the clay has been exposed to the correct amount of temperature for the right length of time, it matures, becoming hard and fused.

a) Bisque firing

After the pieces have dried completely, the kiln is tightly packed with ware made of the same clay. This first firing of dried ware is known as bisque firing. It should be noted that when a kiln is packed, pieces made of different clays should never be included. These odd pieces could have lower melting temperatures that would cause them to melt during higher temperature firings. The melted clay will fuse onto anything it comes in contact with ruining pots, kiln shelves, walls, and electrical elements. A full kiln allows the heat to be evenly distributed throughout the firing chamber. A poorly packed kiln causes cool spots which can result in dunting or cracking of some ware. If pieces are not bone-dry, the temperature rise should be stopped at 100°C, until the uncombined moisture has evaporated from the clay.

After the firing is completed, the kiln must be cooled to below 100°C before it is opened. Premature opening can cause dunting but more seriously, the thermol shock from the sudden influx of cool air can damage the fire brick within the kiln and necessitate costly repairs. But, more importantly, many eager potters have been burned when taking pottery out of a kiln. After the kiln has cooled sufficiently, the ware can be handled safely with asbestos mittens.

3. Glazing Techniques

Commercially produced glazes are adequate for most needs if the classroom is equipped with only a low fire kiln, instruction time is limited, and if the students are small children. But whether you use commercial or your own formulated glazes the manner in which it is applied will affect the quality of the glaze on the fired pot. A glaze that is applied haphazardly could destroy the aesthetic beauty of a piece of work by yielding a glaze that is uneven, rough, dry or bubbled. If the glaze runs off the walls of ware onto the kiln shelf it could glaze the pot to the kiln shelf. Similarly when glazing lids, care should be taken to ensure that the glaze does not run during firing and permanently melt onto the pot. To avoid such disasters there are several techniques to use when glazing.

Dipping a pot into the glaze ensures an overall even coating. However, a large amount of glaze must be produced to allow for sufficient depth for dipping.

Pouring glazes over the bisqued pot is another method of ensuring an even coating of glaze. The glaze should be slightly thinner than heavy cream. Thick glazes are apt to run or bubble when fired while thin watery glazes look dry in appearance after they have been fired and often have rough unpleasant textures. Pouring is particularly suitable for glazing the insides of bottles and bowls. This is done by pouring the glaze inside the bisqued piece and rotating the pice in the hands while at the same time tipping it letting the glaze pour out. The rotating motion ensures an even coating on the inside of the pot.

It is difficult to obtain an even coating of glaze if a brush is used. But sometimes, as in the case of small children where pouring and dipping can be a physical problem, a brush works well.

For smaller pots such as cups or bowls, a glazing technique known as double dipping can be used. The pot should be dipped into the glaze until the side of the pot has been glazed to a desired level. Then with a sudden sharp motion, pull the pot up but not out of the glaze and shake it vigorously. The quick movement draws the glaze into the inside of the pot. The shaking motion distributes the glaze evenly throughout the inside of the pot in seconds.

Commercial ceramic producers and some potters use sprayers to apply glazes. The piece of work is placed on a turntable and sprayed with an even coating of glaze. This process, however, requires a spray-gun, ventilation shafts, masks, goggles and a special area for spraying; and is usually too costly for classroom use.

When glazing pots, it is advisable to cover the side of the pot with glaze to within 1/8"-1/4" of the bottom. More or less space left at the bottom depends on whether the glaze runs a great deal during firing. Some potters, however, will glaze the entire pot including the bottom and then sponge the glaze off the part that will come in contact with the kiln shelf.

Waxing is a good way to prevent lids from becoming glazed to pots and to ensure clean, glaze-free bottoms. Waxing also eliminates rough, ragged edges where the pot and glaze meet. Any area of the pot that is to remain free of glaze can be waxed with a mixture of 50% parafin or beeswax and 50% turpentine heated until liquified. A brush is suitable for applying the mixture but a small piece of sponge tied to a handle holds more wax than a brush. By securing the bisqued pots on the wheel their bottoms, rims, and lips can be waxed evenly by holding the wax-laden sponge next to the turning pot as it is turned gently. Some potters will heat the wax mixture in an old electric frying pan and dip the bottom of the pot into the wax rather than painting it on. If, however, a burner instead of an electric frying pan is used, the wax should be melted in a double boiler to prevent it from overheating and to prevent spilled hot wax from igniting on burner elements. Once the pot is waxed it is then glazed. The wax burns away during firing and does not discolour or leave any marks on the clay body after firing is complete.

a) Surface Design

Potters may design the surfaces of their pots in a variety of ways. Knowing how and what kind of design to add can brighten and lift an ordinary piece of work into a delightful creation. There are several methods of applying simple slip and glaze decorations that could be useful to the student.

Engobes are slip or liquid clay mixtures which contain colouring oxides. The engobes fire to a different colour than the ware on which they are placed. Engobes applied to greenware in an even, dense coating, cling to the pot during shrinking and firing because they and the ware shrink at the same rate. When applied to bisque ware engobes will shrink and eventually flake off as they dry on this clay body which has been previously shrunk.

Mishimia is a Japanese form of decorating where soft, leather hard clay is cut into and the cuts are filled with a different colour clay body. This is then covered with a clear glaze and fired. It is the difference and contrast in clay colours that provide the design.

Slip trailing is an English form of decoration. A slip is prepared from a clay body that is a different colour than the piece to be decorated. The slip is dribbled or trailed over the greenware with an ear syringe or its equivalent. When it is fired the difference in clay bodies produces different colours on the surface of the pot.

Wax resist designs are applied after the pot has been bisqued. A design can be drawn in hot melted wax on either a bisqued surface or on a glazed surface and then the pot can be glazed in different colour glaze. Where the piece has been waxed it will resist the glaze and allow the other surface glaze colour to show through.

Stencils made out of large pieces of cut-out paper can be used in much the same way as wax resist. The cut-out paper design is then laid on the work and the glaze is either sprayed or gently poured over the paper. When the moisture in the glaze has been absorbed remove the paper and fire the piece.

Sgraffito is a design that occurs when greenware is covered with a thin slip, either an engobe or slip of a different clay body, and then scratched to a depth that just penetrates the greenware. The clay of the greenware piece is visible through the scratches in the slip and forms the design.

Silk Screen is an old method of producing prints that can be applied to ceramics. Using a suitable block out such as water mask, glue, or tusche, draw a design on the screen. Instead of ink use a slip which is a different coloured clay body than the pot. Some possibilities are to screen on slab first then create with the slab or to screen directly on large flat surfaces of work. When the work is fired the differences in clay bodies produce different colours.

b) Glaze Firing

In a glaze firing the kiln must be packed with the greatest care. During the bisque firing the kiln is loaded to capacity and pieces are allowed to touch each other. However, in a glaze firing, ware must be stacked evenly so that they neither touch nor have large open areas between them. Every effort must be made to ensure an even firing temperature throughout so that glazes reach their maturing or correct melting points. Before the kiln is stacked, the kiln shelves should be coated with kiln wash (a solution of 50 percent china clay, 50 percent silica). This does not damage the kiln shelf or the pottery but will prevent runny glazes from adhering to the kiln. When loading a kiln for glaze the firing distance between the pieces should be 1/8"-1/4" but if you are not sure that your glaze will run, froth, or swell, then increase the distance between pieces to prevent them from melting together during firing.

Be careful not to cut off the natural circulation of air in gas kilns. Where the kiln is large enough for two kiln shelves per layer to be used, the height of the shelves should be staggered to ensure proper air circulation.

Once the temperature has been reached and the kiln is cooling it should not be "cracked" or opened until the temperature has fallen below 100°C. Mitts should be worn when unloading as a precaution against burns.

c) Raku Firing

Raku firing is an ancient Japanese form of firing that gives the students an opportunity to study the total ceramic experience. A simple up-draught kiln with a brick door in front can be constructed (see Figure 3) from fire bricks. This type of kiln allows the heat to enter from the bottom opening, move up and around the firing chamber and out a small opening at the top. Some Raku kilns have large jar-like saggars in them in which to place the glazed ware. The source of fuel can be gas, wood, charcoal, or bottled gas. Pots are prepared either in the class or on site, glazed, and placed in the pre-heated kiln with the aid of gloves and tongs. Some potters suggest bisquing (about 980°C) first, but this is optional. The glazed pots will become glossy when they are ready to be removed from the kiln. Asbestos gloves and tongs are used to remove the pots which are then immediately thrust into cold water. To avoid cracking and breaking the clay body must be very "open" or coarse which means it must contain a great deal of fire clay or grog.

A simple reduction firing effect can be achieved by rolling the red-hot pot in wet grass, leaves, or sawdust, before immersing it into cold water. When the organic material touches the surface of the pot, it burns. This starves the pot of oxygen which results in a simple reduction firing.

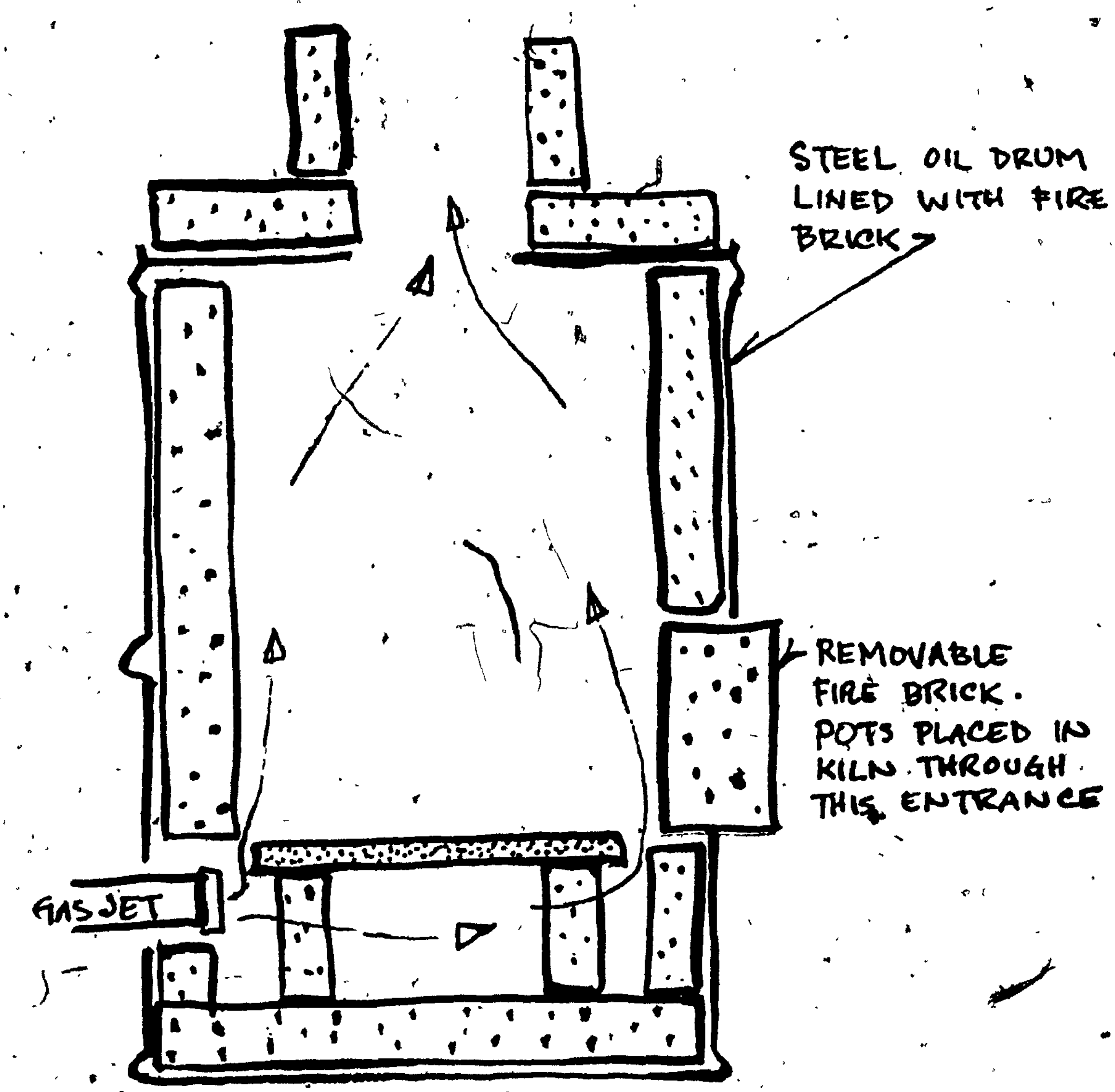

Figure 3. Diagram of Simple Up-Draught Raku Kiln

APPENDIX

Complex Glaze Formula

Complex glaze formulas such as the Raw Lead Glaze below, require a systematic method of calculating.

Formula for Raw Lead Glaze:

RO		R_2O_3		RO_2	
PbO	.7	Al_2O_3	.15	SiO_2	1.75
CaO	.2				
ZnO	.1				
	1.0 Total				

The formula does not tell you how much or even what raw materials must be used. It states that this glaze contains one molecule consisting of lead oxide, calcium oxide, and zinc oxide, .15 of a molecule of aluminum and 1.75 molecules of silica. The formula has to be converted to a batch recipe to determine the quantities of raw materials to use.

Step 1 - Copy the formula so that it is on one line and provide columns for the batch quantity, the raw material, and for the individual oxides.

Batch Quantity	Raw Material	PbO .7	CaO .2	ZnO .1	Al_2O_3 .15	SiO_2 1.75

Step 2 - The first material to be added to the glaze is the .7 of PbO. From Table 3 in the Appendix, find out what raw material furnishes PbO. We will choose white lead. In the raw material column write white lead and in the PbO column write $\frac{.7}{x}$, 7 being the amount of white lead required, while x equals the amount of lead contained in the raw material, in this case 3 PbO. The result of this division is .233

Batch Quantity	Raw Material	PbO .7	CaO .2	ZnO .1	Al_2O_3 .15	SiO_2 1.75
	White Lead	$\frac{.7}{x}$ = .233				

Step 3 - To calculate the batch quantity, multiply the figure .233 by the molecular weight of white lead which is listed as 775. The resultant total is 180.6 weight units of white lead to be used in the batch of glaze.

Step 4 - The same steps are followed for the CaO, using whiting as the raw material and the ZnO, using zinc oxide as the raw material. The results should be recorded on the chart.

Batch Quantity	Raw Material	PbO .7	CaO .2	ZnO .1	Al_2O_3 .15	SiO_2 1.75
180.6	White Lead	.7				
20.0	Whiting		.2			
8.1	Zinc Oxide			.1		

Step 5 - To calculate the alumina, we follow the same procedure as before, finding that china clay will yield the alumina. In this formula, we require 38 units of china clay. You will also note that the china clay yields two molecules of silica and two molecules of water. The H_2O is water of combination and is given off as steam during firing so we can ignore it. The two molecules of silica present in the china clay can help satisfy the SiO_2 that is required in the final column of our formula.

To calculate how much SiO_2 the china clay fulfills, multiply the amount of china clay required by the number of SiO_2 molecules present in the raw material, .15 x 2.00 = .30. Transfer this number to the SiO_2 column. The remainder of SiO_2 to be satisfied is found by subtracting the total supplied by the china clay from the total SiO_2 required: 1.75 - .30 = 1.45.

Step 6 - To calculate the remaining silica the same procedure is followed, except instead of needing 1.75 quantities of silica, we now only require 1.45. The raw material that yields silica is flint with a molecular weight of 60.

The completed chart will give the batch recipe.

Batch Quantity	Raw Material	PbO .7	CaO .2	ZnO .1	Al_2O_3 .15	SiO_2 1.75
180.6	White Lead	.7/3				
20.0	Whiting		.2/1			
8.1	Zinc Oxide			.1/1		
38.0	China Clay				.15/1	.30
87.0	Flint					1.45/1

The batch recipe is now

180.6	White Lead
20.0	Whiting
8.1	Zinc Oxide
38.0	China Clay
87.0	Flint
333.7	

TABLE 1

Table of Elements, Their Symbols and Atomic Weights[7]

Element	Symbol	Atomic Weight	Element	Symbol	Atomic Weight
Aluminum	Al	26.97	Magnesium	Mg	24.32
Antimony	Sb	121.77	Manganese	Mn	54.93
Arsenic	As	74.93	Nickel	Ni	58.69
Barium	Ba	137.36	Nitrogen	N	14.01
Beryllium	Be	9.02	Oxygen	O	16.00
Bismuth	Bi	209.00	Phosphorus	P	31.04
Boron	Bo	10.82	Potassium	K	39.10
Cadmium	Cd	112.41	Silicon	Si	28.06
Calcium	Ca	40.07	Sodium	Na	23.00
Carbon	C	12.00	Strontium	Sr	87.63
Chlorine	Cl	35.46	Sulphur	S	32.06
Chromium	Cr	52.01	Tin	Sn	118.70
Cobalt	Co	58.94	Titanium	Ti	47.90
Copper	Cu	63.57	Tungsten	W	184.00
Fluorine	F	19.00	Uranium	U	238.14
Hydrogen	H	1.01	Vanadium	V	50.96
Iron	Fe	55.84	Zinc	Zn	65.38
Lead	Pb	207.22	Zirconium	Zr	91.22
Lithium	Li	6.94			

[5]Rexford Newcomb, Jr. Ceramic Whitewares (New York and Chicago: Pitman Publishing Corporation, 1947), p. 70.

TABLE 2

Table of Ceramic Raw Materials[8]

Substance	Formula	Molecular Weight	Fired Formula	Fired Weight
Barium Carbonate	$BaCO_3$	197	BaO	153
Bone Ash	$Ca_3(PO_4)_2$	310	CaO	56
Borax	$Na_2O \cdot 2B_2O_3 \cdot 10H_2O$	382	$Na_2O \cdot 2B_2O_3$	202
Boric Acid	$B_2O_3 \cdot 3H_2O$	124	B_2O_3	70
Calcium Borate (Colemanite)	$2CaO \cdot 3B_2O_3 \cdot 5H_2O$	412	$CaO \cdot 1 \cdot 5B_2O_3$	161
China Clay	$Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$	258	$Al_2O_3 \cdot 2SiO_2$	222
Cryolite	Na_3AlF_6	210	$3Na_2O \cdot Al_2O_3$	288
Dolomite	$CaCO_3 \cdot MgCO_3$	184	$CaO \cdot MgO$	96
Feldspars				
Cornwall Stone	CaO .304 Al_2O_3 SiO_2 Na_2O.340 1.075 8.10 K_2O .356	667	Unchanged	667
Godfrey Spar	CaO .097 Al_2O_3 SiO_2 K_2O .426 .985 8.433 Na_2O.377	542	Same	542
Nepheline Syenite	K_2O .25 Al_2O_3 SiO_2 Na_2O .75 1.11 4.65	462	Unchanged	462
Orthoclase	$K_2O \cdot Al_2O_3 \cdot 6SiO_2$	556	Unchanged	556
Oxford Spar	K_2O .631 Al_2O_3 SiO_2 Na_2O.369 1.125 [illegible]7	703 703	Same	730
Flint	SiO_2	60	Unchanged	60
Fluorspar	CaF_2	78	CaO	56
Lead, Red	Pb_3O_4	684	PbO	223

Continued . . .

TABLE 2 - Continued

Substance	Formula	Molecular Weight	Fired Formula	Fired Weight
Lead, White	$2PbCO_3 \cdot Pb(OH)_2$	775	PbO	223
Lead, Yellow Litharge	PbO	~~223~~	Unchanged	223
Lithium Carbonate	Li_2CO_3	74	Li_2O	30
Magnesium Carbonate (Magnesite)	$MgCO_3$	84	MgO	40
Niter	KNO_3	101	K_2O	94
Pearl Ash	K_2CO_3	138	K_2O	94
Potassium Bichromate	$K_2Cr_2O_7$	294	$K_2O \cdot Cr_2O_3$	294
Silica	SiO_2	60	Unchanged	60
Soda Ash	Na_2CO_3	106	Na_2O	62
Sodium Nitrate	$NaNO_3$	85	Na_2O	62
Spondumene	$Li_2O \cdot Al_2O_3 \cdot 4SiO_2$	372	Same	372
Strontium Carbonate	$SrCO_3$	148	SrO	120
Talc (Steatite)	$3MgO \cdot 4SiO_2 \cdot H_2O$	378	$3MgO \cdot 4SiO_2$	360
Tin Oxide	SnO_2	151	Unchanged	151
Titanium Oxide (Rutile)	TiO_2	80	Unchanged	80
Whiting	$CaCO_3$	100	CaO	56
Zinc Oxide	ZnO	81	Unchanged	81
Zircon (Zircopax)	$ZrO_2 \cdot SiO_2$	183	Unchanged	183
Zirconium Oxide	ZrO_2	123	Unchanged	123

[6]Rhodes, Clay and Glazes for the Potter, p. 63.

TABLE 3

Table of Temperature Conversions[9]

°C	°F	°C	°F	°C	°F
0	32	560	1040	1120	2048
20	68	580	1076	1140	2084
40	104	600	1112	1160	2120
60	140	620	1148	1180	2156
80	176	640	1184	1200	2192
100	212	660	1220	1220	2228
120	248	680	1256	1240	2264
140	284	700	1292	1260	2300
160	320	720	1328	1280	2336
180	356	740	1364	1300	2408
200	392	760	1400	1340	2444
220	428	780	1436	1360	2480
240	464	800	1472	1380	2516
260	500	820	1508	1400	2552
280	536	840	1544	1420	2588
300	572	860	1580	1440	2624
320	608	880	1616	1460	2660
340	644	900	1652	1480	2696
360	680	920	1688	1500	2732
380	716	940	1724	1520	2768
400	752	960	1760	1540	2804
420	788	980	1796	1560	2840
440	824	1000	1832	1580	2876
460	860	1020	1868	1600	2912
480	896	1040	1904	1620	2948
500	932	1060	1940	1640	2984
520	968	1080	1976	1660	3020
540	1004	1100	2012		

[7]Rhodes, Clay and Glazes for the Potter, p. 205.

TABLE 4

Temperature Equivalents for Pyrometric Cones[10]

Cone Numbers	Temperature Fahrenheit
020	1175
019	1261
018	1323
017	1377
016	1458
015	1479
014	1540
013	1566
012	1623
011	1641
010	1641
09	1693
08	1751
07	1803
06	1830
05	1915
04	1940
03	2014
02	2048
01	2079
1	2109
2	2124
3	2134
4	2167
5	2185
6	2232
7	2264
8	2305
9	2336
10	2381
11	2399
12	2419
13	2455
14	2491
15	2608

[8] Nelson, Ceramics, p. 197.

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