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By

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NIGER STATE CERAMIC PROJECT; SULEJA

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THESIS ASTRACT

Topics NIGER STATE CERAMIC PROJECT, SULEJA

CLIENT: NIGER STATE GOVERNMENT of NIGERIA

LOCATION: ZONE 'A' OF SULEJA INDUSTRIAL AREA

NAME OF STUDENT: ADAMU, MOHAMMED ABUJA M.Sc. II ARCH, 1980/81 SESSION,

1. Massive construction of dwellings is one of both the federal and Niger State Governments priorities and its being promoted positively. With the siting of the new federal capital ABUJA at the door steps of Niger State and the availability of ceramic raw materials within the State especially around Suleja the former Abuja (Abuja pottery is internationally known for its pottery wares because it was the only pottery Centre in Nigeria in olden times), concept of total ceramic project is highly desirable. Apart from improving the living standard of our existing dwellings, high demand for ceramic tiles and sanitary wares can be expected following the above named programmes. This project when completed will also save large amount of money used or spent on importation of these products by utilizing Niger State Ceramic Raw Materials which has never been used on Industirial base. In fact, this is the first ceramic project and the second industrial project in the State. There are enough reserves of raw material deposits around where this industry is sited. Apart from Plaster of paris or gypsum which is to be imported all other raw materials are within a maximum distance of 68 km, even the glazes are locally found in Suleja Local Government Area.

2. It has always been in my mind right from my early years Architecture Department to contribute tremendously to the industrial development of Niger State and the whole Country in general. It is my wish also to make this country of ours self sufficient in moderm building materials so that living standard our existing dwellings can be improved and save the large amount of money spent on importation of these materials

3. The site for this industry is about 450m by 500m and is a located in Zone 'A' of Suleja Industrial Area. The site is a virgin land. In the first phase of this project about ~~J~~ of the land will be utilized while the remaining 1-4 is for the future expansion of only production halls as I have made adequate arrangement in the designing of Administrative block and workers facilities such that it can accomodate all the staff when the industry is in full production, Maintainance department could expand. The raw materials to be used in the industry include Clay, Feldspar, Limestone, Silica, Kaoline, Plaster of paris or gypsum, quartz and the glazing materials while the products include wall and floor tiles, lavatory pans, wash-hand basin pedestals, soap dishes, China sanitary wares, toilet reservoir tanks, squarting close and their cinters, shower trays and bid

4. It is my design concept to treat industrial design problems with utmost concern and give consideration to both the users the machines. I do hope that the solutions to these problems particular emphasis on my project and the knowledte I acquire during my stay in Architecture Department will be of great

importance to me in the role I am to play as an Architect in practice. To conclude, I also hope this project of mine is a step forward in the right direction as far as my Architectural ideologies are concerned, as it has been my wish to become an Industrial Architect during my professional practice.

Cheers, and may God bless you all, Amen.

Pupil Architect ADAMU, Mohammed Abuja (B.Sc. Arch) Hons. A.B.U.),

D E D I C A T I O N

This thesis is dedicated to:

1. My parents Abubakar Barau Dangaladima (late), his beloved wife Hadizatu Baba Anya and the rest of our family.

2. My Uncle Alhaji Adamu Katsina Makama, his wives and the rest of the family.

3. My dearest Cousin and wife to be Hussaina Bala

4. All Emirs of Abuja and Suleja.

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It isn't easy for me to remember the names of all those who helped me in one way or the other in the production of this work. I will therefore wish to express my profound gratitude to all those who have contributed to make this work a success, at the same time I wish to mention a few names which I can remember, especially those who contributed significantly to the success of this work. Thank you all.

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I N T R O D U C T I O N

The word Ceramios' has been realized to be generally misunderstood as far as these associated with ceramic Industry are concerned. A Layman defines ceramies as pottery wares or figurines. Since production of these items is one of the earliest arts involving some of the old skills in history there has always been a tendency to discuss Ceramic Industry generally in loose or non-scientific terms.

The word Ceramic has been derived from the Greek word KERAMIKOS Origionally meaning burn't stuff or substance developed with the aid of fire. One of the dictionaries defines ceramics as the art and technology of making things of baked clay, e.g. earthenware, pottery, tiles, porcelain and others. One of the Encyclopaedias says that "by ceramics is meant all production which the final result is baked clay in various grades of hardness and purity. Quite a large number of the recent ceramics do not include clay, and some ceramies are produced with out necessarily requiring heat processing. Thus all the above mentioned definitions are some how incomplete or rather inadequate.

Ceramics may be defined as products made from non-metallic, in organic materials, generally speaking it, involves high temperatures in their manufacture. This broader definition includes all the early classic Ceramics and some newer ceramic products. While most of the ceramics are produced from oxides and silicates, many other refractory materials are now used, including beryllides, Carbides, silicides, nitrides, alluminides

and the sulfides, Graphite can also be classified as a ceramic material. Generally, ceramic materials posess quite a desirable number of properties which are good tensile strength, high compressive strength, great resistance to chemical attack and we/athering, excellent electrical resistance and very great stability when exposed to high temperatures. Since there are so many types of ceramics, the individual properties can be varied from one to another, and this is of great importance to both the Architect and the product designer.

Ceramic products are encountered daily in the home and find wide use in practically all types of industry. Ceramic products in the house hold include; dinner and service wares, enamelled cooking utensils, and the enamelled surfaces of the stove, sink, dish washer, refrigerator, and washing machines. In the bathroom things like wall-floor tiles can be found in addition to the enamelled or porcelain fixtures. Electrical insulation and refractories for the home furnaco are two other domestic examples.

In design, Ceramic industry shall mine and quarry ceremic raw materials, produce, sale and distribute ceramic products to all parts of this great country of ours. As 55% of the existing dwelling in this country have no tap borne water and over 80% lack flush toilet facilities, this industry will produce largely the following items: Sanitary wares of all sorts, wall and floor tiles. Sanitary wares include things like wash hand basins, water closets, squarting closes and their Cinterns, bidgets, Laboratory sinks and shower trays.

With regard to nature's ecological balance, there is no effect what so ever being caused due to the removal of ceramic raw materials from the earth crust as the used or rejected ceramic objects sinks back with out causing any pollution to the environment. Ceramics is one of the earliest arts to be develope by man and continues to be one of the most essential activities i the world. These activities help to bring advancement and better way of living which can easily be felt in this our country.

C H A P T E R One

THE CERAMIC RAW MATERIALS

Part I

CLAYS

Clay is a general term for all those naturally occuring earthy deposits which possess the singular property of plasticity consisting essentially of the hydrous silicate of alumina. Natural plastic clays were the only raw materials for pottery in primitive times while in modern ceramics many other raw materials play important roles, but the one played by clay is still the major one. Clay deposits occur in almost overy part of the world. They are of greatly varying nature, as no two deposits have the same 'clay' and it is very easy to find different samples of clay from the same deposits differing in so many ways. Clay has so many functions, it provides an inexpensive source of silica and alumina in addition to that it also serves as a binder and as a suspension aid. Clays generally retain their shape, after their plasticity is distroyed, by the removal of water film which is very essential to the interparticle bond. The dried clay wares don't only retain their shapes but also acquire a fair mechanical strength.

Clay are formed as a result of weathering of some primary igneous rocks like granites, gneisses, feldspars, pregmatites, etc. The weathering of these rocksis normally achieved by the machanical action of water, wind, glaciers and earth movements working together with the Chemical action of water, Carbon dioxide, humic acids,

etc. assisted by high temperatures. In some cases the weathered rocks remain in their original position, these are residual clays while some are being transported by wind and are known as 'loess'; they are not stratified and have much more porous and crumbly structure. And if the transporting agent is water, the deposits are usually in layers and are known as secondary or sedimentary clays.

Although there are so many varieties of clays, they can still be separated into three major types of minerals, moreover they are rarely found in pure state but are usually accompanied by accessery minerals like quartz, calcite, limonite, gypsum and muscovite. The three major classes are listed below:-

1. Kaolinite $AL_2O_3.2^SiO_2.2H_2O$ or can be written as

$H4^AL_2Si_2O5$ or

$(OH)\ 4AL_2Si_2O_5$

2. Montmerillenite $(Mg,Ca)\ O.Al_2O_3.5SiO_2.nH_2O$.

3. Illite K_2O-Al_2O3-SiO_2-H_2O (all in variables)

KaOlinization of feldspar can be represented with the following Chemical equation:-

$K_2O.Al_2O_3.6SiO_2 + 2H_2O + CO_2$ ------ $Al_2O_3.2SiO_2.2H_2O+4SiO_2 + K_2CO_3$

feldspar + water + Carbondioxide ------- Kaolimite, + quartz + Potassium Carbonate.

For the fact that clays are never chemical compounds, materials from different source are never identical therefore, particular clays are identified by their sources and are being classified by their general functions.

Types of Clays:

Various types of clays are formed as a result of different geological, physical and Chemical conditions.

The followings are some of the various types of Clays:

1. Kaolins: are the refractory clays consisting mostly of minerals of the kaolin group which after firing, it becomes white or nearly white colour due to their relatively high purification factor. These very type of clays are, also known as China clays because they were first produced in China. They produce the most tranlucent grades of China ware and are therefore incorporated the finest products.

The Chemical Composition of Two Important Kaolins

(Approx. Percentages)

	Kaolin 1	Kaolin 2
Alumina (Al_2O_3)	37.41	39.18
Silica (SiO_2)	45.52	44.36
Titania TiO_2	1.30	1.33
Iron (Fe_2O_3)	1.68	0.42
Calcia (CaO)	0.004	0.005
Magnesia (MgO)	0.03	0.02
Manganese Oxide (MnO)	0.0005	0.005
Potassia (K_2O)	0.005	0.002
Sada (Na_2O)	0.011	0.01
Sulfurtrioxide (SO_3)	0.13	0.18

Phosphorous Pentaoxide (P_2O5)	0.08	0.10
Water (H_2O)	13.93	14.09

2. Ball Clays: These are secondary clay, mostly characterized by the presence of organic matter, high plasticity, high dry strength, long vitrification range and a light colour when fired. Due to the presence of organic matter and other impurities these clays are not white in their natural state as the Kaolins. They are used in all types of white ware with the exception of the finest China ware.

3. Fire Clays: These clays vary considerably in composition and properties since they include practically all the refractory clay, are generally not white burning. They have low colloidal content and thus relatively poor plasticity in the green state. Some less refractory fire clays contain fluxes and are used for mortars and ladle bricks.

Chemical Analysis of some Ball and Fire Clays:

(Approx. Percentages)

	Ball Clay (1)	Ball Clay(2)	Ball Clay (3)	Fire Clay (1)	Fire Clay (2
Al_2O_3	31.98	30.93	32.47	36.51	23.01
SiO_2	51.72	53.98	52.10	43.04	58.10
Fe_2O_3	0.90	0.74	1.47	2.20	2.40
MgO	0.19	0.20	0.55	0.51	0.95
CaO	0.21	0.14	0.24	0.70	0.75
Na_2O	0.38	0.45	0.48	0.50	0.41
K_2O	0.89	0.72	2.20	1.05	1.75
TiO_2	1.52	1.50	1.31	1.84	1.35
Ign. Loss	12.29	11.40	9.13	13.72	11.10

4. Stone Ware Clays: These type of clays contain feldspar which reduces the fusing temperature and as a result dense and vitrified products are obtained after burning. Before these clays were used to make stone ware but now-adays it is body mixture of several other raw materials to provide better control in manufacture.

5. Slip Clays: These clays contain large proportions of fluxes and iron.

6. Terra Cotta Clays: These clays have a sort of buff-colour after burning. They constitute the principal constituent of ceramics used in building construction. They are commonly found in U.S.A.

7. Bentonite Clays: This clay is formed as a result of the decomposition of volcanic glass. It is characterized by its extreme fine particles. It is principally used as an additive to provide suspension characteristics. This property makes it effective as a plasticizer in refractory mixes.

8. Other Clays:

Preduction

Generally speaking all clays are found on or near the surface as such they are mined by low-cost open pit methods. Normally the top crust soil is easily removed by stripping, thus exposing the clay deposits. Power shovels and trucks remove the clay.

In order to minimize or reduce the cost in transportation, ceramic plants, industries or factories are generally located adjacent to clay deposits. Processing of ceramic materials may vary from almost none as in brick clays production to elaborate grinding and classifying of procedures with some fine Kaolins. The required characteristics are obtained by selection of the source and by blending clay of the needed properties.

Properties of Clays

1. Adsorption Properties of Clay Colloids: The colloidal properties of extremely small clay particles, are derived from the nature of the charges on particle surfaces. Most ceramic properties of clays are related to the surface phenomena arising from charges on the particles. The surface affect

exist throughout the clay, but as the particle size decreases the relative importance of the surface properties increases, until a size is reached at which the surface forces predominate and in this case are unaffected by any force due to the mass of the particle. These particles exhibit coloidal properties and it is on them that properties of the clay as a whole depend.

2. The flow Properties of Clays: Mixture of clay and water show many types of flow depending on the type of clay and also on soluble additions made to the water. Although some clay suspensions may appear to flow as homegeneous which normally show Newtonian - Viscous. Most clays when mixed with water tend to have an infinitely high viscosity at low shearing stress which decreases at higher rates of shear. This terms 'plastic flow' and the graph obtained is either a curve bending away from the axis of the stress and at the same time not passing through the origion.

When deflocculants are added a curve passing through the origion, very near to that of a viscous liquid, is obtained, although the behaviour is never linear. Deflocculants are nothing but a mixture of chimicals used in keeping liquid in suspended condition instead of settling.

3. Plasticity: Clay is said to be plastic when right quantity of water is added to it. In this condition nearly any shape could be achieved with out rupturing when pressure is appli and as soon as the pressure is released, the former shape is retained. The plasticity of clay, generally increases with increase in temperature.

4. Permeability of Clay: It is the ability of water to pass through a layer of clay and this depends on the way particles are packed together, and on the water films adsorbed around and in between the particles. The permeability of clay is a major factor in the drying characteristics of a clay.

5. Afinity of dry Clay for Water: The clay's affinity for water is shown by the fact that heat is given out when clay is wetted. Montmorillonite clay, which absorb reasonable quantity of water has a much larger heat of wetting than kaolinite which absorbs only a little water. Illite has an intermediate value while fired wares generally have low heat of wetting.

6. Drying of Clay: Shrinkage normally occurs when moist clay gradually gives up water to the surrounding atmosphere as a result of evapouration. There after the surface begins to appear dry and as evaporation continues to take place within the piece, little or no shrinkage occurs again. At this point, clay is said to be in leather-hard condition. Further reduction in the moisture contents of the piece produces little or no change in volume right down to dryness.

The general accepted explanation is that no further shrinkage occurs as soon as the piece starts loosing water through certain pores produced during shrinkage.

7. Firing or Clay: When clay is strongly heated, an irreversible hardening reaction takes place and this is another of the features that has been basic to the ceramic industry in early or primitive times. Briefly, on further heating dried clay more water is given off and in due course a hard but porous

piece is formed. Release of gasses may also give rise to expansion but there is almost always an over-all shrinkage. The whole series of these reactions is governed by the mineralogical, chemical and grain size composition of the cl. and therefore different for each clay.

Mining and Preparation of Slip:

Due to technological advancement feldspar can now be separ from quartz and other impurities by floation methods. In those it used to be by only handly mining. This process has proved to be the most effective method of producing large quantities of feldspar relatively free from impurities.

The crushed, ground of is subjected to magnetic separation. Continuous, closed - circuit grinding mills are generally used.

Feldspar is used as the principal flux in nearly all the classic bodies and also used in glaze composition. The amount m be as small as 10% in porous bodies and much higher in dense, hig vitrified bodies, e.g. a dense floor tile may contain more than 50% flux, while dental porcelain may be almost all feldspar.

Tests on the Nature of Clay:

a. Test for plasticity
b. Test for water of plasticity and for dry shrinkage.
c. Test for the presence of lime
d. Test to determine firing range of clay and firing colour by firing samples to various temperatures. Cones 08, 0 1, 4 and 9 might be suitable intervals for the first tes
e. Test for shrinkage and absorption on samples fired to various temperaturos.
f. Test for excess sand or other mineral fragments.

g. Deflocculant tests.

h. Test for soluble impurities.

Part II

G L A Z E S

Glazes are generally, thin mixtures of silicate fused on surfaces of clay wares. In both their physical and chemical nature, they are glasses generally hard, slightly or completely insoluble except in strong acids or bases. It is impermeable to both liquid and gasses. Glazes like glasses, are not definite chemical compound but complex mixtures which are described as under-cooled solutions sice many of their properties are analogous to those observed in ordinary solutions. Generally the surfaces are reflective, lustrous or glossy and all gradations of glossiness or mattness could be observed.

Glazes may be colourless or coloured transparent, translucent or opaque. What ever the appearance might be glazes or similar coating is used to serve one or two of the following purposes:

(i) to render the ware impermeable to both liquid and gasses

(ii) to provide an aesthetically attractive coating or surface which covers up blemishes and provides a decorative effect.

Classification of Glazes

Glazes are classfied into the following groups:-

(1) Lead glazes formed generally from lead oxide, perhaps as part of silica replaced by boric oxide, tinoxide and part of lead oxide by alkaline and alkalies earths.

(2) Earth glazes made from insoluble minerals.

(3) Salt glazes, the result of the action of the fume of common salt.

Glaze Materials

Chemical materials generally compounded in the batching of glazes are as follow:-

1. Bases; these are conspicuously fluxing agents which are of the forms represented by the RO and the R_2O. In ceramic classification formula this includes the alkalies, the alkaline earths and zinc oxide, lead oxide and many other colouring oxides of chromophores.
2. Intermediates; It include amphoteric oxides, the R_2O_3. These are the classes of alumina, as a common example and to which ferric, chromic, maganic and other oxides are sometimes assigned.
3. Acids; These are represented by RO_2 classes, of which silica, phosphoric oxide, Zirconia, and fluorine belong.

Mixing and Milling of Glazes

Formation of a homogenous mixture ready for application to the ware, is the most important step in the preparation of glazes. Except in the primite methods where by glazes are applied in the

form of powder, and this method is seldom employed these days. The international or universal method is to mix glaze ingredients with water to form liquid suspension or slip. This glaze slip must be of a properly calculated composition and consistency that doesn't show any undesirable settling or separation in any reasonable time of standing. The most essential conditions governing glazes preparation are cleaniness and systematic order in the care and use of materials and equipment; thereby loss of time, labour, and materials may be avoided. Further more, it is of psychological effect of spurring the workers to be vigilant which is a prime requisite in the production of good ceramic products. Detailed preparation of glazes has been mention in the Chapter on Industry.

Application of Glazes

There are three methods used in the application of glazes to ware and are named-wet, powder and gasseous. The first method is that of which the solid suspension of glazes in water is applied to a ware. The commonest method is the wet processes of glazes application because they produce the desired thickness and uniformity of the completed coating. The various ways employed for this method of application are:

1. Painting
2. Pouring
3. Immersion or Dipping
4. Spraying and
5. Contact Transfer

Immersion or Dipping method is the method commonly used especially for portable size and shape of ware pieces. This method is used in this Industry for the glazing of tiles while spraying and pouring methods are adapted in the case of sanitary wares as they appear to be larger in size.

Part III

GYPSUM OR PLASTER OF PARIS

Essentially plaster of Paris is nothing but calcium sulphate hemihydrate with formula $CaSO4.\frac{1}{2}H_2O$. It is made from chemical or mineral gypsum, $CaSO4.2H_2O$ which has fairly wide spread in occurrence. It is found in both pure state and with various impurities which colour and modify the properties of the plaster made from it.

Gypsum, $CaSO4.2H_2O$, M·W.172.18, $CaSO_4$, 79.1%, H_2O, 20.9%

Plaster of Paris, $CasO_4\frac{1}{2}H_2O$, MW.154.16.$CaSO_4$, 93.8%,

H_2O, 6.2%

Anhydrite; $CaSO_4$, MW. 136.15 $CaSO_4$, 100%.

The number of possible dehydration products, make the production of satisfactory plaster from gypsum more complicated. There are two different types of hemihydrates namely and ∝ & β

The ∝ type normally produces much stronger and more satisfactory plaste

Plaster is used in ceramic industry for three related purposes:-

1. Model making: This requires a dense uniform plaster which can be easily carved.
2. Making moulds for pressing and jiggering shapes in plastic day

3. Making mould in slip casting wares.

In the shaping of clay in plaster moulds the plaster plays a dual role as doesn't only absorb water and there by make the clay stiffer but the slight solubility of the calcium sulphate in the water accompanying the clay furnishes flocculating ions, both the calcium, (Ca^{++}) and the sulphate $SO_4^{=}$) ions being efficient flocculants. Therefore a deflocculated casting slip poured into the plaster mould is flocculated on the mould surface to give a stiff cast. It is for this reason that a mould for casting slips doesn't need to be more porous than one for jiggering plastic clay; and also the reason why a casting slip will set even in a damp mould that can not withdraw water from it.

Detailed processes for the preparation of mould has been discussed in the chapter on Industry.

It is beyond the scope of this thesis to discuss the process of DEFLOCCULATION, but commonest types of deflocculants used in this Industry for keeping liquid slip in permanent suspension are as follow:-

1. Sodium Silicate.
2. Tetra-Sodium Pyrophosphate.
3. Sodium Hydroxide
4. Sodium Tannate
5. Sodium Pyrophosphate.

C H A P T E R II

KILNS

From a technical point of view, the firing of ceramic object is a very simple process, and kiln is complex, dramatic, exiting, endlessly fascinating in design, construction and op operation. The process of firing ceramic ordinarily involves gradual heating of the kiln to the degree of hotness needed to work on the ceramic object(s) and consequently cooling it again gradually back to room temperature. There is rarely any prolonged holding at one temperature, as in the case of cake baking. Generally speaking, ceramics require a rather slow heating schedule. Much time is needed for the various reactions to take place which change raw clay and unfused glaze materials into the finished fired pieces of ceramic materials. Kilns shouldn't only heat up and cool down evenly and the desired degree of temperature but should also heat up evenly in all parts of a particular section of the ware Chamber. Nearly all kilns fire with a difference of at least one - half cone from part of the kiln to another, but this difference can easily be tolerated. While acquiring a new kiln for firing ceramic objects, stone ware or percelain, so many things have to be considered like kind of fuel to be used, whether to have kiln permanently built or bring in a ready-made portable one to the place. Kilns built in place if properly designed and constructed prove to be cheaper, work better and last longer than

portable ones. As natural gas is readily available in this country it is the most ideal fuel with regards to this industry.

The design, construction and propertioning of kilns is more of an art than a science subject. There are lots of mysteries and uncertainties about this, but existing successful kilns are of so many varied shapes that it looks as if any shape can work. Actually, there is a wide tolerance in kiln designs, and if a few basic principles are strictly followed the kiln will surely work well.

Elements of kilns:

(a) - A fire box, or fire mouth for fuel or gas burning. It deesn't have to be too big but should be sufficient to support large fire.

(b) - A chamber where wares are being placed. The fire box has a direct connection with this but perhaps with a baffle, or at least a narrowed passage in between.

(c) - A fue or hole, to allow the escape of hot gas and smoke.

Materials for the construction of Kilns:

(i) Fire bricks:- Fire bricks are made from fire clay and are sold under one of the three classification - "Low-heat duty", "intermediate - heat duty" and high-heat duty". These classes refer to the degree of heat which the brick will successfully withstand in service. The commonest shapes available are:-

225 x 150 x 62.5 mm

225 x 225 x 62.5mm

225 x 62.6 x 62.5mm

(ii) Insulating fire bricks:

This types of brick are made in such a way that cells, pores or interstices of air are contained in the brick structure. The bricks are usually made from either kaoling or mixture of kaolin with other clays, and there porosity serves as a damp to heat and gives them a high insulating capacity.

(iii) Fire Clay Mortar:

This mortar is made from clay

(iv) Vermiculite:

It is just an expanded mica used for insulation.

Types of kilns

1. Electric kilns:

These kind of kilns are normally being heated by the radiant heat given off by electric elements which offer resistance to the flow of electricity. It is the most portable and convenient type of kiln to use.

2. Muffle kilns:

These types of kinds are accompanied with muffles to protect the ceramic objects from direct flame of the fire.

3. Updraft and downdraft kilns:

In the case of this kind of kiln, the fire enters the updraft kiln from the bottom, rises upwoards the ceramic objects chamber and escapes through flue - at the top of the chimney. While in the case of downdraft kiln, fire enters from the sides of the kiln and is deflected by a baffle wall which forces gases upwards to the top of the kiln.

4. Tunnel Kilns:

They are the type of kilns to be used in this industy due to their advantages over the previously mentioned ones. They are continuous kind of kilns up to a length of 120 metres through which the goods are passed on kiln cars. In these kilns, the cars normally enter from one end and move slowly with the help of automatic pusher machine towards the opposite end and during this process, they gradually pass through different types of heating zones and finally come out well dried or butnt depending on the puppose of the kiln and its maximum burning temperature.

Advantages of Tunnel Kilns:

(a) The ground space requirement is much less than other types of kilns with same output.

(b) The loading and unloading of goods is much easier and faster compared to other types of kilns.

(c) A saving in brick work cost is realized but it is counter balanced by the cost of Cars.

(d) All respective parts are always at a constant temperature,

as such there is less tear and wear on the kilns structure.

(e) The whole fuel is used up effectively and there is virtually no loss through the walls of the kilns.

SITE LOCATION:
NIGER STATE CERAMIC PROJECT,
SULEJA.



KEY
▨ FEDERAL CAPITAL TERRITORY
⊙ PROPOSED NEW FEDERAL CAPITAL

C H A P T E R III

Part (I) Site Selection:

Izom which is about 35Km from Suleja along Minna - Suleja road could have been the site for my Industry but due to the fact that certain facilities are lacking I decided to site the Industry in Suleja. Although Izom is a little bit closer to the Major deposits of raw materials but all the same it will make the Industry uneconomical by siting it there if other conditions like basic facilities are considered.

Before siting an Industry it is very important you consider its distance to the closest City or Town. like in Suleja now facilities like, hospital, Postal Service, Tap borne water system, Electricity, gas and other facilities have already been provided. So by siting an Industry in Suleja, all these basic needs don't need to be provided again unlike if the Industry is to be sited in Izom. After all Izom is on the boarder between Niger State and Abuja Federal Capital Development Authority, so it is not certain whether the whole village shall remain or be resettle elsewhere. Is a risk on Niger State Government side to site this Industry there.

By siting this Industry in Izom it means erecting houses for about 500 staff on the Industry, as the village lacks accommodation facilities, this uneconomical. Apart from that transportation system in the village is virtually absent

and for the Government of Niger State to be transporting this Industry's Staff from Suleja to Izom every working day and during shift hours it is unwise and uneconomical.

The orientation of the site for this Industry with respect to Suleja is North-west, this orientation saves the town from Industrial noise and pollution as other industries will soon spring up but as of now, this is the first Industry on the site and virtually it doesn't have much of these mentioned problems.

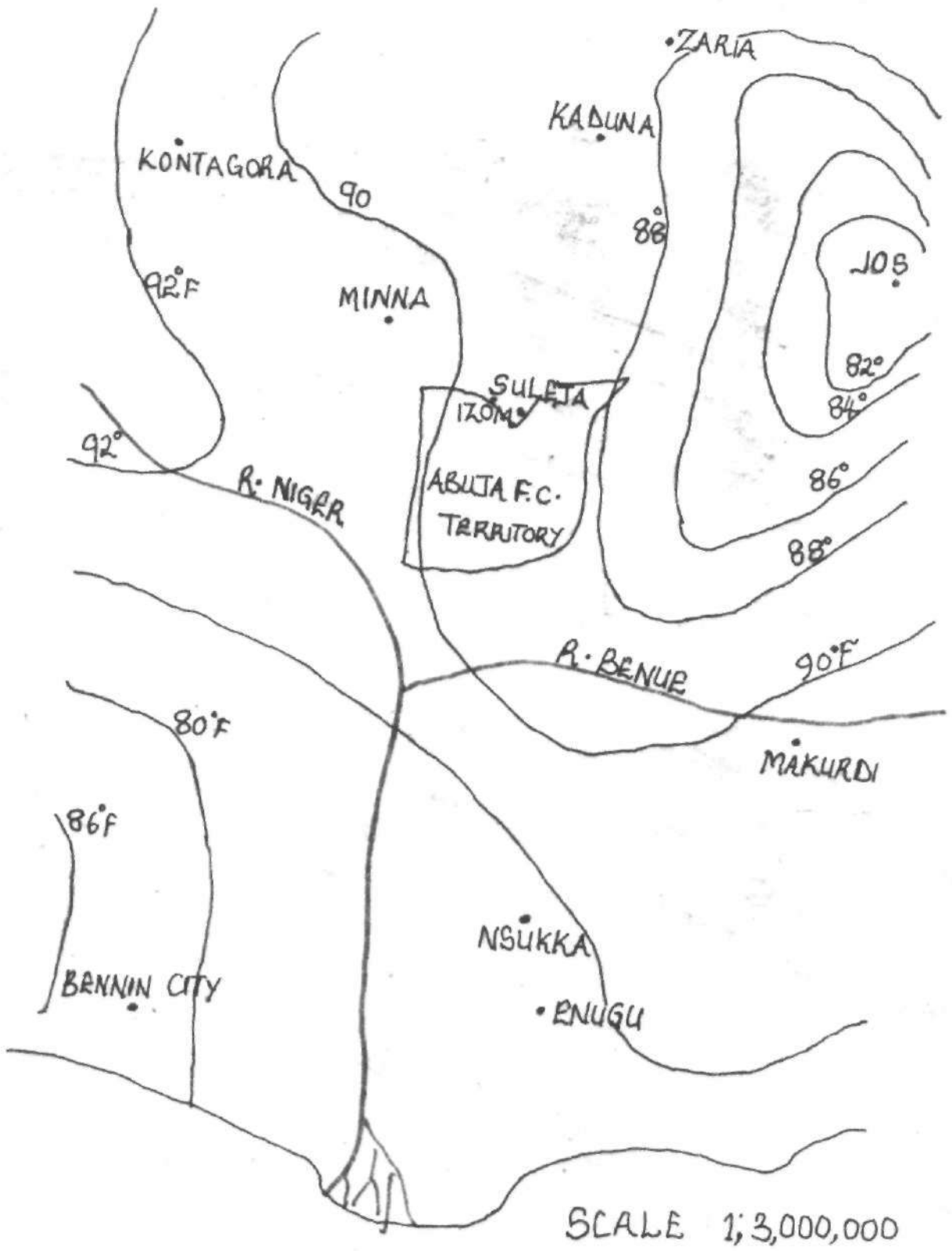
The orientation of the Industry with respect to the site is that the main elevations are facing north and south. This is the most ideal orientation for both sufficient ventilation and natural lighting. It also saves the cost of providing sun shading devices as the angle of sun in these directions is very small unlike the east and west elevations where it is the opposite.

N.E.P.A. is just a few mtres for this Industry as such it would be very easy and economical to supply the Industry with electricity, moreover there is going to be a stand-by generator as I have already provided it in the design.

The Industry is not more than 7km from a national high way linking both northern and southern parts of this country with Abuja the New Federal Capital. The road starts somwhere near Peugeot Assembling Plant in Kaduna and reaches up to Benin via Suleja, Abuja and Lokoja.

River Iku provides Suleja town with water via water works

MEAN ANNUAL MAXIMUM TEMPERATURE



through out the year. So to avoid water shortage this Industry is situated just a few meters from river Iku where water is easily accessible moreover, two water reservoirs with capacity of 50.00m³ each and a water Tower have been provided.

Part II Site Analysis:

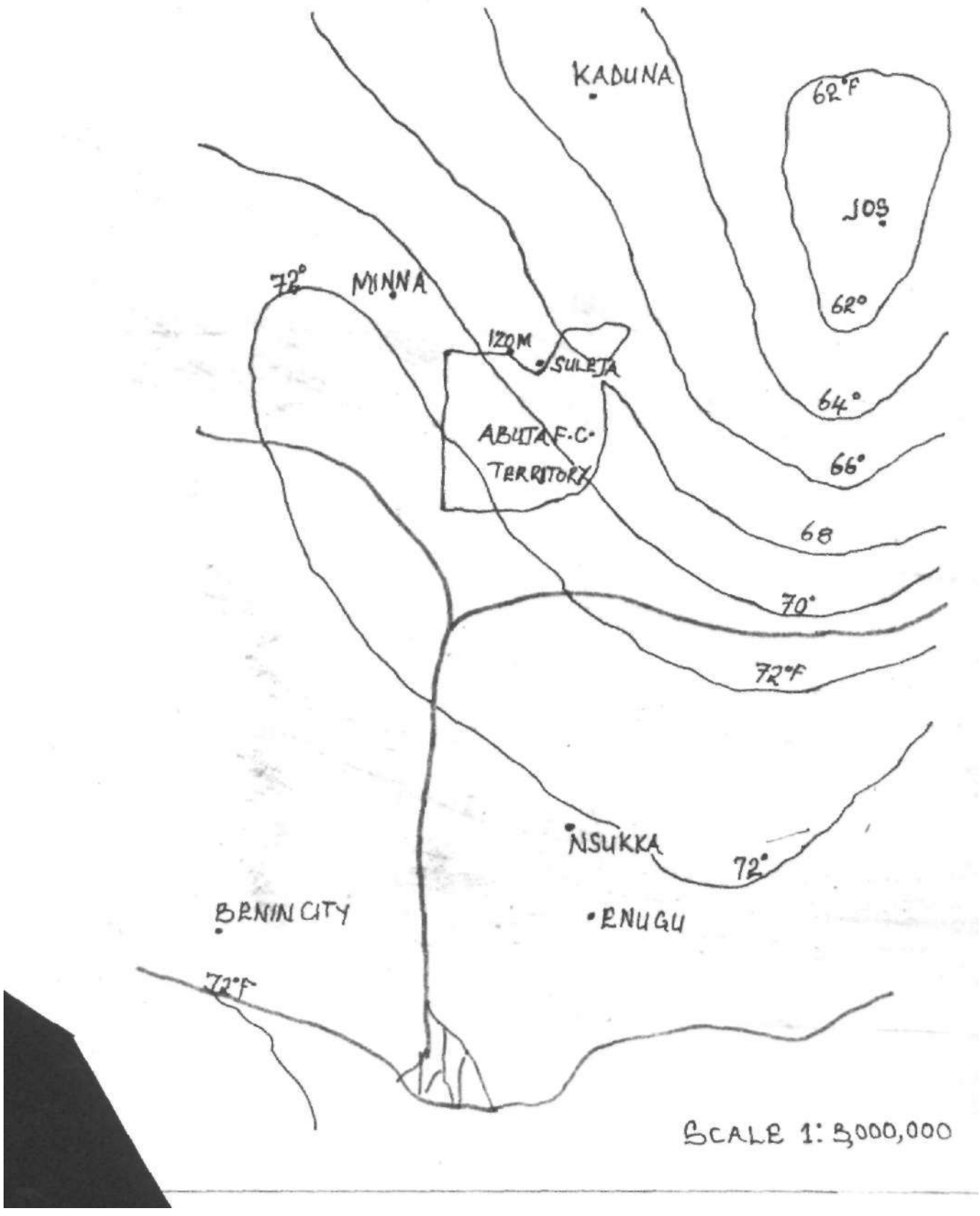
Climate:

While designing a structure, it is of great importance to consider the climatic and micro-climatic factors of the environment as they have unmeasurable significance on the building structure due to their influence on it. The basic climatic factors that influence my site are hereby listed and discussed below:-

(a) Temporature and Humidity:

Like all other parts of the Country, my site is experiences two different types of seasons as a result of interraction between regional temperature and pressure patterns and broad global flow pattern created due to the sun's differential heating effect on land, forest and water. The two seasons are wet or rainy season and dry or Harmattan season. Wet season comes up as from May to October due to the influence of south-west winds which bring rains. The season lasts for a period of six to seven months and this time of the year, it usually hot and stuffy, generally as a result high relative humidy of the moistened air. The over all hotness is however accompanied by numerous instances of cool weather condition during and

MEAN ANNUAL MINIMUM TEMPERATURE



immediately after the rainy season. It is only during this period, that truly refreshing and quite moderate temperatures prevail.

Dry season commences in November immediately after rainy season and last up to April the following year. The season comes up as a result of the influence of North-Easterly Winds or Harmattan which is usually dry and dusty with a relative Humidity as low as 40-50%. Afternoon, Harmattan temperatures result into cool, sometimes cold nights while early morning conditions record an appreciable dinual range. The site has a mean annual minimum temperature of about 70-72°F and mean annual maximum temperature between 88-90°F. No clouds appear o the skies during dry season while rainy season is witnessed with thunderous clouds on the skies...(i.e. the tornadoes of West Africa). There is very high heat generation before and after the rainy season, possibly due to clouless skies as mentioned earlier and the dry air.

Design Implication:

The Industry would have been oriented North-East - South-West in order to achieve maximum ventilation but due to other site factors like topography, Drainage pattern and solar radiation, North-South orientation appears to be ideal because most condition are being satisfied to some extent. Ventilation can also be achieved mechanically by making use of electric fans and air conditioners. Protection of buildings,

against harzadous Harmattan winds can be achieved by providing shutter at vent openings, by minimising the number of openings exposed to the general direction of these winds and also by sufficiently landscaping the whole Industry which I have done.

(b) Rainfall:-

Suleja town is within the Savanah mid-climatic belt with a range of 50" - 60" of mean annual rainfall. The rains normally fall during the massive movement of the moistened South-Westerly winds from the South-West direction. It begins to rain as early as April and stops raining by October. North-Easterly assumes duty for the remaining part of the year till next rainy season. Early rainy season is characterized by thunder storm and short spells of heavy down pours of rainfall, unlike the middle and towards the end of the rains when it is usually quiet and prolonged. The late rains are as stormy as the early ones.

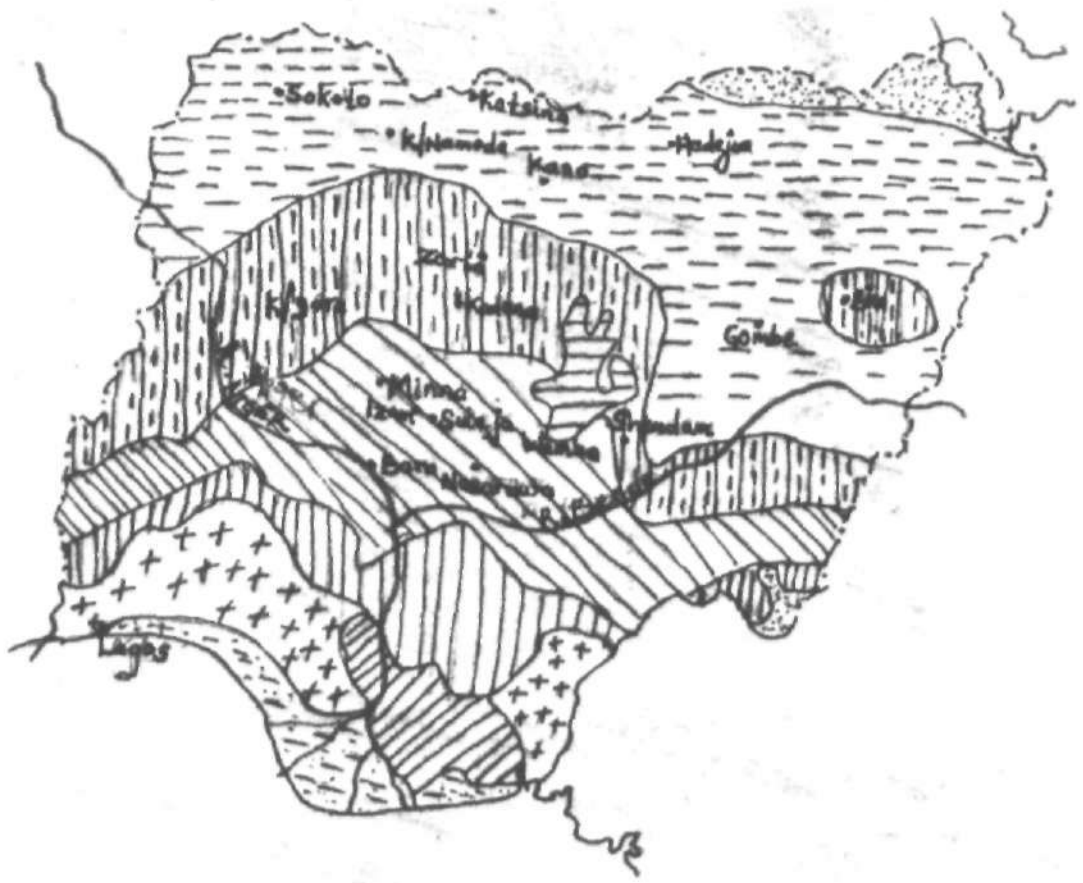
Design Implications:

As a result of heavy storms foundations, columns, beams and roof structures are properly designed to avoid the peril of toppling, and buckling of these structures. Roofs are provided with rain water gutters and pipes for proper drainage.

(c) Solar Radiation:-

The sun path diagram for my site generally follows a basic East-West direction. This exposes Eastern and Western elevations to the aggressive Solar radiation influence.

VEGETATION MAP
NIGERIA



- Swamp forest
- Rainforest
- Oil palm bush
- Derived
- Southern guinea zone
- Northern guinea zone
- Jos plateau
- Sudan zone
- Sahel zone
- Mountain forest & grassland

0 96 192 288 384 480

These harzadous sunny effects are felt mostly during the mid day and afternoon periods when the sun is in the over head position.

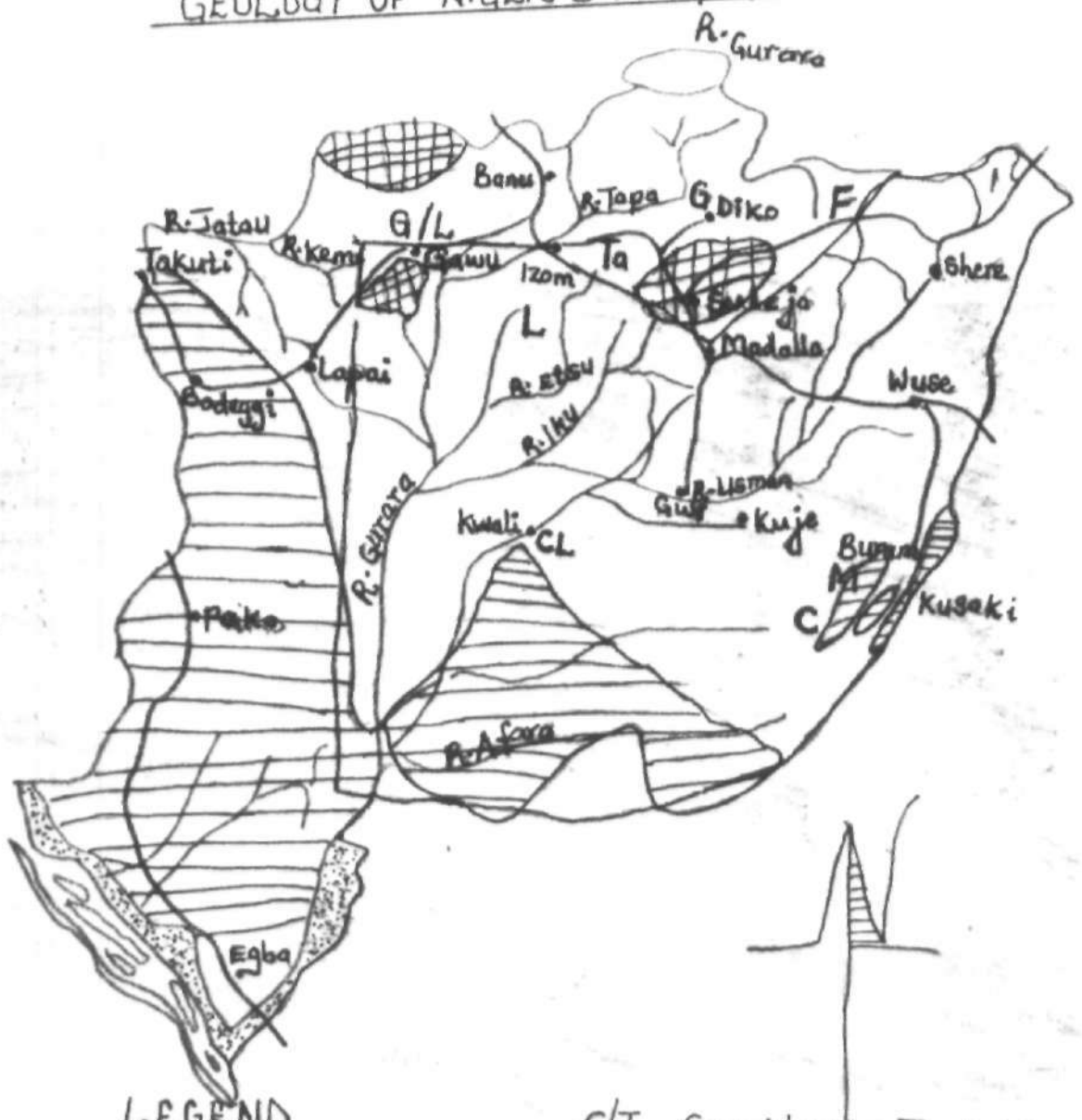
Design Implications:-

Due to the fact that this Industry has two shifts, morning to afternoon and afternoon to evening, I provided sufficient sun shading devices to take care of the angle of the sun from 7.30 a.m. to 5.30 p.m. when the sun is no more strong. External walls are sufficiently isulated to minimise heat transmission, for example in the production Hall I provided aluminium cladding inorder to reflect most of the angles of the sun incident on the wall. Roof covering is also aluminium to serve the same puppose as above. Sufficient landscaping has been provided to counter-act glare effects.

(d) Vegetation:-

The site lies within the Southern Guinea Savannah zone which is basically on open wood land with scattered few ever-green trees with umbrella - shaped canopies. Savannah grasses are as tall as two to three and a half meters. Very few trees survive the dry season with substantial amount of leaves on the while all trees remain evergreen for the period of wet season. Most trees here have an average height of 6 meters. The commonest types of trees in this area are sheabutter, mangoes, melina, isoberlina, locust beans and oil bean trees. A few number of palm trees grow on the river banks. All grassess her die off during dry season except those by the river banks or

GEOLOGY OF NIGER STATE/FEDERAL CAPITAL



Design Implications:

I have planned planting of both trees and grosses for both aesthetics and checking of wind and erosion effects.

(e) Topography:-

Is the over all description of things like terrain, valleys, rivers and roads etc. of an area. Topography has strong influences on the force, direction and moisture content of the air.

As earlier mentioned this project site lies within contours 447 and 459 at interval of three meters. The terrain is relatively flat with less than 4% slope. The site's subdued relief is associated with various types of erosion surfaces as a result of weathering. Most area of this vast land is placed on basement complex rocks, consisting of crystalline rocks of granites, granite-greissess, pegmatites, subordinate mota-sediments and migratites. The remaining land around the site is covered by Cretaceous sediments of Niger and Benue river basins, consisting of an upper clay and lower Nupe sandstone strata.

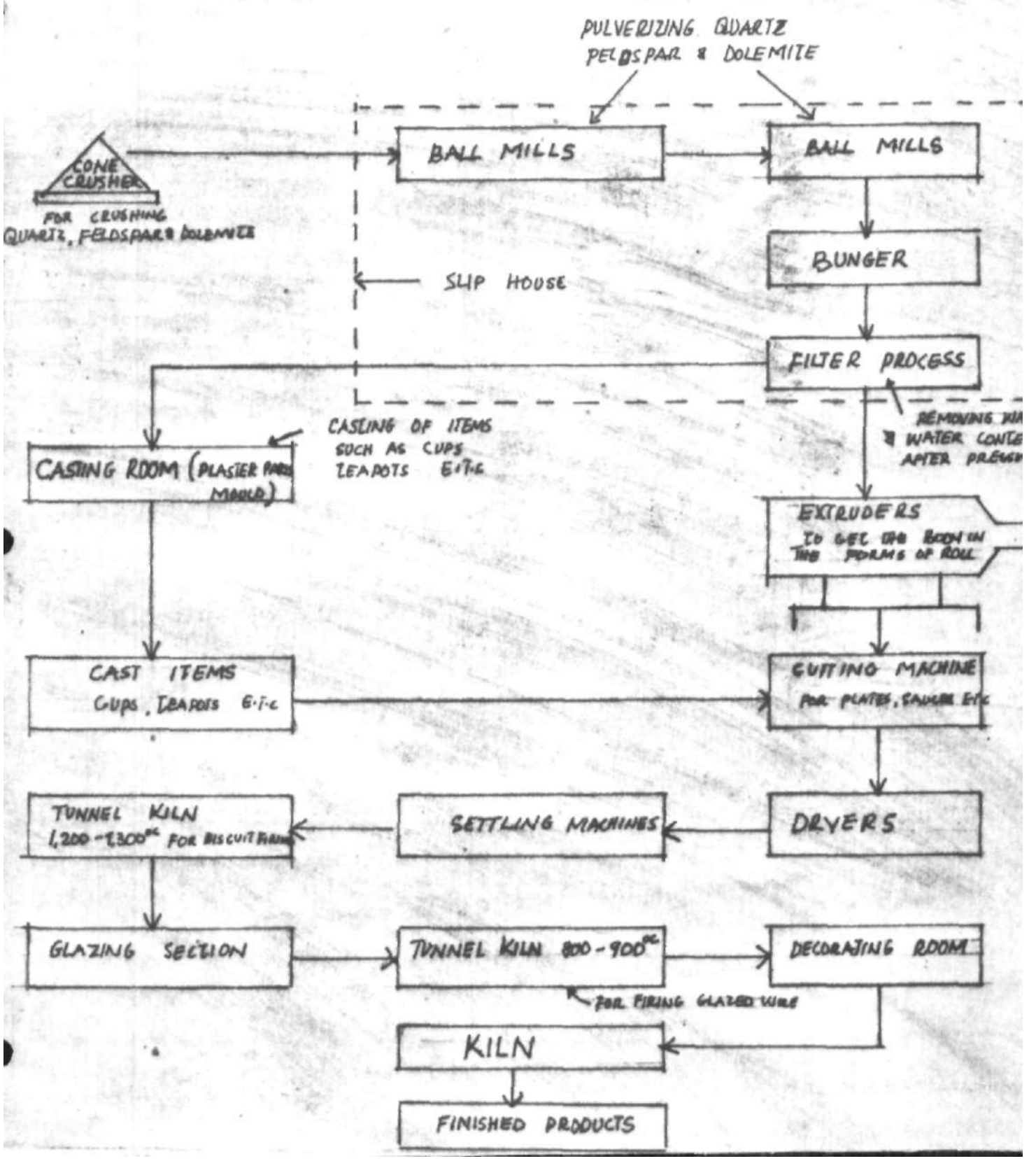
Design Implications:-

The drainage network of this industry is such that natural drainage pattern is strictly followed. Building orientation is such that distant beautiful views are observed from the main elevations. There are series of mountain ranges and some valleys a few kilos from the site.

(f) Soil Structure:-

Dominant red colour ferralitic soils on loosy sand sediments; Ferruginous Tropical soils and fersialitic soils on crystalline acid rocks. Most of the land around this area lies withing alluvial plains very good for agriculture while the underlying rocks are granitic in nature. Even the clayey material on chemical analysis, as such the workmanship for the foundations should be properly done as the structural calculations have already been done.

FLOW DIAGRAM FOR CERAMIC PRODUCTION



CHAPTER – IV

THE INDUSTRY

Basically my Industry is divided into three parts and they are listed below:

(a) Main Hall Production Part: There are two main Hall production areas, one is for both wall and floor tile while the other for the production of sanitary wares. Two storage facilities are attatched on either end of the Production-Halls - one for the storage of raw materials while the other is for the storage of products.

(b) Workers Facilities: This includes Administrative block, Canteen, Changing rooms, Common rooms and First Aid room as hospital is very near to the factory no need providing a Clinic.

Services:

(c) This includes, Mechanical, Electrical and Capentary work-shops, fuel and water services.

Space Requirement:

(a) Production Hall and Storages:-

- Wall and Floor Tiles)
- Sanitary Wares) Production Halls

Raw Materials:-

- Kaolin)
- Clay)
- Feldspar)
- Quartz)
- Glazes)
- Gypsum)

- Water
- Fuels
- Oils
- Defloculants

} Storages.

(b) Workers Facilities:

Administrative Block ... ...

- Entrance Lobby
- Receptionist/Waiting/Show room
- Managing Director, Secretary and a Clerk
- Deputy Managing Director
- General Managers
- Assistant General Manager

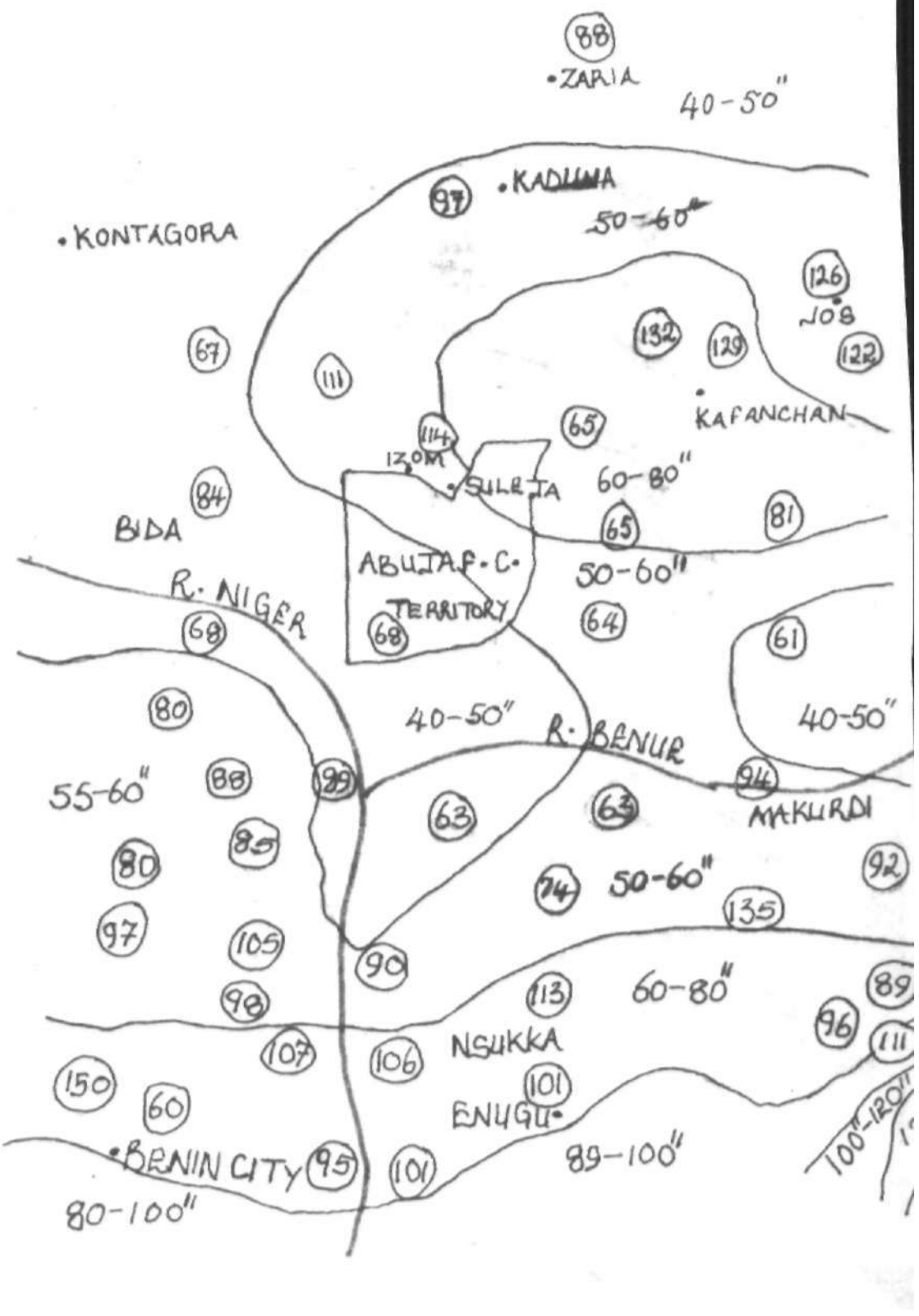
} 1 Secretary and

- Personnel Manager
- Sales Manager

} 1 Secretary and

- Sales Representatives
- Administrative Secretary
- Purchase Manager
- Purchase Clerk
- Principal Accountant
- Accountant II
- Accounts Clerks
- Labour Officer
- Registry or General Office
- Clerks (8 - 12)
- Survey Officer
- Mining Engineer
- Mechanical Engineer

MEAN ANNUAL RAINFALL



- Electrical Engineer
- Clerks (2)
- Soil Engineer
- Factory Officer
- Public Relations Officer
- Clerk (2)
- Production Manager
- Assistant Production Manager
- Laboratory/Lab. Technicians
- Clerks (2 or 3)
- Technical Officer
- Draughtsmen
- Conference Room
- Staff Meeting Room
- First Aid Room
- Toilets for Senior/Junior; Male and Female Staff
- Stores

Social Facilities:

- Entrance Lobby and Cloak Room
- 2 Common Rooms
- Canteen
- Kitchen
- Out Door Kitchen
- Stores
- Foreman's Office
- Male Changing room with Toilets and Showers
- Femal Changing room with Toilets and Showers

(c) Auxiliary Services: ... ...

- Boiler House
- Generator room/Transformer
- Switch Box room
- Electrical Workshop/Stores
- Mechanical Workshop/Stores
- Capentary Workshop/Stores
- Vehicle Service and repair garage
- Filing Station
- Timber Storage.

Parking:

- Bicycle or Motorcycle shade (350)
- Parking for Trucks bringing raw materials (16)
- Parking for Trucks delivering Products (20)
- Staff and Customers Car Parking (40)

THE INDUSTRY REQUIREMENT

Raw Material intake for Sanitarywares Production

Elements	Daily Consumption	Days a Week	Weekly Consumption	Specific Consumption per Ware
1. Raw Material				
- Slip preparation	19,500kg	6	117,000kg	17kg/Ware
- Glazes preparation	1,100kg	6	6,600kg	1kg/Ware
2. Raw Oil - Kilns	5,160kg	7	36,100kg	
3. Water (Industry + Portable)	100m^3	6	600m^3	0.1m^3 Per Ware
4. Electricity				
- For Production Instal and auxilary	4,900kwh	7	34,300kwh	4.9kwh/ware
5. Plaster of Paris	5,112kg	6	30,672kg	5.01kg/ware

The most bulky raw materials is the clay and this is brought 3 days per week by 16 tippers each unloads in the siles or boxes on Mondays, Wednesdays and Fridays. The slip preparation takes place almost daily while the glazes is prepared at interval of two days. The products delivery by vans is daily apart from Sunday.

Raw Material intake for Wall and Floor Tiles

Elements	Daily Consumption	Days Week	Weekly Consumption	Specific Consumption as per 1sq. mater of - Tiles
1. Raw Material				
- Slip preparation	56,000kg	6	336,000kg	12kg/m^2
- Glazes	4,660kg	6	27,960kg	1kg/m^2
2. Raw Oil				
- Spray drier	280kg	6	1,680kg	
- Kilns	8,280kg	7	49,680kg	
			51,360kg	1.81kg/m^2
3. Water				
- (Indust. + Portable)	50m^3	6	300m^3	0.01m^3/m^2
4. Electricity				
(i) for production Instl.				
(a) Motors	9,296kwh	6	55,776kwh	
(b) Kilns	2,709kwh	7	18,963kwh	
			74,739kwh	2.64k.w.h/m^2
(ii) For instal of extra services	252kwh	6	1,512kwh	0.05kwh/m^2
5. Deflocculants	1,500kg	6	9,000kg	0.51kg/m^2

HASHIM IBRAHIM LIBRARY

PRODUCTION ... .

Production Machinery List for Tiles Production:

A - Raw Material Crushing and Weighing Section:

(i) - Mechanic oil blade for transport of raw materials
- 0.5 Cubic meters capacity

(ii) - 1 Installation for the weighing of many Components of raw materials.
- Balance with 3,500kg Capacity
- Register of daily weighing
- Box feeder of 6m length
- Power inst. 15 H.P.

(iii) - 1 Raw material pounder, humidity of 3 - 4%
- This machine reduces clay to pieces of pieces of 25mm
- Capacity 15,000kg/h
- Power Inst. 20 H.P.

(iv) - 1 Fixed Belt conveyor
- Width: 600mm
- Length 4,500mm
- Power Instal; 0.5 H.P.

(v) - 1 Belt conveyer fixed and inclinable
- Length: 24, 500mm
- Width: 600mm
- Power Instal: 3.0 H.P.

(vi) - 1 Belt conveyor and inclinable
- Length: 4, 500mm
- Width: 600mm
- Power instal; 0.5 H.P.

(vii) - 1 Fixed and Inclinable Belt conveyor

- Length: 10,000mm
- Width: 600mm
- Power Instal; 2 H.P.

B - Slip Preparation Section:

(i) - 6 Ball Mills of 16,000 Litres each 7,000kg can easily be discharged by compressed air (including the internal covering and milling Silex load)

- Total power inst; 300 H.P.

(ii) - 3 Mills platforms 16,000L.

(iii) - 1 Water-meter with dosage valve for the mills load

(iv) - 1 Movable electric tally, one rail with motor car.

- Power inst; 4 H.P.

(v) - 4 Vibratory sifters 600 x 900mm for slip control

- Total power instal; 1.5 H.P.

(vi) - 3 Transferer pumps for slip from storage tanks to spray tank.

- Capacity 9,000 L/h each
- Power Inst. 15 H.P.

(vii) - 4 Cement tanks with Internal covering of green tiles for slip retirement, discharge by the mills.

- Capacity 50 cu. meters each

(viii) - 4 Agitators with blades, to be used in the above mention tanks.

- Total power inst; 4.5 H.P.

(ix) 1 Metallic tank to Feed the Spray Drier, equiped with agitator.

- Power inst: 5 H.P.

- Capacity $4m^3$

(x) - 1 Vibratory Sifter 600 x 900mm with permanent magnet for the slip control.

- Power inst. 0.5 H.P.

C - Spray Drier and Powder Storage Section:

(i) - 1 Spray drier (drier for the production of the powder to be pressed to form green tiles)

Technical Figures:

- Evapouration power 2,000kg/h (Water evapouration)
- Water quantity in slip 40%
- Termic consumption 900k. cal/kg of evapourated water
- Power inst. 140 H.P.

The Spray Drier is made up of the following Clements:

(a) - Drying Camera in steel structure, internally covered by inox. steel equiped with glass wool between the internal and external parts.

(b) - Tubulation for hot air and tubulation for discharge

(c) - Heat genorator

(d) - Cyclones

(e) - Exhauters and diffusers for cooling

(f) - Pendular Valve

(g) - Humid air Ventilator

(h) - Sustenance Structure for the Cyclones drying Camera

(i) - 2 Feeder pumps (one on reserve)

(j) - 1 Conjuct of Sprayers and injecters

(k) - 2 Electromagnetic Hammers

(l) - 1 Discharge Valve

(m) - 1 Electric Panel

(ii) - 1 Vibratory sifters 600 x 900mm to control power

- Power inst. 0.5 H.P.

(iii) - 1 Fixed Belt conveyor

- Length 9,000mm

- Width 600mm

- Power inst. 1 H.P.

(iv) - 1 Cans elevator of 17m for the transportation of atomized powder

- Capacity: 15,000kg/h

- Potency; 7.5 H.P.

(v) - 1 Belt conveyor, movable and reversible

- Length: 6,000mm

- Width: 600mm

- Power inst. 1 H.P.

(vi) - 4 Metallic Silos for powder storage

- Capacity 100 Cu. meters each

(vii) - 8 Level indicators for the above mentioned silos (4 of maximum/4 of minimum levels)

(viii) 3 Extractor Vibrator dosers to be used in the 4 above mentioned silos

- Total power inst. 6 H.P.

(ix) - 1 Fixed Belt conveyor

- Length 12,000mm

- Width 600mm

- Power inst. 1.0 H.P.

(x) - 1 Vibratory sifter 600 x 900mm for control of the powder to be pressed

- Power inst. 0.5 H.P.

(xi) - 1 Fixed and inclined Belt conveyor

- Length 22,000mm
- Width 600mm
- Power inst. 2 H.P.

(xii) - 1 Movable and reversible Belt conveyor

- Length 21,000mm
- Width 600mm
- Power inst. 2 H.P.

D - Tile Pressing Section:

(i) - 4 Automatic presses (2 each for wall/floor tile bodies) with mill receptacle, service, platform, model retiring pilers, pannel control and regulation of the models temperature.

- Total power inst. 250 H.P.

(ii) - 8 Level indicators for the silos presses (4 maximum and 4 minimum levels)

E - Drying and Burning Section:

(i) - 1 Continuous tunnel drier working to recuperate the hot air of the cooling place in the tunnel kiln.

Technical Figures

- Length: 92.000mm

- Forseen drying cycle 48 hours approximately
- Meximum temperature 130°C
- Power inst. 46 H.P.

ii) - Continuous Tunnel Kiln, with oil heating

Technical Figures

- Length: 92,000mm
- Useful Section of Load
- Width 1050mm
- Height 1020mm
- Cars working in the kiln: 38
- Load on the Car (one) 222m^{2}of 150 x 150 x 5.5mm of wall and floor tiles.
- Forseen burning cycle 48 hours approximately
- Forseen burning temperature 1020°C
- Max. burning temperature 1150°C
- Daily production 4,000m^2
- Consumption: 980 k.cal/kg of net product
- Potency: 89 H.P.

(iii) - 4 Transferer cars to carry the little kiln cars from the drier to the tunnel kiln

(iv) - Little wagons for the drier and kiln with metallic part, refactory and isolating.

- Little wagons in drier: 38
- Little wagons in kiln: 38
- Little wagons for a storage of 36 hours: 26
- Little wagons in circulation and maintenance: 8

E - Glaze Preparation Section:

(i) - Balance for weighing of glazing raw materials
- Capacity: 1,500kg

(ii) - 2 Metallic recipients, movable with wheels for the glazing material loading.

(iii) - 1 Electrical tally, movable with car on one rail
- Capacity 2,000kg
- Power inst. 4 H.P.

(iv) - 2 Metallic platforms for the mills loading

(v) - 4 Ball Mills, 5,000L Capacity and are able to be discharged by compressed air for milling the compon of glazes.
- Total power inst. 80 H.P.

(vi) - 1 Water meter with doser, for loading the mills

(vii) - 1 Pump for the transfer of glazes
- Capacity: 2,000L/h
- Power inst. 2 H.P.

(viii) - 7 Metallic tanks with blade agitators

(ix) - 2 Vibratory sifters 300 x 500mm to the glaze control

(x) - 4 Little cars with inox. tank
- Capacity: 420L. each

G - Glazing and Glaze Burning:

(i) - 4 Autematic tubular enamel, 94m length + 25m for the little wagons loading to be put in the tunnel kil
- Potency: 115 H.P.

(ii) - 1 Tunnel kiln, oil heating, for the enamel burning of the tiles.

Technical Figures

- Length 91,750mm
- Useful loading Section
- Width 150mm
- Heigth 1,150mm
- Little wagons in the kiln: 55
- Little wagons for 48 hour's storage and reservation: 205
- Total Little wagons: 260
- Charge on one little wagon: 47.5m^2 of tiles 150 x 150 x 5.5mm
- Burning temperature 980°C
- Max. burning temperature 1,150°C
- Burning Cycle 15 hours 30 mins.
- Daily Production 85 little wagons equivalent to 4.037m^2 of tiles (wall and floor).
- Consumption 1,100 k.cal/kg of liquid load
- Total power inst; 80 H.P.

(iii)
- 222 Little wagons for the Kiln with metallic part refractory
- Little wagons in the Kiln: 55
- Little wagons in Circulation and maintenance: 15
- Little wagons for 48 hours storage: 155

(iv) - 4 Transferrer Cars able to transport 2 wagons at a time

(v) - 2,678 Meters rail lines TR-25

H - Choicing and Packing Section:

(i) - 2 Chocing line Compounded by
- 1 Feeding Part
- 1 Part for handly choice by 2 persons
- 1 Part for packing
- 1 Part for Card boxes
- Power inst; 4 H.P.

(ii) - 2 Pillers by oil
- Capacity 1,500kg each

I - Technical Figures for Installation:

8 (i) - Electrical power: 220/380 V.

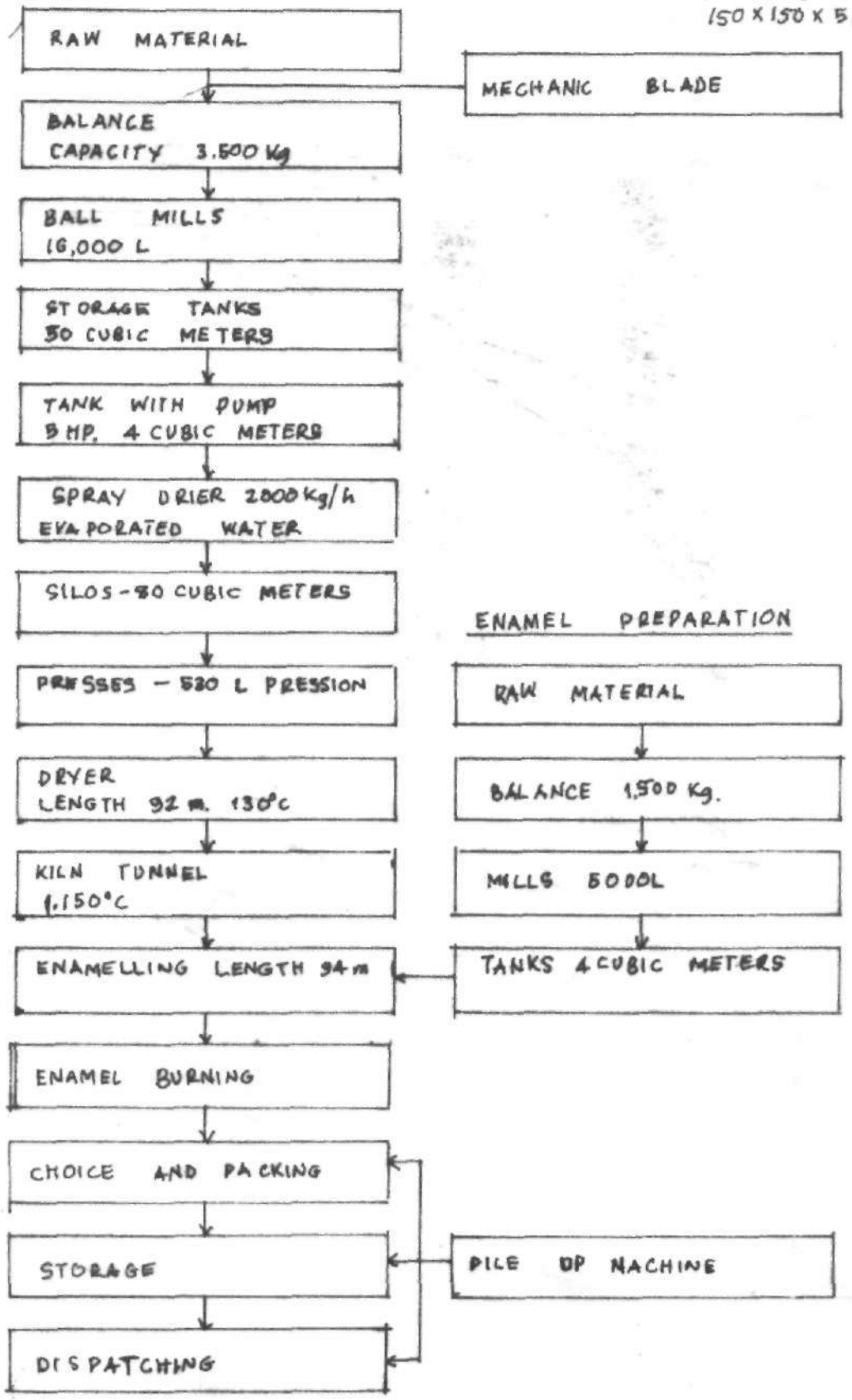
(ii) - Frequency: 60 H_2

Sections

		H. P.
(a)	For Production Installation	
-	Raw material crushing and weighing	43.5
-	Slip Preparation	369.0
-	Spray Drier	117.5
-	Pressing	250.0
-	Drying and Biscuit Firing	135.0
-	Glaze Preparation	108.0
-	Glazing and Burning	195.0
-	Choicing	4.0
		1,282.0
(b)	For Auxiliary Installations	120.0
	Total (a + b)	1,402.0

T PRODUCTION CHART FLOW
WALL TILES

MONTH PRODUCTION
120.000 SQ/M
MEASURES
150 X 150 X 5,5 mm



(iii)- Oil Necessity

- Inst. Capacity: 430kg/h
- Security 20%
- Oil Calorific Power 10,000 k.cal/kg

(iv) - Water Necessity

- Installation Capacity 50m^2/h there is Industrial water, a pression of 4kg/m^2approximately.

TECHNOLOGICAL PRODUCTION PROCESS OF TILES

Raw Materials:

The raw materials will come to the Industry by tippers about 16 in number. The raw material goes to the balance with the help of mechanic blade. From the balance it is carried into the ball mills via belt conveyors or lifts and it is also passed to the raw material pounder before being carried into the ball mills.

Slip Preparation:

The ball mills are covered internally by silex. When raw material is already in the ball mills, Calculated quantities of both water and deflocculants are added. After milling for a specified number of hours, the slip is discharged with the help of compressed air through the vibratory sifters into the storage tanks which are equiped with agitators. From the storage tanks, slip is transfered with the help of membrane pump, through the vibratory sifters into the feeding tank of spray drier. The vibratory sifters are equiped with complete magnet. The slip is carried out of the tank by the pump of the spray rier.

Atomizing and Powder Storage:

The liquid slip is dried and reduced to powder by the "spray drier". The powder is carried into the storage silos with the help of a fixed belt conveyor through the vibratory sifter. The silos are equiped with indicators of levels max/min. and with dosing of discharge extractor. The powder is carried from the silos to the presses silos with the help of belt conveyors and one movable and reversible belt conveyor. The granular size of the powder is checked by a vibratory sifter.

Pressing of the Tiles:

From the silos, the powder is fed onto the automatic presses provided with stampers. At 400 atmospheric pressure floor tiles are being produced by two presses while the remaining two presses produce wall tiles at 300 atmospheres but are called green tiles at this stage. From the presses tiles are automatically piled up.

Drying and Burning of Green Tiles:

The piled up tiles are carried in little wagons into the drier and then into the Kiln for both drying and burning respectively with help of transfer cars. After burning the little wagons are sent to the enameler where the tiles are discharged.

Glaze Praparation:

The preparation of glazes is the same precess as slip preparation the only difference is that of storage. In the case

through sifters provided with permanent magnet for checking.

Glazing and Glaze Burning:

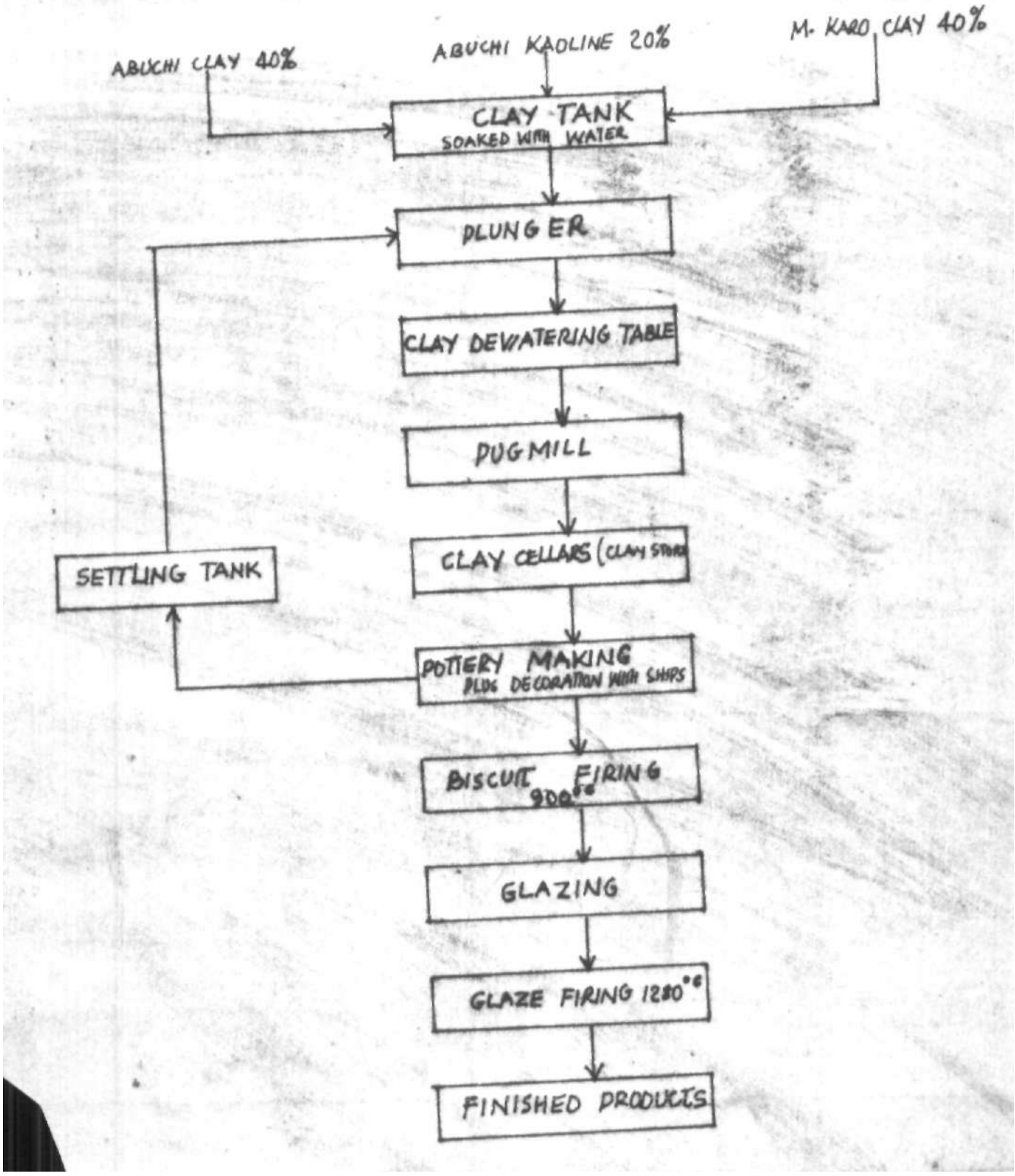
The glazing is by automatic glazers complete with serigraphic headstocks for the tiles decoration. At the end of the glazing lines, the tiles are carried manually into the little wagons of the tunnel kiln for burning the glaze. The little wagons for burning the glaze are taken by rails and transferrer cars till the entry point of the kiln.

The burning takes place in tunnel kiln, internally refractory. The tiles are carried in boxes, fixed on the cars. After coming out of the kilns, tiles are cooled and later retired and discharged manually onto the choicing desks.

Choicing and Packing:

The choicing is also done manually. After packing and locking of tiles in boxes, they are sent to the Storage area by Pallets and Pilled up machines.

SULEJA POTTERY-
FLOW DIAGRAM



PERSONNEL (Tiles Section):

SECTIONS	Days a Week	Turns by Day	Employees by Turn	Total Employees
(a) For Production Installation				
Raw material crushing and weighing	6	2	2	4
Slip Preparation	6	2	2	4
Spray Drier	6	3	1	3
Pressing	6	2	10	20
Tiles Drying and Burning	7	3	3	9
Glaze Preparation	6	2	2	4
Glazing	6	2	20	40
Glaze Burning	7	3	3	9
Choicing and Packing	6	1	12	12
(b) For Installation and Auxiliary Services			B/F	105
Maintenance	6	3	4	12
Various Services	6	1	2	2
Turning Change	6	1	8	8
T O T A L				127

Production Machinery list for Sanitary wares Production:-

AI - Raw material Crushing Section:

(i) - 1 Raw material pounder

- power inst. 15H. p.

A2 - Raw material Weighing Section:

(i) - 1 Fixed balance with out Improssor, for raw material weighing

- Capacity 2,000 kg.

(ii) - 6 Metallic recipients

- Capacity 1,600 kg. each

(iii) - 1 Movable electric tally, one rail with meter

- Capacity 2,000 kg.

- Power inst. 5 H. P.

(iv) - 1 Mechanic blade

(v) - 2 Little wagon with rubber wheels

B - Slip Preparation:

(i) - 1 Water meter for quality control of water in the mills complete with electre valve.

(ii) - 4 Ball mills of 16,000L each for raw material milling able to be discharged by compressed air. Complete with internal covering and milling silex load.

- Power inst; 30 H.P. each

(iii) - 2 Membrane pump for the mills discharge.

- Capacity 9,000L/h each

(iv) - 2 Storage cement tanks

- Capacity 14m^3 each

(v) - 4 Agitators turbines for clay mixing.

(vi) - 2 Membrane pumps for the storage tanks discharge

- Capacity 9,000L/h each

(vii) - 2 Vibratory sifters for the slip control, 600 x 900mm complete with magnetic separaters.

(viii) - 4 Mixing tanks, cylindrical and subterranean, for slip homogenization.

- Capacity: 48m^3 each.

(ix) - Agitator blades for tanks before being exposed

(x) - 2 Membrane pumps for the discharge of slip from the mixing tanks to gluing section.

- Capacity: 9,000L/h each.

C - Glazes Preparation Section:

(iii) - 2 Ball mills of 3,000L, completed by internal covering and milling streatite lead.

(iv) - 2 Ball mills of 500L capacity each completed by internal covering and milling steetite load

(v) - 2 Membrane pumps for glazes

- Capacity: 2,000L/h

(vi) - 8 Tanks for glaze storage completed by blade agitators

- Capacity $4m^3$ each

(vii) - 2 Vibratory sifters completed with magnetic separator of 500 x 300mm.

(viii) - 20 Cylindrical recipients, ^{c}mx.stell, 50L each for the transpertation of glazes directly to the storage tanks, for glazes pulverization.

D - Gluing or Casting Section:

(i) - 380 Wood tables for pieces gluing

(ii) - 60 Wood tables manual turn bench for pieces finishing.

(iii) - 1 Column mixing machine, immersion type for slip preparation.

(iv) - 1 Emery machine for the pieces finishing

(v) - 15 Buckets with discharge registers.

(vi) - 2 Little cars with wheels for the handly transport of the buckets, complete.

(vii) - 1 Centrifugal pump, immersion type

(viii) - Complete conjuct of tools for this section

E - Confection and Storage of Gypsum Moulds:

(i) - 1 Fixed balance for gypsum weighing

(ii) - 1 Agitator with vertical axle for gypsum mixing moulds confection.

(iii) - 6 Steel movable recipients with wheels for the gypsum storage.

- Diameter 600mm
- Height 750mm

(iv) - 4 Tables for the moulds confection with marble cover

(v) - 30 Wood tables for moulds gluing

- Dimensions 2000 x 750mm

(vi) - 1 Transport cars with "forks" for moulds

(vii) - 1000 Wood pallets

(viii) - 1 Drier moulds, operating with hot air from the kiln.

(ix) - 1 Complete conjuct of matrixes for the gypsum moulds production.

F - Raw Pieces Drying Section:

(i) - 1 Aerial transporter to take the pieces from the gluing section to the glazing and inspection section complete by electrical installation and automatic lubrification.

Technical Figures:

- Total length of transporter: 1,500mm apprex.
- Space between balance: 1,625mm
- Medium load in each balance: 100kg.

(ii) - 1 Support conjuct for the above mentioned transporter

(iii) - 923 Balances of metallic structure and wood floor for raw pieces.

G - Inspection and Glazing Section:

(i) - 6 Cabins for inspection and cleaning of raw pieces.

(ii) - 4 Glazing cabins

(iii) - 3 Rotative tables for glazing and rotative tables for the positioning of the pieces.

(iv) - 10 Glazing Units, spray type with pression tanks for raw pieces glazing comprising of:
Pression tank of 50L capacity
Pulverization pistol, special for ceramic glazes

(v) - 12 Pistols of compressed air for inspection cabin

(vi) - 25 Wood tables

(vii) - 120 Storage recipients for glazes pieces (48 hour storage)

H - Burning Section:

(i) - 1 Tunnel kiln for sanitaries burning invitreous Chi

Technical Figures for the Kiln:

- Kiln's total length 67,100mm
- Useful dimention of load in a little car:
- Width: 1,400mm.
- Height: 750mm.
- Length 2,135mm
- Cars working in the kiln: 32
- Pieces in each car: 18
- Exercise temperature 1,250°C
- Maximum burning temperature 1,280°C
- Burning Cycle 24.00 hours
- Production during 27 h. of continuous work: 650 of vitreous China sanitaries.

- Combustible: Oil 63
- Consume: Like the burning conditions above mentioned, the consumption will be 2,100 k.cal/kg of set product in the kilns.
- Tolerances 10%

) - 55 cars for the kiln, 52 of which are to be used in the kiln while 23 for 10 hour storage.

Material for the Cars

- metallic structure and retative parts
- mansory
- car borundum plates.

i) - 1,344 meter rail lines TR - 25

- Choicing and packing section:
- 1 Installation for hydraulic tests of sanitary vessel and bidets, to be done by Customer.

) - 1 Belt conveyor for the selection and classification of finished products.
- length: 20,000mm approx.
- width: 600mm

i) - 1 Car with wheels for handly transport of pallets

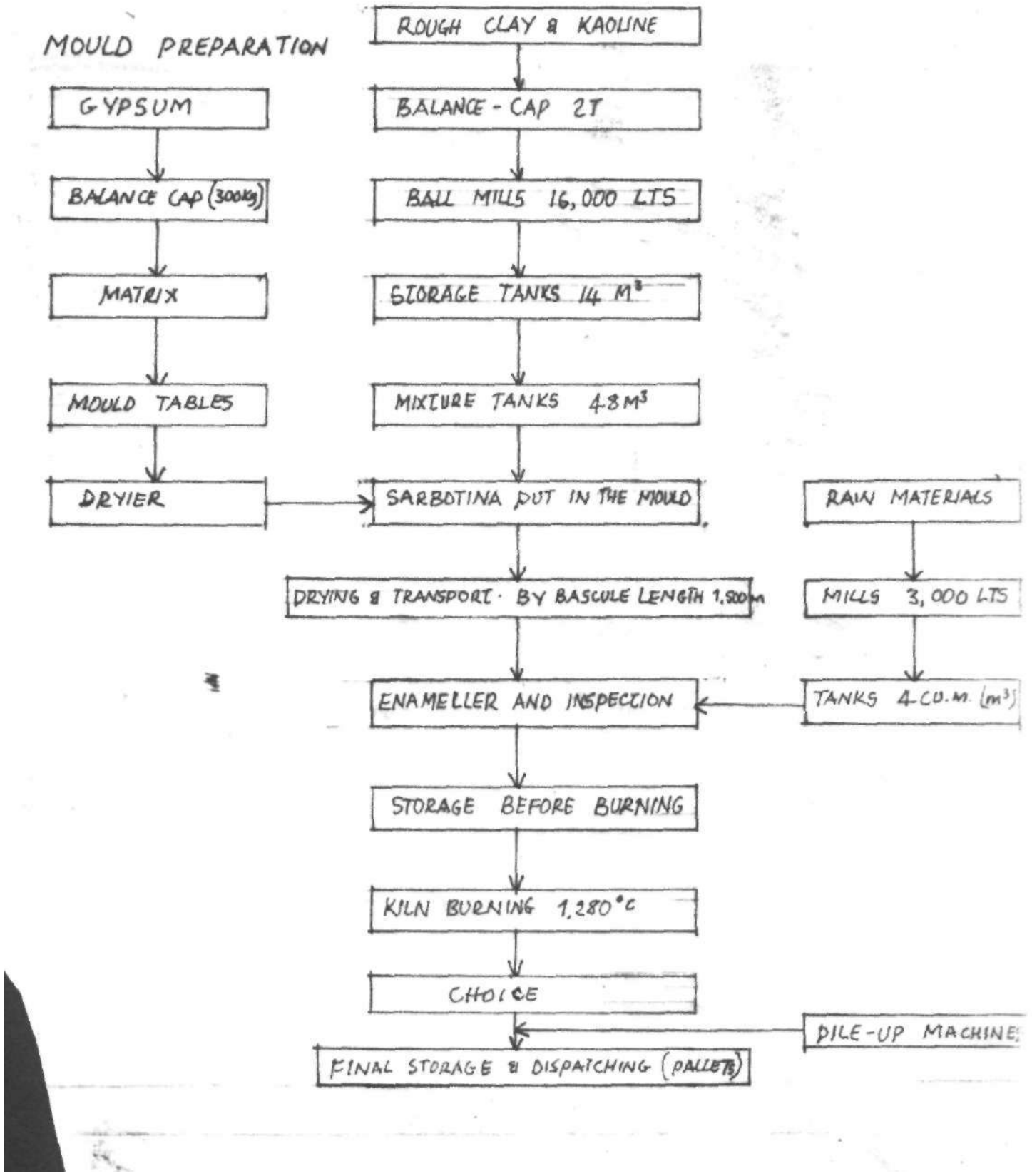
) - 100 Wood Pallets with lateral supports to transport the finished products to the storage area.

- Retification finishing machine of bidets and sanitary vessels:
- vertical type.

FLOW CHART DIAGRAMS

(SANITARY WARE PRODUCTION)

HOW MANY PIECES DO YOU PRODUCE PER MONTH ? (approx).



(vii) - Retification and finishing machine of lavatory basins and columns:
- horizental type.

(viii) - 2 Pile up machines (diesel)
- Capacity: 1,500 kg.

TECHNOLOGICAL PROCESSES FOR THE PRODUCTION OF SANITARIES:-

Raw material storage section:

The boxes provided are used for the storage of raw material kaoline and clay: quartz and feldspar. The total area is calculated to receive the different types of clays from different geographical location. Two of Kaoline, Four of feldspars and Quartz Three to Four different types. They can be stored for a maximum period of two to three months.

One box is reserved for gupsum while two are for the glazing materials. The raw materials is weighed with the help of balance from there is sent to slip preparation section via an electric tally or a lift.

Slip Preparation:

It is the same process as in the case of slip preparation for the production of wall and floor tiles.

Gluing or Casting Section:

This section is compounded with many tables, to support the gypsum moulds, in which is injected the liquid slip. On these tables, open and close the moulds operation takes place which liquid slip injected into the moulds under pressure

with the help of rubber tubes and special registers.

Confection and storage of gypsum moulds:

After adding correct quantity of water to weighed amount of gypsum, it is then put in a vibratory sifter with vertical axle. After the mixing process is over, the Can is sent to tables to prepare the moulds. Tables with marmol cover, for gluing of moulds, rotative tables for the finishing and for the washing and cleaning of Cans. The moulds are transported to an appreciable drier by pick up machine. The temperature and humidity air control of this drier is such that perfect dried moulds are obtained.

Raw pieces drying Section:

The fused pieces before being sent to the glazing section they are dried first with the help of dispersed heat from the kiln. With the help of bascule aerial transportation system, the pieces are carried to the burning section and finally returned to the inspection and glazing section.

Glaze preparation:

It is the same technological process as in the glaze preparation for the production of wall and floor tiles.

Glazing and Inspection Section:

The dry pieces are removed from the earial transportation system and carefully inspected by the operators, in cabins provided with section equipments and powder collector. After inspection, the pieces go to the glazing cabins, equiped

with glaze recuperator and a suction system. The glazing is done by compressed air pistols, continuously fed by pression cans, with the glaze proceeding from the glaze section. The glazed pieces are put in wagons near the kiln service line.

Burning of the glaze:

The burning takes place in Kiln of oil burners and the little wagons are put on the Canal of the Kiln. Maximum burning temperature is 1,280°C. Some ventilators keep the aspiration and exhaustion of the gases, the jet at the exit and entry, hot air circulation and the quick cooling of the pieces. The number of wagons are the normally used once plus storage of 36 hours. There is a switch controlling the temperature and other techincal figures of the kiln. The continuous entry of little wagons into the kiln is maintained by an automatic ail dynamic pusher.

Choicing and Dispatching Section:

The pieces are transported from the kiln to the choicing tables which are based on the quality control and hydraulic test operation.

PERSONNEL (Sanitaries Section):-

Section Chieves:-

1. For slip and glaze preparation.
1. For gluing or casting section.
1. For confection and storage of gypsum moulds.
1. For inspection and glazing section.
1. For burning section.
1. For choicing and delivery.

Installation of production and auxilliary services:-

Work turn and hand work:

- Slip and glaze preparation section

  1 work turn of 8 hours, 5 days a week

- Gluing or Casting Section

  1 work turn of 8 hours, 5 days a week

- Inspection and glazing section

  1 work turn of 8 hours, 5 days a week

- Mould preparation section

  1 work turn of 8 hours, 5 days a week

- Choicing, Storage and delivery section

  1 work turn of 8 hours, 5 days a week

- Burning Section

  1 work turn of 8 hours, 5 days a week

  Charge and discharge of the kiln cars:

  Kiln operation - 3 turns of 8 hours, 7 days a week

  Total Number of Forseen Personnel for this section:

  200 - 250 persons.

  Examples for the daily intake of raw materials

  (Nigergrob ceramics Ltd. Abeokuta)

(a) Sanitaryware slip body preparation:-

Feldspar	2,464 kg.
Silica sand	864 kg
Oshielo clay	552 kg
New Ibamajo clay	840 kg
Old Ibamajo clay	840 kg
Degesin clay	840 kg
Shium clay	800 kg
Ball clay	800 kg
Deflocculants (chemicals)	20 kg
Water	3,000 litres
Time	60 hours rolling in Ball Mills.

(b) Tiles slip body preparation:-

Biscuit tiles	1,440 kg
Itori clay	1,600 kg
New Ibamajo clay	640 kg
Oshielo clay	2,000 kg
Limestone	500 kg
Shium clay	400 kg
Silica sand	500 kg
Degesin clay	300 kg
Water	3,500 litres
Deflocculants	20 kg
Time	15 Hours rolling in Ball Mills.

C H A P T E R V

Part I: Raw Material Supply:-

Suleja as already mentioned is where this industry is located and practically almost all the necessary raw material are obtainable within a maximum distance of 100 km. The raw materials obtained include ball clay, kaoline, limestone, feldspar, sand and even some of the glazing materials are locally mined, while gypsum or paster of Paris is to be imported together with modern glazing materials. Mining of these materials has never been carried out on industrial scale but within a techincal know-how of the consultants that carried out the survey assured the Niger State Government that the materials can be usedto produce both sanitaries and wall and floor tiles.

The plants Maximum Capacity is between 18,600 - 19000 tons per year of raw materials approximately. And these gifures have been further broken down to the following:-

1. Ball clay 4,600 - 5,000 tons approximately
2. Kaoline Clay 2,000 - 2,200 tons approximately
3. Feldspar 2,000 - 2,200 tons approximately.
4. Limestone 1,600 - 1,800 tons approximately
5. Silica Sand 9,000 - 1,200 tons approximately
6. Red Clay 5,000 - 5,200 tons approximately

All the above listed materials are obtained in the following places; Abuchi, Dangara, Stada-Ball Clay; Dadi, Dangara - Kaoline; Burum, Takushara - Feldspar; Limestone

Chemical Composition:

Ig.Loss	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Ti_2O	T
7.51	62.02	16.88	6.33	0.99	1.0	3.45	0.95	0.8	

Mineral Composition:

Sericite in a very small quantity

Felspar in a very small quantity

Quartz is a very a large quantity

Firing Characteristics:

Firing Temperature °C	1050	11000	1150	1200
Shrinkage %	3.4	4.4	4.8	6.8
Water Absorption %	9.0	7.2	5.4	2.2
Bending Strength Kg/Cm^2	72	95	116	181
L (%)	42.3	38.9	34.4	32
Chromaticity (a) (G-R)	17.4	14.0	11.9	8.1
(b) (B-Y)	16.5	13.1	10.0	5.7

Summary Evaluation:

(i) This clay is very special one, it contains both Sericite and feldspar. There is large content of Fe_2O_3 (about 6.33%) and on firing it turns strongly reddish.

(ii) The plasticity of the clay is very large and is very suitable as a plasticizer, but its high Iron content makes it unsuitable for vitreous table and table wares although it is suitable for sanitary wares, wall and floor tiles.

..-I (b) Dangara Clay

Location:

The clay deposits is situated in a village called Dangara at about 48 km south of Suleja .3% of Suleja Pottery clay comes from these deposits.

Chemical Composition:

Ig.Loss	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	TiO_2	Total
7.95	68.47	20.13	0.97	0.18	tr	0.15	0.13	1.33	99.31

Minieral Composition:

Quartz

Kaoline

Firing Characteristics:

Firing Temperature ^oD	1050	1100	1150	1200
Shrinkage %	1.1	1.7	3.0	4.5
Water Absorption %	16.0	15.7	13.5	11.2
Bending Strength Kg/Cm^2	41	62	92	118
L (%)	82.2	83.5	83.6	83.4
Chromaticity (a) (G-R)	1.8	1.3	0.8	0.4
(b) B-Y)	6.7	7.0	8.8	13.5

Sunary Evaluation:

(i) The clay is very sutable as a plasticizer for earthwares wall tile body material, judging from its chemical composition.

(ii) Becuase of its white firing chromaticity due to low F_2O_3 content, it is sutable for table wares and sanitaries. It can also be used as a glazing material, as its plasticity is very large.

A-I (c) Mallam Karo Clay:

The deposts of these materials, is situated at this village and its less than 10 km north west of Suleja ny industry site. All technical data's are the sane as those discussed for Abuchi Clay above.

A-2 Suleja Laterite:

Location and Ore deposits:-

Deposits are located within Suleja town and it provides colour stain for Suleja Pottery Centre.

Chenical Composition:

Ig, Loss	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	NaO	TiO_2	Total
8.72	48.51	13.04	27.60	0.23	0.12	0.72	0.08	0.58	99.[illegible]

Mineral Composition:

Quartz

Geothite and Hematite

Sunary Evaluation:

Due to geothite contents in the laterite it can not be used for the production of tiles and table wares but it is suitable as a colour stain due to its high Fe_2O_3 content.

A-3 Abuja Silicate Stone:

Large deposits of silicate stone are found within Suleja environment and it is used as glazing material by Suleja Pottery Centre.

Chemical Composition:

Ig.Loss	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	TiO_2	Total
0.32	98.63	-	Tr	-	-	-	-	-	98.95

Mineral Composition:

Quartz only.

Summary Evaluation:

(i) High purity silica stone with practically zero Iron (Fe_2O_3) content, this is most suitable for glazing.

A-4 Burun Feldspar

Location and Ore Deposit(s):

It is found in large deposits, about 60 km south of Suleja in Niger State but now belongs to the Abuja Federal Capital Development Authority. Suleja Pottery Traing Centre uses this feldspar for glazing after precalcining. No much information is know about the mineral and mining quantity.

Chemical Compostion:

Ig.Loss	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	TiO_2	Total
0.80	74.61	15.18	0.08	-	-	0.32	7.08	-	98.07

Mineral Composition:

Albite

Quartz

Firing Characteristics:

Firing Temperature ^oC	1050	1100	1150	1200
Strinkage %	0.4	1.39	14.2	15.8
Water Absorption %	19.5	18.0	0.6	0
Bending Strength Kg/Cm^2	6	62	254	375
L (%)	94.2	93.9	87.0	67.3
Chromaticity (a) (G-R)	1.6	0.6	0	0.6
(b) (B-Y)	5.7	4.1	3.8	3.5

Summary Evaluation:

(i) Feldspar is one of the raw materials and consist of high grade albite.

(ii) Having a melting point of 1,120^oC, it is a suitable material for vitreous products. It is also used as glazing material.

A-5 Takushara Feldspar

Location and Ore Deposits:

The Ore deposits are situated, south of Suleja at a distance of about 100 km. Suleja Pottery Training Centre makes use of these materials as glazing materials. Available information is lacking as regards to the Ore reserve and mining quantity, etc.

Chemical Composition:

Ig.Loss	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	Total
1.39	62.46	18.76	0.09	-	-	13.60	2.52	98.82

Mineral Composition:

Orthoclase

Summary Evaluation:

1. An Orthoclase of high purity
2. It has a variety of uses, as a body material and glazes for tiles, sanitary ware and table ware.

A-6 Shanagu Tale

Location and Ore Deposits:

This mineral is deposited to the sourth west of Suleja at a distance of about 30km. Suleja Pottery Training Centre use these materials as its glazing materials. No detail information about the ore reserve, ning, etc. is available.

Chemical Composition:

Ig. Loss	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	TiO_2	Total
7.41	52.28	3.75	7.70	1.52	24.19	0.37	0.12	Tr	97.34

Mineral Composition:

Tale

Montmorllenite and Al-Chorite

Firing Characteristics:

Firing Temperature ^oC	1050	1100	1150	120
Bending Strenth Kg/Cm^2	153	155	325	473
Shrinkage %	2.3	2.3	2.8	3.0
Water Absorption %	12.9	12.9	11.4	9.
L(%)	53.1	51.2	44.1	39.4
Chromaticity (a) (G-R)	13.8	13.2	103	8.7
(b) (B-Y)	17.0	15.8	13.1	9.5

Summary Evaluation:

1. Low grade tale, has high Fe_2O_3 content.
2. 20% of red quarry tile body can be this material.

4-7 Kwakuti Linestone

Location and Ore Deposit:

Ore deposit is located in Kwakuti north west of Suleja along Suleja - Minna road at a distance of about 45km.

Chemical Composition:

Ig. Loss	SiO_2	Al_2O	Fe_2O_3	CaO	MgO	K_2O	Na_2	Total
34.59	13.60	0.21	0.18	37.76	12.20	- -		98.60

Mineral Composition:

Calcite

Dolomite

Chlorite

Firing Characteristics:

Firing Temperature ^oC	1050	1100	1150	1200
Shrinkage %	0.9	3.7	4.0	10.1
Water Absorption %	57.8	53.0	48.1	40.0
Bending Strength Kg/Cm^2	16	38	50	77
L (%)	77.7	75.5	73.8	71.5
Chromaticity (a) (G-R)	-1.2	-0.9	-1.2	1.6
(b) (B-Y)	11.9	11.9	11.7	11.4

Summary Evaluation:

1. Contamination due to presence of dolomite, chlerite, 13.7% SiO_2 and 0.18 Fe_2O_3 results into its low purity.

2. The Firing Chromaticity is strongly yellowish, b = 11=12 and is for the production of white body tile, less than 10% is added as the limit.

A-8 C.C.C. Limepowder:

Location and Ore Deposits:

The material is got from C.C.C. Limestone Kawkuti after it has been crushed and screened by City Construction Co., Ltd. ready for sell. The powder is normally under size.

Chemical Composition:

Ig.Loss	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	Total
35.53	11.33	1.19	0.63	43.97	6.01	-	-	98.67

Mineral Composition:

- Calcite
- Dolomite
- Mica

Summary Evaluation:

1. Higher CaO content and low MgO content in powder compared to original limestone but the powder is of the same grade (Low) as the limestone.
2. As with limestone, addition of this mineral to body material is less than 10%.

Location:

Deposits are found near water reservoir and filtration plant on the north west of Suleja at a distance of about 65km from Suleja along Suleja - Bida road. In this area the surface soildconsists of silica and sand, underneath which lies strata of silicilic clay. The depths of silica clay in this area is estimated to be more than 10 meters.

Chemical Composition:

Ig.Loss	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	Na_2O	TiO_2 T
4.14	83.87	8.04	1.27	0.34	Tr	0.97	0.18	0.90

Mineral Composition:

Mostly Quartz

Felspar in a very small quantity.

Firing Characteristics:

Firing Temperatur ^oC	1050	1100	1150	1200
Shrinkage %	0.5	0.4.	0.4	0.4
Water Absorption %	11.2	10.3	10.3	9.9
Bending Strength Kg/Cm^2	1.17	17	19	22
L(%)	67.3	63.7	60.4	61.4
Chromaticity (a) (G-R)	8.8	11.4	10.1	7.1
(b) (B-Y)	22.3	23.6	23.3	21.7

Summary Evaluation:

1. The clay's richness in silica content is more than 80%.

Less than 10% of this clay can be added to the body materia for the production of tile and sanitary ware.

2. Veriation of Shrinkange, water absorption, Strength, and Chromaticity is small when firing temperature is varied, it thus gives stable result.

Part II: Market or Demand forecast:-

Below are the statistical data gathered by me from a book written by some group of consultants. The skeletal demand forecast for both sanitary wares and ceramic tiles is estimated proportionally to the number of houses or dwellings by the housin and other building programmes.

(a) The housing programme by the Nigerian Government for 1975-1980 development period gives the following data.

Total ₦2,256,000/5 year.

Year	₦ Million	Growth Rate
1975/76	237.59	1.0%
1976/77	346.43	146%
1977/78	447.30	130%
1978/79	556.75	125%
1979/80	668.32	120%
1980/81	802.50	120%
1981/82	947.400	120%

There is a some-how high rate increase of 20-25% in expenditure yearly but, when annual inrease of about 7% in construction cost is considered, the net increase is estimated at 13-15%. 200,00 will be constructed all of which are to be low cost.

The following is the Total housing investment including private.

(b) Planned and Projected investment in buildings.

Year	Growth	Govt. Investment in Building ₦ million	Private investment in Building ₦ million	Total Ivestment in Building in ₦ m.
1976/77	-	346	1,498	1,844
1977/78	12.6%	447	1,898	2,345
1978/79	124%	556	2,344	2,901
1979/80	118%	658	2,762	3,430
1980/81	123%	802	3,417	4,219
1981/82	123%	947	4,242	5,190

Private investment is almost 4 times the Government investment and increases at a very fast rate of 20-23% annually of the building investment, we need to estimate how much

ceramic products is need. Clark ceramic consultants give 1% for conversion of the building investment into demands of ceramics, while according to Danto Co. Ltd's data, the import during 1976 of ceramic tiles and sanitaries is:

Ceramic tile	₦8,500000 approximately
Sanitary ware	₦6,000,000 "
Total	₦14,500,000 approximately

against ₦1,844,000,000 for the total housing investment to give the ratio of 0.78% approximately. $15m^2$ of ceramic tile is being used per house of low cost housing now uner construction in Kaduna area. The Governments budget for low cost housing given in the programme is ₦10,000 per house approximately, and the price of $15m^2$ of ceramic tile is $15m^2 \times ₦7/m^2 = ₦105$ per house and this gives a ratio of 10%. It is not easy for me to give data other than low cost housing, but the ratio of 1% seems to be reasonable as the average for all kinds of houses.

(c) Total demand for Ceramics (₦ million)

Year	Demand in ₦ Million			Growth Rate
	Government	Private	Total	
1976/77	3.64	14.98	18.62	-
1977/78	4.47	18.99	23.46	126%
1978/79	5.57	22.44	29.01	124%
1979/80	6.68	27.62	34.30	118%
1980/81	8.03	34.17	42.20	123%
1981/82	9.47	42.43	51.90	123%

Ceramic demand in 10 northern states where the products from this industry are expected to be sold and the estimated demand in Niger State where the factory is situated are as floows:

(d)

Year	10 Northern State ₦ Million)		
	(a)Public	(b) Private	Total
1976/77	2.40	7.98	10.38
1977/78	2.52	10.10	12,62
1978/79	3.03	12.45	15.48
1979/80	3.60	14.67	18.27
1980/81	4.29	18.14	22.43
1981/82	5.10	22.49	27.59

Year	Niger State in (₦ Million)		
	(a) Public	(b)Government	Total
1976/77	0.27	0.51	0.78
1976/78	0.36	0.65	1.01
1978/79	0 ·5	0.80	1.25
1979/80	0.54	0.94	1.48
1980/81	0.65	1,16	1.18
1981/82	0.78	1.44	2.22

The figures above show that the total share in 10 Northern States is 52% and that their consumption level in 1980, the

year this project with a yearly increase rate of 23%.

The figures for Niger State alone is about 8% of that of 10 Northern States.

(e) 58% was given as the share of Ceramic tile out of 100 of both the Ceramic tile and Sanitary ware imported into this Country last year. From this statistics, it is not possible for me to break down various percentages of wall, mosaic and floor tiles. As such an investigation which was carried out with major distributors in Lagos, Kaduna, Minna and Kano by Danto Co., Ltd. obtained the following results.

Wall tiles	60% approximately.
Mosaic tiles	25% approximately.
Floor tiles	15% approximately.

10 Northern States (₦ Million)	1979/80	1980/81	1981/82
Ceramic Demand	18.27	22.13	27.59
Total Ceramic Tile (58%)	10.59	13.00	16.00
Wall Tile (34.8%)	6.35	7.80	9.60 (11.6) (13.27)
Mosaic Tile (14.5%)	2.65	3.25	4.00
Floor Tile (8.7%)	1.58	1.95	2.40 (2.88) (3.45)

Accordingly, the scale of the market for the product from my industry in 10 Northern States is:

Year	1979	1980	1981	1982	1983
Demand Wall & Floor Tile	₦8,250,000	₦9,950,000	₦12,000,000	₦13,940,000	₦16,7[illegible] 0,0[illegible]

It is necessary to decide on the Industry's scale with efficient consideration on the probable error in the estimate of the market scale and possible delay of this industry's construction.

(f) Capacity of the Ceramic Tile project and product mix.

1. Plants Capacity.

The calculations involving quantities of wall and floor tiles demand were made from the said total price and unit price as follows;

Year	1979/80	1980/81	1981/82	1982/83
(a) Wall Tile Price of Consumption	₦6,350,000 @ ₦7.5/m^2 846,600m^2	₦7,800,00 @ ₦7.8/m^2 1,000,000m^2	₦9,600,00 @ ₦8.2/m^3 1.170,000m^3	₦500,000 @ 8.7/m^2 1,272,000m^2
(b) Floor Tile Quarry Tile Glazed Floor Tile	₦1,580,000 @ ₦15/m^2 105,300m^2	₦1,950,000 @ ₦15.7/m^2 124,400m^2	₦2,400,000 @ ₦16.5/m^2 145,400m^2	₦2,880,00 @ ₦17.3/m^2 166,400m^2

The main products of this industry are Sanitary wares, Wall and Floor tiles and the Plant's maximum capacity is set at 50% of the above consumption estimate. So far there is no producer out of the 10 Northern States and products are expected to be marketed from Nigeria and the remaining Niger State while the New Federal Capital Territory will be the main market as the Plats location is just within its boundary.

(3) In determining the product mix, the following conditions are to be considered.

(i) Cobining Daily marketable good to cope with the market needs.

(ii) Cobination of different types of similar goods in a good proportion to the market need to achieve high profit rate.

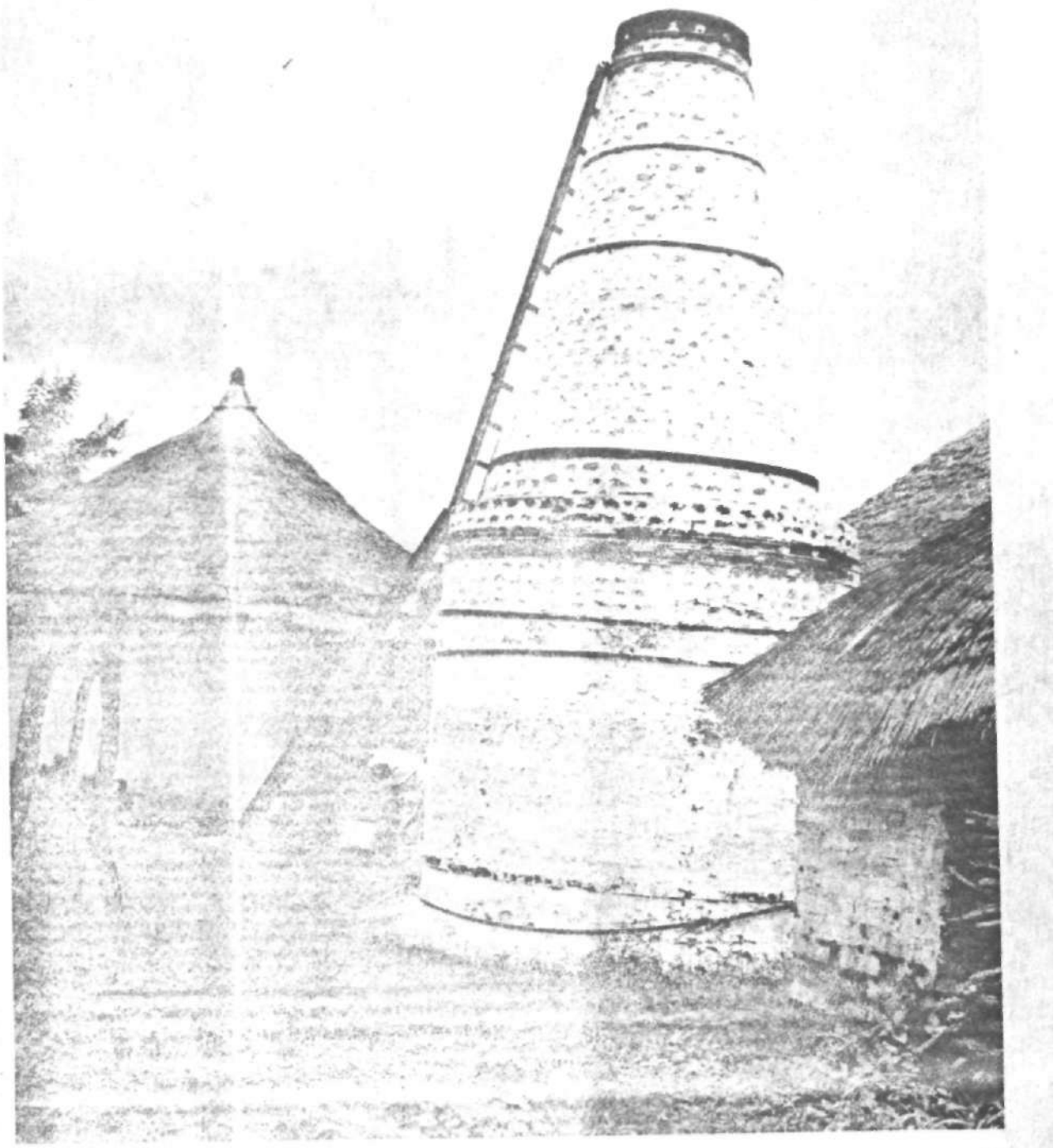
According to the research conducted, every house constructed uses about 20m^2 of vinyl floor tiles in the living room of low cost housing. But for people living in places with high temperatures like this country is not the best solution for flooring as these things come off easily and give a dummy touch to the feet. Vinyi tiles have much short life span compared to ceramic tiles. One of the reasons why people still use vinyl tiles is due to the fact that they are much cheaper than ceramic tiles. For example vinyl tiles cost about ₦3.00 while ceramic tiles is around ₦10.00 or so. Strictly based on my research in Lagos of newly erected dwellings of high standard, it shows that ceramic tiles are mainly used their living rooms.



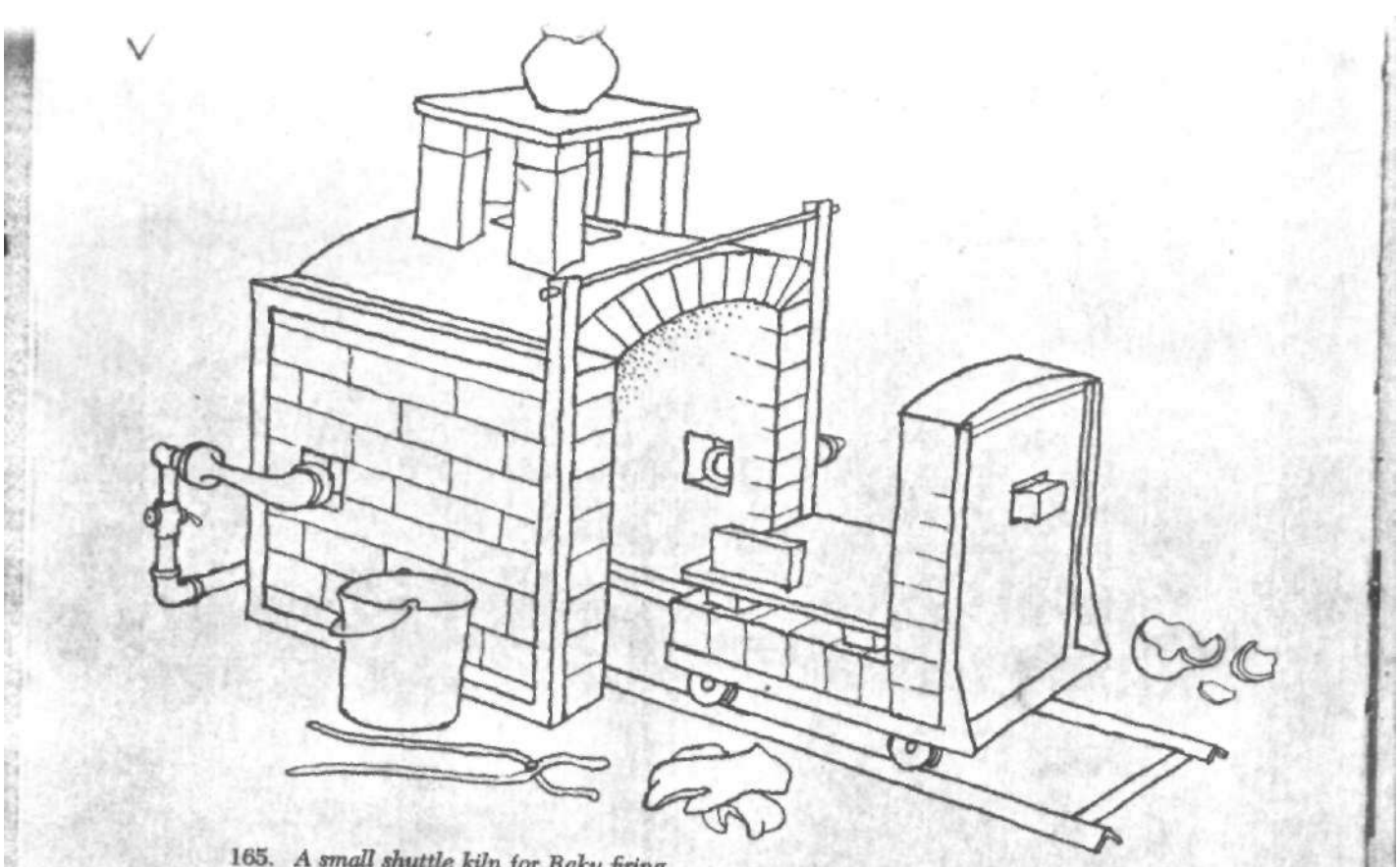
65. *Potter at Abuja. Photo by Francis Uher.*

temperatures in excess of 1300° C. can be reached. At that heat, the roar of combustion and the white hot intensity of the fireboxes let one know that a firing is really in process, and each new piece of wood tossed into the inferno almost explodes into pure incandescent heat. It is exciting.

Management of a wood fire requires some experience and considerable care. The wood must be split down to pieces of the proper size and must be thoroughly dry. If the wood is even slightly damp, the heat required to volatilize the water as steam will tend to cancel any gain in temperature. It is wise to provide a drying rack near or over the kiln where the fuel can be stored until used. In Japan the potters pile

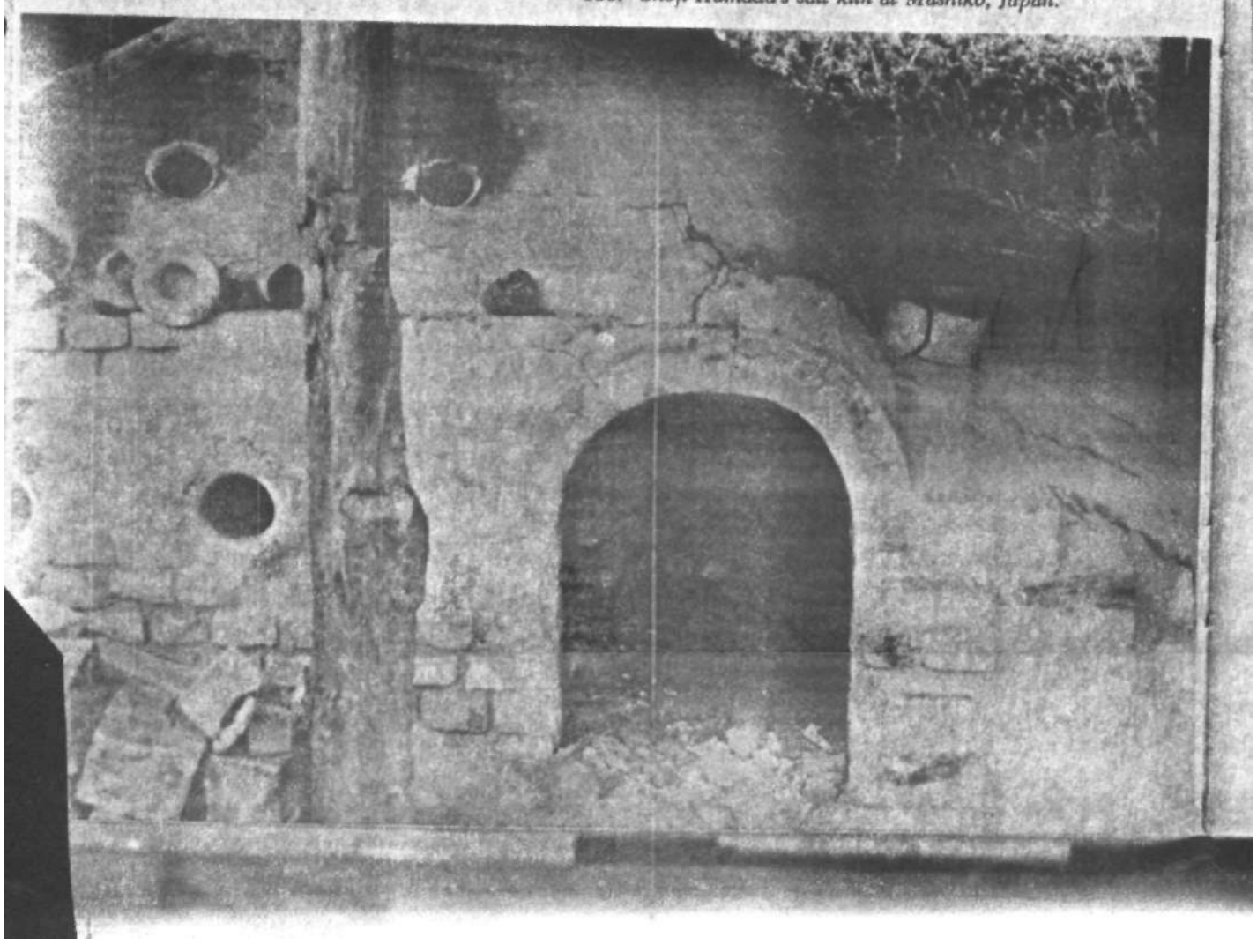


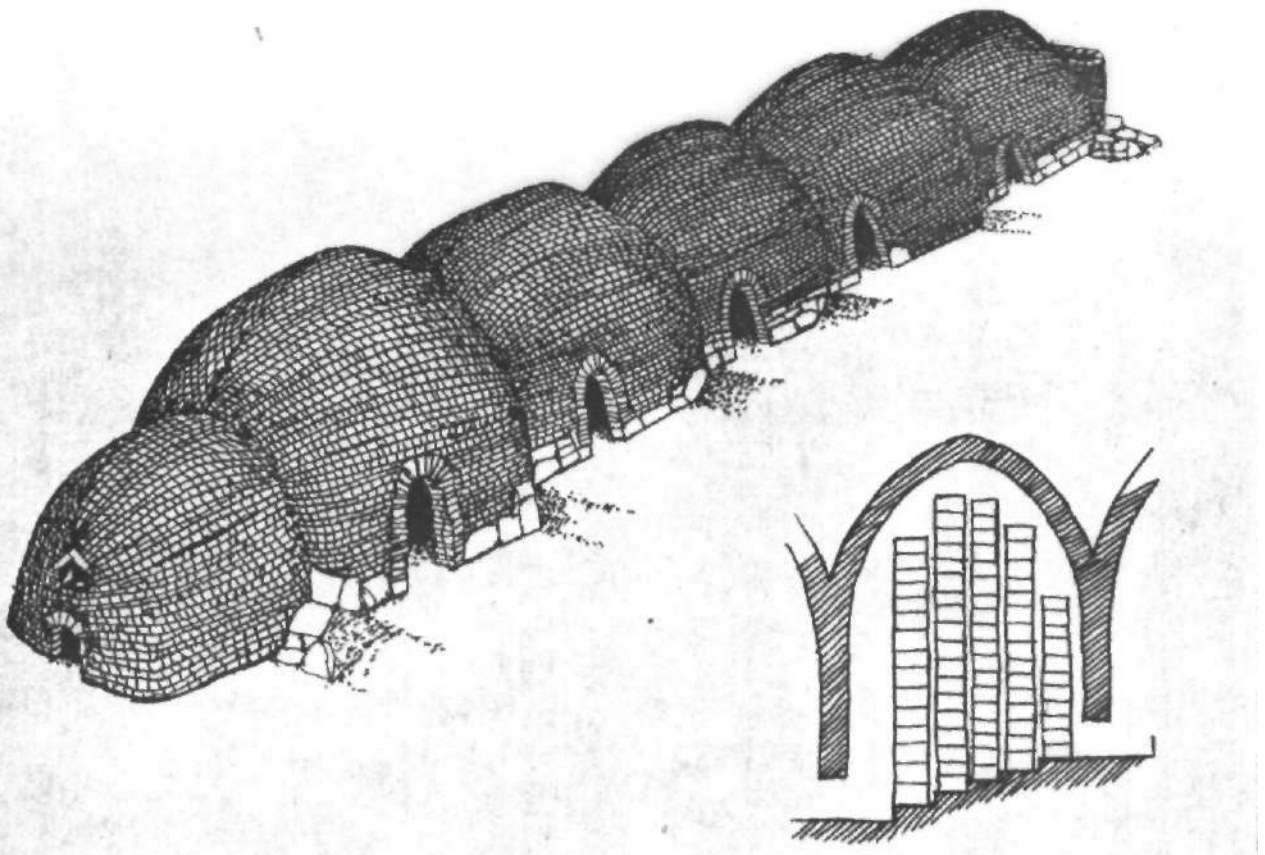
64. *Back of the Abuja kiln. Photo by Francis Uher.*



165. *A small shuttle kiln for Raku firing.*

166. *Shoji Hamada's salt kiln at Mashiko, Japan.*





27. *Large chamber kiln for porcelain at Tewah, Fukien Province, China. Drawing based on data supplied by Dr. W. J. Sutton.*

28. *A Korean "split bamboo" kiln.*

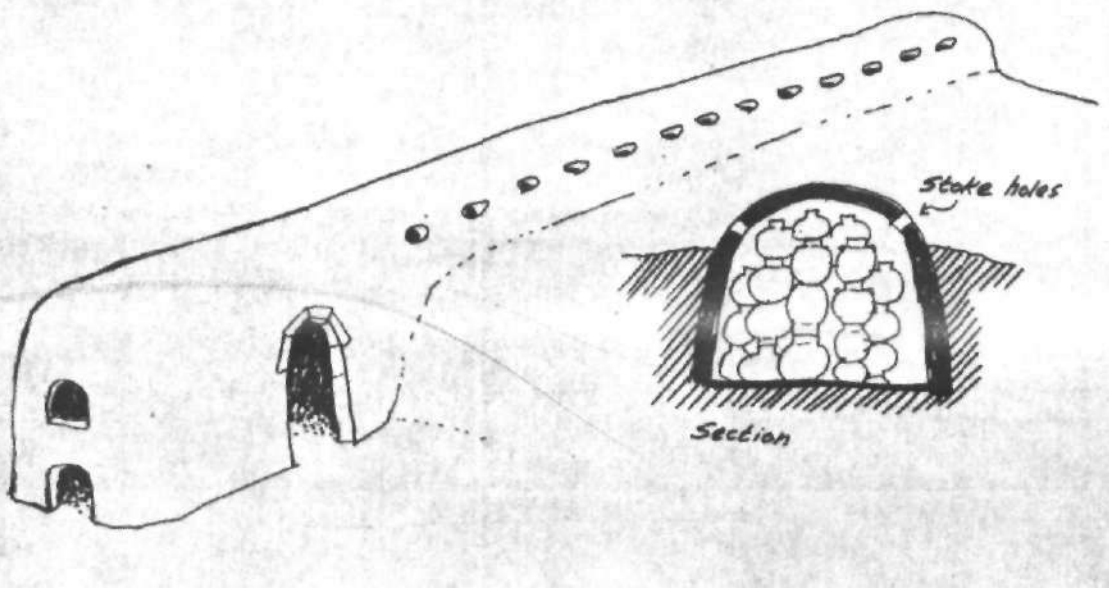


TABLE 37—(*contd.*)

No.	Name	Formula	M.W.	S.G.	M.P. (° C)	M.P. (° F)	No.	Oxides entering fusion
60	Tungsten oxide	WO_3	231·92	7·2	1473	2683	60	WO_3
61	Tungstic acid	H_2WO_4	249·94	5·5	$-\frac{1}{2}H_2O$. 100	$-\frac{1}{2}H_2O$. 21	61	WO_3
62	Uranium oxides						62	
	uranous	UO_2	270·07	10·9	2176	3949		UO_2
	uranous-uranic	$UO_2.2UO_3$	842·21	7·3	d.	d.		UO_2
	uranyl	UO_3	286·07	7·3	d.	d.		UO_3
63	Sodium uranate (commercially known as yellow uranium oxide)	$Na_2U_2O_7$	634·122	—	—	—	63	Na_2O UO_2
64	Vanadium pentoxide	V_2O_5	181·90	3·4	690	1274	64	V_2O_5

AUXILIARY RAW MATERIALS

There are a number of materials which do not form a part of finished ceramic products but are nevertheless vital to the preparation of the ware. The most important of these is water; there are the water-soluble salts that modify the interaction of the clay colloids with the water; there are also the organic binders which assist in shaping and in holding the particles of green ware together and chemicals to aid its drying. Further important auxiliary materials worked in the ceramic factories are plaster of paris for moulds for ware pressed or jiggered in plastic clay, or slip cast, and iron and steel moulds and dies for dry pressing and extrusion.

Water

Water is of such prime importance to life that settlements rarely rise up in its absence; there is therefore no need to discuss its distribution.

Normal sources of water in approximate order of their purity are: underground wells, pumps and fresh springs, lakes, rivers and the sea. The impurities are organic and suspended matter, soluble magnesium, calcium, sodium and potassium carbonates, chlorides and sulphates. This water is filtered and freed from bacteria and sometimes softened before being supplied in normal town mains. The soluble salts that are harmless in drinking water are left in and their nature and quantity may vary.

The physical properties of water are now known very accurately and frequently form the unit for different measuring systems.

H_2O, M.W. 18·016. S.G., 1·0 at 4° C. Sp. ht., 1. M.P., 0° C (32° F) under one atmosphere pressure. The change of boiling point with pressure is frequently made use of to produce high temperatures. A short table of corresponding values is therefore given (Table 38). Normal boiling point under 1 atm pressure (760 mm of Hg), 100° C (212° F).

TABLE 149

Miscellaneous Glazes for the Lower Temperature Range

No.	Application	Ref.	Cone		Na_2O	K_2O	MgO	CaO	—	PbO	B_2O_3	Al_2O_3	SiO_2	—	Batch
1	Cordierite		015/014 800° C	M.F. %					ZnO 0·216 4·76	0·784 47·43	0·433 8·22	0·199 5·52	1·693 27·58	ZrO_2 0·194 6·48	
2	High-titania bodies	A16	08/07 950° C	M.F. %	0·08 0·16	0·02 0·60	0·02 0·23	0·30 4·65		0·58 36·50	0·48 9·49	0·32 9·50	2·18 37·04	Fe_2O_3 0·15 TiO_2 trace Ign. loss 0·52	
3	Once-fired German stove tiles	A8	07	M.F. %		0·09 2·58				0·91 61·82		0·35 10·90	1·35 24·70		Lead oxide 60 Stoneware clay 20 Feldspar 15 Quartz 5
4	Building bricks	H123	05–03 1000° C– 1048° C	M.F. %	Li_2O Na_2O 0·065 0·072 0·65 1·49	0·095 2·99	0·096 1·29	0·228 4·28	BaO 0·387 19·84		0·432 10·11	0·279 9·54	2·479 49·80		Flint 25·0 Kaolin 3·6 Talc 3·6 $BaCO_3$ 22·6 Nepheline syenite 13·5 Colemanite 17·6 Lepidolite 14·1
5	Albany slip glaze for stoneware	S90	(4–12)	M.F. %		0·23 4·24	0·21 1·66	0·42 4·61	FeO 0·14 1·97			0·80 15·99	6·09 71·54		
6	Albany slip glaze for stoneware	S90	(4–12)	M.F. %		0·19 5·24	0·18 2·13	0·36 5·91	FeO 0·27 5·68			0·51 15·26	3·74 65·78		
7	Feldspathic glaze for stoneware	S90	(4–12)	M.F.		0·2	0·1	0·7				0·4–1·0	3·5–9·0		

TABLE 150

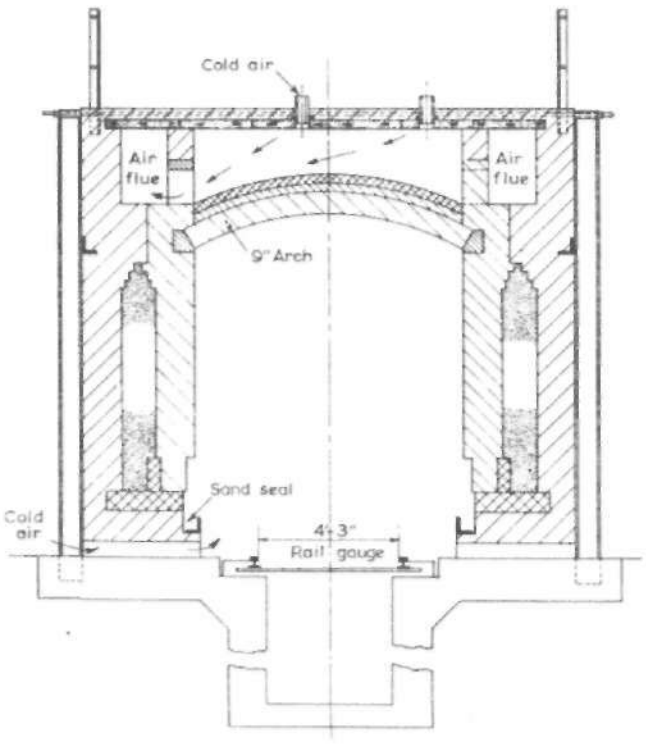
Glazes General (mostly from S108)

Type	Ref.	Cone		Na_2O	K_2O	MgO	CaO	ZnO	SrO	B_2O_3	Al_2O_3	SiO_2	Batch
		7	M.F. %		0·2 6·0	0·1 1·3	0·7 12·5				0·4 13·0	3·5 67·2	
		7	M.F. %		0·2 5·5	0·1 1·2	0·7 11·2			0·1 2·0	0·45 13·1	3·90 67·0	
		8	M.F. %		0·2 5·5	0·1 1·2	0·7 11·4				0·45 13·4	3·90 68·5	
		8	M.F. %		0·2 4·3	0·1 0·9	0·7 9·0			0·2 3·2	0·6 13·9	5·0 68·7	
		9	M.F. %		0·2 5·1	0·1 1·1	0·7 10·5				0·5 13·7	4·3 69·6	
		9	M.F. %	0·2 2·4	0·3 5·5		0·5 5·5			1·0 13·6	0·6 11·9	5·2 61·1	
		10	M.F. %		0·2 4·0	0·1 0·9	0·7 8·4			0·1 1·5	0·65 14·2	5·5 71·0	
Alkali-free		11	M.F. %			0·22 3·4	0·78 16·6				0·3 11·6	3·0 68·4	
		11	M.F. %		0·2 2·9	0·1 0·6	0·7 6·0			0·2 2·1	0·9 14·2	8·0 74·2	
English Porcelain	M88	9–14	M.F. %	0·13 2·3	0·19 5·2		0·66 10·8				0·48 14·3	3·85 67·4	
		12	M.F. %		0·2 3·1	0·1 0·7	0·7 6·6			0·1 1·1	0·85 14·2	7·5 74·3	
		12	M.F. %		0·2 3·5	0·1 0·8	0·7 7·4				0·75 14·4	6·5 73·9	
		13	M.F. %		0·2 3·1	0·1 0·7	0·7 6·5				0·85 14·5	7·5 75·2	
Lead-free		14	M.F. %				1·0 13·4				0·6 14·6	5·0 72·0	
Lead-free		14	M.F. %			0·5 4·8	0·5 6·8				0·6 14·9	5·0 73·5	
		14	M.F. %	0·4 3·7	0·4 5·7		0·2 1·7				1·1 16·8	8·0 72·1	

TABLE 39

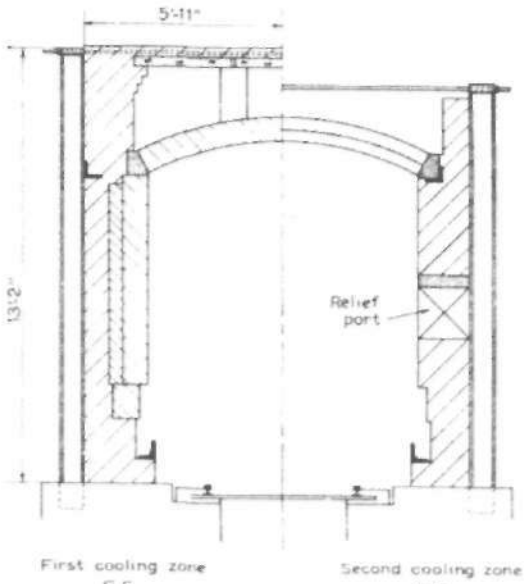
Inorganic Deflocculants

Name	Formula	M.W.	S.G.	Solubility in water (g/100 ml)	Remarks
Sodium hydroxide (caustic soda)	NaOH	40·01	2·1	42 at 0° C, 347 at 100° C	
Sodium silicate (water glass)	Variable from $Na_2O.1{\cdot}6SiO_2$ to $Na_2O.4SiO_2$	158·09 to 302·23		from 156 to 43	
Best composition of sodium silicate for deflocculation	$Na_2O.3{\cdot}3SiO_2$	260·19			The best deflocculant in widespread use.
Sodium carbonate (soda ash)	Na_2CO_3	106·00	2·5	7·1 at 0° C, 45·5 at 100° C	Less effective per equivalent of Na_2O than the *silicate but used in conjunction with it.*
(washing soda)	$Na_2CO_3.10H_2O$	286·17	1·4	*21·52 at 0° C, 421 at 100° C*	
Sodium phosphates: (pyrophosphate)	$Na_4P_2O_7$	266·03	2·5	3·16 at 0° C, 40·26 at 100° C	Very efficient deflocculant. Not in widespread commercial use.
(tetraphosphate) (hexametaphosphate)	$Na_6P_4O_{13}$	469·90			For porcelain.
Sodium aluminate	$Na_2O.Al_2O_3$	163·94		Soluble in cold, very soluble in hot	Can be used instead of the silicate and carbonate with better results.
Sodium oxalate	$Na_2C_2O_4$	134·01	2·34	3·7 at 20° C, 6·33 at 100° C	*See* ammonium oxalate.
Sodium gallate					*Very good deflocculant.*
Sodium tannate					
Ammonium oxalate	$(NH_4)_2C_2O_4.H_2O$	142·12	1·5	2·54 at 0° C, 4·0 at 16·8° C, 11·8 at 50° C	Essentially to precipitate soluble calcium, in conjunction with other deflocculants.
Lithium hydroxide	LiOH	23·95	1·4	12·7 at 0° C, 14·9 at 100° C	
Lithium carbonate	Li_2CO_3	73·89	2·1	1·54 at 0° C, 1·33 at 20° C, 0·72 at 100° C	
Lithium aluminate	$LiAlO_2$	65·91			
Lithium citrate	$Li_3C_6H_5O_7.4H_2O$	281·99		74·5 at 25° C, 66·7 at *100° C*	



DD - Fire zone between burners

(e)



First cooling zone
E E

Second cooling zone
F F

(f)

Fig. 11.45 (*contd.*)

TABLE 3

Selection of Analyses of Various Types of Clay

[Cols. 1 to 9: China Clays and Kaolins]

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Name District	J.M. Cornish clay	M Cornish china clay	Kernick or No. 10 Cornish china clay	L.M.B. or 24 or Lee Moor Best Cornish china clay	S.C. Devon china clay	C.C. china clay Devon	Kemmlitz kaolin	Zettlitz kaolin	Börtewitz raw kaolin
Mining firm			E.C.L.P.	E.C.L.P.	Watts, Blake	Watts, Blake			Erbslöh
Ref.	**R42**	**R42**	**R42**	**R42**	**R42**	**R42**	**S83**	**S83**	**E21**
Country	Brit.	Brit.	Brit.	Brit.	Brit.	Brit.	Germ.	Czechoslovakia	Germ.
Analysis: SiO_2	47·17	45·45	48·1	47·0	46·96	46·72	58·30	46·09	75·6
TiO_2	0·01	0·34	0·03	0·06	0·13	0·13			
Al_2O_3	38·90	38·33	37·0	38·2	38·78	37·52	29·31	39·28	17·6
Fe_2O_3	0·25	0·55	0·55	0·5	0·86	0·50	0·87	0·76	0·2
MgO	0·15	0·12	0·26	0·19	0·04	0·19	trace		0·2
CaO	0·17	0·06	0·14	0·22	0·09	0·18	0·51	0·15	
Na_2O	0·04	0·43	0·04	0·2	0·34	0·20	1·26	0·03	0·1
K_2O	1·09	2·22	1·6	1·0	0·78	2·10		0·12	
MnO	—	—	0·02	0·02					
SO_3	—								
Loss on ignition	12·37	12·44	12·2		12·51	12·00	10·62	13·58	6·2
Vitrification					32	32			34
Initial deformation refractoriness cone									
Special properties			high exchange capacity	low-exchange capacity					
Modulus of rupture (lb/in²)					85	35·4			
(kg/cm²)					6	2·5			
Rational analysis: Method									Kallauner-Steinbrecher
Clay substance							54·9	98·3	43·9
Potash mica							43·8	1·2	54·5
Soda mica							1·3	0·4	1·6
Quartz									
Feldspar									
TiO_2									
Fe_2O_3									
MgO									
CaO									
Organic matter									
Fired colour								white	
Temp. (°C)									
Dry-to-fired contraction Temp. (°C)									
(%)									
Uses					bone china porcelain earthenware white wall tiles	earthenware white wall tiles bone china porcelain			

B I B L I O G R A P H Y

1. CERAMICS BY P. William Lee.

2. STONEWARE AND PORCELAIN (The Art of High-Fire Potterr)
   By Daniel Rhodes.

3. CERAMIC PROCESSING BEFORE FIRING
   By George Y. Onoda, Jr. and Larry L. Hench.

4. KILNS - Design, Construction and Operation
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5. INDUSTRIAL CERAMICS
   By Felic Singer and Sonja S. Singer.

6. ABUJA CHRONICLE
   By Hassan Dallatu and Shuaibu Na'ibi.

7. FEASIBILITY STUDY ON NIGERIAN CERAMIC RAW MATERIALS
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