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TECHNOLOGICAL INFORMATION

PACKAGE

NON-METALLIC RAW MATERIALS AND THEIR UTILIZATION

/KAOLIN, PERLITE, FIRECLAY AND SILICA/

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I. INTRODUCTION

The materials discussed in this paper belong to the important ones in non-metallic minerals based industries. Kaolin, perlite, fireclay and silica find a wide range of applications, from ceramics to agriculture and environmetal protection. They are therefore interesting materials also for economies of developing countries. On the one side the non-metallic minerals based industries usually do not require too high investment expenditures and sophisticated know-how, on the other side the products condition the development of many significant industrial branches, such as metallurgy, paper, plastics and rubber productions.

This publication describes the most important features of the matter, such as raw material properties, processing methods, nece[illegible] equipment and its suppliers and energy management aspects. It aims at securing the basic information for technicians, managers and decision-makers in developing countries when planning the exploitation of local raw material reserves, establishment and/or expansion of local non-metallic minerals based industries. The decision on the establishment of refining and production plants is to be based on a detailed analysis of local conditions. The geological and physico-chemical evaluation of raw material reserves must be done, their accessibility considered and balanced with the local market potentiality, possible exports and production costs. The establishment of a production plant is feasible if the market requirements are higher or at least the same as the break-even-point of the production.

The scope of the publication does not allow it to be exhaustive and present all the details which may be of a reader's interest. The bibliography gives references to different publications specialized in individual items which provide further information. The UNIDO-Czechoslovakia Joint Programme for International Co-operation in the Field of Ceramics, Building Materials and Non-metallic Minerals Based Industries in Pilsen is ready to provide on request more information and/or mediate a technical assistance in respective fields.

II. RAW MATERIALS

A Kaolin

From the mineralogical point of view, kaolin is a group of hydrated aluminium silicate minerals, which include the clay minerals kaolinite, nacrite and dickite. Halloysite is also sometimes added to the group of kaolins.

When the term kaolin is used as an industrial mineral we have to understand a clay consisting of substantially pure kaolinite or related clay minerals, which is natural or can be beneficiated by a refining process. Such a clay must, however, reflect the following properties: white or nearly white colour, colour after firing will also be white or nearly white, it is amendable to beneficiation by known methods to make it suitable for use in whiteware, paper, rubber, paint, cosmetics and similar use; it is also refractory.

Occurrence in the Nature

Kaolin deposits show in the nature different degrees of their purity. Some of kaolin deposits are essentially pure and require less operations during preparation for the market. Other deposits contain smaller percentages of kaolinite and these must be washed, separated, sedimented, filtered and dried to recover marketable kaolin.

The purity of kaolin deposits mainly depends on their origin. Kaolin deposits are classified as primary and secondary /sedimentary/ones. Primary deposits are those formed from the alteration of crystalline rocks and remain in the place where they were formed. Such deposits usually contain 10 to 30% of pure kaolinite. Secondary deposits of kaolin are sedimentary and have been transferred from their place of origin by water, wind or glaciers and deposited in beds or lenses. Such deposits usually contain 30 to 100% of pure kaolinite. Table 1 shows the comparison of primary and secondary deposits.

The primary kaolins show extremely variable composition within a given deposit and in different deposits. The composition of the parent rock as well as condit... of alternation are factors influencing the clay minerals. Quartz, feldspar and mica in varying amounts are the most abundant non-kaolinitic components of primary kaolin deposits. Because of the transfer from the place of origin to the actual deposit, the particle size of sedimentary kaolins is much smaller than that of primary kaolins. The thickness of secondary deposits is usually smaller as these deposits were sedime... d. The sedimentation process can be considered as the first step of natural classification, and, therefore, sedimentary kaolins are usually more valuable than the primary ones. However, the most usual kaolin deposits are the primary ones.

B Perlite

Perlite is a glassy, volcanic rock which has the ability to expand to about 15-times its original volume when heated to a temperature within its softening range. The expansion is due to the vapourization of combined water which swells the individual particles forming a glassy foam. The result is a product of low density accompanied by properties of low thermal conductivity and high sound absorption. Petrographically, perlite is a rhyolitic rock having a pearl-like lustre - hence the original name of pearlstone - and generally possessing an onion-like structure of concentric cracks. Chemically, crude perlite is a metastable amorphous aluminium silicate. An average chemical composition is given in Table 2. Perlite is chemically inert and has the pH value of around 7.

Table 1 Comparison of Primary and Sedimentary Kaolins

	Primary kaolins	Sedimentary kaolins
Occurrence	irregular geological formation	beds, lenses, as sediments
Thickness of the deposit	bigger	thinner
Content of kaolinite	lower 10 - 30%	higher 30 - 100%
Variability	very high	high
Particle size	bigger	smaller
Content of non-kaolin clay minerals	lower	higher

Table 2 Average Chemical Composition of World's Perlites

Chemical composition	Orientation data /%/	Fusion point /°C/	Mohs hardness	Colour	pH coefficient
SiO_2	69.8 - 73.5			dark-grey	
Al_2O_3 + TiO_2	12.5 - 13.7			brown	
Fe_2O_3	1.5 - 2.3	900	5 - 7	green	7
CaO+MgO	3.1 - 5.0	- 1300		black	
K_2O+Na_2O	5.5 - 7.0				
H_2O					

Physical and optical properties of raw perlite can be described as follows:

- index of refraction - 1.490 to 1.610
- hardness - 5.5 to 7.0 on Mohs' scale
- colour - pale to dark grey, brown, green and black
- melting point - 760 to 1320^{o}C
- specific density - 2.3 to 2.8

It is worth noting that when expanded the colour of the material will vary from snow to off-white.

In a commercial sence, the term perlite embraces a wider range of mineral compositions. Pure perlite may vary in chemical composition from andesite to rhyolite and have a combined water content of between 2 and 3%. The commercial classification extends to include obsidian with below 2% combined water and, at the other end of the scale, pitch-stone with more than 5% of combined water.

It is relevant to point out that all the countries where perlite is exploited are characterized by recent volcanic activity and nearly all deposits of a commercial nature are linked with lava flows and domes of eocene or oligocene ages. As volcanic glasses devitrify into cryptocrystalline or microcrystalline quartz-feldspar rocks over a long period of time, so perlite deposits older than the tertiary period are not likely to be found.

C <u>Fireclay Refractories</u>

Fireclay refractories are produced usually from natural raw materials. In some cases some raw materials are refined before used in fireclay blends.

Each blend is composed of two basic parts:

a/ plastic part, such as clays and kaolins

b/ non-plastic part, such as grog (culls and fired clays), flint clays and sand.

Refractory clays /china clays, ball clays, fireclays and others/ are classified into two major groups, namely residual clays - where the material is found in the location in which it is formed, and sedimentary clays, when the clay has been transported in some way and deposited elsewhere. The basic component of refractory clays are alumino-silicate minerals, usually so-called clay minerals. These minerals show the workability and can be transformed (by addition of water) into a plastic blend.

The most important substance of refractory clays is the group of minerals of kaolinite, with a chemical composition corresponding closely to $Al_2O_3 \cdot 2\ SiO_2 \cdot 2\ H_2O$. Such minerals confer both a refractory character and plasticity of clays in which they are present. Refractory clays are contaminated by only small amounts of alkalies, iron and titanium compounds and other fluxes. Their properties fluctuate in respect of chemical composition, refractoriness, plasticity, drying and firing shrinkage, so that it is a common practice to use several plastic clays mixed together or with flint clays and kaolins for any particular product. Refractory clays also contain, in smaller or bigger amounts, silica minerals, namely quartz. In addition to quartz, other crystalline, amorphous or noncrystalline hydrated silica may be present but all have the chemical composition SiO_2.

Kaolins are other plastic raw materials which are used in some fireclay body compositions. They contain practically pure clay mineral kaolinite. In comparison with clays, kaolins show higher purity, white colour after firing, coarser particles and, therefore, lower plasticity.

To control the shrinkage during drying and firing and to regulate the properties of finished products, fireclay bodies must also contain a non-plastic part. This non-plastic portion of the siliceous and low-duty fireclay blends can be represented by natural minerals, such as quartz sand, added to the blends or present in clays or raw kaolins. Culls, fired clays and flint clays are added into medium-, high- and super-duty fireclay bricks in the amount of 30 to 90% of the total, referring to the quality of fireclay bricks produced. In general, to produce a fireclay brick under usual industrial conditions, total non-plastic raw materials in the fireclay blend have usually to amount to at least 50% of the total.

Culls are firebricks which may already have been used in furnace lining or elsewhere, crushed to a size suitable for incorporation in a batch. Also wastes from the own fireclay manufacture are used for remaking into bricks. As the porosity of culls is always higher than that of fired clays, the addition of culls into a fireclay blend is limited according to the quality of finished products.

Fired clays and flint clays

All types of high- and super-duty fireclay bricks must contain fired clays and/or flint clays. Flint clay is a non-plastic refractory clay which is kaolinitic, possibly contaminated with diaspor or boehmite. After firing, flint clays contain 42 - 45% of alumina. Their refractoriness reaches Pyrometric Cone Equivalent 34 to 35. These are materials of an extremely hard dense texture. Although they are rich in kaolinite they are consolidated to such an extent that even fine grinding will not develop any significant plasticity. Fired clays are fired in a rotary, shaft or tunnel kiln. Fired clays strengthen the skeleton of the body, decrease the plasticity of a green body as well as its shrinkage after drying and firing. The higher amount of fired clays in the blend, the more accurate dimensions of finished products.

Sands can be added into blends of siliceous fireclay materials in order to increase the amount of natural non-plastic materials. Any of quartz sands is suitable for the technology provided that it is not contaminated by other fluxing materials.

Aside basic raw materials, different organic matters can be used as bonds to increase the plasticity and crushing strength of green products.

D Silica Refractories

The chief refractory component in silica products is silica - SiO_2 which occurs in several modifications. The basic modifications are: quartz, tridymite, cristobalite and quartz glass, each of which may transform into any of the others (possibly also into meta-stable forms of SiO_2), at various temperatures. Each transformation is accompanied by a change in volume bringing a change in the specific gravity of the individual modifications of SiO_2.

Silica is widely distributed in minerals and rocks. However, the most suitable raw materials for silica products are quartzites, sandstones and ganisters, containing at least 95% SiO_2 and alumina less than 2%. It is necessary to add a suitable bonding agent that will hold the non-plastic silica grains in both the raw and fired state. Hydrated lime is usually added in the amount of 2% of the total, as well as sulphite lye to increase mech...l properties of green products.

The conversion of low temperature quartz modifications into high temperature ones can be accelerated by the presence of mineralisers, such as iron oxides.

Quartzites, as well as sandstones and ganisters, are sedimentary types of quartz. The shape of sand grains depends on the extent of erosion they have undergone and any other matter that may have coated them. Fine grained quartzites with a large content of amorphous or microcrystalline basalt cement, are excellent for their quick and easy transformation into high temperature modification. The other type of quartzite, showing bigg... ...ns, practically with the minimum of erosion and missing the basalt cement, needs usually the addition of mineralisers and more specific granulometric composition in order to prepare a suitable body composition.

III. PROCESSING METHODS, MACHINERY AND EQUIPMENT

A Main Technological Steps in Washed Kaolin Production

The main technological steps in the washing technology are as follows:

1. Blunging
2. Particle Separation
3. Drainage - Dewatering

1. Blunging

Blunging of a raw kaolin is the technological process in which the kaolin minerals are freed from the raw ones. The blunding is made by

a/ mechanical mixing of the raw kaolin with water in blungers

b/ spraying water on the raw kaolin, either directly in the depo[illegible] or on the homogenized, crushed raw ore.

If raw kaolin contains bigger grains of quartz or other hard minerals, they are removed during blunging.

2. Particle Separation

The mixture of kaolin and finer sand are then sorted. The efficiency of particle separation depends on different fact[illegible]s, such as freeing of all kaolin particles from the raw ore, hardness of water used, temperature, thickness of the kaolin slurry, type of kaolin, etc.

The kaolin raw slip usually contains 40 to 80 g of solid particles in one litre, exceptionally up to 500 g per litre. The biggest grain size can be from 100 to 500 microns.

The sorting process is based on two main principles:

a/ sedimentary effect, i.e. solid particles are heavier than water and they sediment. However, the specific density of kaolin and quartz do not differ too much and, therefore, the size and shape of solid particles is important for the separation of kaolin from other solid particles. As kaolin particles are always smaller than particles of quartz, separation can be done. The sedimentary sorting is applicable in all washing processes, using thin as well as thick kaolin slips. The disadvantage of sedimentary sorting remains in very large sedimentary areas as well as mostly in the discontinuous processing.

b/ centrifugal effect; separation of bigger particles from the smaller ones is made by centrifugal forces in several stages. Two types of basic machines utilize centrifugal forces in sorting the kaolin slurry, i.e. hydrocyclones and centrifuges.
Hydrocyclones are applied in such technologies where thin slurries are to be sorted /less than 100 g per litre/. If very fine particles are to be sorted out, numerous hydrocyclones of small diameters must be employed.
Centrifuges are suitable for sorting of thick slurries so that no thickening of slurries is needed before filtration. Centrifuges are applicable for sorting of fine kaolin particles, if no bigger amount of sand is present in the kaolin slip.

Either the sedimentary effect or centrifugal forces can hardly separate from the kaolin slip those particles which show extreme shapes, such as flat particles of mica. Therefore, at the end of kaolin particle separation, the kaolin slip is screened on a stationary or rotary screen with meshes of 60 microns.

3. Drainage - Dewatering of Kaolin Slips

The kaolin slip, which flows from the particle separation, contains so much water that it is unusable for the industrial exploitation. It must be dewatered to its final humidity below 1% for the rubber industry or usually to 10% up to 15% of water content for other types of industries. Exceptionally, thick kaolin slip is supplied to the customers.

The drainage of kaolin slurries is carried out in three steps:

a/ thickening
b/ filtration
c/ drying

a/ Thickening of the kaolin slip is applied in order to prepare the slip for filtration. In order to speed up the thickening process, different flocculation agents are added into the kaolin slip close before the kaolin slip inlet into settling tanks. Fine kaolin particles agglomerate, they get heavier and sediment much quicker than without flocculating agents. Kaolin slip settles in the settling tanks and clean water is led away into a tank. This water will be used again in the washing process. The flocculating effect of application of calcium or aluminium·hydrated salts is exploited which decrease the negative electric charge of clay particles and support their agglomeration. The modern method utilizes synthetic polymers with long chains, such as polyacrylamid, polycrylate and polyamine.

The kaolin slurry is thickened to at least 150 g of solid particles in one litre. This operation can be made in periodically working basins in smaller plants or continuously working thickeners in big plants. The centrifuge can also be used for thickening the kaolin slurry, particularly in the case when water-soluble salts are to be washed out from the kaolin. In such a case, the centrifuge is combined with a rotary vacuum filter which is very convenient for flushing the thin kaolin layer with clean water.

b/ Filtration

The usual second operation in dewatering of kaolin slips is filtration. The principle of filtration is based on withholding solid particles of kaolin on a porous cloth, which let the water through while solid particles build up into so-called kaolin cakes.

This operation can be made in filter presses or in rotary vacuum filters.

A filter press is composed of a number of chambers separated by partitions which are covered with a cloth. The kaolin slip is pumped into the filter press through the hole in the middle of partitions under the pressure of 1.5 MPa. Water is pressed through the filter press cloths and leaves the filter press. The thickness of the cake amounts to 20 to 50 mm. The output of the filter press is influenced by the following main factors:

- thickness of the slurry
- temperature of the slurry
- thickness of kaolin cakes
- maximum pressure of the filtration.

The real output of filter press can fluctuate very much, depending also on the gram composition of the kaolin. 1 m^2 of filtration area of the filter press can filter 3 kg to 5 kg of fine grained ceramic kaolin as well as 15 kg of coarse grained kaolins. The filter press is a manufacturing equipment which works discontinuously.

The vacuum rotary filter is a drum with perforated mantle, covered with a cloth, fixed to the drum. The internal part of the drum is devided into sectors by long partitions. The front part of the drum is provided with holes, which connect internal sectors with exterior ones, in order to keep them alternately under overpressure or underpressure. The lower part of the drum is immersed in the kaolin slip which is to be filtered. The filtration starts by the atmospheric pressure when the respective sector is in underpressure. Kaolin starts to sediment on the mantle of the drum and air is draining water out of the suspension. In this position kaolin, nted on the mantle, can be washed by clean water to free all water soluble salts remaining there from bleaching or of other origin. The drum rotates slowly, and, in the particular position, the underpressure changes to overpressure. The kaolin coat can be taken continuously from the drum by a knife, by stripgs or by a rubber cylinder. The thickness of the drained kaolin coat is usually 5 to 10 mm.

Vacuum filters work continuously. However, the content of water of their kaolin coats is always higher than in the filter press cakes, reaching as much as 35 to 40% of the total. The higher moisture of kaolin increases the drying costs because of higher consumption of energy. Vacuum rotary filters also show relatively lower output. On the other hand, they can advantageously be combined with a spray drier directly.

Centrifuges can also be applied for de-watering of the kaolin slip. But special attention must be paid to the agglomeration of fine kaolin particles by special flocculating agents in order to increase efficiency of the centrifugal de-watering.

c/ Drying is the technological operation which regulates the kaolin moisture content according to the needs of the buyer. The water is evaporated using thermal energy. The speed of drying depends on different factors, such as

- temperature and relative humidity of air
- size of kaolin lumps
- plasticity of kaolin
- amount of hot air available for drying, etc.

In general, driers for kaolin drying can be devided into two groups:

Unheated Driers

In warm dry climates kaolin can be dried easily when exposed to the atmosphere. In northern climates or in climates with rainy seasons there must be at least a roof with overhanging eaves over the kaolin cakes. Unheated drying takes a number of weeks, depending on the nature of the kaolin and climatic conditions, so that a large amount of space has to be given over to it. Such installations require a lot of labour. Where fuel is very expensive or where the capacity of the kaolin washing plant is small it can be nevertheless economical to use natural drying methods.

Heated Driers

Different types of heated driers are used. A simple heated drier is the hot floor drier. Drying of kaolin cakes on a hot floor has become an established practice in many developing countries. Pieces of wet kaolin are spread out in a single layer on the floor which is heated either directly from the bottom by coal or wood, or using steam pipes or kiln waste heat.

Chamber or corridor driers are other periodically working types of heated driers. Pieces of wet kaolin are placed on pallets, pallets are driven into the drier and placed above each other. When the drier is loaded, the chambers or corridors are closed and the drying process starts. Depending on conditions, such drying process takes a couple of days.

Continuously working heated driers shorten their drying cycle to hours or minutes only. Such driers are usually employed in high-capacity washing plants and they are:
- tunnel driers
- spray driers
- belt driers
- drying mills and many others.

According to the requirements of the buyer, the washed kaolin is supplied as a lump clay, pulverized clay or predispersed clay. It is transported either in bags on pallets or in special containers by road or by train.

Figures 1, 2 and 3 show different industrial processings of washed kaolin, starting with a simple one to the most sophisticated manufactures.

B Expanded Perlite Production

Concisely said, the expanded perlite production is almost invariable as far as the technology flow is concerned. Perlite is usually mined by open cast methods, then crushed and graded in the mine or as close as possible to the pit. The graded material is transported to the expansion plants where processing sets in. The ore input is usually a blend of different grades.

The expanded perlite is passed through a system of cyclone classifiers where fines are removed and sent to dust collectors for contingent other uses.

The bagging and shipping ways depend on the end-use. Expanded perlite is an extremely light and bulky product so that transport is very expensive and should be as short as possible. Consequently, the expansion plants usually serve local markets or strive to produce as wide as possible range of end-products, particularly higher density compositions.

1. Raw Perlite Mining

Perlite is almost exclusively won by open cast mining, first the ore is blasted and ore pieces then loaded on trucks to be transported into up-grading plants. As for costs in extraction, a considerable item is frequently the removal of overburden. According to the pit dimensions and ratio between the overburden and the ore proper, systems of transports are designed.

A very important question to be solved is the method of extraction, either selective or universal. It depends on the quality of ore, its homogeneity and admixture quantities the ore consists of.

The equipment installed in the upgrading plant is also to be taken into account. An efficient disintegrating and sorting equipment will enable the treatment of less uniform materials.

The universal mining can be applied only to a certain degree depending on the quantity of contaminating admixtures since a large quantity of the wor material passes through the beneficiation equipment. In addition, some admixtures are difficult to be separated or cause a rapid wearing of the equipment. The expansion methods and quality requirements of final products must be taken into account since they determine the limit of contamination of input. Generally, this method is being applied on condition that the pit is rich in perlite of a uniform quality.

The selective method is demanding for the control of the extraction which must follow the quality requirements. Only particular parts of the deposit are taken which have the required parameters. As for the shape of the pit proper, the deposit selectively mined is usually of lower richness and larger dimensions.

2. Raw Perlite Upgrading

A very important process of perlite upgrading is the step-by-step disintegration by crushing, drying, milling and sorting the raw material input. The ore is pre-crushed by means of jaw crushers or hammer mills.

The most effective way of drying runs in cylindrical driers since further sorting is facilitated, especially, removal of grains smaller than 0.2 mm. Then the crushed and dried perlite is driven into silos as the upgrading is a process of large bulk of work in progress since natural homogenization is a technological requisite of further processes affecting the final product quality.

The silos feed then the roller mill which is set up to provide the grades of perlite optimal from the point of view of the expansion. Then the milled material passes through a series of sieves to be classified into respective fractions stored in silos. Each upgrading plant is provided with an effective dust-suction plant removing the dust generated during disintegration. Some of the dust fractions are further used. Upgrading plants are usually located closer to the pits while the expansion is usually carried out in the places of consumption. The reason is the immense change of bulk density during the expansion and, henceforth, the multiplied transportation space required. It is not rare that crude perlite is transported into 2 or 3 thousand kilometers remote places, e.g. in the U.S.A. or transport between Greece and Western Europe.

Crude perlite is graded according to the granulometry and expandability. For respective industrial uses, different grades of fractions are produced since the grain dimension is a decisive factor of expansion. It is notorious that the heat transmission with too large grains is limited so that expansion is prolonged. The effect is especially undesirable if perlite contains a lot of water which brings about tearing the perlite grains. On the contrary, if perlite fractions are too fine, the outlet of fines is great lowering the output. In addition, the fine particles cling to the furnace walls during the expansion.

As usual grading of crude perlite according to the expandability is as follows:

- raw material having less than 80 kg/m^3 after expansion,
- raw material having between 80 - 150 kg/m^3 after
- raw material having between 150 - 200 kg/m^3 after expansion,
- raw material having between 200 - 250 kg/m^3 after expansion.

In order to get as much as possible st... and uniform parameters, the space homogenization of graded perlite is necessary. The auditing of quality parameters of gr... perlite is very important activity which must be pres... in all the phases of input preparation, especially physical properties and chemical composition must ... ...cked carefully. The graded perlite is delivered packed in containers, tanks or paper bags. The crude perlite must be kept away from wetting during transportation and storage.

3. Expanded and Hydrophobic Perlite Production

The expansion techniques applied all over the world are almost invariable, consequently, the description of a representative will be sufficient to give the reader a concise information on this process as far as the material and energy flows and manpower consumption are concerned.

The annual capacity 60 000 cu.m of expanded perlite was selected to demonstrate a typical production line since such a plant makes use of economy of numerals well and it is the type from which usually smaller or larger units are derived. The following production sections are operated:

- Transport and storage of raw graded perlite is carried out by lorries, hoppers, loading devices, such as bucket elevators and belt feeders and silos
- Production of expanded perlite
  The expanding furnaces are fed by means of appropriate equipment. After passing through the furnaces by means of hot combustion product flow, separating equipment is fed. The cyclone separators are arranged into the line to remove the main fraction, e.g. perlite of 150 kg/cu.m bulk density. Another cyclone separator is arranged for separating other fractions and cloth filters for catching the fines. There are also installed dust section equipments to exhaust gases. The expanded perlite is collected in steel silos which are linked up with either the packaging devices or the hydrophobization line. It is worth noting that the perlite intended to be packed into PE bags is cooled by cooling air driven into the storage bins and, also, the cloth filters must be cooled. The packaging line is provided with dust suction equipments.
- Production of hydrophobic perlite
  The expanded perlite fraction determined for hydrophobizing feeds then the hydrophobization line. The process starts with moistening grains of expanded perlite by hydrophobic agents and subsequent drying-up water while active substances remain on the perlite grain surfaces. The line consists of feeders provided with augers to drive perlite under the equipment spraying the hydrophobic agent.

Subsequently, the adjusted perlite is dried in the drier with vibrating bottom and control and waste gas filtering equipment. Hydrophobic perlite input amounts to 15% of water and the output has 2% of water. Mixing tanks to prepare the hydrophobic agent are components of the line.

- Perlite shipping

  Packaging equipment for filling PE bags and their welding, dust suction equipment and lifting trucks for loading bags are usual equipments. The plant also consists of relevant services - maintenance shop, laboratory, sets ... devices, supporting construction and other services.

C Manufacture of Fireclay Refractories

There are three main processes in the manufacture of fireclay refractories:

1. Stiff Mud Process
2. Dry-press Process
3. Casting Process

1. Stiff Mud Process (Figure 4)

Stiff mud bricks are formed by forcing the plastic material through a die from which it comes out as a more or less homogeneous column that can be cut off into required lengths. This column is generally produced by a deairing auger, consisting of a propeller-shaped screw running in a trough which forces the clay with high pressure through a die.

To receive a plastic body, water is added to the mixture with either a wet pan or a pug mill. The latter is generally preferred, because it is a continuous process and better adopted to feeding the auger.

The pug mill is a long, trough-shaped container with usually two horizontal shafts running down the center, having attached to them suitable blades for kneading and mixing the clay and propelling it gradually toward the exit end. Water can be added to the material in a pug mill to bring the mixture to the proper consistence.

The auger must be designed so as to prevent laminations which often occur in the center of the column as a crack. The die itself is genrally lubricated with oil to reduce the surface friction, and often it is steam heated for the same purpose. Deairing of clay has become a common practice in stiff mud brick making and it enables the production of good quality bricks with a denser structure. However, to reach the required effect, vaccum has to reach up to 700 to 730 mm of Hg.

The column of clay from the auger is cut into uniform sections with a wire cutter. Some of cutters work with one, the other with two wires. The latter ones provide sections of more accurate length. For the same reason, some of producers prefer sizing of sections before they are repressed. Re-pressing of clay sections makes up the required shape to the brick. After being repressed, bricks are quite firm and can readily be handled and stacked on the drier cars.

For hand shaping softer clay is prepared in order to be workable with lower force.

Ageing of the prepared clay sections is a useful operation to increase the plasticity of the mixture and to decrease the sensitivity of some blends to cracking during the drying process.

2. Dry-press Process (Figure 5)

In the dry-press process of making fireclay bricks the clay has a consistence of a rough powder containing 6 to 10% water. Only by high pressure such clay can be consolidated into a homogeneous body.

The preparation of particular raw materials is similar to that one in the stiff mud process. The modern technology, however, seems to be favouring the more careful control of the sizing of the grog by screening and recombining in definite proportions. The mixture of dry materials is moistened in a pan mixer and brought up to the proper consistence. There are different types of mixers used for this purpose. The mixed material is delivered to a hopper over the dry press, where the mixing action is continued and permitted to flow into the dry press as needed.

Different types of dry presses are used, such as toggle type, hydraulic presses or friction presses, pressing one or more pressings in one stroke.

3. Casting Process

In preparing the body, casting process is used usually for special types of fireclay products only.

Considerable experience is needed to make up a good casting sl... The type and amount of the clays are important as well as the sizing of the grog. The amount of deflocculant must carefully be adjusted. The casting process is less productive than other molding methods.

Therefore, in establishing the fireclay industry in a country it is not recommendable to start with the casting process unless local technicians are trained satisfactorily.

Note: It is necessary to mention that, in many countries, siliceous and low duty fireclay refractories are also produced in a red brick plant, following basic operation of the red brick flow diagram. To add fireclay manufacture as a by-production of red bricks is a good compromising step in the developing period during the establishing the refractory industry. However, kilns for red brick firing can never afford the firing temperatures needed in the manufacture of good quality fireclay bricks. In case fireclay products are to be produced in a brick plant, at least one chamber kiln should be added suitable to create proper conditions for firing fireclay products.

Drying Process

In the manufacture of dry-press fireclay bricks the drying problems are becoming quite simplified. However, those products, produced by soft-mud, stiff-mud processing, by hand shaping or those of a large shape must be dried carefully to obtain efficiency in the operation.

During the drying process the clay shrinks while water is being evaporated. As shrinkage, which causes cracking, is equal in volume to that of the water removed during the constant rate period, i.e. most of it, it is clear that the more water in the body the more occasion there is for drying cracks. The water is chiefly bound up with plastic clays. Before the green products can be fired, the humidity has to be decreased below 2%.

In installing drying equipment a lot of factors are to be taken into consideration, such as amount and type of products to be dried per day, the available space, manpower need, fuel and time efficiency and the maximum rate of safe drying. Main types of driers used in the fireclay manufacture are as follows:

Unheated driers - fireclay products can easily be dried when exposed to the atmosphere in warm and dry climates.
Heated driers - when the heat is supplied to the bricks by convection, conduction and radiations. Heated driers can be constructed as

- hot floor driers

  Fireclay products are placed in a single or several layers on a heated floor using the kiln waste heat. Such a floor, in the same time, can be the crown of the kiln. Hot floor driers are very easy to be installed and they fit to smaller capacities of the plant, but their disadvantages are many, such as high manpower need, large space needed and uneven drying.

- chamber driers

  Products are placed on pallets of the same width as the chamber, as soon as they are made. These are then loaded on a car which carries pallets in the drier. After products are dried unloading is undertaken in the same way. Chamber driers are usually built up to dry products of a plant with higher manufacturing capacity.

- continuous driers

  In the fireclay refractories production tunnel driers is the most common type of driers applied to dry products. The ware is moved through the tunnel on track trucks. The direction of the air flow may be either counter- or concurrent with the car motion. The countercurrent air flow tunnel driers are more usual in the fireclay manufacture. They have an air inlet where the bricks are removed and an exhaust stack where they are put in. Tunnel driers represent a modern type of driers, as temperature, time and humidity control can effectively be maintained by various dampers and can be made automatic to comply with a predetermined drying curve. Tunnel driers are usually applied in a fireclay plant of a high capacity.

Firing Process

The firing process of fireclay refractories is the most essential part in the technological flow. This process of heat treatment is applied in a kiln to develop a vitreous or crystalline bond, thus giving the product the required properties which differ from properties of green products distinctly.

The usual required firing temperatures of fireclay refractories are:

Type of fireclay	Firing temperature /°C/
Siliceous	1 250 - 1 350
Low duty	1 350 - 1 410
Medium duty	1 380 - 1 410
High duty	1 410 - 1 450
Super duty	1 450 - 1 500

In general, fireclay materials should be fired to a temperature well above that at which it will be used. This rule is valid for the majority of different fireclay refractories.

In the practice the firing process of fireclay refractories is devided at least into three periods:

a/ The preheating period which is necessary to remove volatile compounds /such as mechanical or chemical water and organic matters/ by heating and/or oxidation.

b/ The heating period to develop a strong body as a result of reactions which ensure that no further significant change will take place when fireclays are used in service.

c/ The cooling period to cool the products down to the room temperature.

Kilns

While red bricks can be fired even in the simplest way, such as in clamp, fireclay refractories, due to the requested firing temperature, are fired in two main types of kilns:

a/ Periodic kilns /such as round or rectangular ones/
b/ Continuous kilns /such as Hoffmann or Mandheim kilns and tunnel kilns/

a/ <u>Periodic kilns</u> can be operated on the up-draught, horizontal-draught or the down-draught principle. The best results are obtained in the operation of kilns on the down-draught principle. The firing process of fireclays in a periodic kiln is based on placing ware in the kiln, on the gradual heating up of the kiln, on keeping at maximum temperature for the necessary period and on cooling the ware. The ware can then be removed and a fresh setting can be put in.

It is clear that apart from the inefficiency by heat losses through walls, a periodic kiln must use a large amount of fuel to heat up the structure for each batch of ware, all of which is lost during the cooling. On the other hand, periodic kilns can be used for very small manufacturing yearly capacities.

Shuttle kilns are a special and modern type of periodic kilns. They are used successfully for firing of special refractories because of the ease of setting and drawing and the very flexible firing cycle which can be adapted in accordance with the requirements of products fired. There is often a considerable saving in fuel and labour over the older type of periodic kilns. They are used for smaller capacities and often fired up to 1 600 to 1 700°C.

They also show a high degree of flexibility in applying different firing cycles according to the product fired.

b/ Continuous kilns, such as of Hoffmann or Mandheim type, utilize the waste heat given off during cooling. In the reality, continuous kilns consist of a number of periodic kilns connected in a circuit. The fresh air flow passes first through ware that has been fired and is in the cooling operation and then the preheated air moves on to the kiln that is being fired. The hot waste gases pass on to ware which is to be fired. Green products are preheated so that they need less fuel for their own firing process. The main principle of this type of continuously working kilns is based on the fact that the fire always keeps moving while products remain in the same position. Waste heat is utilized for preheating of green products but the kiln structure still has to be heated and cooled for each batch.

In the tunnel kilns the reverse process is applied. A tunnel structure is devided into fields. at constant, different temperatures corresponding the required firing curve. The ware is slowly pushed through the kiln on kiln trucks. Because of its high efficiency the tunnel kiln has been recognized as the best kiln for mass production of uniform products, although improved intermittent kilns can continue to be used for small or individual batches, especially of heavy pieces.

D Manufacture of Silica Refractories

Body Preparation

Figure 6 shows a typical flow diagram for the manufacture of silica bricks.

Quartzites are first crushed in a jaw crusher or Symmons granulator into smaller pieces up to about 60 mm. Fine grinding is usually realized in dry pan mills. In order to enrich the finest particles in the blend /below 90 microns/, a part of the quartzites is ground in vibrating or other mills.

Silica wasters are ground separately. Hydrated lime as well as sulphite lye are diluted and added into the mixer at the beginning of the mixing operation. If mineralisers are to be added they are either mixed with the hydrated lime or blended into ground quartzite in the mixer before it is moistened.

The moisture content of the mass differs for dry pressing and for hand shaping. While the blend for dry pressing requires the moisture content of 5 to 7%, for hand shaping 8 to 9% are necessary.

The majority of silica products is manufactured by dry pressing. A successful pressing operation is very important for the quality of finished products. The bigger pressing force, the lower porosity, the lower permeability and the bigger crushing strength of finished products. Therefore, some of high silica products are pressed by several strokes during the pressing operation. Different types of presses are used, such as friction, toggle and hydraulic presses.

Before pressed silica bricks are dry they must be handled carefully because of their low green strength.

Drying Process

The drying process of silica products is much simpler than that one of fireclay bricks since there are almost no volume changes. While water content is decreased the green strength of products grows up to 3 to 5 MPa. The growth of the mechanical strength is caused by the sulphite lye as well as by the cristallization of hydrated lime.

The drying process of silica bricks is operated by high temperature which, sometimes, exceeds 200°C. While floor driers are mostly used for drying of hand shaped products, chamber or tunnel driers are applied usually for dry pressed products.

Firing Process and Kilns

Silica bricks must undergo the firing process which converts the green products irreversibly into a hard product of required properties.

The usually required firing temperature of silica products amounts to 1400 - 1480°C, i.e. Seger Cone 13/14 and 17. The soaking temperature must be regulated in accordance to the quality of silica bricks manufactured. While silica bricks for the steel industry can be fired at lower temperature, the same products for coke ovens and gasworks are to be fired at higher temperature in order to secure better conversion of quartz modifications. A very slow firing, including prolonged soaking, is necessary to allow for the solid-state reactions to be completed, and to prevent rapid volume changes during inversions.

The firing schedule must be regulated very carefully in the temperature interval below 800°C.

The firing process is divided at least into three main operations:

a/ preheating

b/ firing

c/ cooling

An average fired silica brick is a mixture of different quartz modifications, containing about 45 to 60% of cristobalite, 12 to 15% of tridymite, 5 to 30% of inconverted quartz and 10 to 15% of quartz glass.

Different types of kilns are used for silica firing. All of them, however, must be well controllable absolute evenness of temperature is essential and the required firing temperature, which exceeds usually that one for fireclay bricks firing, must be checked.

For bigger plant capacities (20,000 tons to 50,000 tons per year), a tunnel kiln is recommendable, as the slow rate of heating and cooling can be realized easily. The firing cycle of a tunnel kiln can take 6 to 10 days.

Calculations show that for smaller plant capacities (5,000 tons to 10,000 tons) periodic kilns can be more economic, although their firing cycle can take up to 3 - 4 weeks.

While tunnel kilns are heated by gas or fuel oil, some of periodic kilns for silica firing can also be fired by coal.

Super Duty Silica Bricks

Super duty silica refractories are silica bricks with strictly controlled flux content. As a result of that superduty silica refractories can be used under load in higher temperatures than normal silica bricks, sometimes even higher than 1 700^{o}C.

To produce super duty silica bricks, the body composition must be strictly controlled. Only selected quartzites or ganisters are used together with other additives, such as hydrated lime and sulphite lyes. More careful selection and washing is usually required in order to keep the flux content as low as possible. Different standards show different limits for the content of fluxes in the super duty silica blends. Silica bricks, containing not more than 0.5% alumina and with a total of alumina plus alkalis not exceeding 0.7% are super duty silica refractories.

The other manufacturing processes of super duty silica bricks are the same as those of usual silica refractories. The increased strength and the decreased permeability and porosity of super duty silica refractories increase life of different kilns by 10 to 30% over normal silica bricks.

E Selected Equipment Suppliers

Supplier /Producer	Equipment
Alpine Aktiengesellschaft Augsburg P.O.Box 101109 D-8900 Augsburg 1, F.R.G.	equipment for production of fine mineral powders
Amberger Kaolinwerke GmbH P.O.Box 1140 D-8452Hirschau, F.R.G.	equipment for kaolin processing plants
Bickley Furnaces 550 State Rd. P.O.Box 6069 Philadelphia, PA 19114 U.S.A.	ceramic kilns, energy recovery systems, material handling equipment
Boulton, William Ltd., Naviagation Rd., Burslem, Stoke-on-Trent ST6 3BQ G.B.	filter presses, mills, mixers, screening machines
Bradley Pulverizer Comp. 6, Lambeth Rd. St. George's Circus London SE1 6HT G.B.	ring roll mills for mineral grinding
Dorstener Maschinenfabrick AG, P.P.Box 2027 4270 Dorsten 21 F.R.G.	presses for refractory bricks and hydraulic presses
Edwards and Jones Ltd., Whittle Rd., Meir Stoke-on-Trent ST3 7QD G.B.	blungers, feeders, filter presses, grinding mills, mixers and mixing equipment, pumps, screening machines, magnetic separators, pug mills and extruders
Harrop Industries Inc., 3470 East Fifth Av. Columbus, OH 43219-1797 U.S.A.	chamber and tunnel kilns, energy recovery systems, different types of kilns
Heimsoth Ker. Öfen GmbH P.O.Box 329 3200 Hildesheim F.R.G.	ceramic kilns, heat recovery equipment

KWS Strohmenger GmbH 8524 Neunkirchen am Brand F.R.G.	ceramic kilns, chamber kilns
Laeis GmbH P.O.Box 2560 5500 Trier F.R.G.	hydraulic presses, fettling and sponging machines, presses for casting pit refractories and refractory bricks
Ludwig Riedhammer GmbH Schleifweg 45 P.O.Box 120169 D-8500 Nürnberg F.R.G.	ceramic kilns, energy recovery systems
Madam Pumps Atlantic Street, Broadheath, Actrincham, Cheshire WA14 5DA G.B.	pumps for clay slip and slurry
Makino Iron Works Co. Ltd. 3-1, Ohso-cho P.O.Box 23 Tokoname-shi, Aichi-ken 479 Japan	crushers, feeders, filter presses, grinders, mills, pumps, screening machines, magnetic separators
Maquiceram SA, Apartado 16 Majahadonha - Madrid Spain	feeders, mixers, mills, extrusion machines, driers, shuttle and tunnel kilns
Mineral Processing Systems, Inc. 240 Arch Street P.O.Box M-312 York, PA 17405 U.S.A.	grinding and air classification equipment
Mitsuishi Fukai Iron Works Co., Ltd. Mitsuishi, Bizen-shi Okayama-ken, Japan	presses for refractory industry
Netzsch Gebr. Maschinenfabrik P.O.Box 1460 8672 Selb F.R.G.	filterpresses, mills, extruders, shredders, mixers

A/S Niro Atomizer Gladsaxevej 305 DK-2860 Soeborg-Kopenhagen Denmark	spray driers
Přerov Machinery 750 53 Přerov Czechoslovakia	mills, kilns, grinders, disintegrators by flotation, crushers, mixers
Steele and Sons, Inc. P.O.Box 951 710 Mulberry Street Statesville, NC 28677 U.S.A.	feeders, mixing equipment, de-airing pug mills and extruders, cutters

IV. ENERGY MANAGEMENT ASPECTS

The task of any ceramic technology is to develop the manufacturing process which will create, from local non-metallic raw materials at minimum production costs and energy consumption, a product with the required homogeneity and properties, i.e. the product which corresponds International Standards.

The ceramic industry is one of the leading consumers of thermal energy. Its consumption consists in average of 86% production consumption (usually 22% for drying and 64% for firing) and 14% overhead. Practically the majority of ceramic products is fired once or several times to be finished. This fact demonstrates the dependence of the ceramic industry on energy sources as well as on the world energy tendencies. This issue shows the necessity to realize all possible changes and arrangements which may positively influence the energy consumption and which may improve the prospects of ceramic industry in the future.

Energy Management represents a wide, organization- and control-demanding complex of activities based on the detailed analyses of actual conditions, studies on technically feasible targets and determination of gradual steps for their realization.

Energy Management in the ceramic industry is characterized by the following fields of activities:

1. <u>Non-traditional technologies with lowered energy demand</u>

The application of low fluxing raw materials or of fluxes as such lowers the firing temperature. The technology can be simplified, raw material requirements can be reduced and progressive operations applied.

2. Thermal process optimization

To reach the optimum heat consumption during the firing process, two factors are to be analyzed:

a/ Limiting firing conditions of the products, which depend on different structural changes of the blend during their heat treatment, such as loss of chemical water, decomposition of kaolinite, crystallographic changes of silica modification, changes of alumina structure, etc. Many of those changes must be respected during drying and firing to avoid any damage to the green products.

b/ Kiln output

It is obvious that the specific heat consumption grows if the kiln is only partly loaded with dry products. Each kiln's output shows an optimum of energy consumption since overloading of the kilns will waste the energy again.

3. Energy diagnostics of heat processes

The objective data of the actual stay of the kiln or drier are necessary as the basis for the improvement of processing. To obtain these data, the diagnostic measurements are performed by a Mobile Diagnostic Unit, which is equipped with instruments, recorders and evaluating units enabling to perform the analyses of thermal processes as well as the heat balance of production units. The main contribution of diagnostic

measurements in ceramics and refractories are
a/ energy conservation,
b/ output increase,
c/ reduction of rejects,
d/ quality improvement.

4. Thermal equipment modernization means the step in which a capital input is already necessary. Therefore, the modernization is to be considered in two different levels:

a/ Partial modernization which is usually realized according to a feasibility study. It covers, for example, the change of burners, increasing the cooling capacity, installation of mixing fans to the preheating zone, etc. The increased efficiency of the kiln will cover the costs spent on the partial modernization.

b/ Complex innovation of the unit which requires high investments and, therefore, this step is applied when the increased output is requested and it must be based on a feasibility study. The traditional lining is replaced by new insulating materials, the kiln can be extended, the automated regulation applied, etc.

5. Waste heat utilization

Waste heat is the heat rejected from the thermal process at the temperature high enough above the ambient temperature to permit the extraction and utilization of additional value from it. Usual sources of waste heat in the ceramic and refractory industries are combustion gases, the air from the cooling zone of kilns and driers outlet. Such heat is utilized either directly or indirectly, transferred in a heat exchanger.

6. Climate conditions which differ according to the geographical location and which, therefore, also influence the heat consumption of a plant. The temperature, pressure and relative moisture content of the air must be respected.

7. Motivation of personnel, attendance of kilns, driers and other energy consuming equipment in energy conservation.

An effective application of energy management in the production brings about significant energy savings. The following table compares fuel consumptions in the production on traditional and modern equipment.

Table 3 Comparison of Energy Requirements in Different Productions

Product	Specific fuel consumption	
	Traditional equipment	Modern equipment
Washed kaolin+/	2.5 - 3.0 GJ/t	2.0 - 2.2 GJ/t
Perlite	0.5 - 0.8 GJ/cu.m	0.2 - 0.3 GJ/cu.m
Fireclay	6.0 - 10 GJ/t	3.0 - 3.5 GJ/t
Silica	12.0 - 16 GJ/t	5.0 - 8.0 GJ/t

+/ Total specific energy consumption.

V. RELATED INDUSTRIES

The products presented in this publication find a wide field of applications in various industries.

Kaolins are used practically in all traditional ceramic productions, refractory industry, paper industry, rubber, plastic and blue anorganic pigments productions.

In the developing countries, ceramic industries are usually the most important consumers of kaolins, as ceramics can be developed in the country in the very early stage of industrialization.

Kaolins are valuable materials for the production of refractories. Because of a usual low content of fluxing impurities, fireclay and high alumina products based on kaolins show excellent resistance against corrosion, high refractoriness under load and very good mechanical properties.

In the paper industry, depending on the type of paper produced, up to 30% of washed kaolin is applied to fill the batch. If coated paper is produced, the usual weight of the coating layer fluctuates from 40 up to 250 g per 1 m^2, according to the quality of the basic paper and according to the number of coatings. Coating kaolin amounts to 70% from the coating layer, the balance is represented by other pigments, such as titanium dioxide and by glue, such as latex, CMC, etc.

According to the type of rubber produced, 25% up to 60% of kaolin is added into the batch. The bigger addition of kaolin, the higher hardness of the product is achieved.

In the cable industry, 22% of kaolin from the total batch composition are usually added.

Different types of plastics can be filled with washed kaolins, such as polyethylenes, polyurethanes, etc. The possibility to replace expensive polymers with properly upgraded washed kaolins is interesting for any country, which does pay attention to the chemical industry. The usual amount of kaolin applied as a filler in the industry of plastics can reach up to 40 to 60% from the total. At the same time, the added kaolin influences positively some properties of plastics, such as resistance against heat, mechanical properties, etc.

The industrial uses of perlite (expanded and/or hydrophobized) are various, among the more important ones the following can be instanced:

- production of abrasives, accoustical plaster and tile insulations, concrete construction aggregates, filter aids, inert carriers, insulating board fillers, fertilizer extenders, insecticide and pesticide carriers, paint texturisers, packaging media, loose insulations, pipe insulations, soil conditioners, light weight insulating concrete, inter alia.

For the time being, the most important user of expanded perlite is the construction industry which accounts for about 60 - 70% of the overall consumption of perlite. Perlite incombustibility and low water absorption make it a really ideal insulating material. Perlite plaster aggregates are used widely to fireproof steel constructions and to reduce the weight of ceilings and interior walls.

Perlite is a very good filter aid used by breweries to filter out fine solids such as bacteria, by water companies to make water drinkable and by many other industries in the processing of nourishment, waxes, plastics, antibiotics and others.

Perlite application as a filler is very important in paper and paint manufactures. It is also used as a carrier of insecticides, pesticides and chemical fertilizers. It is applied to reclaiming soils because perlite is chemically inert and lasting and does not alter the pH of soils. Its cellular structure enables it to retain several times its own weight in water and provide the roots with a prompt supply of moisture.

Other important applications for the expanded perlite include its use as a cryogenic insulator to hold gases (liquid oxygen) at very low temperatures, as an oil adsorbent on water and dry surfaces, as a cleaner of effluent containing oily wastes.

Fireclay refractories are employed in a great extent in many industrial branches. They are used at higher temperature in so called "dry glow" processes as well as in processes with the action of molten metals or other materials.

In the iron and steel industry the fireclay refractories are employed for the lining of all parts of blast furnaces and their accessories, i.e. the hot blast air stove, insulation of air ducts for the temperatures over 800°C, for the lining of pig iron ladles and as tapping bodies, further for the lining and heat insulation of open hearth furnaces and pig iron mixers, electric arc and induction melting furnaces and for steel mills, casting equipment as lining of casting ladles, stoppers, nozzles, stopper sleeves and rods, casting sleeves, cones, runners, lining of heads, cast-iron moulds and tapping runners and granular fireclay materials are used in this industry as mouldables, ramming and gunite mixes for repairs.

In foundries the fireclay refractories are used for the lining and insulation of cupola furnaces, reverberatory and similar furnaces, rolling and rotary furnaces, electric induction furnaces, further for the lining of burners, as thin-walled shapes for the masonry subjected to strains at the temperatures below 1200^{o}C, as ladle bricks, and finally as granular fireclay mouldables and mixes for repairs of the masonry.

In the gas and coke manufacture the fireclay products are used for the upper furnace construction, i.e. masonry of retort walls consisting of air, heating and flue channels, for the bottom furnace construction, i.e. recuperators, regenerators, for thin-walled shapes as dampers, heating channels, etc., one-piece retorts, for the masonry subjected to strains and wear at the temperature below 1200^{o}C, as shapes for doors, for stoppers and burner nozzles, as heat insulation for lower and medium temperature and as jointing and lining mouldables for the maintenance of retort walls.

In other branches of industrial furnaces and boilers the fireclay products are used for the arches, masonry and heat insulation in medium and high temperature units, for the lining of tunnel kiln cars, for the kiln furniture in firing ceramic ware, thin-walled shapes for recuperators, ampers, etc., shapes for kiln doors and inspection holes, for the masonry subjected to special temperature changes and for different types of mouldables as ramming and lining mixes for the repair of furnaces and boilers.

In the <u>glass industry</u> the fireclay refractories are employed for the outside masonry of glass pot furnaces, bench blocks, door shapes and other different parts of furnaces, in tank furnaces for burners, tank blocks, shapes for walls, charging ports, bridges and floaters coming into contact with molten glass and bridge shapes closing the tanks. In other parts of furnaces the fireclay products are used for the chamber walls and arches of recuperators and regenerators, for the checker, for channels, dampers, door and inspection holes, for those parts of the masonry which do not come into contacts with the glass. Furthermore, different types of fireclay mouldables are applied as ramming and jointing mixes for repairs and maintenance.

In the <u>cement industry</u> the fireclay products are used for the lining subjected especially to very high wear and as lining or insulation without any great requirements.

In the <u>chemical industry</u> the fireclay masonry is a part of roasting and calcining furnaces of pyrites and sulphates, fireclay products are used for the bottoms of these kilns, etc., where the masonry is subjected to the action of agressive gases at the temperature 1200 - 1300°C.

In last years there was a worldwide effort to replace the formed refractory products wherever possible with unshaped or so called monolithic refractories, i.e. mouldables and gunite mixes, refractory concretes, etc., which leads to the decrease of heat energy consumption and substantial reduction of labour.

Silica refractories are used especially in the steel industry, in the glass industry and in the coke and gas industry. The silica refractories find use on places with high requirements on refractoriness under load, on volume stability during their service with minimum after-expansion and on high compression strength.

The ordinary silica finds use for the lining of heating- and checker-chambers.

The high-duty silica is employed for less stressed arches and walls of metallurgical and glass furnaces operated at high temperatures, likewise for the walls of coke and gas-ovens.

The super-duty silica can be used in arches and walls of iron-steel furnaces and continuous kilns which are not cooled under 700°C, and for use in coke ovens, mainly for floors.

Compared with fireclay products, silica refractories show the following main advantages and disadvantages:

1. Silica refractories show high refractoriness under load. Because of this property, silica bricks are good for use in metallurgical furnaces, operated at high temperatures.
2. Silica bricks do not contract on reheating but show an after-expansion which means that they can well be applied in the construction of roofs with large spans.

3. In temperatures above 1000°C, silica products show a 50%-higher thermal conductivity than fireclay materials. This property makes them suitable for gaswork

and coke ovens of which the carbonization chambers are heated externally by conduction of heat through the walls of chamber.

4. In spite of high refractoriness under load, silica bricks rapidly deform after initial softening, i.e. the overheating of the construction above its critical point can lead to the collaps of the work.

5. The other disadvantage of silica bricks is in their sensitivity to thermal changes at lower temperatures /up to 700°C/. Therefore, the heating of kilns newly lined with silica materials must be gradual, especially around the temperatures of 230 and 575°C. Furnaces and kilns with silica refractories roofs must not be cooled under 700°C.

VI. FINAL NOTE

A growing attention has been paid to non-metallic minerals based industries in developing countries during recent years. A frequent occurrence of raw materials, labour intensive processing and production requiring low capital expenditures and simple equipment together with a wide application of products which often condition the development of related industries, are the features which make the non-metallics interesting materials for the developing countries. Though the expenditures on energy form a considerable part of the total production costs in the non-metallic industries, the system of energy management introduced into the production helps to keep these expenditures at a reasonable level.

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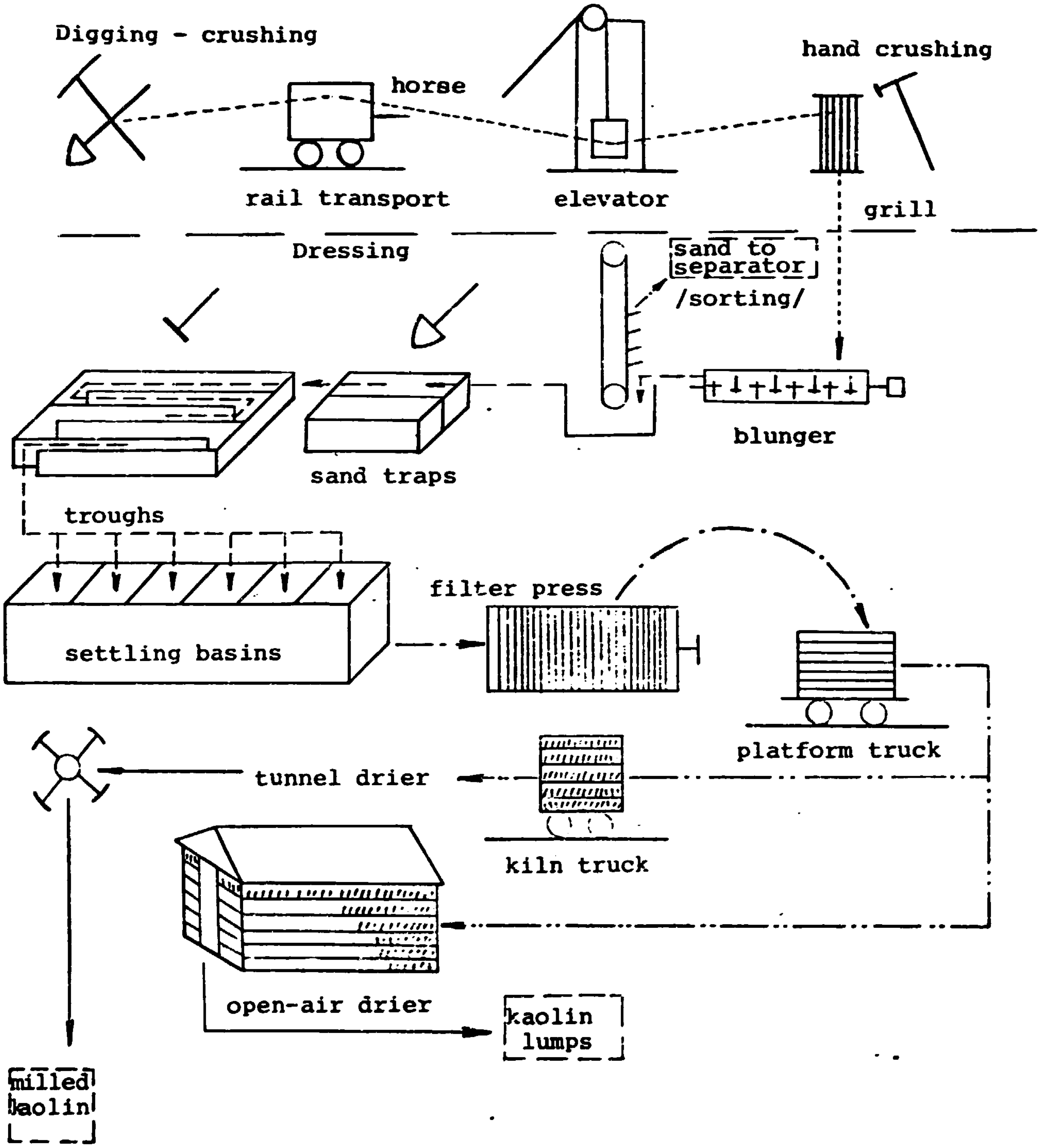
LIST OF FIGURES

Figure 1 Simple Washed Kaolin Manufacture



raw material

suspension in a sorting cycle

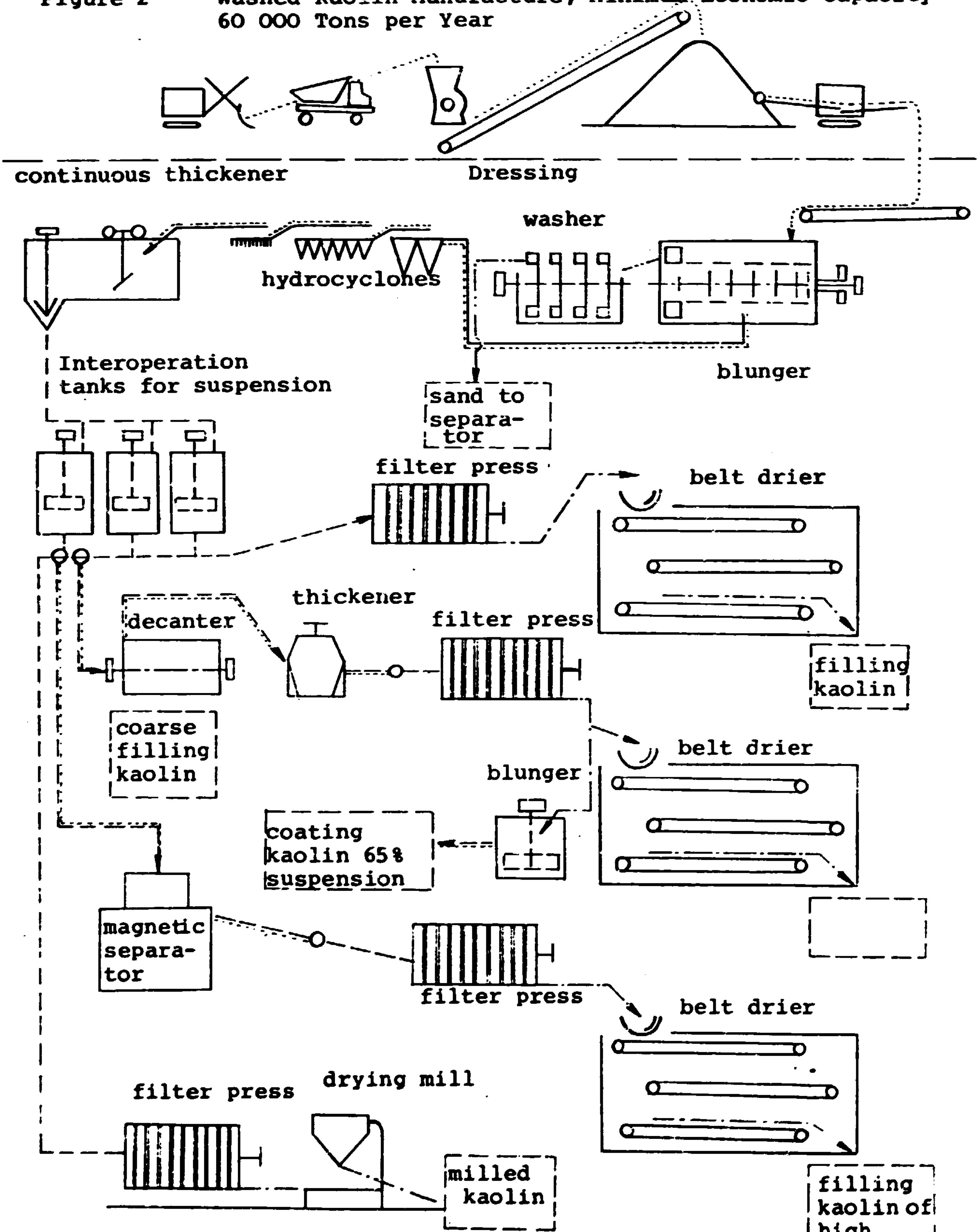
thickened sorted suspension

dewatered kaolin

dry kaolin - final product

sand from the sand separator

Figure 2 Washed Kaolin Manufacture, Minimum Economic Capacity 60 000 Tons per Year



raw material
non-thickened suspension in the primary sorting cycle
the same thickened flocculated suspension
thickened deflocculated suspension, re-sorted, if necessary
dewatered kaolin
dry kaolin - final product

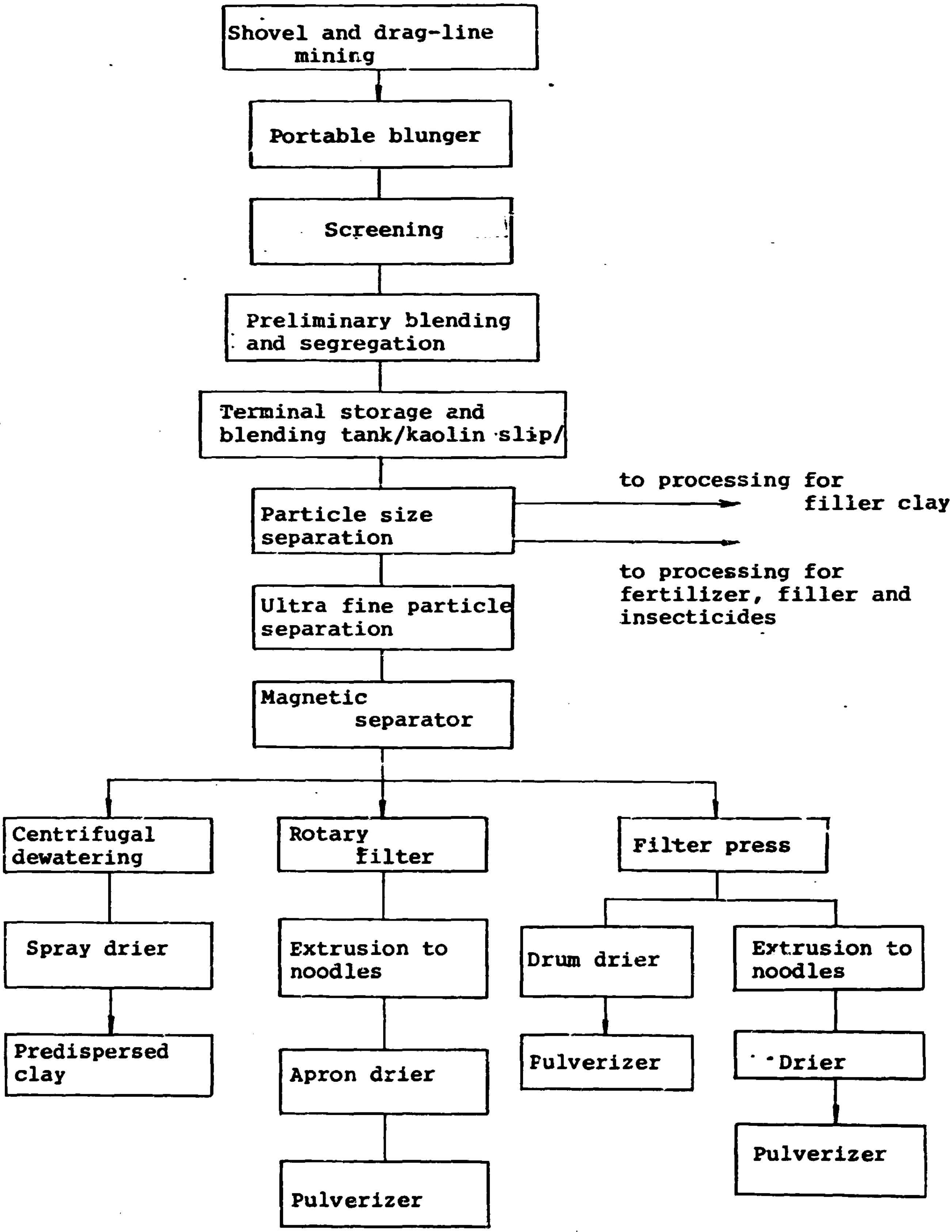


Figure 3 Washed Kaolin Manufacture
Different Dewatering Technologies

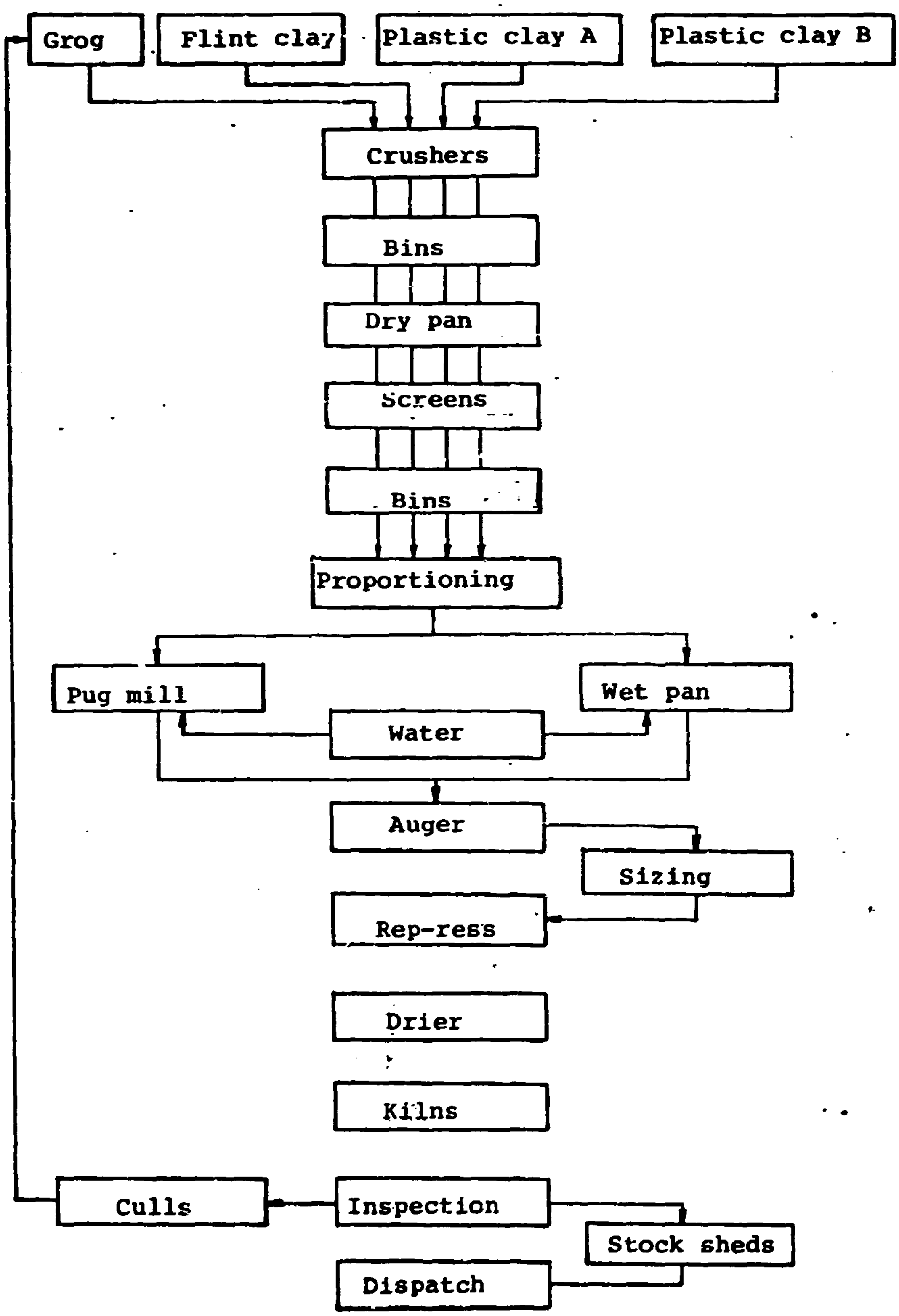


Figure 4 Flow Diagram for the Manufacture of Stiff Mud Fireclay Bricks

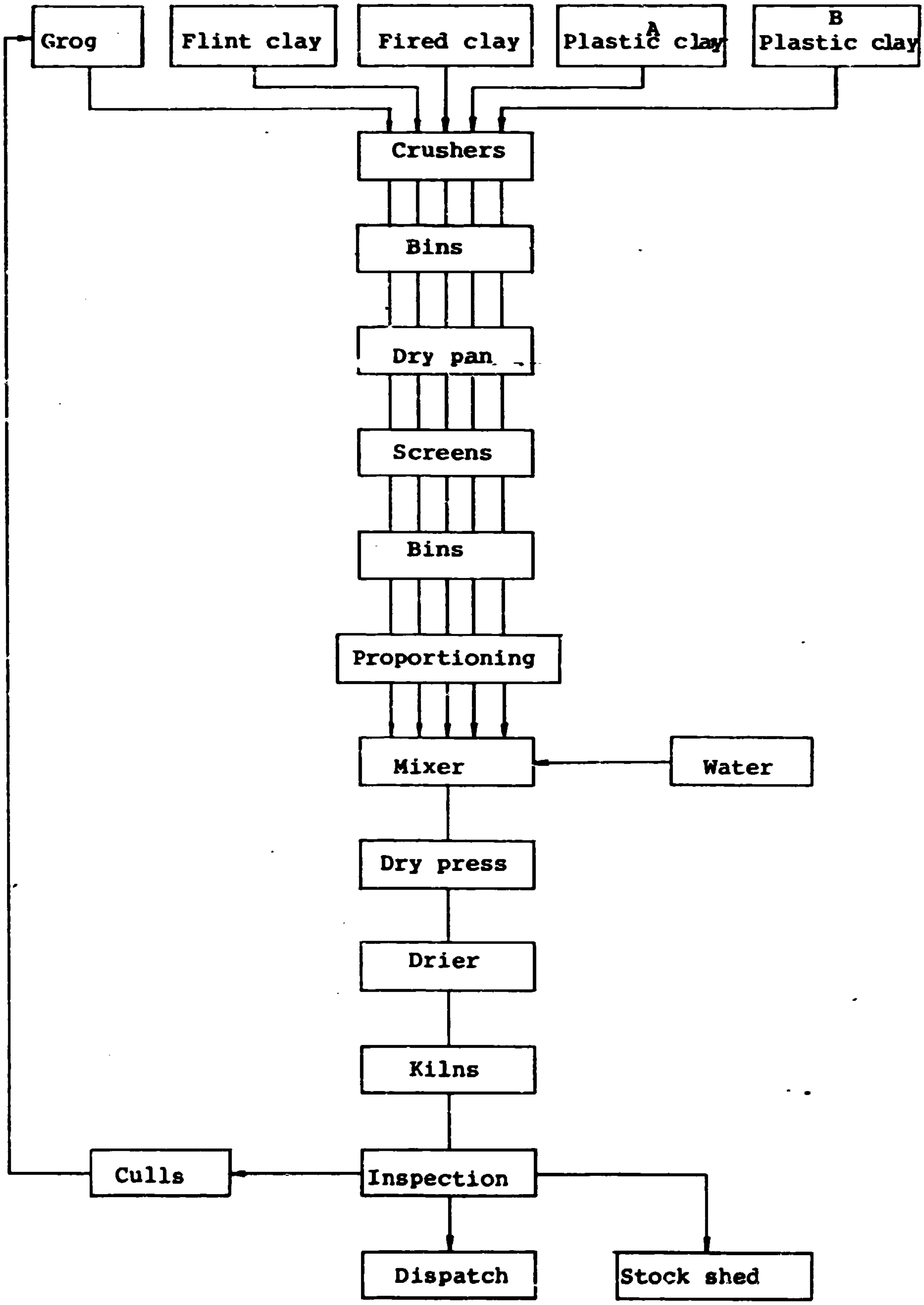


Figure 5 Flow Diagram for the Manufacture of Dry-pressed Fireclay Bricks

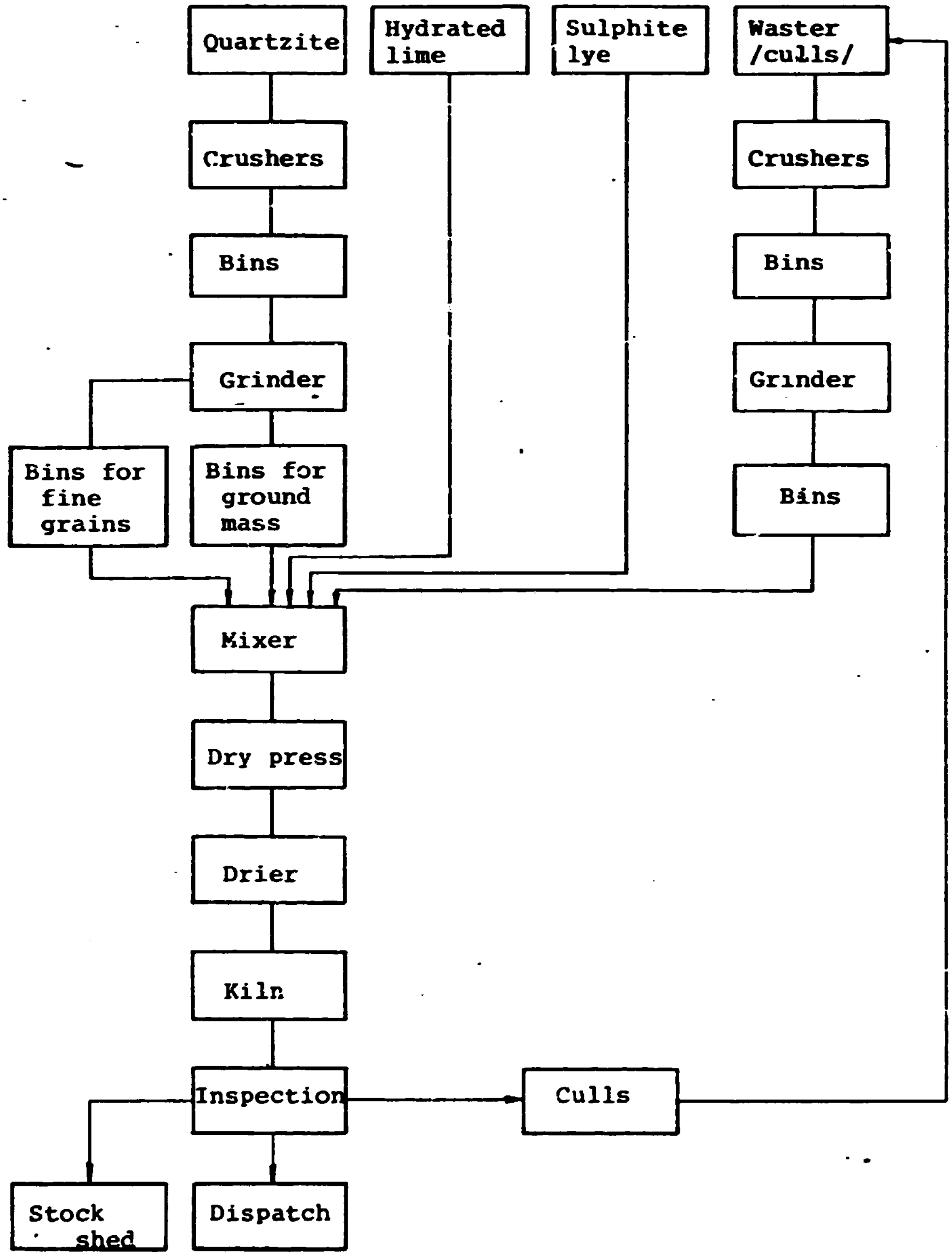


Figure 6 Flow Diagram for the Manufacture of Dry-pressed Silica Bricks