OCCASION

This publication has been made available to the public on the occasion of the 50th anniversary of the United Nations Industrial Development Organisation.

DISCLAIMER

FAIR USE POLICY

CONTACT

Please contact publications@unido.org for further information concerning UNIDO publications.

For more information about UNIDO, please visit us at www.unido.org

UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION
Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
Tel: (+43-1) 26026-0 · www.unido.org · unido@unido.org

15467

Distr.
LIMITED

IPCT.35
19 June 1987

ENGLISH

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

TECHNOLOGY PROFILE ON MINI LIME PLANTS *

Prepared for

INTIB - THE INDUSTRIAL AND TECHNOLOGICAL INFORMATION BANK

by
R. Spence**
UNIDO Consultant

---

* Mention of firm names and commercial products does not imply the endorsement of the Secretatiat of UNIDO. This document has been reproduced without formal editing.

** The Martin Centre for Architectural and Urban Studies, Cambridge, England.

V.87-86209

CONTENTS

SYNOPSIS

The overall purpose of this document is to enable planners and potential lime producers in developing countries to make informed choices of technology at the pre-investment stages of projects. The document provides:

- background information on the lime and limestone industry: uses, raw materials and their implications on choice of technology;
- an overall technology profile of lime production plant in the 1 - 100 tonne per day (tpd) capacity range;
- detailed technical and operational information on several alternative lime kiln systems in the 1 - 100 tpd capacity range. The choice will be such as to illustrate the different technological forms these systems can take at the various levels of capacity;
- a review of the economic implications and factors influencing the choice between conventional large scale plant and mini-lime plant.

SECTION 1. THE LIME AND LIMESTONE INDUSTRY: RAW MATERIALS, USES AND CHOICE OF TECHNOLOGY

Lime and limestone, in their various forms, are the most widely used and versatile raw materials of industry. Limestone can be processed to produce a material suitable for a wide range of industrial applications. Its relatively common occurrence and the ample size of the deposits, render it an economic alternative in many industries.

Limestone is a material which is predominantly composed of calcium carbonate ($CaCO_3$) with varying amounts of magnesium carbonate ($MgCO_3$), and silica, alumina and iron oxides. Its chemical composition varies from high calcium limestone with more than 95% $CaCO_3$ through to magnesian limestone and dolomite, which has an $MgCO_3$ content of around 40 - 42% (Table I). Physically limestone varies in hardness, strength, porosity and crystallinity. The chemical purity, as well as the physical character of the limestone, depend on its depositional environment and the subsequent geological process which it has undergone.

The most commonly exploited limestone is in the form of lithified sedimentary rock, which ranges from a dense, hard, non-porous material such as the carboniferous limestone of Britain to a weakly cemented, porous rock such as chalk. In general terms, but by no means always, older limestones (paleozoic or mesozoic age) tend to be harder than the younger rocks of Tertiary or Quarternary age. Other forms of calcium carbonate used are sea shells, coral, marl, carbonatite, partially or wholly dolomitized limestones, and marble, which is a metamorphosed limestone. In all cases however, irrespective of type, for a deposit to be of commercial importance, its physical and chemical properties must be of adequate quality, consistently through the deposit. It must also be of sufficient quantity and in a geological form that allows for economic quarrying.

The physical and chemical properties of the limestone determine the potential applications. Each industrial application requires and makes use of a specific set of chemical and/or physical properties. The processing is therefore determined by the requirement of the market. The process technology that is used however, is also dependent on the nature of the raw materials available.

TYPICAL RANGES OF CHEMICAL ANALYSES OF LIMES

CaO	92.00 - 98.00	76.00 - 92.00	54.00 - 65.00
MgO	0.30 - 3.00	5.00 - 20.00	30.00 - 41.00
SiO2	0.20 - 2.50	0.25 - 3.00	0.10 - 2.50
Fe2O3	0.10 - 0.50	0.10 - 0.50	0.05 - 0.50
Al2O3	0.10 - 0.70	0.20 - 1.00	0.10 - 1.00
CO2	0.50 - 3.00	0.50 - 3.00	0.25 - 2.00
SO3	0.01 - 0.10	0.01 - 0.10	0.01 - 0.10
P	Trace - 0.05	Trace - 0.05	Trace - 0.05

TABLE I

USES OF LIMESTONE

APPLICATION	FORM AND PROCESSING REQUIREMENT	EVALUATION PARAMETERS
Dimension stone. "Marble"	Quarried in large blocks, cut into slabs and polished	Block size, fracturing, colour, porosity, frost resistance.
Building stone	Quarried in blocks of around 30cm.	Appearance, compressive strength, porosity.
Rip rap or armour stone	Boulders of around 30cm. Oversize rock from blasting	Compressive and impact strength, density, porosity, frost resistance.
Aggregate for use in concrete, as road-stone, railway ballast, roofing granules, terrazzo and stucco.	Rock from 1 - 20cm produced by crushing and screening.	Impact and crushing strength, abrasion resistance, resistance to polishing.
Filter bed stone	Crushed and screened to material of a size from 3 - 8cm.	Compressive strength, chemical purity, moisture absorption, abrasion resistance (dust formation).
Poultry grit	Crushed and screened to 3 - 8cm.	Grain shape.
Glass and chemical manufacture	Crushed, milled and sized to range from 0,2 - 5cm.	Chemical purity, organic matter, abrasion resistance (dust formation).
Agriculture	Crushed and screened to size <4mm.	Chemical purity .
Metallurgical industry - ferrous and non-ferrous	Crushed, milled and sized to < 3mm.	Chemical purity.
Asphalt filler	Pulverized limestone used, including dust collector discharge. Size < 0,2mm.	Particle size
Filler and extender in plastics, rubber, paint, paper and putty manufacture.	Crushed, milled and sized to <0,2mm generally to very stringent specifications.	Chemical purity, size distribution, brightness, oil absorption, pH and grit content.
Mild abrasives in domestic products	Crushed, milled and sized to <0,2mm.	Hardness, colour, quartz content.
Glazes, enamels, mine dust, fungicide and insecticide carrier.	Crushed, milled and sized to <0,2mm.	Chemical purity, colour, organic matter.
Flue gas desulphurization	Crushed, milled and sized to < 0,1mm.	Chemical purity, surface area, microporosity.
Acid neutralization	Crushed, milled and sized to < 0,1mm.	Chemical purity
Portland cement manufacture	crushed and milled to material < 75μm.	Chemical suitability relative to other raw materials.
Lime manufacture	Crushed and screened to size required by kiln system.	Chemical purity, porosity, compressive strength, abrasion resistance.

TABLE II

Limestone is used in the chemical and metallurgical industries, in portland cement manufacture, as an industrial filler and extender, in the civil engineering industry, in agriculture and in a variety of other industrial end uses. Its major use however, is in the production of lime. (See Table II)

Lime and hydrated or slaked lime are used in as wide a range of applications. They are used in the chemical, metallurgical and industrial sectors, the construction and civil engineering industries and in agriculture. (See Table III)

The very diversity of consumers of limestone products, including lime, makes for a potentially very cost effective production process which has a limited amount of waste. It is essential, to take full advantage of this potential, that projects to exploit limestone deposits be planned with a view to supplying the full range of limestone products. Figure 1 presents diagrammatically a simplified production flow sheet of a conventional, complete lime and limestone plant. This illustrates the key components of the production process and the extent to which it can be sub-divided, depending on the requirement of the market.

Lime calcination is the most complex component of the production process. It is highly sensitive to and dependent on a variety of interrelated factors, including the raw material available, lime kiln design and method of operation, and the form of product required. It is therefore most susceptible to inefficiency and even failure. Selection of the appropriate lime kiln system, including both design and operation, is possibly the most important technological decision of the project team. The lime kiln is also generally the most expensive single component of the production process. The emphasis of this document is on this aspect of the production process, to provide a broader perspective of the technology available and its economic implications.

USES OF LIME AND LIME HYDRATE

Metallurgical:	Steelmaking flux; iron ore agglomeration; beneficiation of non-ferrous metals such as copper, alumina and magnesium metal; and a wide range of other minor uses such as wire drawing and neutralization of metallurgical waste.
Chemical:	Manufacture of sodium alkalis such as sodium carbonate, bicarbonate and hydroxide; inorganic salts and bases such as magnesium oxide and hydroxide; calcium carbide; and a host of other calcium chemicals such as hypochlorite, nitrate, soda-lime and precipitated calcium carbonate.
Sanitation:	Water and effluent treatment
Ceramics:	Glass manufacture, refractories and building products such as sand-lime bricks and cellular concrete products.
Pulp and paper:	Causticizing sodium carbonate solution.
Food and by-products	Sugar refining, leather tanning and citrus pulp processing.
Petroleum:	Grease manufacture, petroleum refining and drilling muds.
Paints and coatings	Protective coatings, varnish, paints and pigments.
Construction:	Masonry mortar, plaster and stucco, whitewash, lime-cement paint and soil stabilization.
Agriculture:	Direct soil liming; soil neutralization and fertilization; liming of forests, lakes and ponds (in industrialized areas).

The industrial applications referred to use lime in a variety of forms. Physically, it is used in sizes ranging from 0,05mm to 50mm. All industries apart from the construction industry and agriculture demand a lime of high chemical purity. Some industries however, use dolomitic lime, either in a soft-burnt reactive form or as a so-called dead-burnt dolomite. Another form used is hydrated lime ($Ca(OH)_2$), mostly in construction and agriculture but aalso in sanitation, and other industrial applications.

The processing required is calcination, crushing, grinding and sizing, if a quicklime product is required. Alternatively, the quicklime is crushed and slaked to produce a lime hydrate. Quicklime is marketed in a granular or pulverized form. It is a material which is reactive in the presence of moisture. It is therefore stored and transported in airtight containers, to prevent air slaking and thus preserve the reactivity for which it is valued, and to make for safe handling.

TABLE III

TYPICAL PRODUCTION FLOWSHEET OF LIME AND LIMESTONE PRODUCTS

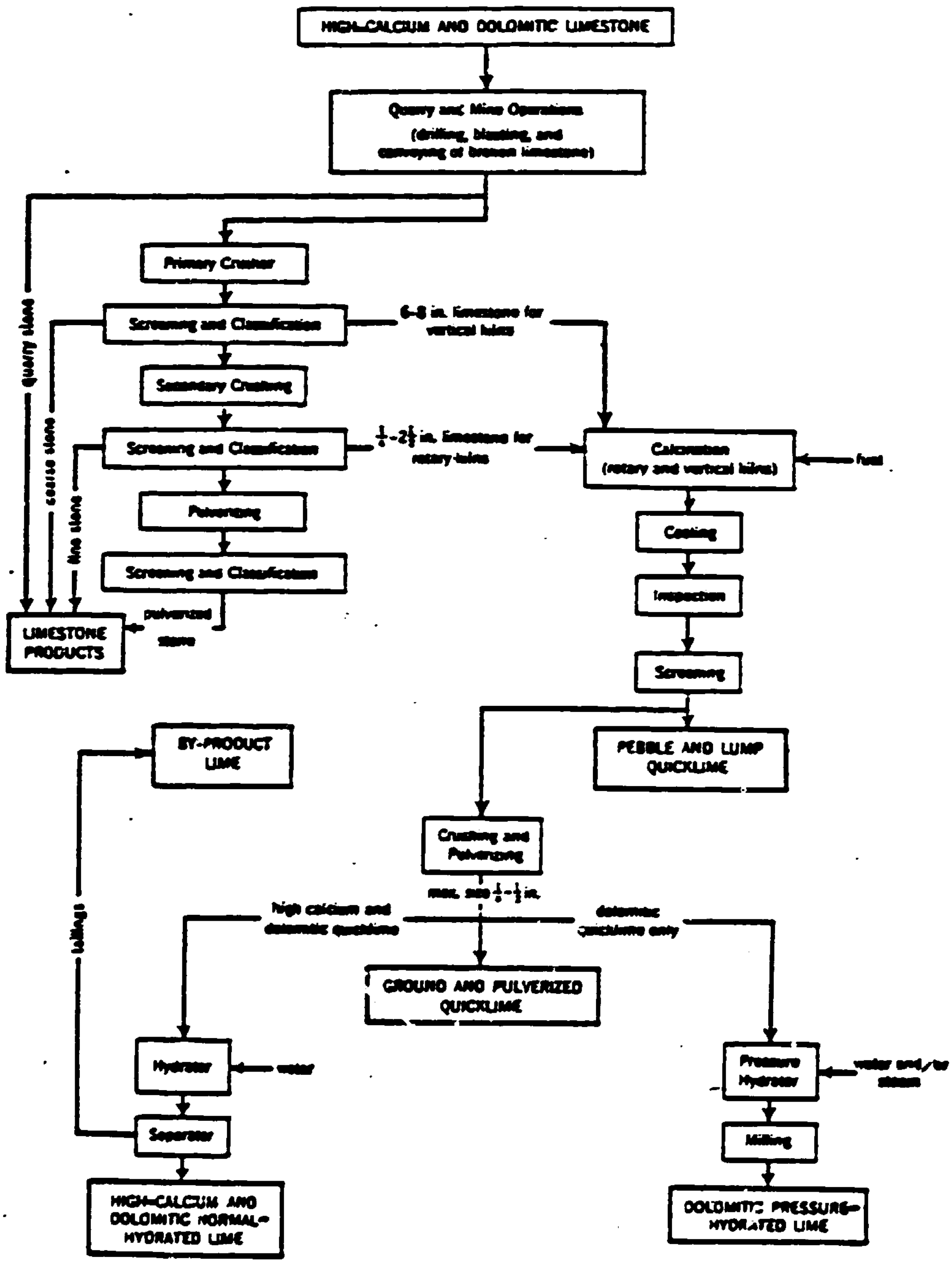


FIGURE 1

SECTION 2. GENERAL REVIEW OF LIME CALCINATION PLANT

The aim of the kiln designer can be briefly stated as the design of a kiln which will produce the required quantity of lime of the required quality with the lowest possible fuel consumption, and with the lowest possible capital, maintenance and operating cost. The kiln design and operation is bound by the conditions in the particular circumstances. These limiting conditions are:

- quantity and quality of output
- characteristics of limestone available
- alternative fuel types available
- availability, cost, productivity and skills levels of manpower
- materials, machinery and equipment available for kiln construction and operation.
- spares and repair and maintenance facilities available

The kiln designer, having accumulated this information, goes through an iterative process of assessment of alternative kiln design concepts in terms of the limiting conditions and, after optimizing the implications of each option, makes a choice. This choice of kiln design is then engineered in detail, based on the numerous interdependent variables of lime calcination.

The purpose of this section is esssentially to present a range of kiln designs that have been used, to provide a broad view of the kiln design concepts available. In addition, to assist with assessment of the alternatives, it will include a brief resumé of the theory of calcination and the factors related to the limestone and fuel types available which affect the choice.

Theory of calcination and factors affecting kiln design and operation

The calcination of limestone is a simple chemical reaction. In practice however, it is surprisingly complex, often requiring, at the initial stages, modifications in design and operation, based on a process of trial and error, for efficient kiln performance.

The limestone is heated to a TEMPERATURE at which carbon dioxide (CO_2) is driven off the limestone ($CaCO_3$). This will depend on the pressure and CO_2 concentration in the kiln. At 1 atm. pressure for 100% CO_2, limestone begins to dissociate at 898°C. In dolomitic or magnesian limestones however, at 1 atm. for 100% CO_2 concentration, for coarse crystalline types, CO_2 dissociation commences at about 750° and for dense fine grained types at about 500°C. A good average would be around 725°C.

CO_2 dissociation commences at the surface of the limestone lump and penetrates inwards towards the core. Generally, for fixed temperature and kiln atmosphere conditions, the larger the diameter of the limestone lump, the longer the duration of calcination required to calcine to the centre of the lump and vice versa. If dissociation of the lump is incomplete there remains in the centre of the lump an uncalcined core of carbonate. Although this is not deleterious it serves to reduce the quantitiy of available lime in the final product. If the quicklime lump is hydrated and the core screened out a reduction in the potential output results. Calcination is therefore a function (inverse relationship) of temperature and duration of calcination. In practice the choice of these is dependent on the size, porosity and purity of the limestone type, the rate of output required, and the quality of output required.

There is a tendency in practice to reduce the duration of calcination so as to maximize throughput. This can only be done by raising the temperature of calcination. Above a certain point however, (normally about 1300° for high calcium limestone and above 1100°C for dolomitic limestones) the quicklime becomes hard burnt and difficult to hydrate. Therefore, within the physical constraints of a particular limestone, a compromise needs to be reached between the temperature of operation and the throughput so as to maximize the quality. Generally, temperature of around 1150°C for high calcium limestones, and 1000°C for dolomites produces the best quality product at a reasonably economic rate of production. To maximize the quality of the output it is necessary to avoid subjecting the limestone to a sudden change in temperature. The limestone should be gradually preheated to the calcining temperature.

The SIZE of the limestone lump that can be used is dependent on its strength, and the resistance to abrasion during its passage through the kiln. There is a requirement to maximize the length of the kiln shaft so as to maximize the length of the preheating zone and thus recuperate as much heat as possible from the rising hot gases. The limestone must be sufficiently strong to withstand the vertical load of the column of material. It must also resist abrasion during its passage down the kiln shaft so that an excess of fines, which would impede the flow of hot gases through the packed bed, is avoided. The longer the shaft length, the greater the extent of abrasion.

The size of the limestone feed is also dependent on its POROSITY. The more porous limestones have a faster rate of calcination. The finegrained limestones are generally more porous whereas the coarse crystalline types are less so. To achieve the same rate of calcination the latter must therefore be smaller in size.

The limestone must be as near to cubical in SHAPE as possible. Assuming an even distribution of heat such a stone will calcine evenly all round its surface. Furthermore, in all vertical shaft kilns there must be ample space (30 - 35%) betweeen the stones to allow for adequate circulation of the hot kiln gases. A broad size gradation will reduce the volume of space which will result in uneven firing (small stones calcined and large not). Both a broad size gradation and flaky stone shape will also result in the formation of channels in the packed limestone bed through which the hot gases will flow. The maximum stone size recommended for a hard, dense limestone is 150mm with a size gradation of no more than 1:2, ie maximum spread of 75 -150mm. A more even gradation is preferable but may be uneconomic. The feed size for a soft, porous limestone such as chalk can go up to 250mm.

IMPURITIES in lime are derived primarily from the limestone itself, but also from certain fuels. The presence of impurities affects the quality of calcination. At calcining temperatures the CaO and to a lesser extent the MgO will combine chemically with the impurities to form calcium and magnesium silicates, aluminates and ferrites. The formation of these compounds reduces the calcining process by clogging the micropores in the stone, thereby impeding the flow of CO_2 out of the limestone lump. Higher temperatures are consequently required to complete calcination. Chemically, the presence of impurities reduces the quantity of available lime, ie if there are 10% impurities in the limestone there will be around 20% in the quicklime produced.

Impurities derived from FUELS occur primarily from mixed feed firing with coal, particularly with types that have a high ash content. Silica, carbon, iron and alumina contained in the ash contaminate the lime both in a free state and by the formation of silicates and aluminates. Sulphur absorbed in large quantities from the combustion gases discolours the lime. This happens not only in a mixed feed operation, but also from coal derived producer gas, oil and natural gas to a lesser extent. Such contamination is not normally a problem with building and agricultural limes but can be for other end uses. Of all fuels wood has the least potential for contaminating limes. If economically available it is the ideal fuel for limeburning.

DECREPITATION is the disintegration or fracture of a rock into fines when heated to the calcination temperature. The heat causes an expansion of individual crystals which, particularly with coarse crystalline marbles, results in high internal stresses and decrepitation. However, although decrepitation is most common with coarse crystalline rock it is known to occur with other limestone types.

Dolomite is particularly difficult to fire satisfactorily since the temperature necessary to dissociate the CO_2 from the $MgCO_3$ component of dolomite is lower than that necessary for the $CaCO_3$. Firing at temperatures required for the calcination of $CaCO_3$ will, to a greater or lesser extent, overburn the $MgCO_3$ component making it difficult to hydrate.

Kiln designs

Kiln designs and methods of operation vary essentially in the manner in which the fuel is used to effect calcination, in the manner in which the raw materials are handled, and in the materials used in the construction of the kiln. Kiln types can be subdivided into vertical shaft kilns, rotary kilns, tunnel kilns and other more sophisticated varieties. Traditionally, vertical shaft kilns, and tunnel kilns, have been used fairly effectively to produce lime at the low levels of output. In recent times however, major changes have taken place in vertical kiln design. There are now a large number of kiln types available, using the whole range of different fuel types in different ways. Lime kiln designers have come a long way to develop kilns which will produce high quality lime, have a low fuel consumption, a low capital cost per unit output, and a low labour requirement. Most development however, has been carried out in the context of the economic and technical environment of industrialized countries. This has resulted in many of these technologically advanced pieces of engineering having characteristics inappropriate for most developing countries. Several kiln designers do have scaled down versions of their technologies. At the same time traditional kiln designs are being developed and used in less industrialized countries, to produce a consistent, high quality product at a level between the very low output and generally inefficient traditional kilns and the high technology options. The following are kiln designs, including traditional types, which can be used to produce lime in the capacity range 1 - 100 tonnes per day.

A. <u>Vertical shaft kilns - Batch operation</u>

Batch kilns are the oldest and most well tried method of calcination. They fire one volume of limestone at a time.
There are two types of batch fired kilns:

- the flare or updraught kiln (Fig.2,3 & 4)
- the mixed feed type where the limestone and fuel are charged in alternate layers in the shaft (Fig.5,6 & 7)

FLARE KILNS are either heavy stone structures or are built into the side of an embankment or hill. Firing is carried out in a chamber at the base of the kiln which is either an arch or dome of large pieces of limestone, rebuilt with each firing; or it is a permanent feature of the structure. In both instances there is no means of ascertaining when the limestone has been completely fired except by regular inspection through holes in the kiln wall. The colour of the limestone should be a bright cherry red when the calcination temperature is reached.

The quality of the lime produced is very much dependent on the skill and experience of the kiln operator, firstly in loading the kiln with the required size of stone at the different levels, to ensure maximum calcination, and secondly in the actual firing, to ensure that the required temperature is reached and maintained for the required time. A fairly large proportion of waste can be expected.

The MIXED FEED BATCH KILNS have a major advantage over the flare kilns in that they require relatively little attention during firing. Fuel and limestone are charged in alternate layers at the top of the kiln and, after the fuel has been completely burnt out and the material has cooled, the quicklime lumps are withdrawn through a discharge opening at the base. The disadvantage of these kilns is the excessive waste of heat as the fire

Indian flare kiln

Indian flare kiln

Chinese flare kiln

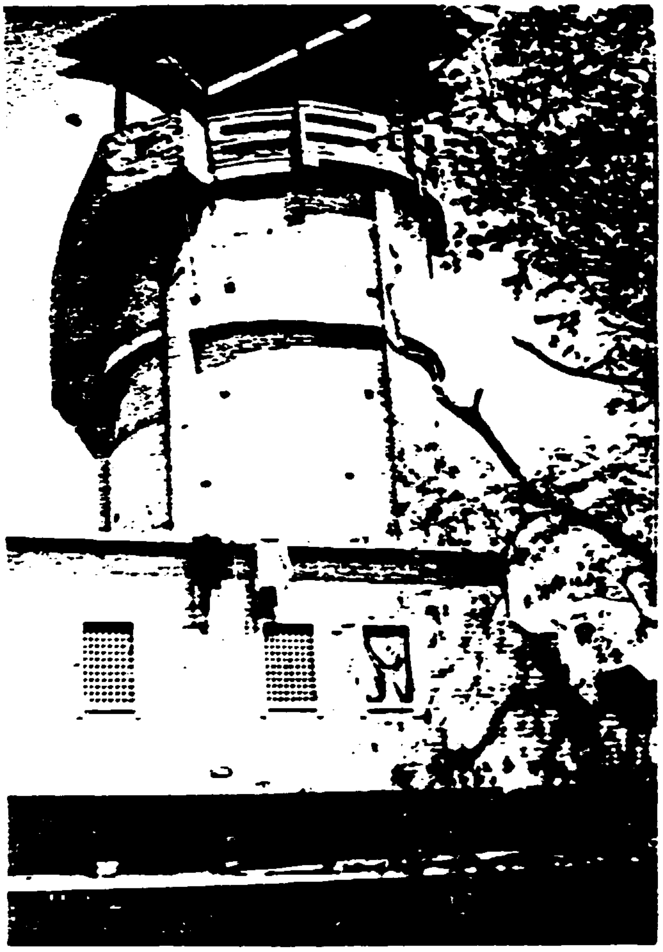
rises towards the top of the shaft. The heat lost to the environment would, in a continuously operated kiln, be used to preheat successive layers of limestone.

B. Vertical shaft kilns - Continuous operation

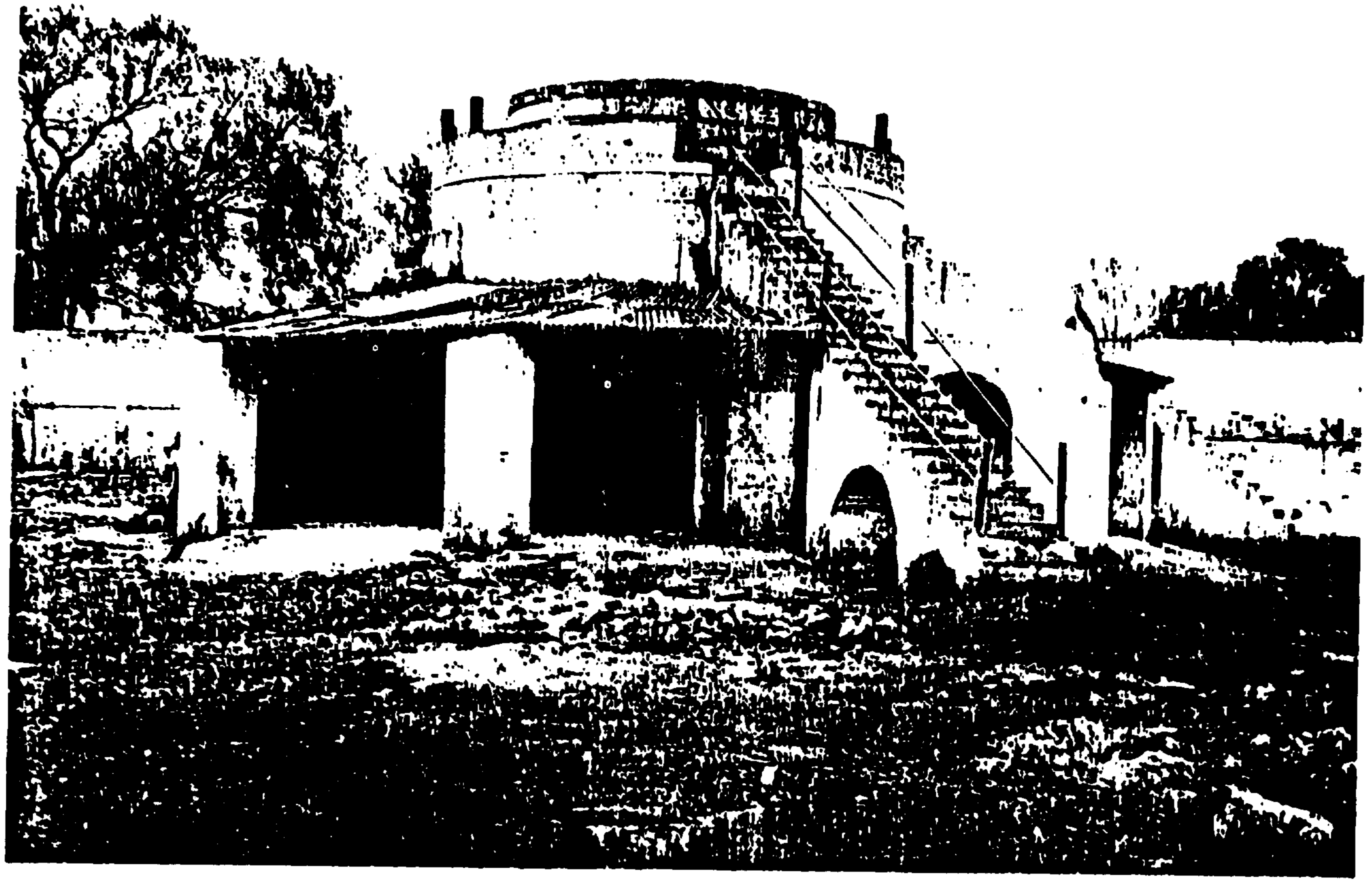
Continuous operation is potentially the most thermally efficient way of using vertical shaft kilns. Kilns operated in this way can be classified into two groups: mixed-feed kilns, and externally fired kilns.

MIXED FEED KILNS. There is a great diversity of kilns in this category, ranging from the very simple, low capital cost, and low output kilns, to the more sophisticated high technology types. Their big advantage is that they are potentially very simple to construct and operate, and are very flexible in the materials that can be used to construct them. An obvious limitation is that only solid fuels can be used, ie coal of different qualities, coke and wood. It is also possible to use some waste products such as nut shells and wood shavings in a briquetted form. Although a fairly good quality quicklime can be produced by mixed feed operation it is unlikely that a product of sufficient chemical purity will be produced for chemical, metallurgical and most industrial applications, unless a very high quality coal such as anthracite, or coke, which have a low ash content, are used. Impurities from the fuels mixed in with the limestone will generally not render the lime produced inadequate for the construction industry and agriculture. Lime of adequate quality can be produced even with the most simple, low output kilns, provided their design is sound and they are operated correctly.

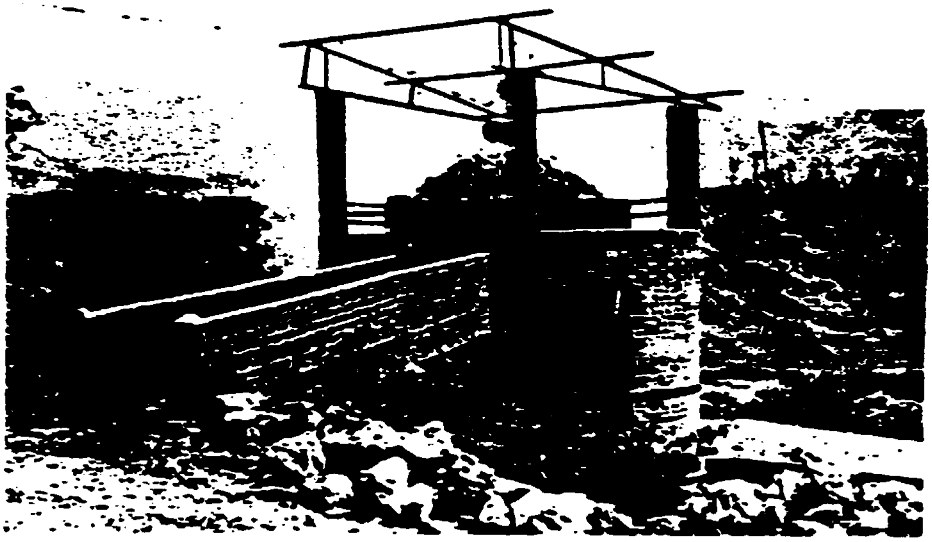
Vertical shaft kilns, operated continuously, function as calcination systems on the basis of material flowing down the kiln shaft while hot gases flow up the shaft. For the hot gases to flow up the shaft there must be a draught through the packed bed of limestone. The draught may be generated naturally, by the convection current caused by the rising hot gas, or it may forced up from the base through the bed by means of electrically driven fans, or induced from the top by the same means or by using a chimney stack. The advantage of forced or induced draught is that smaller stone sizes can be used without running the risk of overburning or reducing the kiln throughput to any extent. It is possible to recirculate exhaust gases through the kiln and thus maximize utilization of the heat generated in the kiln.



Indian 15 tonne per day mixed feed kiln



Indian mixed feed kiln.



Charging arrangement, Indian mixed feed kiln.

[illegible]

Forced and induced draught, and recirculation of exhaust gases, are ways of maximizing the production and thermal efficiency of the kiln system. Since such techniques do not influence the quality of the quicklime produced, it is quite possible to avoid them for the sake of simplicity of construction and operation, and to limit the added maintenance requirement implicit in mechanization.

Finally, mixed feed kilns vary in the materials used in their construction, and in the manner in which the raw materials and the product are handled. The kiln shaft can be constructed of stone, brick or reinforced concrete, with an inner lining of refractory bricks. The more sophisticated designs are usually a refractory lined steel or boiler plate shell. For maximum thermal efficiency kilns should be constructed with an insulation layer between the outer shell, whatever it is made of, and the inner refractory lining. The refractory bricks used are usually medium to high duty fire clay refractories. The most sophisticated designs use mechanized charging and discharging methods, operated automatically or semi-automatically. Smaller output kilns lend themselves to more labour-intensive operation.

EXTERNALLY FIRED KILNS. a)Furnace kilns. The first of these kilns was developed to avoid contamination by the fuel ash in mixed feed operations. Separate fireboxes were constructed in the wall at the lower and the middle thirds of the kiln shaft, in which coal, coke or wood was fired. Wood is considered to be the best fuel for this type of kiln since it produces a long cool flame which can penetrate into the mass of the limestone in the shaft more easily. If coal or coke, which produce shorter, moe intense flames, are used, steam or recycled flue gases passed through the fuel bed could lengthen and cool the flames. The disadvantage of this type of kiln is that fuel combustion takes place outside the shaft, resulting in low thermal efficiency.

b)Producer gas fired kilns. To improve the thermal efficiency of the furnace kilns the fireboxes were modified to convert the fuel into producer gas , which was drawn into the kiln shaft and brought to combustion by the hot secondary gases inside the shaft.

Solid fuel can be converted to producer gas either in a series of producers in the kiln wall or in a separate structure. The producers built into the kiln wall are similar to the fireboxes except that the bed of fuel is deeper. Controlled amounts of air and steam are passed through the bed of fuel (primary air), in quantities that will ensure gasification of the fuel. The advantage of producers separate from the kiln is that they tend to be easier to operate and the gas can be cleaned if necessary.

Operation with producer gas facilitates the use of fuels which would otherwise be of little value: lignite, peat and high volatility coal as well as certain agricultural waste material such as coconut shells, rice husks and olive pips. A good quality lime can be produced using this system, but it is of vital importance that the producer is well designed and operated.

c)<u>Oil fired kilns</u>. In the simplest form oil is burnt in combustion chambers in the wall of the kiln at around the bottom of the middle third of the kiln shaft. Heavy oil (Bunker C) is atomized by steam or air under pressure, mixed in the right proportions, and ignited. Successful firing requires accurate regulation of the mixture of oil and air or steam to produce a flame of suitable length and intensity. An intense flame will tend to overburn the limestone whereas a very long flame with an inadequate amount of air will tend to choke the pores of the limestone and be thermally inefficient. The capacity of these simple kilns can be scaled down to 3 - 4 tpd with relative ease.

The more sophisticated oil fired kiln designs gasify the oil in different ways, in sealed gasification chambers in the kiln, and the hot gas produced is drawn into the bed of limestone and ignited by the hot secondary gases. These kiln designs are generally more thermally efficient, but do not make for simplicity of construction, maintenance and operation as do the former type. They are usually highly automated, kiln conditions are controllable, and some are designed especially to cope with a small feed size, and feed with a wide size distribution. The primary advantage of oil fired kilns is that it is possible to produce a more reactive, uniform lime, with very little contamination. Unfortunately however, for economic reasons they are generally only feasible in countries which produce their own oil.

There are a wide range of vertical kilns at the upper end of the 1 - 100 tpd range which are also able to use natural, as well as other gas types, as fuel.

C. Rotary Kilns

Despite the lower fuel efficiency compared with modern vertical kilns, rotary kiln installations have increased in number, particularly in the USA where fuel is cheap and labour expensive, and large scale production is required. They are highly mechanized, and instrumentation is so well developed that one person could operate two or more kilns efficiently.

The rotary kiln has the advantage of burning stone as small as 10mm but it can also handle a feed size of up to 50mm. The feed is however, limited to a fairly narrow size distribution.

Rotary kiln capacities vary from 25 - 600 tpd. They are mounted on two or more wheels, are set at a slope of 1:15-30, and rotate at 40-60 rph. The speed of rotation is determined primarily by the rate of production and the quality of lime required. The types of fuels that are used are pulverized coal, natural gas and fuel oil.

D. Tunnel Kilns

Tunnel kilns can be built in a straight line to operate on a batch basis, or they can be built in an elliptical or ring shape for continuous operation (eg Hoffman kiln). The characteristic features of tunnel kilns are that they have a fairly high capital cost per unit output and that the operation is very labour intensive. At the same time it is a fairly fuel efficient operation from which good quality lime can be produced, but successful operation requires careful attention. Coal, wood or oil can be used as a fuel.

See Section 3 and Appendix I for drawings of various lime kilns.

SECTION 3. TECHNICAL AND OPERATIONAL INFORMATION ON SELECTED KILN SYSTEMS IN THE RANGE OF 1 - 100 TONNES PER DAY

1. Khadi and Village Industries Commission type kiln - Botswana
   3 tonnes per day.

2. Homa Lime Company - Kenya
   20 tonnes per day

3. Dyerslime and Chemicals Pvt. Ltd. - India
   20 tonnes per day

4. H. Eberhardt GmbH type K 100 kiln - West Germany
   50 tonnes per day

5. Ceramic Research and Development Institute - Indonesia
   6 tonnes per day

6. H. Eberhardt GmbH type ÖW 75 kiln - West Germany
   47 - 73 tonnes per day

KHADI AND VILLAGE INDUSTRIES COMMISSION TYPE KILN - BOTSWANA

3 TONNES PER DAY

CALCINATION SYSTEM	Coal fired, mixed feed, vertical shaft kiln, natural draught operation.
OUTPUT	3 onnes lime per 24 hours. Kiln designs available with capacities 3, 5, 10 tpd.
MODE OF OPERATION	Manual, continuous operation. This kiln can also be operated semi-continuously and on a batch basis.
ORIGINATOR OF TECHNOLOGY	Khadi and Village Industries Commision (KVIC) 3 Irla Rd, Vile Parle (West) Bombay - 56AS India
SERVICES AVAILABLE	Kiln designs, hydration plant design
PATENT DETAILS	Refer to originator of technology
TECHNICAL INFORMATION	
RAW MATERIALS -	
LIMESTONE	High calcium limestone, 85% toral oxide content
FEED SIZE	90 - 125mm / 100 - 150mm depending on limestone.
FEED REQUIREMENT	6 tonnes limestone in 24 hours, ie 1000kg charged manually every 4 hours.
FUEL TYPE	Coal, calorific value of 5300 kcal/kg.
FEED SIZE	25/50mm
FEED REQUIREMENT	Maximum 1200kg coal in 24 hours, fed in alternate layers with limestone.
FUEL CONSUMPTION	1900 - 2100kcal/kg lime produced.
MANPOWER REQUIREMENT	21 people in 24 hours. 7 people per shift.

LIME KILN -

SHAFT DIAMETER	1000mm
EFFECTIVE SHAFT HEIGHT	4000mm
SHAFT SHAPE	Cylindrical

KILN CONSTRUCTION

Masonry outer shell with a medium duty refractory lining and 50mm of insulation material between. Steel bands are strapped around the masonry shell to prevent cracking due to thermal expansion on firing.

KILN OPERATION

Kiln operation is manual. Limestone and coal are brought to the top of the kiln in wheelbarrows or buckets and fed in alternate layers. At the base of the kiln are four discharge openings from which the calcined lime is drawn manually and taken away for sorting and hydration.

The system can be operated semi-continuously (working a long day shift or two 8 hour shifts) or on a batch basis. Wood and charcoal can also be used as fuels.

AUXILIARY PLANT AND EQUIPMENT	Shovels and wheelbarrows or buckets
UTILITY REQUIREMENT	None
MAINENANCE REQUIREMENT	Replacement of refractories once every two years. Replcement of wheelbarrows and shovels every two years.
APPROX. ANNUAL MAINTENANCE AND REPLACEMENT COST	US$ 1200,00
APPROX. PLANT COST	US$ 2500,00
APPROX. INSTALLATION COST	US$ 1300,00

OUTPUT

LIME	2 - 3 tonnes every 24 hours
USES	Building lime, agricultural lime, soil stabilization, sewage treatment and any other applica-

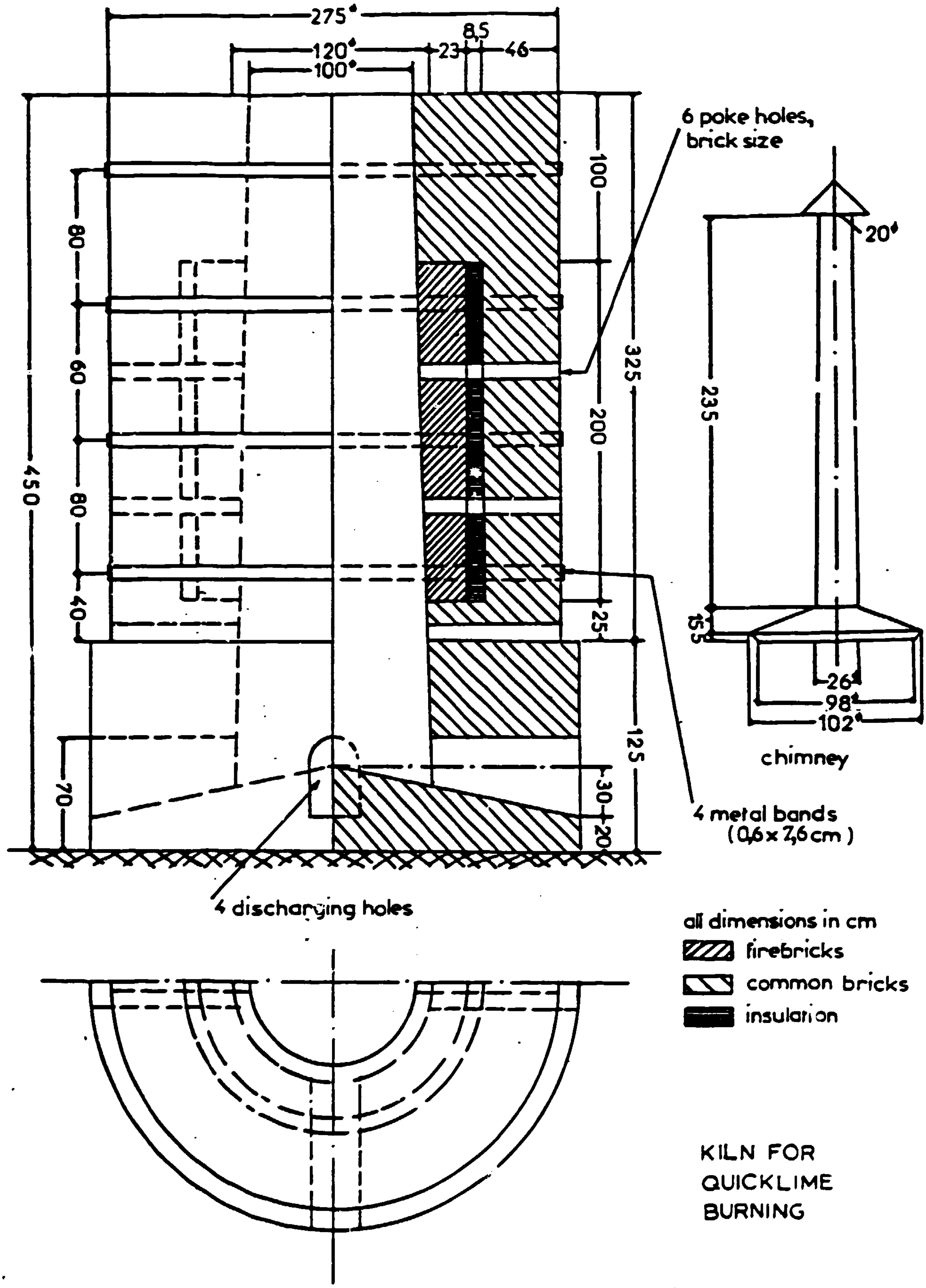
tion which can tolerate the impurities arising from the fuel ash.

MAJOR ADVANTAGES:

- Low capital cost
- Very flexible in the materials that can be used in its construction
- Labour intensive operation
- Low maintenance cost and no mechanization

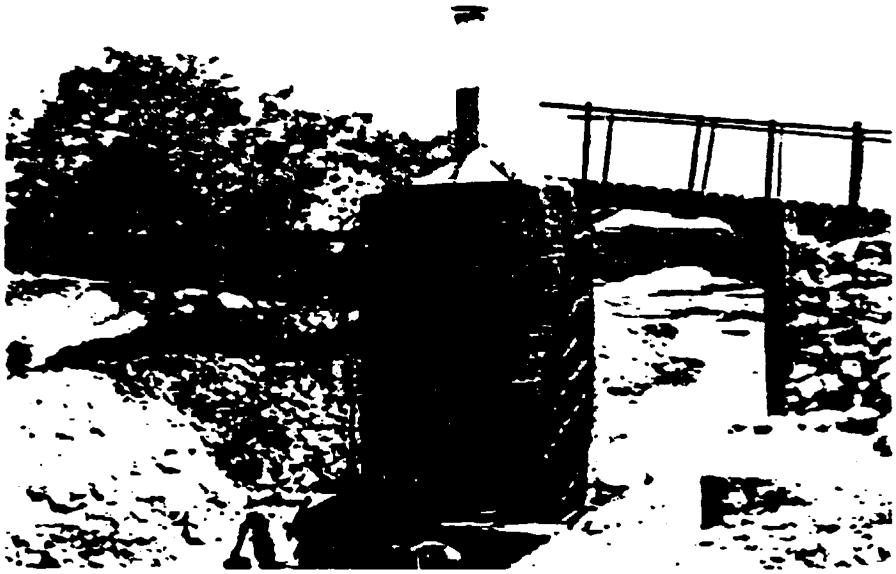
MAJOR DISADVANTAGES:

- High labour cost per unit output
- Low level of control on kiln operating conditions resulting in a variable quality output.
- High fuel consumption per unit output.



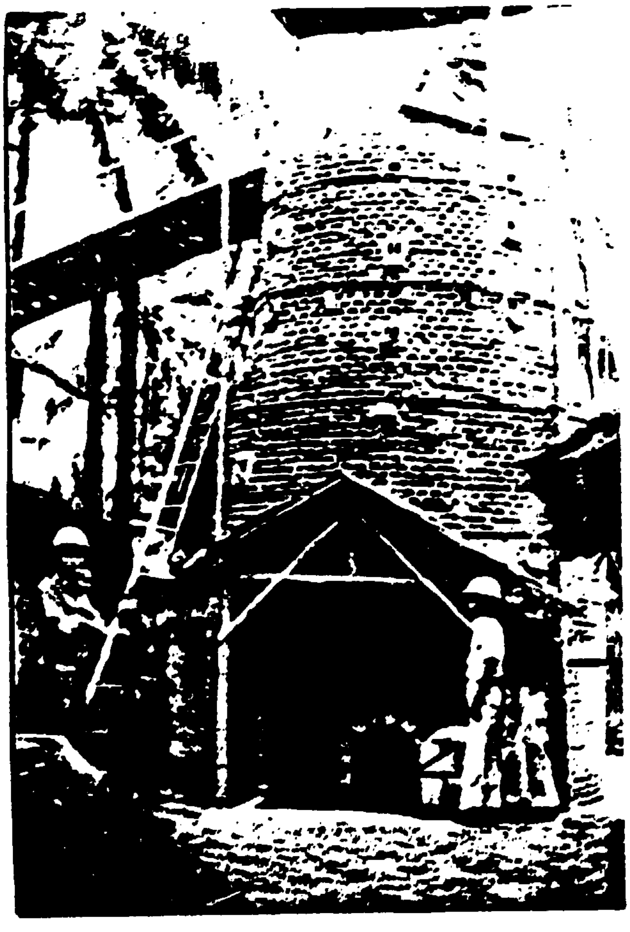
Khadi and Village Industries type kiln

FIGURE 7



KVIC type mixed feed,
3 tonne per day kiln.

Indonesian mixed feed,
5 tonne per day kiln.



HOMA LIME COMPANY - KENYA

20 TONNES PER DAY

CALCINATION SYSTEM	Wood fired, mixed feed, vertical shaft, forced draught kiln
OUTPUT	20 tonnes lime per 24 hours.
MODE OF OPERATION	Continuous, manually operated.
SUPPLIER	Homa Lime Company P.O. Box 1 Koru Kenya
SERVICES AVAILABLE	Advice on kiln design and operation.
PATENT DETAILS	Refer to supplier

TECHNICAL INFORMATION

RAW MATERIALS -	
LIMESTONE	Kilns currently in operation use coralline limestone (95% $CaCO_3$) and carbonatite (85% $CaCO_3$).
FEED SIZE	70 - 150mm diameter.
FEED REQUIREMENT	40 tonnes in 24 hours, ie 1600kg per hour, fed continuously.
FUEL TYPE	Wood fuel: air-dried eucalyptus (8081 Btu/lb)
FEED SIZE	Approx. 900mm lengths
FEED REQUIREMENT	1 tonne wood/tonne lime
FUEL CONSUMPTION	2500 - 2600kcal/kg lime
MANPOWER REQUIREMENT	24 people in 24 hours 8 people per shift

LIME KILN -	
SHAFT DIAMETER	2400mm
EFFECTIVE SHAFT HEIGHT	10500mm
SHAFT SHAPE	Cylindrical

KILN CONSTRUCTION

Reinforced concrete outer shell with a medium duty refractory brick lining, a skin of ordinary stock brick inside the refractory lining, and 50mm of loose diatomite fill as an insulating layer between the stock brick skin and the reinforced concrete outer shell.

KILN OPERATION

Kiln operation is completely manual. Limestone and wood are brought to the top of the kiln in wheelbarrows. The kiln is charged with alternate layers of limestone and wood. At the base of the shaft are four discharge openings. Lime is drawn from these with shovels and moved to the hydration plant in wheelbarrows. The discharge openings are kept shut when lime is not being discharged to facilitate effective operation of the forced draught system. Air is pumped through a centrally placed ceramic cone at the base of the shaft, through the packed bed of limestone to the top of the kiln.

AUXILIARY PLANT AND EQUIPMENT	Electric motor and fan, wheelbarrows,shovels.
UTILITY REQUIREMENT	Electricity (mains).
CONSUMPTION	8kWh/tonne lime
MAINTENANCE REQUIREMENT	Replacement of refractories once every two years. Repair and maintenance of electric motor and fan. Replacement of wheelbarrows and shovels every two years.
APPROX. ANNUAL MAINTENANCE AND REPLACEMENT COST	US$ 3000
APPROX. PLANT COST	US$ 40000
APPROX. INSTALLATION COST	US$ 12000
OUTPUT	
LIME	20 tonnes per 24 hours
USES	Contamination by fuel ash in mixed feed operation when wood is used as a fuel is minimal. The lime could therefore be used in most appli-

cations except for those which require a chemically very pure lime.

MAJOR ADVANTAGES:

- Low level of mechanization, and therefore reduced maintenance requirement.
- Labour intensive operation
- Use of locally available construction materials

MAJOR DISADVANTAGES:

- High labour cost per unit output

Homa Lime Company. 25 tonnes per day.

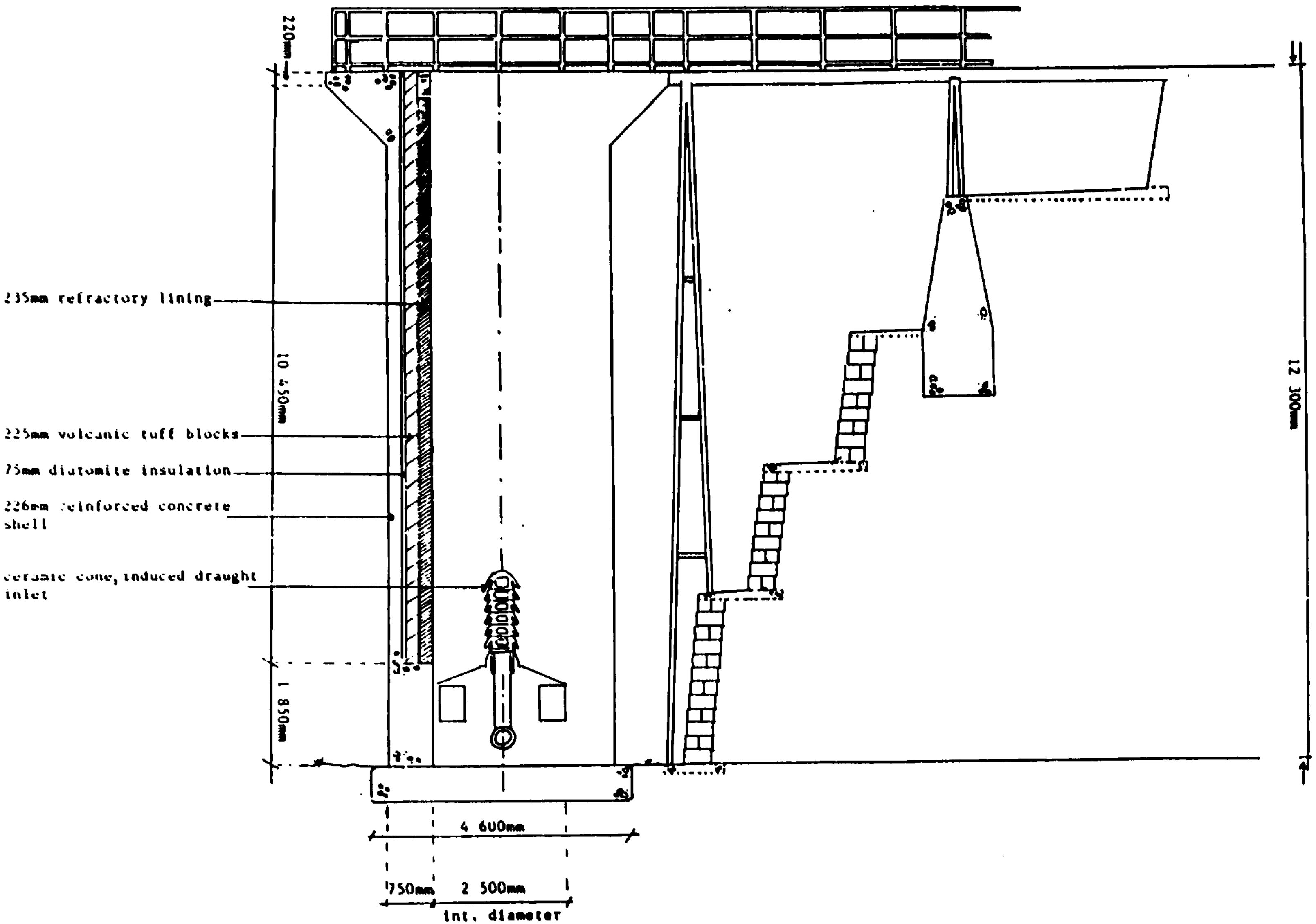


FIGURE 9

Homa Lime Company 20 tonne per day mixed feed kiln.

DYERSLIME AND CHEMICALS PVT. LTD. - INDIA
20 TONNES PER DAY

CALCINATION SYSTEM	Coal fired, mixed feed, vertical shaft, forced draught kiln.
OUTPUT	20 tonnes lime per 24 hours. Could produce up to 40 tonnes per 24 hours with continuous operation.
MODE OF OPERATION	Semi-automated, semi-continuous operation (day shift of 12 hours).
ORIGINATOR OF TECHNOLOGY	Dyerslime and Chemicals Pvt. Ltd. 10, Alipur Road Delhi - 110054 India.
SERVICE PROVIDED	Turnkey services
PATENT DETAILS	Nil
TECHNICAL INFORMATION	
RAW MATERIALS -	
LIMESTONE	High calcium limestone
FEED SIZE	90 - 125mm
FEED REQUIREMENT	Approx. 40 tonnes limestone in 24 hours, ie 3300kg per hour fed continuously for 12 hours by mechanical means.
FUEL TYPES	Coal of minimum calorific value of 5000k.cal/kg.
FEED SIZE	40/60 mm
FEED REQUIREMENT	Assuming minimum 5000kcal/kg fuel, 7200 - 8000 kg coal per 24 hours, fed in alternate layers with limestone.
FUEL CONSUMPTION	1800 - 2000kcal/kg lime produced.
MANPOWER REQUIREMENT	35 people in the following functions: -Plant supervisor 1 -Admin. staff 3 -Laboratory staff 1 -Kiln operators 30

LIME KILN -

SHAFT DIAMETER	3660mm
SHAFT HEIGHT	12200mm
SHAFT SHAPE	Cylindrical

KILN CONSTRUCTION

Masonry outer shell with medium duty refractory lining and 50mm of insulation material between. Steel bands are strapped around the masonry shell to prevent cracking due to thermal expansion during firing.

KILN OPERATION

Kiln operation is semi-automated. A skip bucket is manually loaded with predetermined quantities by weight of limestone and coal in alternate layers at the base of the kiln. The bucket is then pulled up parallel rails to the top of the kiln by an electrically driven winch and the contents are fed into the kiln by a manually operated top distribution assembly at various points for uniform distribution. The kiln is provided with a forced draught blower to regulate air intake.

The system could be operated continuously 24 hours a day. This would result in the doubling of output and of operating cost, but since the capital and fixed costs would remain the same, they would be halved per unit output.

AUXILIARY PLANT AND EQUIPMENT	Skip on rails with winch and electric motor, blower, top distribution assembly, shovels and wheelbarrows.
UTILITY REQUIREMENT	Electricity (diesel generator or mains)
CONSUMPTION	8KWh/tonne lime produced
MAINTENANCE REQUIREMENT	Replacement of refractories once every two years or more depending on the quality of the refractories used and the workmanship of construction. Repair and maintenance of electric motor, winch and skip. Replacement of wheelbarrows and shovels approximately every two years.

APPROX. ANNUAL MAINTENANCE AND REPLACEMENT COST	0,1 million Indian Rupees
APPROX. PLANT COST	2 million Indian rupees
APPROX. INSTALLATION COST	0,5 million Indian rupees
TURNKEY COST	2,5 million Indian rupees (includes kiln erection, kiln shed and equipment)

OUTPUT

LIME	20 tonnes per 24 hours.
USES	The quality of lime produced is suitable for building grade lime, and could also be used in agriculture, soil stabilization and sewage treatment.

MAJOR ADVANTAGES:

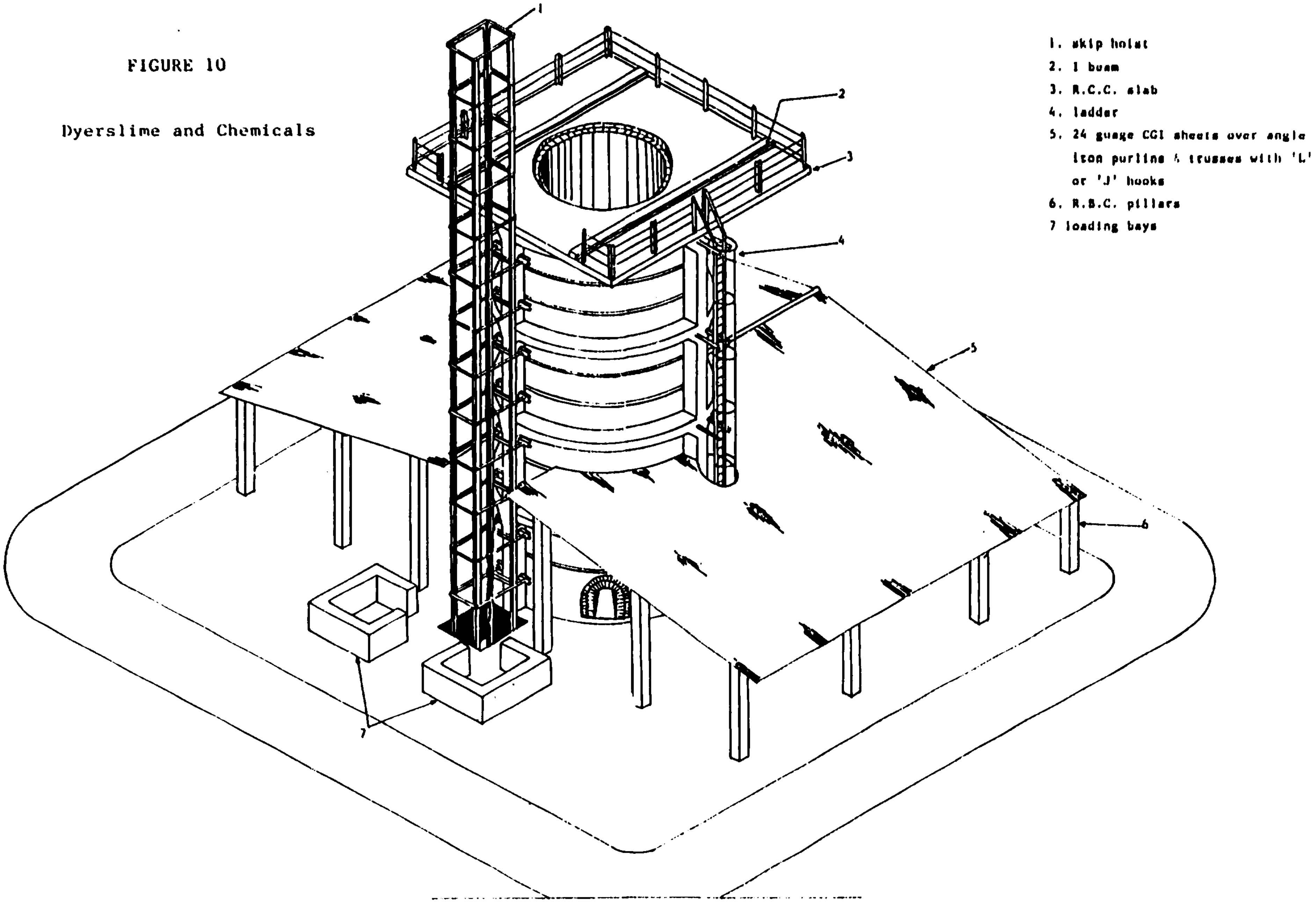
- Relatively low level of mechanization and hence low maintenance requirement.
- Labour intensive.

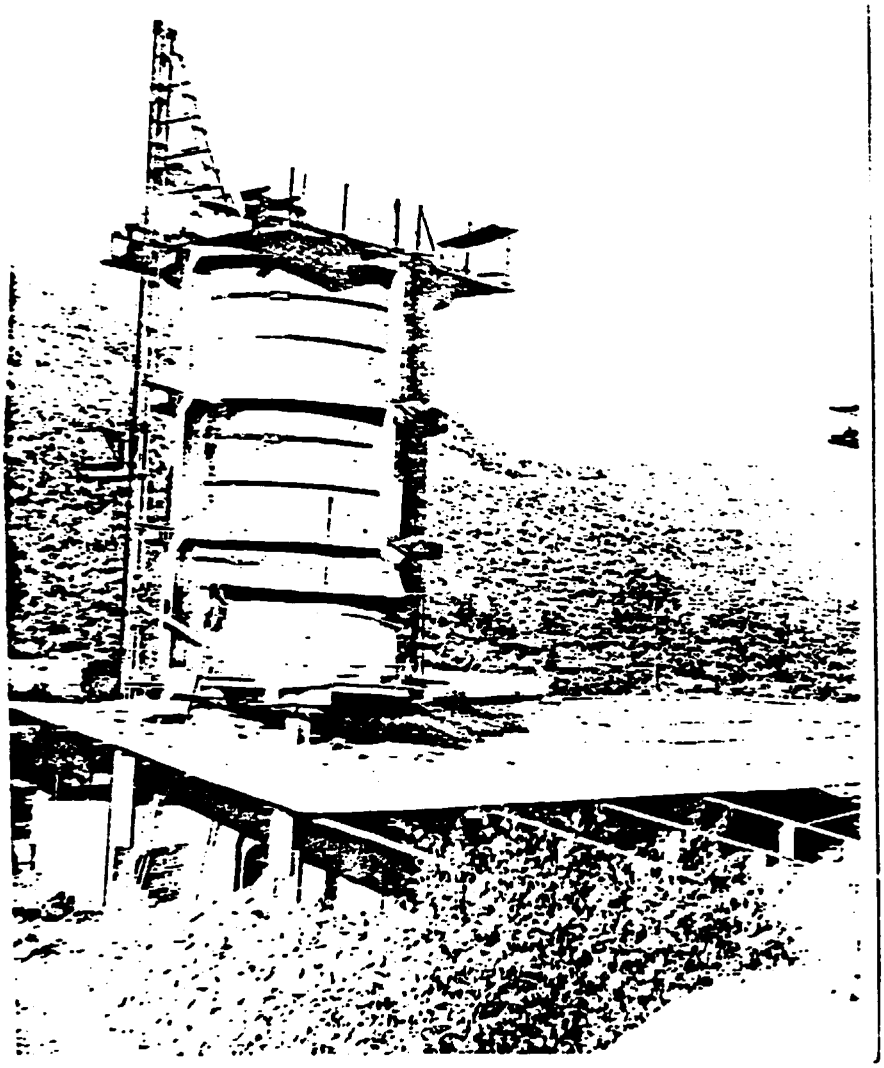
MAJOR DISADVANTAGES

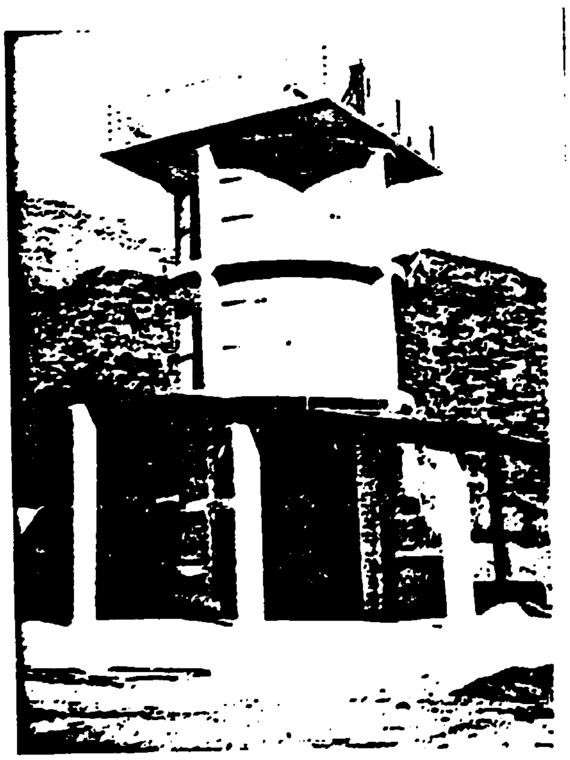
- High labour cost per unit output.

FIGURE 10

Dyerslime and Chemicals







Dyerslime and Chemicals 20/40 tonne per day mixed feed kiln.

H. EBERHARDT GmbH TYPE K 100 KILN - WEST GERMANY

50 TONNES PER DAY

CALCINATION SYSTEM	Coke fired, mixed feed, vertical shaft kiln, operated either on induced draught or forced air.
OUTPUT	50 tonnes per day. The range of kiln capacities available in this system is from 20 tpd to 100 tpd.
MODE OF OPERATION	Fully automatically controlled plant. Semi-automatic operation possible on plant up to 50 tpd capacity.
ORIGINATOR OF TECHNOLOGY	H. Eberhardt GmbH & Co Postfach 1266 D 3340 Wolfenbüttel federal Republic of Germany
SERVICES AVAILABLE	Supply and erection of vertical shaft kiln systems including auxiliary plant and equipment. Milk of lime, gas purification and sulphur combustion plant are also supplied.
PATENT DETAILS	Eberhardt patent
TECHNICAL INFORMATION	
RAW MATERIALS -	
LIMESTONE	High calcium limestone
FEED SIZE	80 - 120, 100 - 150, or 120 - 180 mm depending on limestone type.
FEED REQUIREMENT	Approx. 95 tpd, ie approx. 3900kg limestone per hour fed continuously.
FUEL TYPE	Coke with calorific value of 6883kcal/kg
FEED SIZE	20 -40, 40 - 60, or 60 - 80 granulation dependent on limestone feed size.
FUEL REQUIREMENT	6538kg per 24 hours.
FUEL CONSUMPTION	Max. 900kcal/kg lime produced

MANPOWER REQUIREMENT	Automatic operation 1 man/shift; semi-automatic operation 3 men/shift. 1 person in day shift to fill limestone charge bin.

LIME KILN

SHAFT DIAMETER	3600mm
SHAFT HEIGHT	38000mm
SHAFT SHAPE	Cylindrical

KILN CONSTRUCTION

The kiln wall is made up of a series of refractory and insulating layers, and is encased in a steel shell.

KILN OPERATION

Limestone and coke are stored in feed bins and measured by weight onto a horizontal conveyer which discharges the feed into a bucket. The bucket is taken to the top of the kiln by a vertical hoist. At the top of the kiln is a special carriage for the horizontal movement of the bucket. The feed is discharged directly into the kiln shaft once the bucket is moved exactly to the kiln centre. The charging system is designed to ensure that the kiln is kept gas- and airtight even during charging. Lime is discharged by means of 2 vibrating conveyers. The kiln is fired either on an induced draught or on forced air. If the latter is used a double gate arrangement is provided at the kiln discharge with the vibrating conveyers. The plant can be operated automatically, in which case gamma-ray level measurement devices are provided. Alternatively it can be semi-automated in which case the levels in the kiln and the charging and discharging mechanisms can be manually monitored and operated.

AUXILIARY PLANT AND EQUIPMENT	Storage bins, weigh batching equipment, conveyers, and bucket and vertical hoist. Piping and air compressor or fan for forced air or induced air operation.
UTILITY REQUIREMENT	Electricity (mains)
MAINTENANCE REQUIREMENT	Replacement of refractories and repair and maintenance of equipment.

APPROX. ANNUAL MAINTENANCE AND REPLACEMENT COST	DM 100 000
APPROX. PLANT COST	DM 2,5 million
APPROX. INSTALLATION COST + COMMISSIONING	DM 1,0 million

OUTPUT

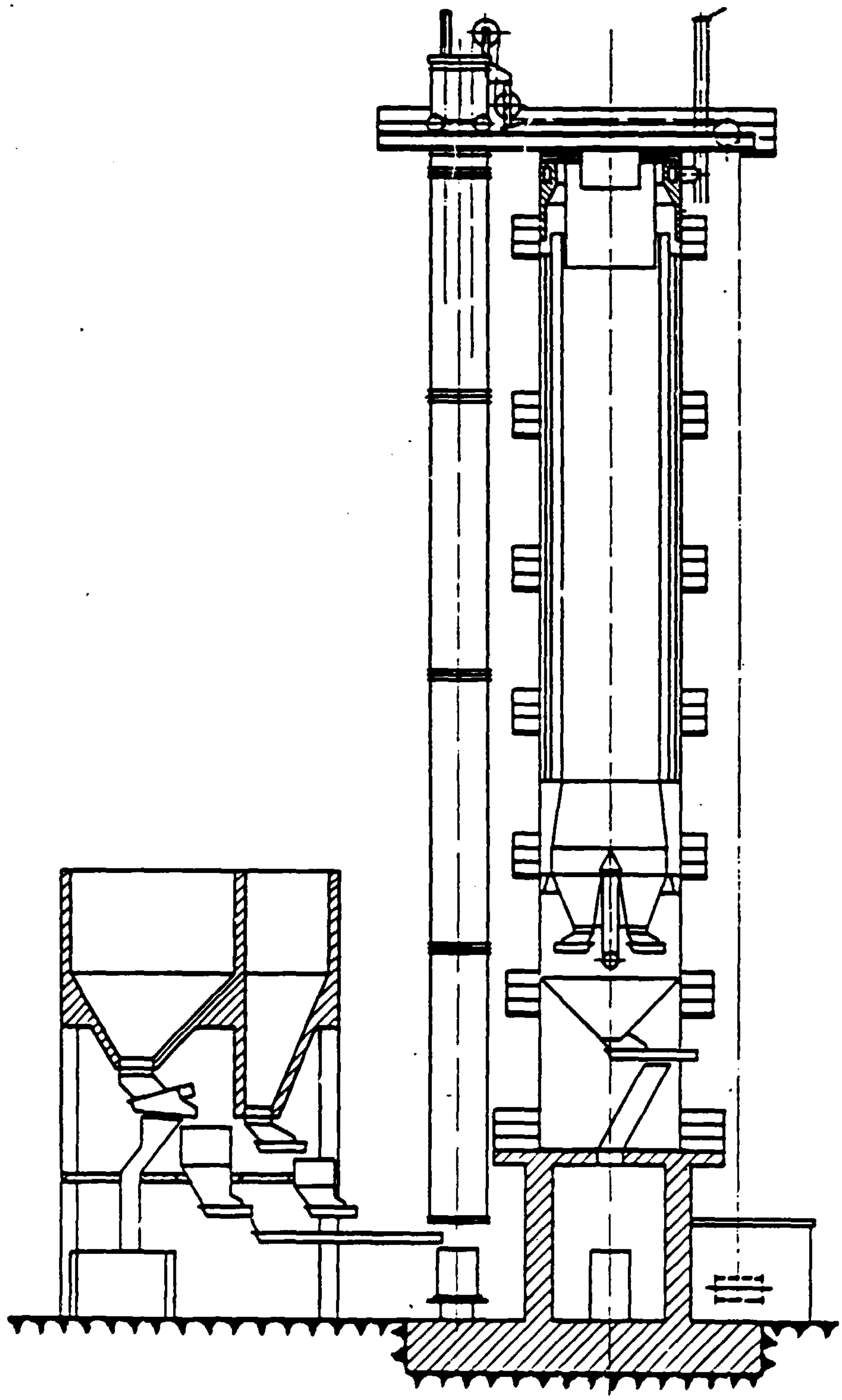
LIME	50 tonnes per 24 hours high reactivity lime with residual CO_2 content of $<2\%$.
CO_2	38% by volume in waste gas - induced draught operation. $>40\%$ by volume in waste gas - forced air operation.
USES	Lime produced could be used in most industrial applications, except for those which have a very low tolerance for fuel ash impurities.

MAJOR ADVANTAGES:

- High quality and consistent product
- Low fuel consumption
- Low labour cost per unit output

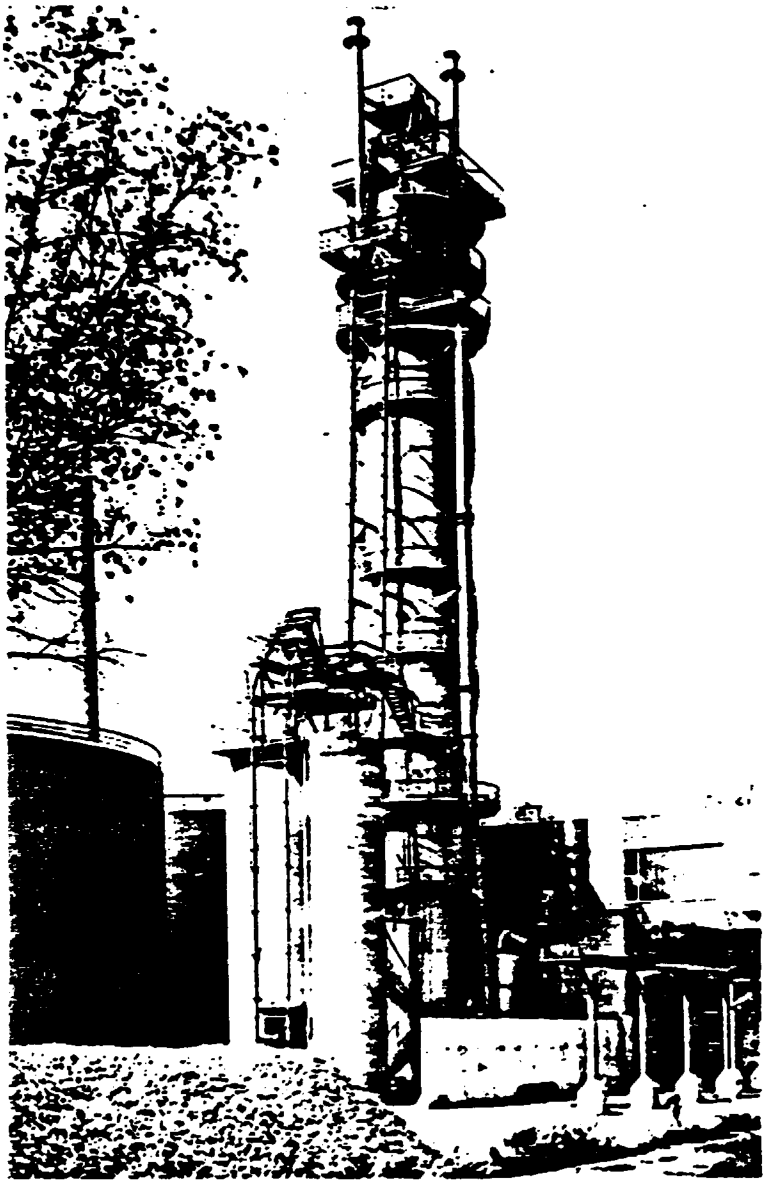
MAJOR DISADVANTAGES

- High capital cost
- High maintenance requirement
- Skilled operators required
- Requires high cost materials of construction which are not generally available.



Eberhardt type K

FIGURE 12



Eberhardt mixed feed kiln.

CERAMIC RESEARCH AND DEVELOPMENT INSTITUTE - INDONESIA

6 TONNES PER DAY

CALCINATION SYSTEM	Oil fired, natural draught, vertical shaft kiln.
OUTPUT	6 tonnes per 24 hours
MODE OF OPERATION	Continuous, manually operated.
ORIGINATOR OF TECHNOLOGY	Ceramic Research and Development Institute Jalan A. Yani 392 Bandung Indonesia Directorate of Building Research Jalan Tamansari 84 Bandung Indonesia in co-operation with UNDP/UNIDO Building Materials Project in Indonesia
SERVICES AVAILABLE	Advice on kiln design
PATENT DETAILS	Refer to originator of technology
TECHNICAL INFORMATION	
RAW MATERIALS -	
LIMESTONE	The kiln has been designed to cater for a wide range of limestone types, including soft limestones such as those from Bali.
FEED SIZE	100 - 200mm diameter, with the harder, more dense limestons at the lower end and the soft, porous types at the upper.
FEED REQUIREMENT	Approx. 12 tonnes per 24 hours, ie 500kg per hour, fed continuously
FUEL TYPES	Medium and heavy fuel oil. Storage tank and piping taking fuel oil to combustion may need insulation or to be attached to the kiln side so that oil is heated. This will reduce the oil viscosity and facilitate atomization.

FUEL REQUIREMENT	1086 litres heavy fuel oil in 24 hours.
FUEL CONSUMPTION	1800kcal/kg lime
MANPOWER REQUIREMENT	18 people per 24 hours 6 people per shift

LIME KILN -

SHAFT DIAMETER	1250mm
EFFECTIVE SHAFT HEIGHT	9500mm
SHAFT SHAPE	Cylindrical

KILN CONSTRUCTION

The kiln is a 12m high fired clay brick structure, reinforced with steel straps and lined with refractories. A 10cm thick insulation layer is built between the brick outer shell and the refractories. The outer shell and the lining are connected by 3 bricks in every horizontal layer of brickwork. The 9,5m shaft is topped by a 2,5m conical chimney with an internal diameter tapering from 1,25m to 0,67m. A loading opening is located at the 9,85m level. There are 3 discharge openings at the base of the kiln and 3 firing openings at the 3,7m level. A timber platform is constructed round the kiln at this level for the operation of the oil burners.

KILN OPERATION

Assuming the kiln is freestanding, a 12m high steel tower is built adjacent to the kiln which functions as a charging tower. Limestone is brought to the 9,85m level (charging opening) by means of a simple, hand operated hoist. A horizontal charging ramp connects the charging tower with the top of the kiln. The tower also houses the water and oil tanks. If the kiln is built adjacent to a slope, a horizontal loading ramp could be used to connect the slope to the top of the kiln and limestone could be brought to the top of the kiln by means of wheelbarrows. The water and oil tanks would then be located on the slope.

The firing system consists of 3 steam propelled static diffusion burners. The steam is generated in three small boilers located in the firing opening but not exposed directly to the flames. The burner is of a simple design and could be produced by the local blacksmith from boilerpipe. The piping connecting the burners with the tanks can be made of galvanised steel pipes. The lime product is drawn from 3 discharge openings at the base of the kiln using shovels, and is taken away in wheelbarrows to the slaking sheds.

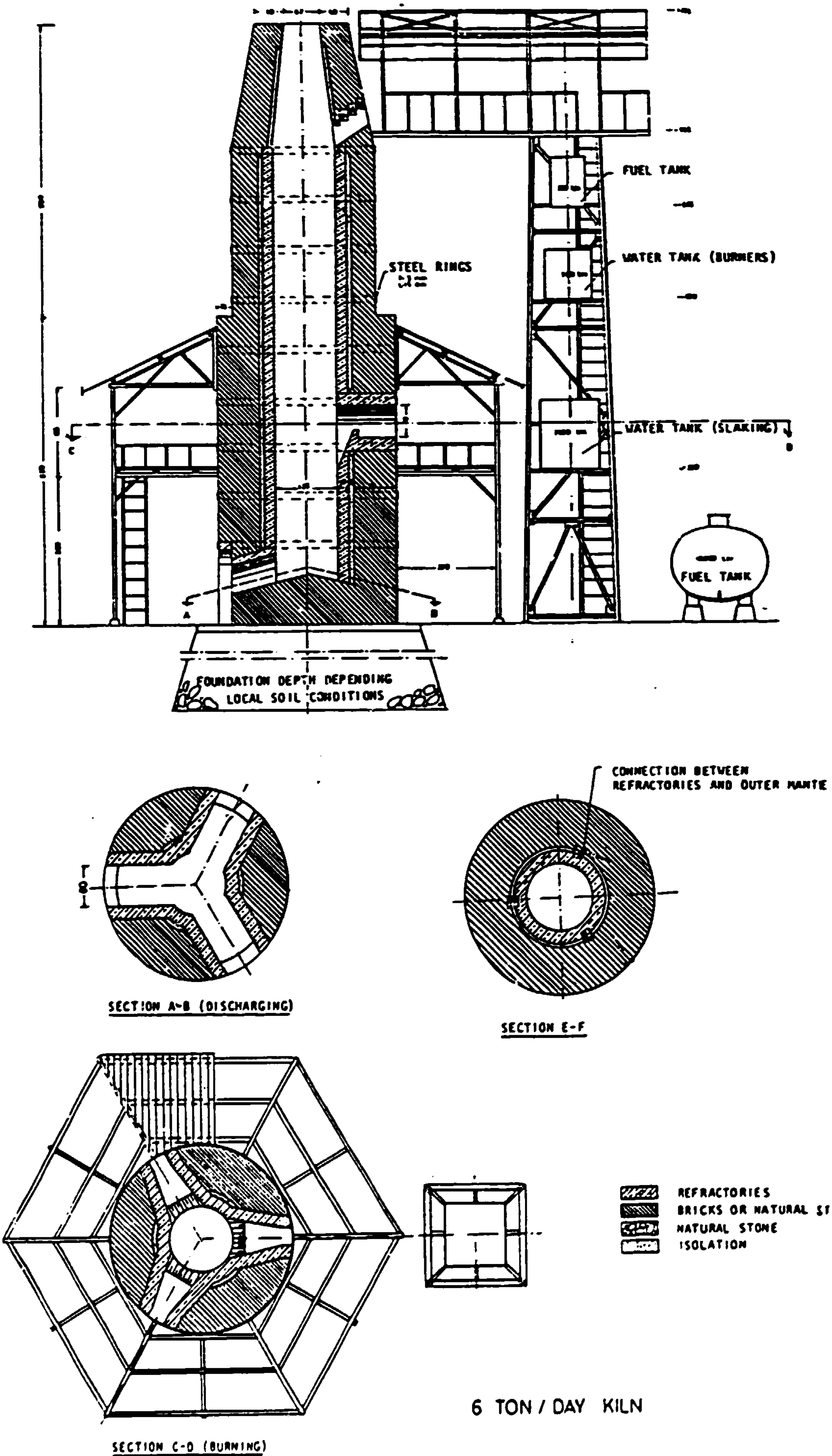
AUXILIARY PLANT AND EQUIPMENT	Water and oil tanks, including piping. Hand operated, winch driven hoist, wheelbarrows and shovels.
UTILITY REQUIREMENT	Electricity for lighting night operations. Water for diffusion burners.
CONSUMPTION	3KWh per day
MAINTENANCE REQUIREMENT	Refractories replaced every two years. Repair and maintenance of diffusion burners. Replacement of wheelbarrows and shovels every two years.
APPROX. ANNUAL MAINTENANCE AND REPLACEMENT COST	US$ 1500
APPROX. PLANT COST (including auxiliary equipment)	US$ 6500
APPROX. INSTALLATION COST	US$ 3000
OUTPUT	
LIME	6 tonnes per 24 hours
USES	Lime produced can be used in most applications. The impurity level from the fuel is minimal, therefore suitability is only dependent on the quality of the limestone used.

MAJOR ADVANTAGES:

- Low capital cost
- Very flexible in materials that can be used in its construction
- Labour intensive operation
- Low maintenance cost and no mechanization
- Limited contamination of lime by fuel.

MAJOR DISADVANTAGES:

- High labour cost per unit output
- Low level of control on kiln operating conditions (natural draught), resulting in variable kiln efficiency
- High fuel consumption per unit output.



6 TON / DAY KILN

FIGURE 18

H. EBERHARDT GmbH TYPE ÖW 75 KILN - WEST GERMANY

47 - 73 TONNES PER DAY

CALCINATION SYSTEM	Oil fired, vertical shaft kiln, induced draught operation.
OUTPUT	47 - 73 Tonnes lime per 24 hours. Range of capacities available from 17 - 30 to 111 - 172.
MODE OF OPERATION	Continuous operation, automatic control using induced draught system.
ORIGINATOR OF TECHNOLOGY	West
SUPPLIER OF TECHNOLOGY	H. Eberhardt GmbH & Co Postfach 1266 D-3340 Wolfenbüttel Federal Republic of Germany
PATENT DETAILS	West patent (supplied under licence by H. Eberhardt)
TECHNICAL INFORMATION	
RAW MATERIALS -	
LIMESTONE	High calcium limestone (approx. 96% $CaCO_3$). $MgCO_3$ content < 5% Fe_2O_3 + Al_2O_3 < 2% SiO_2 content < 1% Requirement dependent on application for which lime is produced.
FEED SIZE	90 - 130, 100 - 150 depending on limestone type.
FEED REQUIREMENT	Max. of 135 tpd limestone, ie approx. 5,6 tonnes per hour.
FUEL TYPE	Heavy oil to DIN51603 specifications.
FUEL REQUIREMENT	5040 - 7825 litres in 24 hours depending on output in the circumstances.
FUEL CONSUMPTION	Max. 1150kcal/kg lime.
MANPOWER REQUIREMENT	1 person per shift and 1 more person during day shift to fill limestone bunker. A qualified engineer is required on a permanent basis for kiln operation.

LIME KILN -

SHAFT DIAMETER	3500mm
SHAFT HEIGHT	38000mm
SHAFT SHAPE	Cylindrical

KILN CONSTRUCTION AND OPERATION

The kiln wall is made up of a series of refractory and insulating layers encased in a steel shell. Limestone is brought up to the top of the shaft by skip hoist and discharged into the charging bin. The charging bin is supplied with a double lock system and automatic material requisition.

The kiln has a circular section with WEST-type oil gasification chambers located at one level only. The oil is gasified by being sprayed into the wall of the pipe-shaped chamber by a rotating nozzle. The chambers are heated to the cracking temperature of the oil through radiation of the material in the kiln. The suction induced in the shaft results in the oil gas being drawn into the kiln. Combustion of oil gas takes place by means of the hot secondary air in the shaft. Primary air is introduced into the combustion chambers, and the kiln exhaust gases are recirculated. Lime is discharged intermittently through clam doors into a weigh hopper. The plant is controlled and operated automatically.

AUXILIARY PLANT AND EQUIPMENT	Storage bin, skip hoist, induced air fan and piping.
UTILITY REQUIREMENT	Electricity (mains)
MAINTENANCE REQUIREMENT	Replacement of refractories and repair and maintenance of plant and equipment.
APPROX. ANNUAL MAINTENANCE AND RELACEMENT COST	DM 250000
APPROX. PLANT COST	DM 3,5 million
APPROX. INSTALLATION COST	DM 1,4 million

OUTPUT

LIME	High reactivity lime with residual CO_2 content less than 3%

CO_2	Waste gas with CO_2 content >28% by volume
USES	High, consistent quality lime produced could be used in any industrial application. The CO_2 bi-product could be useful after adequate scrubbing.

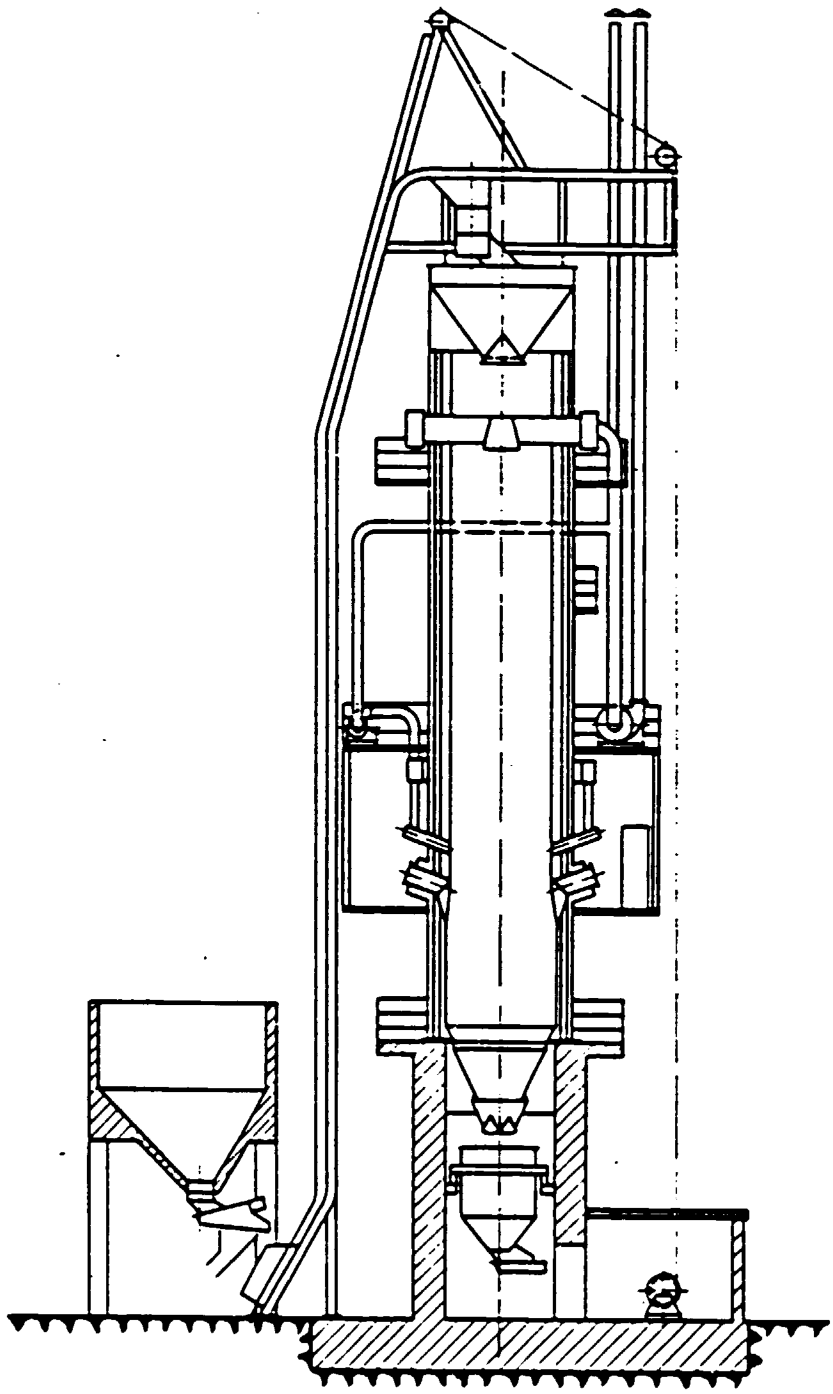
MAJOR ADVANTAGES:

-High quality and consistent product

- Low fuel consumption
- Low labour cost per unit output

MAJOR DISADVANTAGES:

- High capital cost
- High maintenance requirement
- Skilled operators requireu
- Requires high cost materials of construction unlikely to be locally available.



Eberhardt type ÖW

FIGURE 22

SECTION 4. FACTORS AFFECTING THE CHOICE OF TECHNOLOGY AND EVALUATION OF THE KILN SYSTEMS PRESENTED

The factors affecting the choice of lime kiln technology in developing countries have a distinctly different emphasis and importance to those in industrialized countries. Many factors which are, to a greater or lesser extent, taken for granted in industrialized countries must be carefully considered in developing countries. For example, the availability of spares and the skilled manpower to maintain the kiln system selected, are crucial issues to be taken into consideration. In less industrialized countries spares and skilled manpower are generally not easily accessible and in the event of breakdown there may be long periods with no production.

Unlike the situation in industrialized countries, potential for maximizing the labour component of the operation becomes important, in many cases beyond the purely commercial consideration. In this situation the capital cost required per job created is an important parameter for evaluation.

Thermal efficiency of the kiln system is a major factor by which kiln systems are evaluated in industrialized countries. In developing countries it is very likely that it takes a less prominent role as a criterion for selection, and that the ability to ensure a regular supply of a good and consistent quality of lime is likely to be much more important. A robust, reliable design with limited potential for breakdown may be preferred to the more elegant, technologically sophisticated, thermally efficient kiln systems. The maintenance facility and the spares required, which may have to be brought in over long distances and at a high cost, are not the only reasons for this. Bearing in mind that the kiln location may be remote or at a fair distance from the source of materials required for its construction, it also becomes important to view this factor with some care. The cost of transporting these materials to the planned location of the kiln may be a formidable and possibly prohibitive sum. There may therefore be a need to limit the choice of technology to kiln systems which use mostly locally available materials and equipment.

There is the factor of the market that is to be supplied, and the specifications it sets on the product. The quality lime produced is dependent on the technology used to produce it. Low technology options which rely on natural draught for combustion, inevitably produce a variable quality product. Further, when coal is used as a fuel in mixed feed operation, the lime is contaminated to an extent which generally limits its marketability to the industries which do not require a very pure product, such as the construction industry and agriculture. The quantity of lime required influences the type of kiln system presented as an option under a particular set of circumstances. For example, if there is a market for 50 tonnes of lime per day, to supply the construction industry and agriculture, depending on the availability and cost of labour, lime can be produced either by a battery of low technology kilns or a single technologically sophisticated kiln.. Alternatively, if a high quality lime is required but only in small quantities, and the cost of transporting from other sources to the point of use is high, it may be commercially viable to use a scaled down version of a high technology option.

The finance available to the potential lime producer will further influence the choice, as will the broader financial considerations in the particular circumstances. For example a short 'payback' period maybe required, ie a very rapid recovery of the investment cost. This may be for a variety of reasons, including the possibility of taking advantage of a very short term demand for lime.

It is evident that there is a wide range of considerations which need to be evaluated, in the light of one another, to make an appropriate choice. The parameters by which the technology needs to be assessed can be broadly stated as follows:

- quality and quantity of lime that can be produced in view of the requirements of the market;
- level of control that can be exercised to obtain a product of consistent quality;
- installation and commissioning implications;
- materials for construction that can be used, including consideration of those that would be required in repair and maintenance;
- repair and maintenance requirement;
- level of skill required in operation;
- potential for employment creation, ie potential for manual operation.
- finance available and other financial implications of circumstances;
- flexibility in the mode of operation, ie potential for operation at reduced levels. This may be necessary in certain circumstances in developing countries either due to seasonal fluctuations in demand or

due to the need to conform with seasonal patterns of occupation of the labour force, for example the need to work in agriculture during certain times of the year.

Table IV compares the features of the alternative kiln systems presented. It becomes evident on examination of the summary that 'conventional', high technology options are, in the majority of cases, unlikely to be an appropriate choice for the conditions in developing countries. They are expensive to install, difficult to operate and expensive to maintain. In addition they are not conducive to maximizing the use of labour which is available in large numbers and usually at a low cost. These kilns are geared to conditions in the industrialized world which have led designers to limit the labour requirement. The advantages of the high technology kilns lie in the consistently high quality lime that can be produced, and also in the low fuel consumption.

The mini-lime plant, or low and intermediate technology kiln systems lend themselves more easily to conditions in developing countries. They are easier to construct and operate, have a lower investment cost, a lower maintenance requirement and the designs are sufficiently flexible to enable locally available materials to be used in their construction.

SUMMARY OF FEATURES OF SELECTED KILN SYSTEMS

SOLID FUEL MIXED FEED KILNS	CAPACITY (tpd)	QUALITY PRODUCT	LEVEL OF CONTROL ON QUALITY	EASE OF CONSTRUCTION	EASE OF OPERATION	MAN-HOURS PER TONNE OUTPUT	INVESTMENT COST PER JOB CREATED (US$)	INVESTMENT COST (US$)	INVESTMENT COST PER TONNE OUTPUT	MAINTENANCE REQUIREMENT	MAINTENANCE COST PER ANNUM (US$)	FUEL CONSUMPTION (kcal/kg lime)
VIC Type - Botswana (coal fired)	2 - 3	low/ medium	low	high	high	56	181	3 800	1 270	low	800	1 900 - 2 100
Homa Lime Co - Kenya (wood fired)	20	medium	medium	medium	medium	9,6	2 166	52 000	2 170	low/medium	3 000	2 500 - 2 600
Overslime and chemicals - India (coal fired, semi-continuous operation)	20/40	medium/ low	medium	medium	medium	18	6 833	205 000	10 250	low/medium	8 475	1 800 - 2 000
Eberhardt - W. Germany Type K 100 (coke fired)	50	medium/ high	high	low	low	semi-auto. operation 1,60	157 500	1,575 mill.	31 500	high	45 000	max. 900
OIL FIRED												
CRDI - Indonesia	6	medium	low	high	medium	32	528	9 500	1 580	low/medium	1 500	1 800
Eberhardt - W. Germany Type OW 75	47 - 73	high	high	low	low	automatic max. 0,68	506 250	2,025 mill.	max. 43 085	very high	112 500	max. 1 150

TABLE IV

APPENDIX I: DRAWINGS

NOTES

FLARE KILNS

Figure 2 - Honduran, hillside, wood fired flare kiln with capacity of 15 - 150 tonnes lime, fired for 2 -8 days.
The complete operating cycle, including loading, firing, cooling and emptying, requires between 1 and 4 weeks.

Figure 3 - Medani-Sennar-Kosti road project, Sudan. Free standing flare kiln with capacity of 12 tonnes lime, fired for 6 days. The complete operating cycle of 14 days includes loading (2 days), firing (6 days), cooling (2 days), unloading (2 days), kiln maintenance (2 days).

Figure 4 - Ghanaian updraught kiln

MIXED FEED - BATCH KILNS

Figure 5 - Somali, batch fired, mixed feed vertical shaft kiln using wood as fuel. Burning time should be around 5 days. The average operating cycle would be 10 days with an output of 10 -12 tonnes lime per burn. Coal could be used as a fuel.

Figure 6 - Papua/New guinea, batch fired mixed feed vertical shaft kiln, using wood as a fuel. Alternatively the kiln could be fired with coal.

MIXED FEED - BATCH OR CONTINUOUS OPERATION

Figure 7 - KVIC kiln design (see section 3). Could be operated on a batch or continuous basis with either wood or coal as a fuel. Kiln capacity on a batch basis is between 2,5 and 3,0 tonnes lime every 5 days.(using coal), and about the same on a continuous 24 hour operation. This kiln has been designed to produce lime in the range 3-10 tpd.

Figure 8 - Indonesian, mixed feed vertical shaft kiln design.
Could be operated on a batch or continuous basis, using either wood or coal as a fuel. Capacity on batch operation is between 4,5 and 5 tonnes lime in every 7-8 days. On continuous 24 hour operation the kiln's capacity would be approximately the same.

MIXED FEED - CONTINUOUS

Figure 9 - Homa lime company (see section 3). Wood fired, mixed feed, vertical shaft kiln, forced draught operation. Output 25 tonnes per day on continuous 24 hour operation.

Figure 10 - Dyerslime and Chemicals (see section 3). Coal fired, mixed feed, vertical shaft, natural draught kiln. Output 20 tonnes per day on semi-continuous operation (12 hour shift). Operated continuously (24 hours per day), the kiln would produce 40 tpd.

Figure 11 - Eberhardt - Kiln type KS. Coke fired, mixed feed, vertical shaft kiln, induced draught operation. Range of kilns available with outputs from 5 - 30 tpd on continuous operation.

Figure 12 - Eberhardt - Kiln type K (see section 3). Coke fired, mixed feed, vertical shaft kiln, induced or forced draught operation. Range of kilns available with outputs from 20 - 100 tpd.

EXTERNALLY FIRED FURNACE KILNS

Figure 13 - Arnold kiln

Figure 14 - Nigerian, (SOBEK design), wood fired furnace kiln with induced draught operation. Capacity of kiln is 20 - 25 tOnnes per day.

PRODUCER GAS FIRED KILNS

Figure 15 - Small capacity (AZBE) producer gas kiln using coal as a fuel.

Figure 16 - Medium capacity (AZBE) producer gas kiln using coal as a fuel. Coal is fed automatically to producer.

OIL FIRED KILNS

Figure 17 - Ceramic Research and Development Institute (CRDI), Indonesian design oil fired, vertical shaft kiln, natural draught operation. 3 - 4 tonnes per day capacity.

Figure 18 - Ceramic Research and Development Institute (CRDI), (see section 3). Indonesian design oil fired vertical shaft kiln, natural draught operation. 6 tonnes per day capacity.

Figure 19 - Site layout of CRDI oil fired kilns, free standing and kiln adjacent to slope.

Figure 20 - Indonesian (SOBEK design) 10 tonnes per day oil fired, vertical shaft kiln, natural draught operation.

Figure 21 - SOBEK system, 10 - 15 tpd oil fired, vertical shaft kiln, induced draught operation.

Figure 22 - Eberhardt - Kiln type ŐW (see section 3). Oil fired, vertical shaft kiln, automatic control using an induced draught system.
Kiln capacities available from 17-30 to 111-172 tpd.

Figure 23 - Schematic diagram of rotary kiln

Figure 24 - Greek elliptical tunnel kiln or'Hoffman' kiln.

Honduran Type Kiln

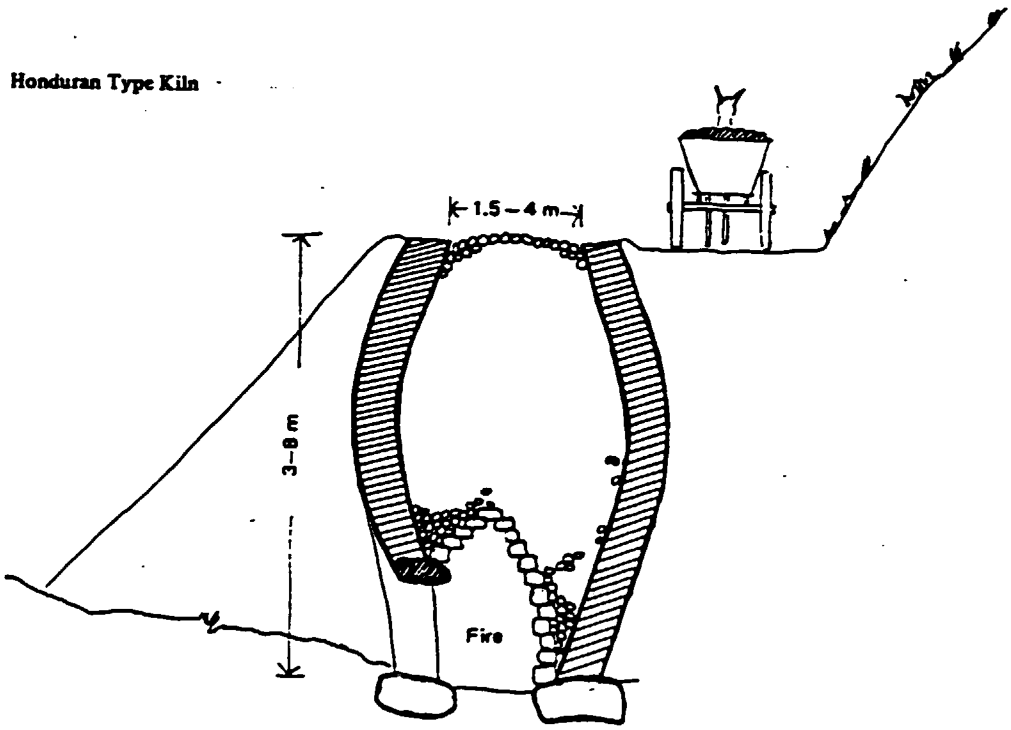
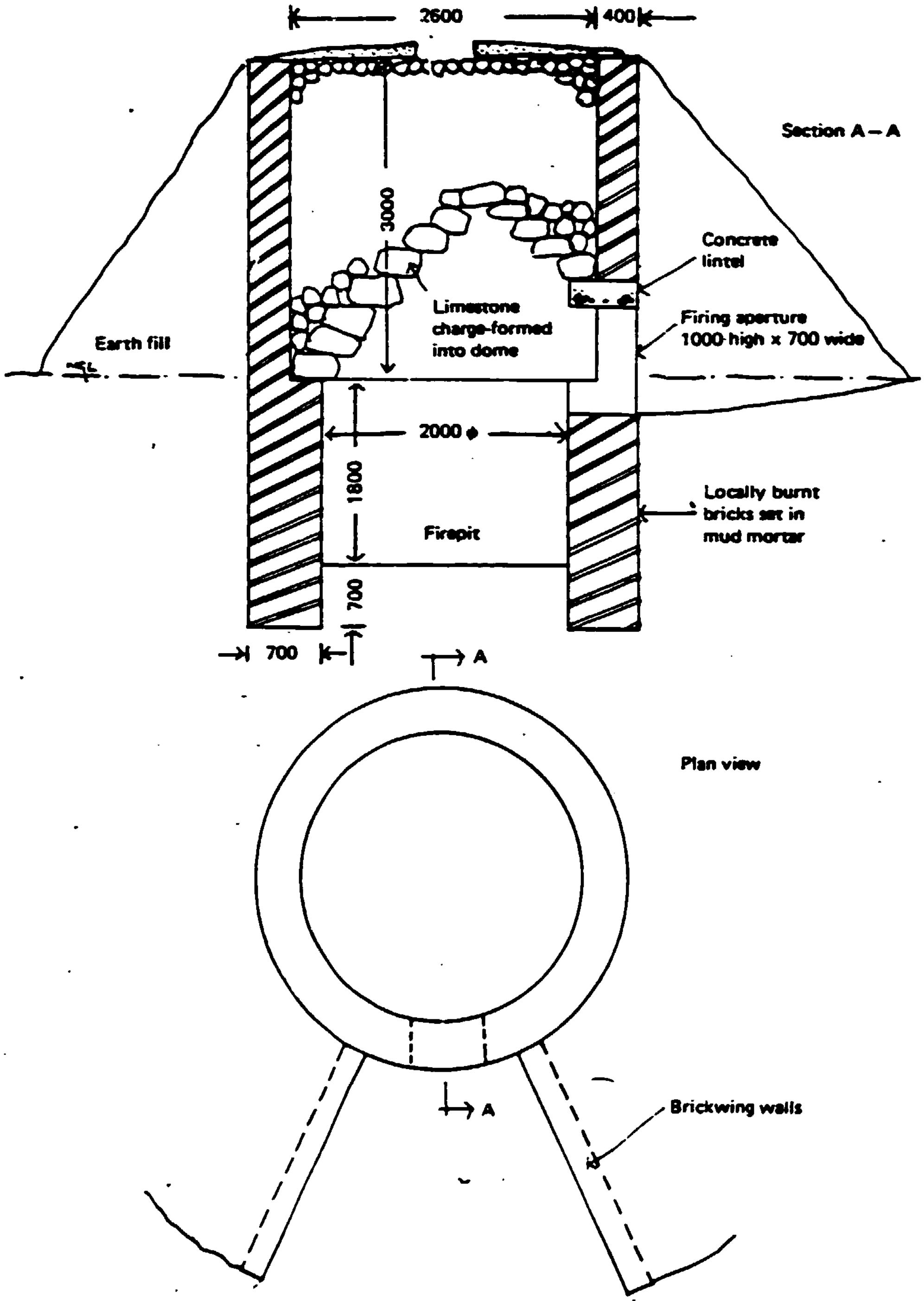
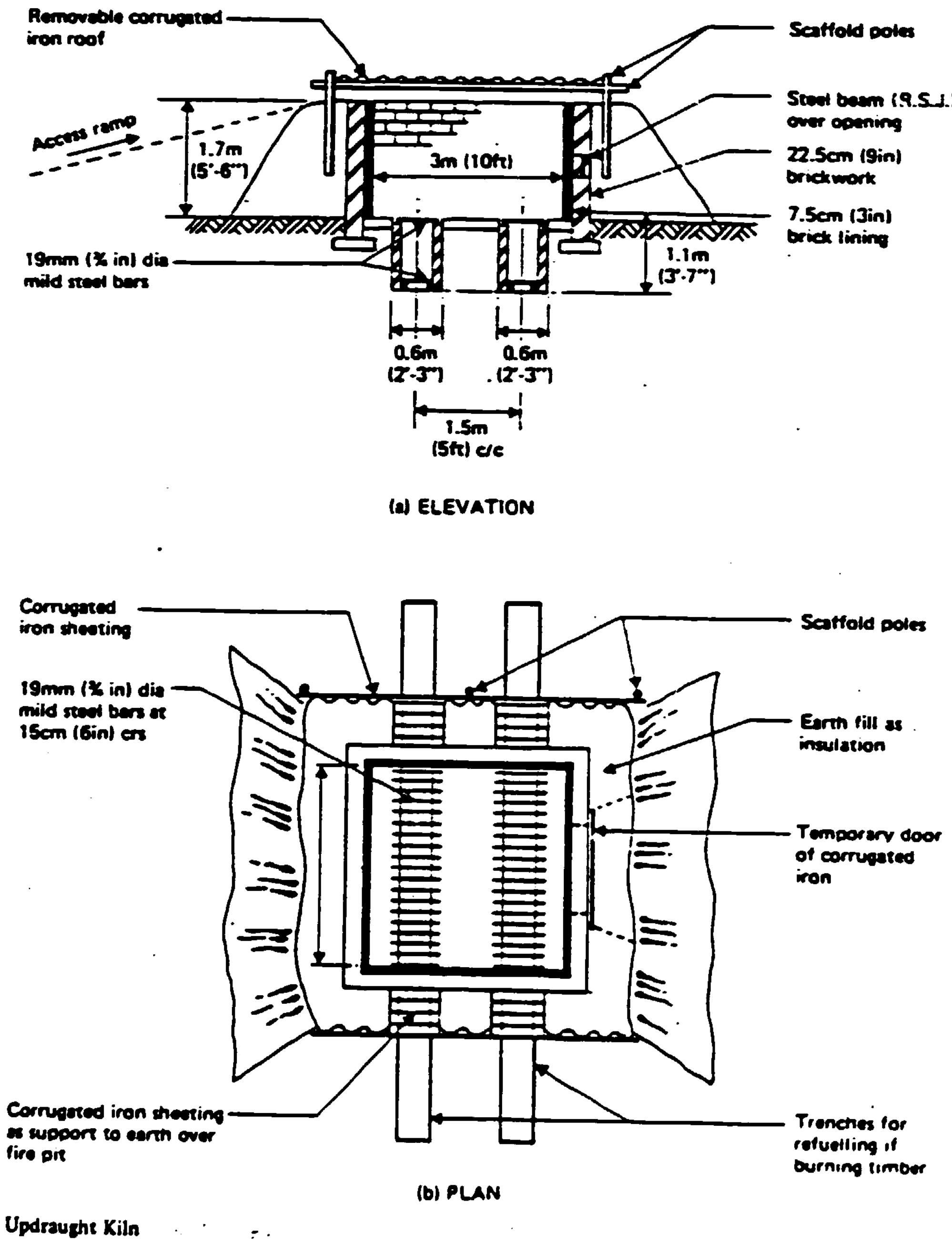


FIGURE 2



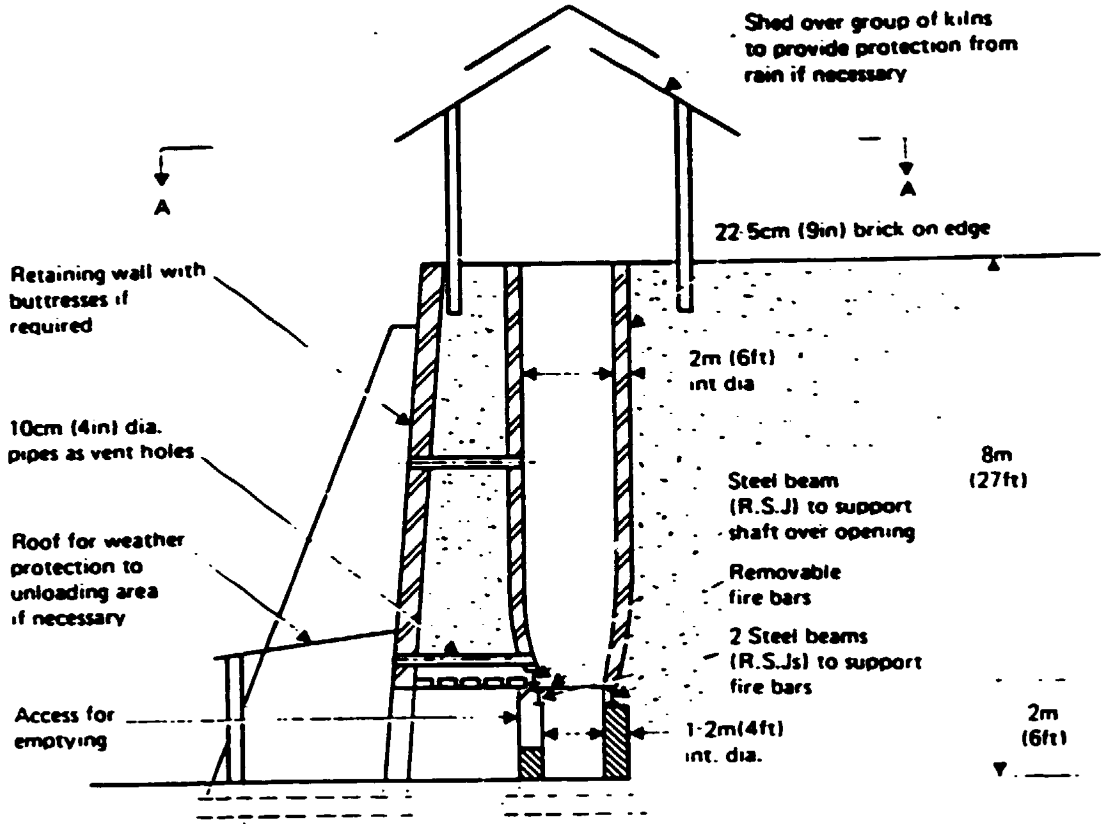
Example of Kilns Used on the Medani-Sennar-Kosti Road in Sudan

FIGURE 3

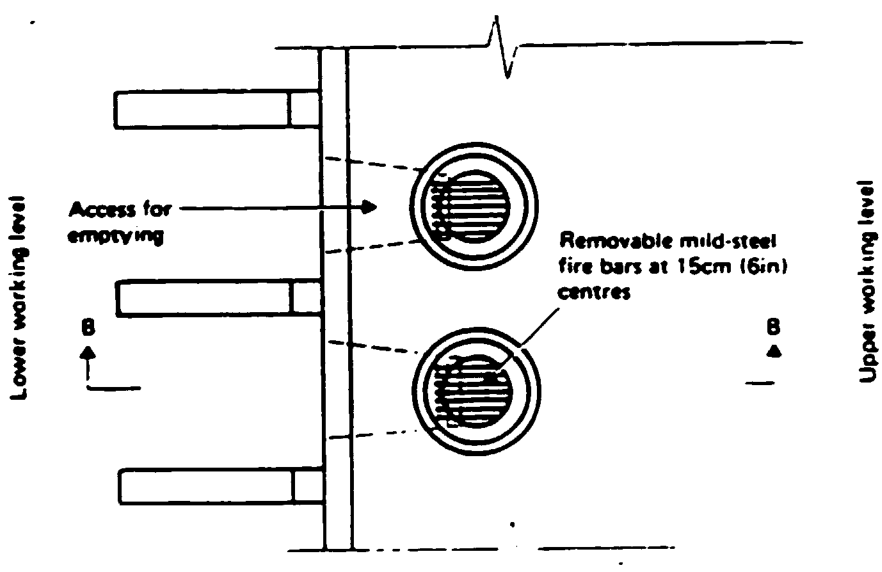


Updraught Kiln

FIGURE 4



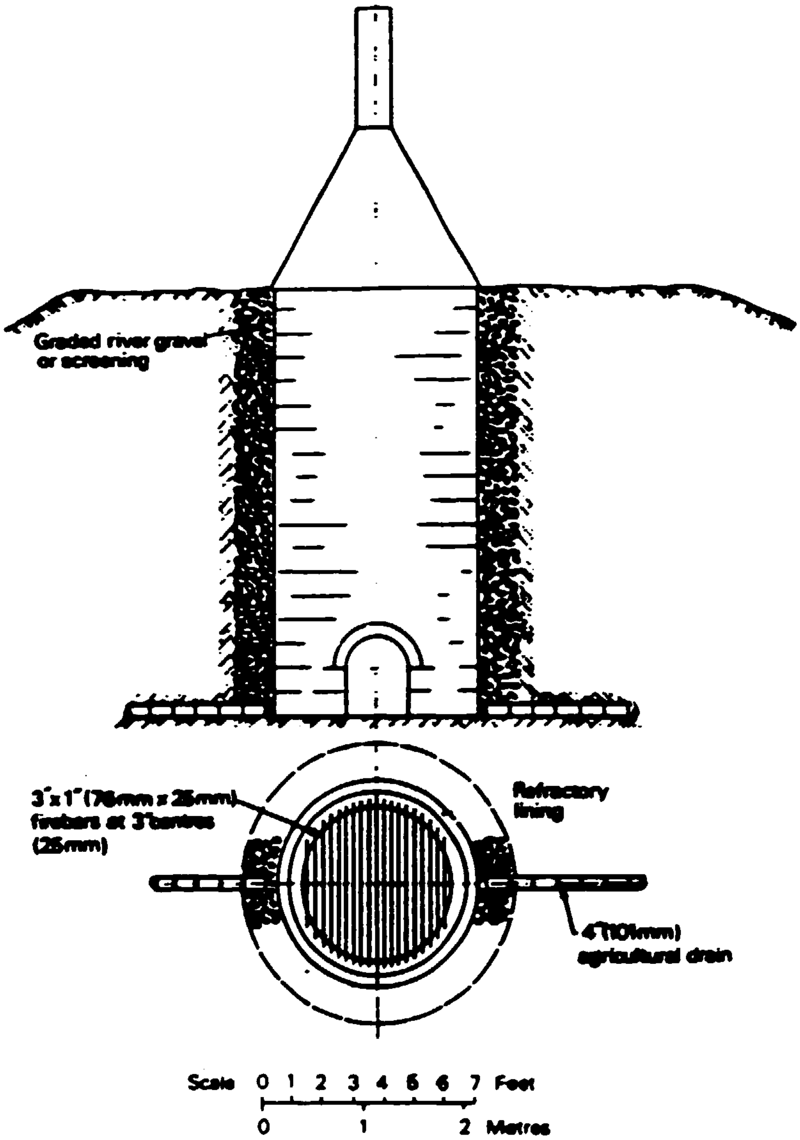
SECTION B-B



PLAN ON A-A

SOMALI KILN

FIGURE 5



A simple shaft kiln for wood-firing

FIGURE 6

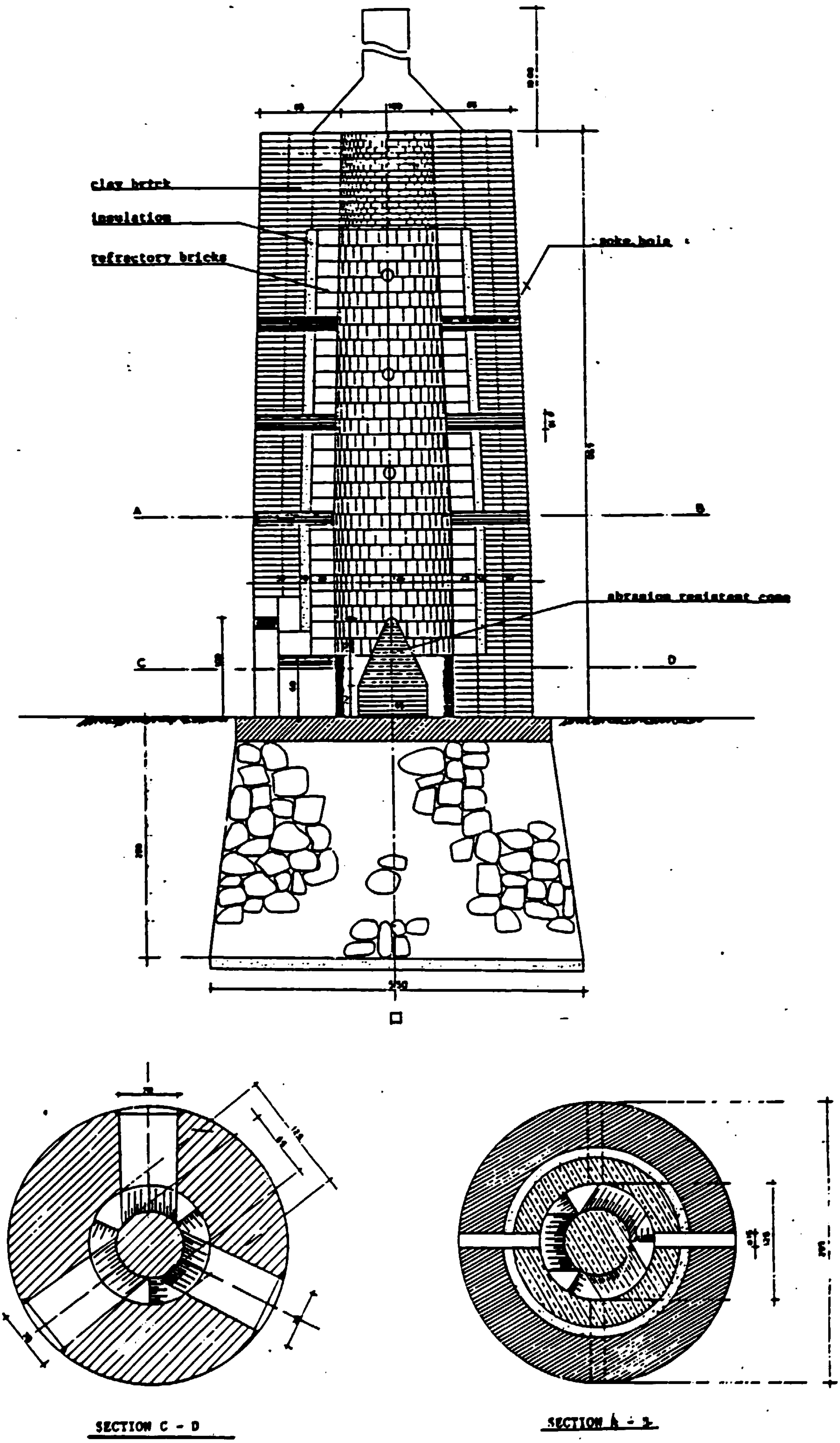
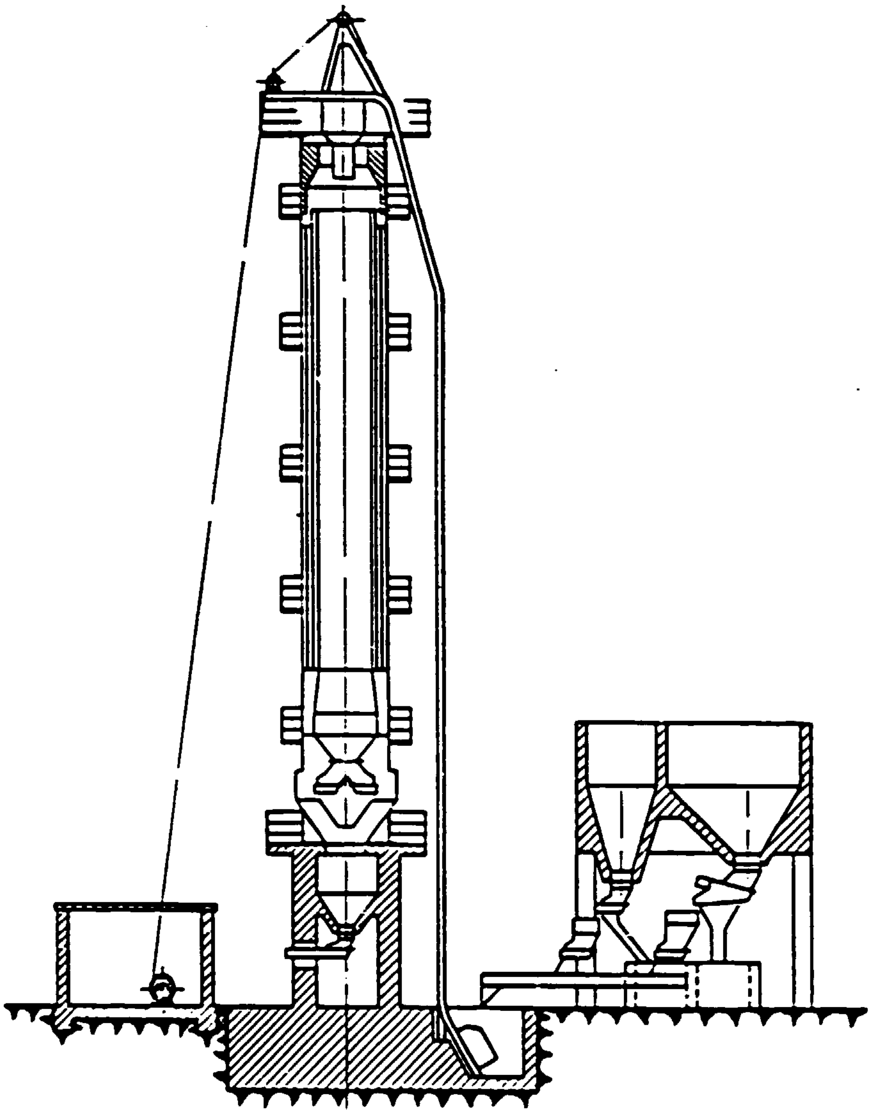
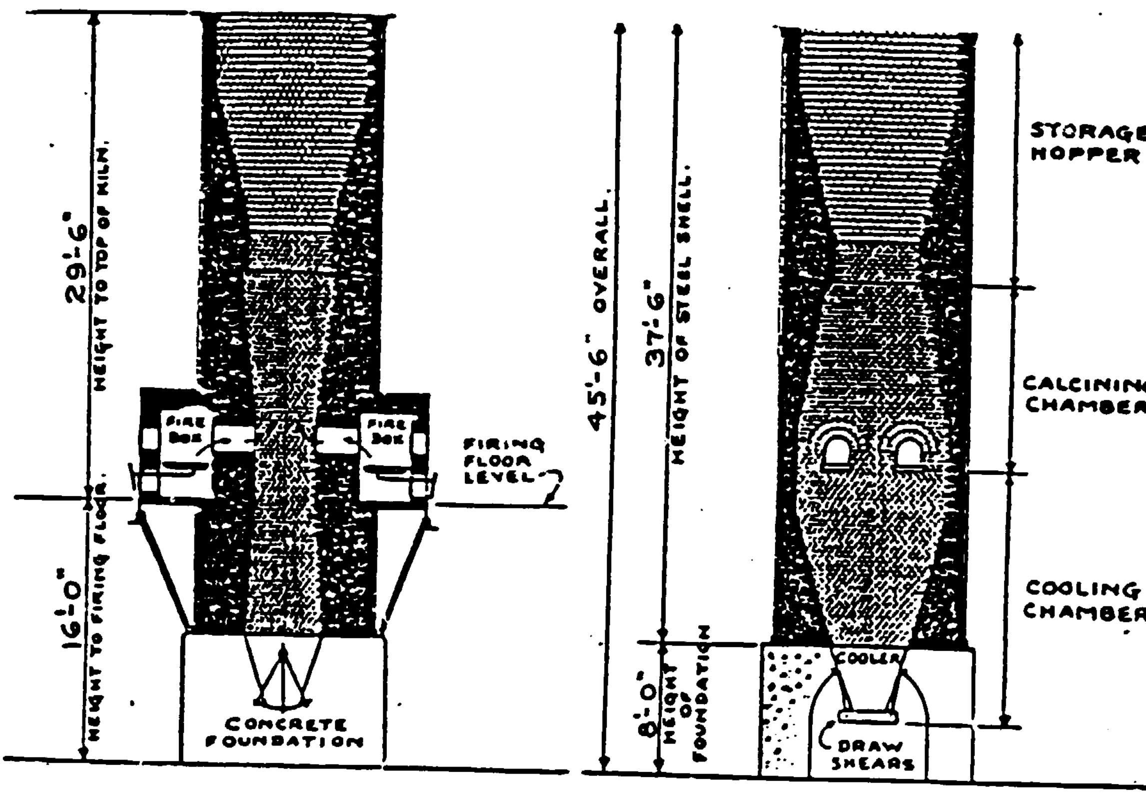

clay brick
insulation
refractory bricks
poke hole
abrasion resistant cone
A
B
C
D
SECTION C - D
SECTION A - B

FIGURE 8



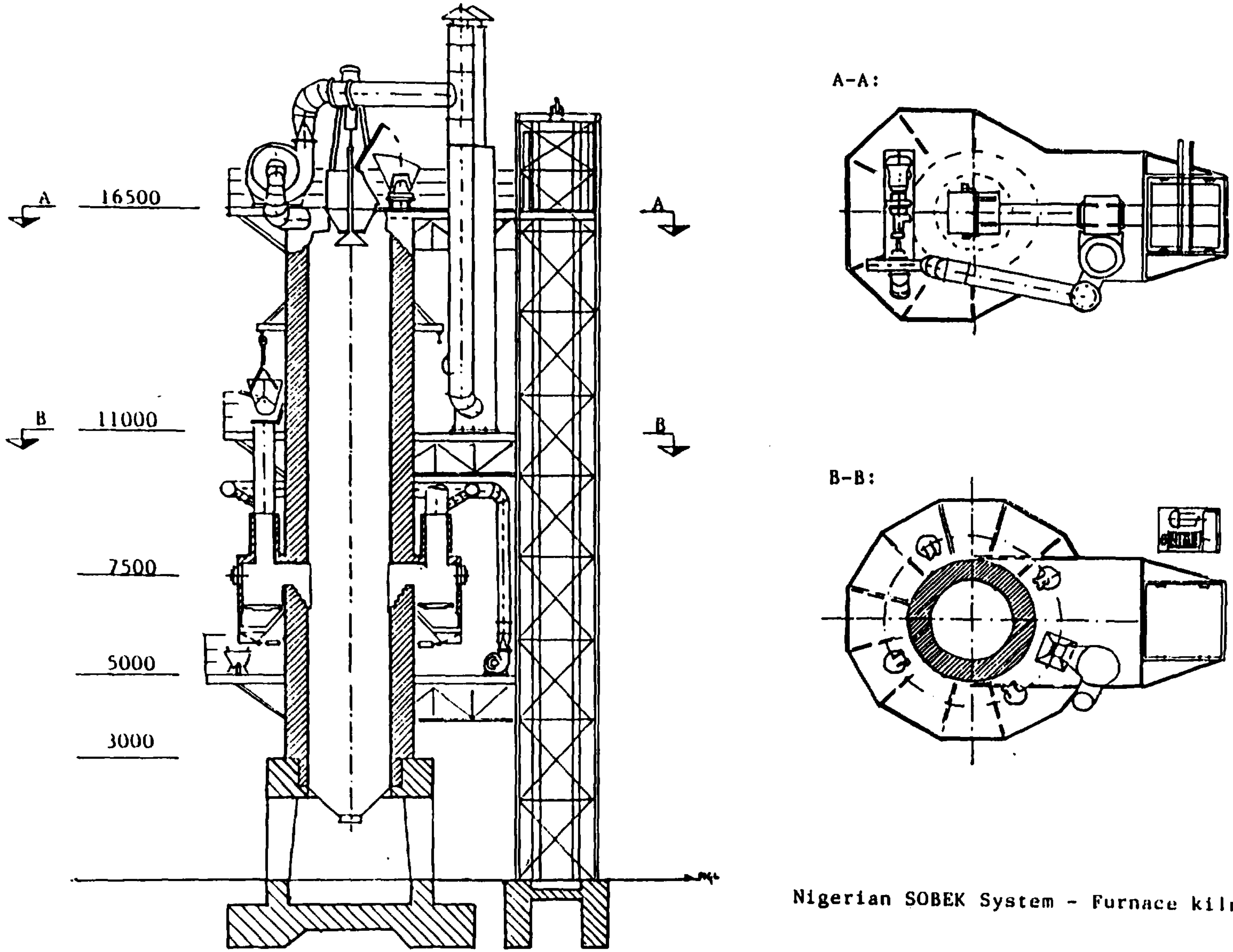
Eberhardt type KS

FIGURE 11



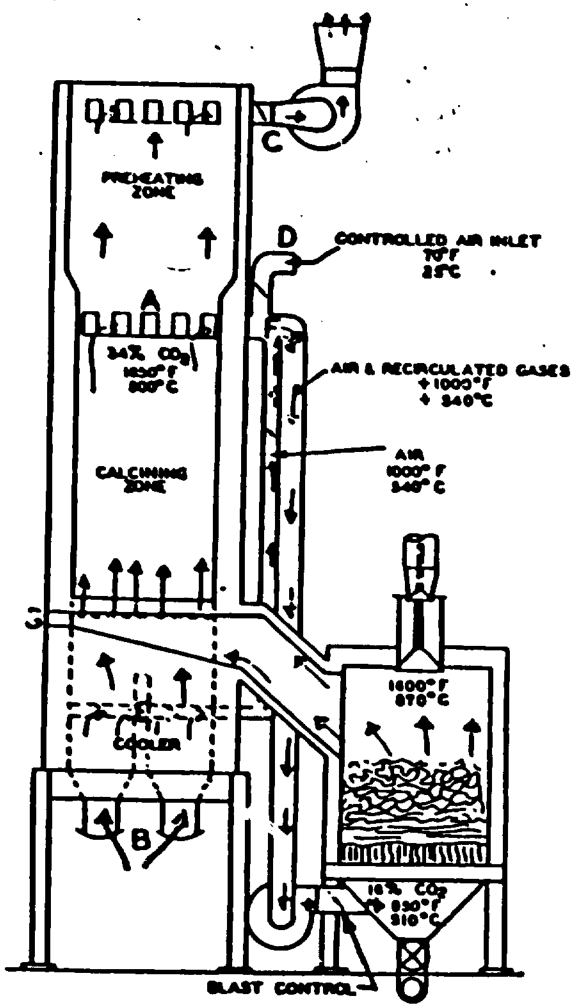
Arnold kiln

FIGURE 13



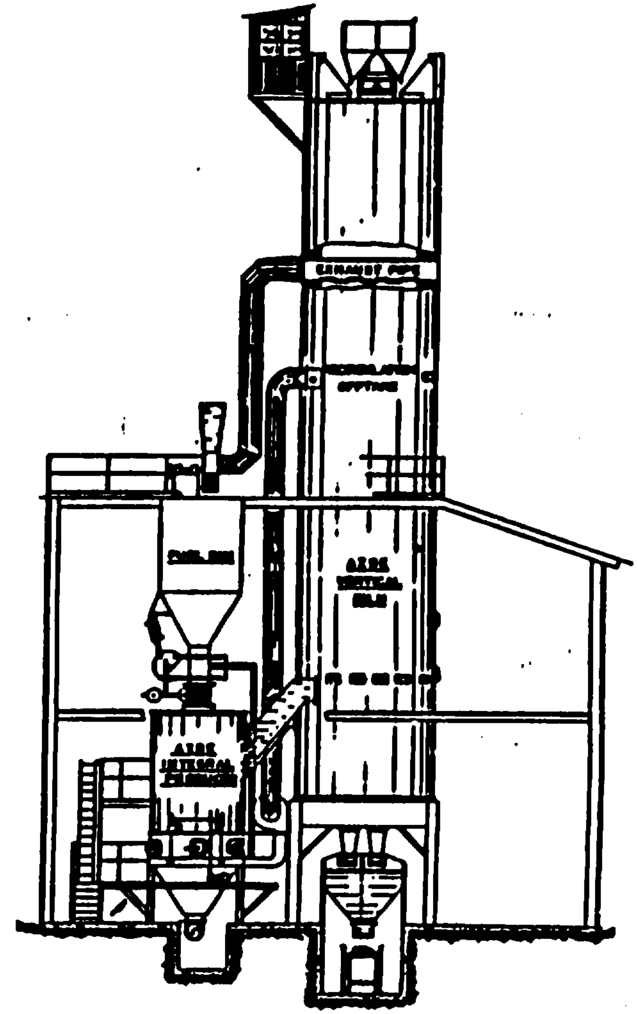
Nigerian SOBEK System - Furnace kiln

FIGURE 14



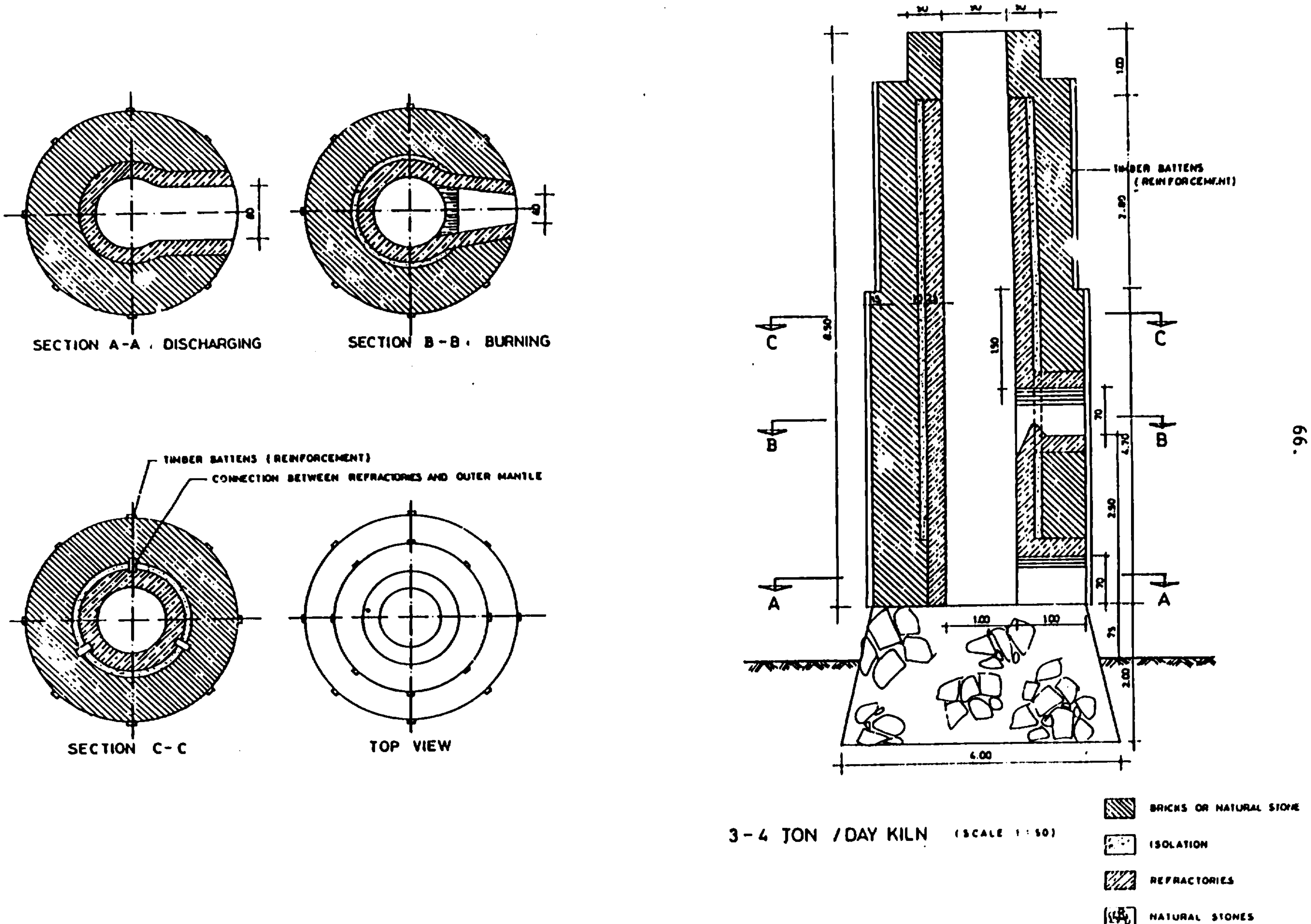
Small capacity, wood fired, producer gas kiln (AZBE)

FIGURE 15



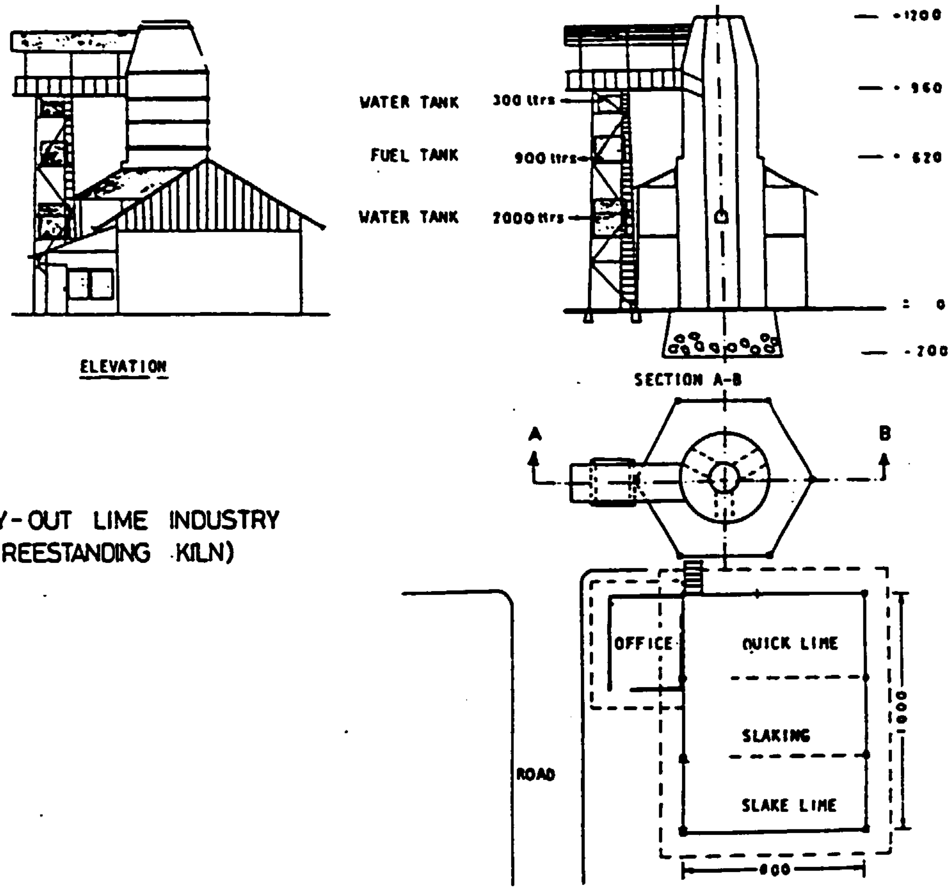
Medium capacity, coal fired, producer gas kiln (AZBE)

FIGURE 16

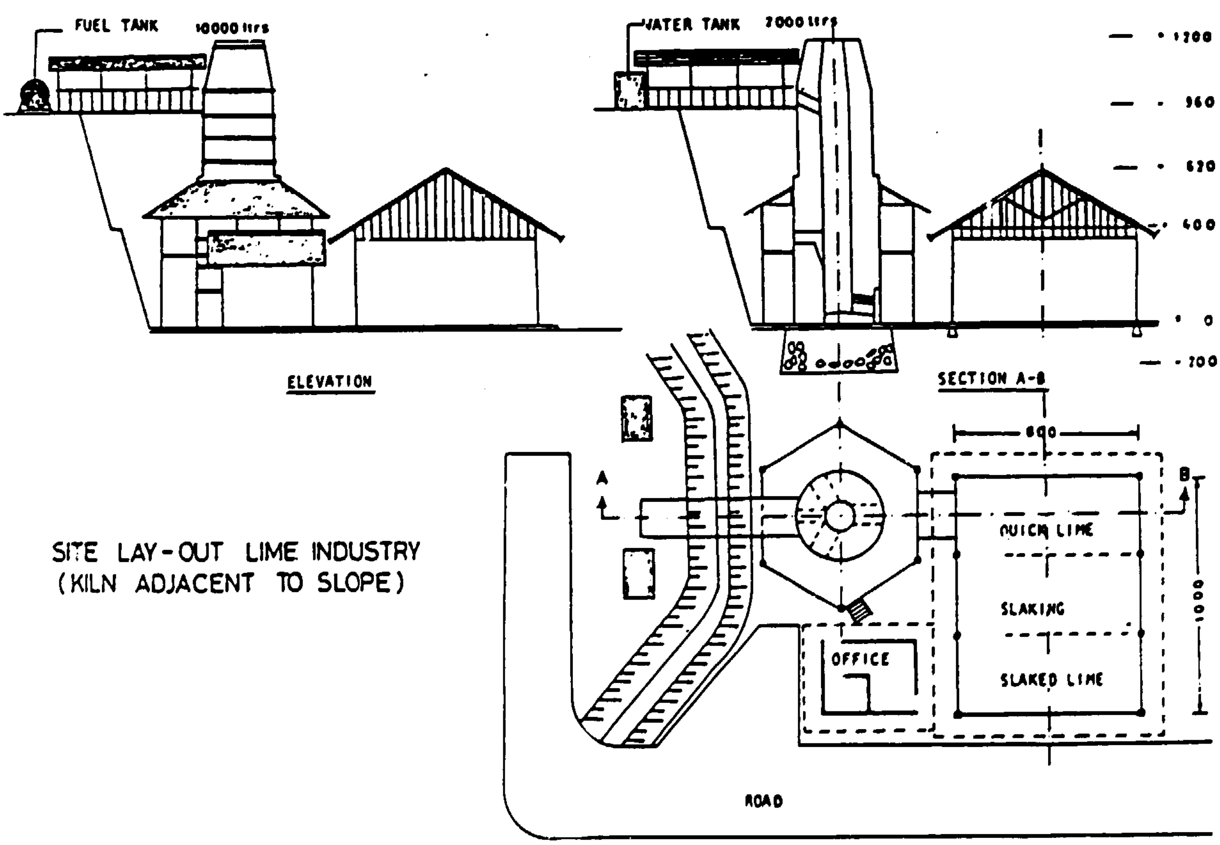


SECTION A-A , DISCHARGING
SECTION B-B , BURNING
TIMBER BATTENS (REINFORCEMENT)
CONNECTION BETWEEN REFRACTORIES AND OUTER MANTLE
SECTION C-C
TOP VIEW
TIMBER BATTENS (REINFORCEMENT)
C
B
A
1.00
2.80
6.50
1.50
4.70
2.50
1.00
1.00
2.00
4.00
3-4 TON /DAY KILN (SCALE 1:50)
BRICKS OR NATURAL STONE
ISOLATION
REFRACTORIES
NATURAL STONES

FIGURE 17



SITE LAY-OUT LIME INDUSTRY
(FREESTANDING KILN)



SITE LAY-OUT LIME INDUSTRY
(KILN ADJACENT TO SLOPE)

FIGURE 19

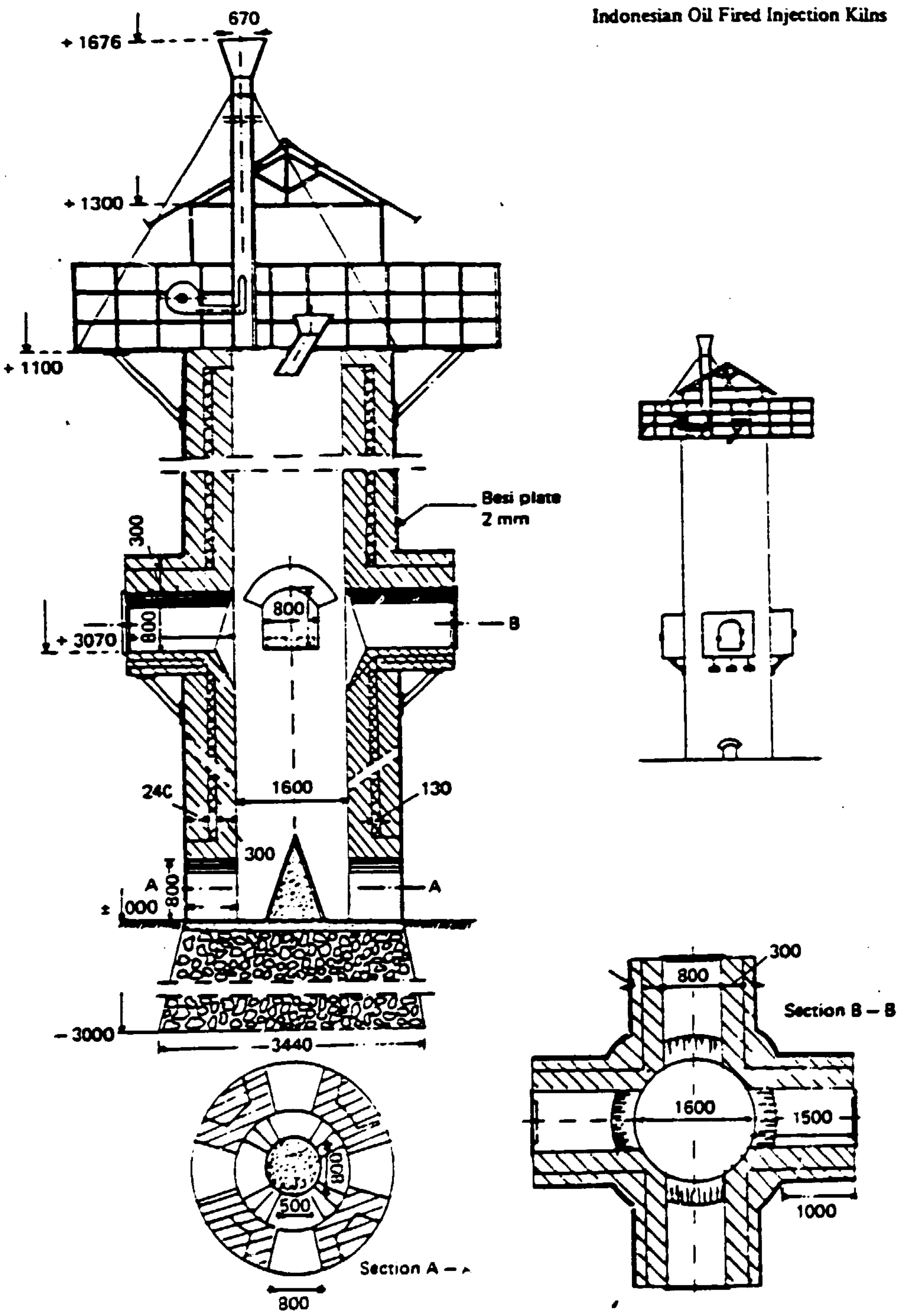

Indonesian Oil Fired Injection Kilns
670
+ 1676
+ 1300
+ 1100
Besi plate
2 mm
300
800
+ 3070
800
B
24C
1600
130
300
A
800
± 000
A
– 3000
3440
500
800
Section A – A
800
300
800
Section B – B
1600
1500
1000

FIGURE 20

SOBEK System 10/15 tpd oil fired kiln

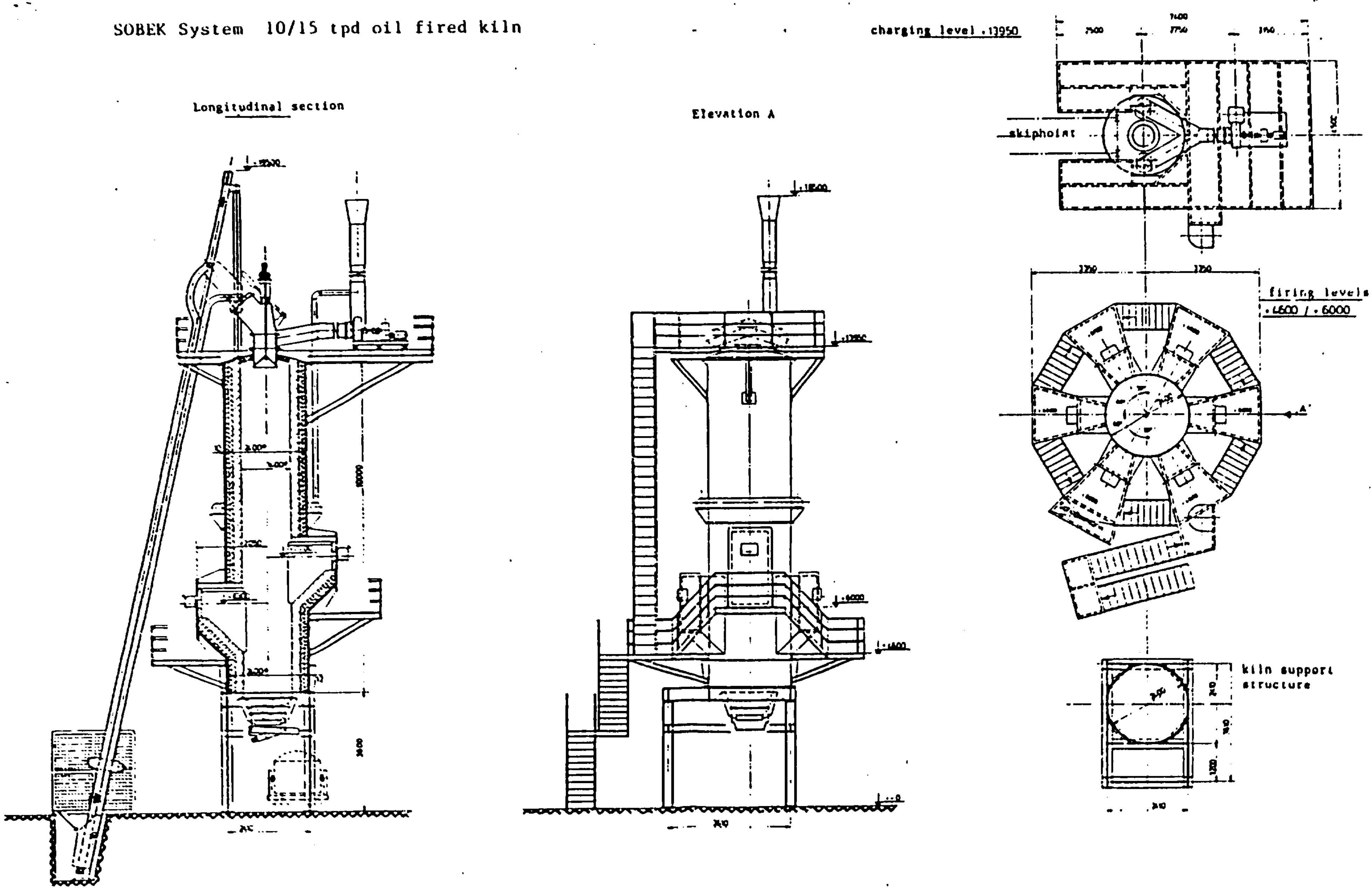


FIGURE 21

Medium-sized rotary kiln equipped with satellite coolers

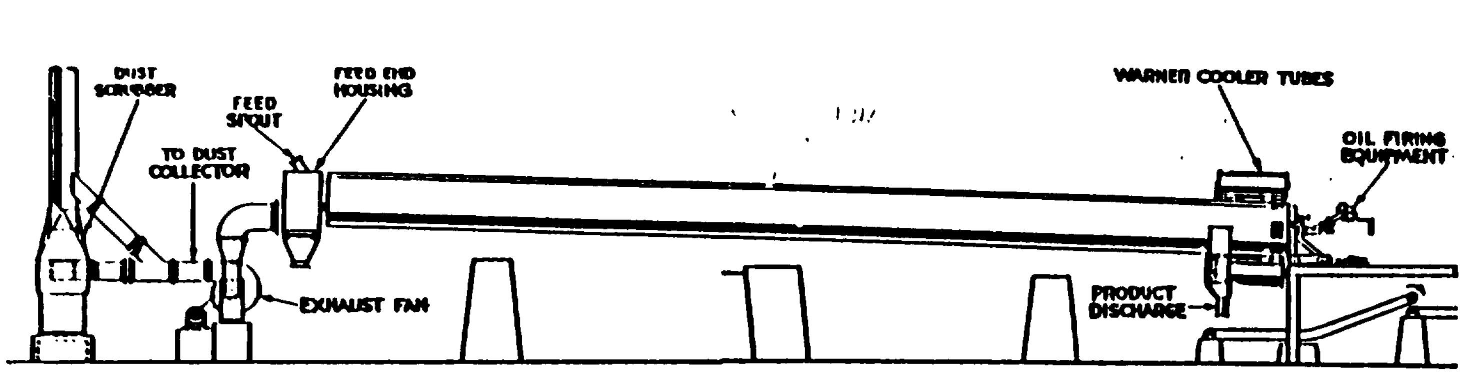
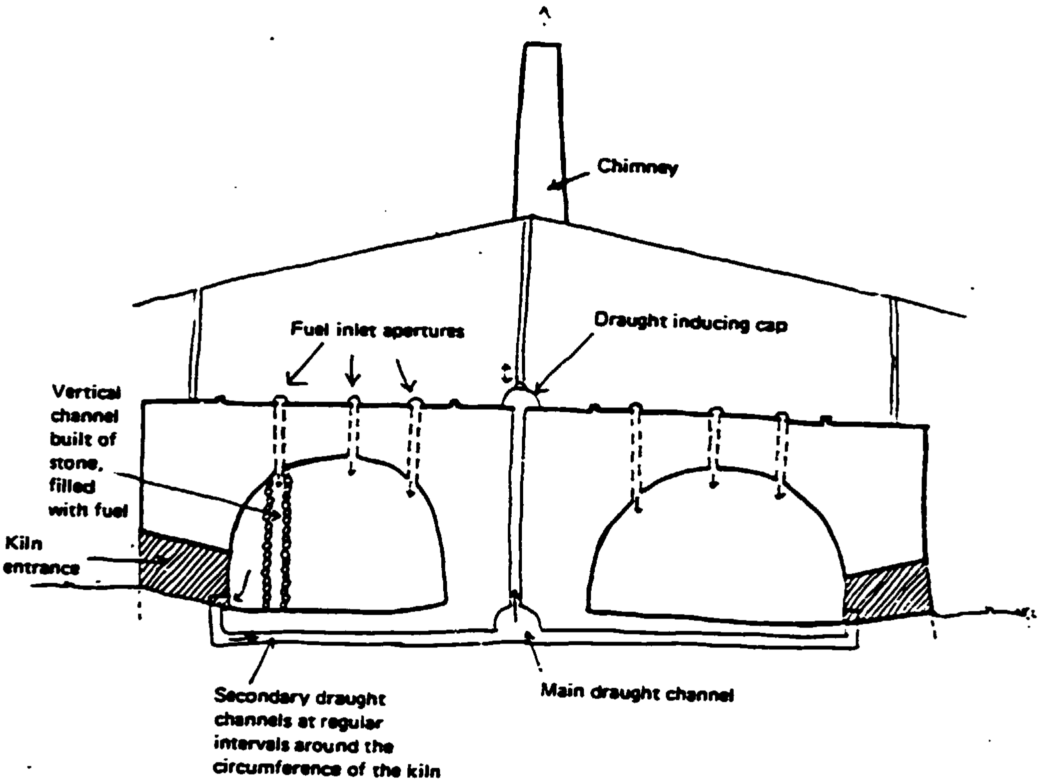
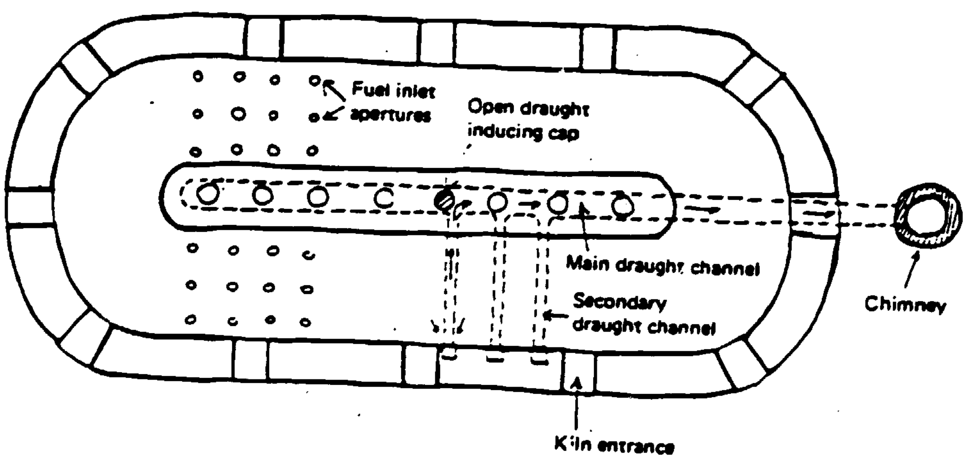


FIGURE 23





Hoffman Kiln, Observed in Greece

FIGURE 24

REFERENCES

Bessey, G.E. Production and use of lime in developing countries. Overseas Building Note No. 161. Building Research Station. Garston, Watford. 1975.

Boynton, R.S. Chemistry and technology of lime and limestone. John Wiley and Sons Inc. New York. 1980.

Boynton,R.S. and K.A.Gutschick Building Lime, its properties,uses and manufacture. United Nations Development Organization. Workshop on organizational and technical measures for the development of building materials. Moscow, USSR. 25/9 - 19/10/1968.

Ellis,C.I. Village scale production of lime for road construction in Ghana. Transport and Road Research Laboratory. Crowthorne, Berkshire. 1974.

Hosking, J.S. Limestone and lime in the Territory of Papua and New Guinea. Technical Paper No. 21. Division of Building Research, CSIRO. Melbourne. 1967.

Kölsch-Fölzer-Werke AG. Quotation for 1 complete oil heated, sucked Low Pressure Lime Burning Furnace with an output of 10/15 tons of burnt lime per day. System: SOBEK Siegen/Düsseldorf. 1/10/1976.

Searle,A. Limestone and its products. E.Benn Ltd. London. 1935.

Sobek,F. Manufacturing guide. Lime industry. United Nations Industrial Development Organization. May, 1975.

Spiropoulos, J. Small Scale Production of Lime for Building. Deutsches Zentrum für Entwicklungstechnologien - GATE in: Deutsches Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH. Friedr. Vieweg & Sohn. Braunschweig/Wiesbaden. 1985.

Wingate, M. Small-scale Lime-burning. A practical introduction. Intermediate Technology Publications. London. 1985.