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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

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LIME IN INDUSTRIAL DEVELOPMENT:
A UNIDO GUIDE TO ITS USES AND MANUFACTURE IN DEVELOPING COUNTRIES

Sectoral Studies Series
No.18

SECTORAL STUDIES BRANCH
DIVISION FOR INDUSTRIAL STUDIES

Main results of the study work on industrial sectors are presented in the Sectoral Studies Series. In addition a series of Sectoral Working Papers is issued.

This document presents major results of work under the element Studies on Building Materials Industries in UNIDO's programme of Industrial Studies 1984/85.

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Preface

This study has been prepared by UNIDO's Division for Industrial Studies, Sectoral Studies Branch. The study discusses present and potential uses of lime in industrial development and seeks to provide basic information on lime which will encourage its development. Material contained within this study is useful to present and future producers of lime in developing countries.

This study, together with the UNIDO Lime Industry Directory containing a list of organizations and suppliers of technology, the UNIDO Lime Bibliography and the UNIDO Lime Data Base (production, trade and user information) which have been prepared simultaneously, will assist producers in developing countries.

The author of this study is Dr. Robin Spence, Intermediate Technology Consultants.

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EXECUTIVE SUMMARY

Objective and scope

This report has been undertaken by UNIDO with the intention of promoting the lime industry in developing countries. UNIDO has identified the lime industry as an industry which has significant potential for growth, and whose development should be encouraged.

The report is intended to be read by present and potential lime producers and by government officials. It gives particular emphasis to small-scale lime production, and shows that, in appropriate circumstances, small-scale operation can be both technically successful and profitable to the investor.

The report is organized into six chapters. Chapter 1 discusses the uses of lime and considers new and growing markets for developing countries. Chapter 2 describes the technology of lime production and considers the factors affecting the choice of an appropriate technology. Chapter 3 reviews financial and economic factors which should be considered in project planning and implementation. Chapter 4 presents a recent case study of small-scale lime production, discussing the technological and economic aspects of its planning and operation. Chapter 5 reviews the assistance required to establish a new lime manufacturing enterprise, and gives guidance on how to find assistance. Chapter 6 restates the principal arguments in support of the promotion of lime production.

The report is supplemented by three further computerized sources of information: The UNIDO Lime Industry Directory lists organizations country by country which are involved in one way or another in support of the lime industry. The UNIDO Lime Bibliography lists documents, books, periodicals, technical papers and reports which are of interest to lime producers and lime industry planners. The UNIDO Lime Database is a country by country file on lime production, consumption, trade and prices. Chapter 5 describes the contents of these records in more detail.

The lime industry

The lime industry in one of the oldest, established and most important of the mineral processing industries. It is based on raw materials which are widely available and easily extracted; the processing technology used is relatively simple, economical and flexible in fuel use, and can be carried out economically at small or large scales of production; and the end-product, lime, has an enormous variety of potential uses, in agriculture, numerous processing industries and in construction.

In the industrialized countries the production of lime is concentrated in a relatively small number of large, automated plants producing many hundreds of tons per day, and the principal uses of lime are in the metallurgical and chemical industries, with relatively smaller amounts used in building and agriculture. In the developing countries, although a small modern industrial sector often exists, lime production is largely carried out on a small scale, using simple labour-intensive methods, and the lime produced is principally used in building and road construction, agriculture and the food processing industries.

There is potential for substantial growth of the lime industry in developing countries to meet two different needs. First, to provide the lime required as an input to other industries in a growing industrial sector. Secondly, to complement and in some circumstances replace cement as a basic binding material in the construction sector. The purpose of this report and the accompanying directory, bibliography and database is to provide practical support for the development of the lime industry to meet these needs.

Uses of lime

In the industrialized countries, the biggest users of lime are the metallurgical industries, especially the steel industry, where lime is used as a flux in refining processes. Lime is also used in the manufacture of caustic soda and other basic chemicals. The demand for lime in these large-scale industries is growing in developing countries also, but because the scale of demand is large and strict standards of control and chemical composition are applied, such lime is often produced by captive lime plants within the industry.

A traditional use of lime has been in agriculture in the liming of land to reduce soil acidity and improve soil structure. Lime in smaller quantities also has a number of other uses in the agricultural sector. The potential for this use in developing countries is considerable, although liming is nowadays usually done with pulverized limestone or chalk, which is often cheaper to produce than burnt lime. Agricultural lime, because of its small-scale pattern of demand, is likely to be an important market for a small scale limeworks.

There is a growing demand for lime in a group of uses commonly described as environmental protection. Lime is used for treatment of drinking water, for waste water and sludge treatment, and for stackgas purification; lime for all these uses can be produced by small-scale producers, provided that adequate quality control standards are maintained.

The construction sector is an important developing market for lime, and the major market for small-scale producers. As a binder and workability agent, lime is a valuable component of mortars and plasters; it is very effective in the stabilization of certain soil types and is therefore used for road construction and for the manufacture of stabilized soil building blocks; it is used to make lime wash; and is essential in the manufacture of certain building materials such as sand-lime bricks and autoclaved blocks. In a number of these applications lime, or lime-based materials, can either wholly or partially replace cement or cement-based materials, making possible greater use of the products of a small-scale local industry. The potential market in these applications is very large.

Lime is also used in a great variety of applications in numerous industries; some of the most common are sugar processing, tanneries, glue production, glass production and paper production, as well as numerous food industries. In some of these industries the lime needed is commonly supplied through captive lime plants, but all of them can be regarded as potential markets for the independent lime producer.

Choice of technology for lime production

Lime is produced from limestone by firing the stone in a kiln at a temperature in excess of 900°C and then slaking it with water to produce a lime powder, putty or slurry. A wide variety of processing techniques may be used for different raw materials and fuels to produce different types of lime and for different scales of production and the choice must consider:

(a) The raw materials available, their extent, composition and properties;

(b) The types of fuel available;

(c) The size and pattern of the demand for lime;

(d) The type of lime required and the standards applicable;

(e) The location of potential suppliers of processing equipment and kilns;

(f) The levels of technical and managerial skills available;

(g) The existing technological infrastructure (roads, power supply, etc.);

(h) Economic factors.

The raw material required for lime production is limestone; this has a variety of naturally occurring forms, but not all of these are suitable and some are of limited applicability. The principal qualities of a limestone are that its chemical composition should suit the type of lime required, it should occur in a form which can easily be quarried and processed and its behaviour during firing should suit the type of kiln to be used.

The process of lime production involves quarrying and stone preparation, firing (or calcination), slaking (or hydration) and packing. Firing takes place in a kiln which is the central and most expensive part of the processing technology and for which the widest range of technological alternatives exists. Kilns are of three principal types, batch kilns, vertical shaft kilns and rotary kilns.

Batch kilns use simple cheap technology, but are inefficient in energy use and produce a poor quality lime.

Vertical shaft kilns range from simple small-scale systems producing 10 tons/day or less to highly automated kilns producing up to 500 tons/day. They are much more efficient in energy use than batch kilns and different designs are available to accommodate different fuels, sizes of stone and scales of production.

Rotary kilns may be used for scales of production in excess of 300 tons per day; they are less efficient in energy use than vertical shaft kilns, but easier to control.

Large plants are not necessarily more efficient in fuel use, or able to produce a better quality lime. The most appropriate kiln design will emerge from consideration of all the conditions of production. It is important to select a kiln so that overcapacity is avoided.

Hydration plants are also available for different scales and levels of technology, ranging from simple small non-mechanical processes to fully automated plants with outputs in excess of 20 tons per hour; the technology appropriate to a given situation is closely linked to the kiln output and the quality and type of lime required. Plant safety and the environmental effects of lime production should be considered in all projects, at whatever scale of operation.

Financial and economic factors

A key factor in the development of a successful lime production plant is a realistic economic feasibility study. For a small plant this need not be detailed, but should include:

(a) Investigation of the demand, price and availability of the potential market for lime;

(b) A review of alternative marketing strategies;

(c) A production programme based on the proposed technology;

(d) An assessment of the availability of suitable staff and skilled labour and of wage levels;

(e) An assessment of total investment costs including both fixed and working costs and a cashflow plan;

(f) Assessment of production costs and calculation of the return on investment or payback period.

Based on this information, financing for the project can be sought. Possible sources of finance in addition to the owner's capital may include short-term bank loans for working capital, leasing or hire purchase for equipment or vehicles and support from development finance institutions for larger and longer term capital investments.

Case study of lime production in Botswana

The case study describes a recent experience of establishing lime production in Botswana, at a scale of about 3 tons/day, to provide a locally produced material as an alternative to imports from the neighbouring Republic of South Africa. The study records the factors considered in the technical feasiblity study leading to the choice of a production unit based on a small vertical shaft kiln. The market investigation showed that there was a substantial potential demand in building and road construction and agriculture, and the economic feasibility study showed that lime produced by the chosen technology could be sold for only 65 per cent of the cost of imported lime. The advantages of the small-scale low technology approach were found to include:

(a) Low initial capital cost;
(b) Short pay-back period;
(c) Simplicity of construction using local materials;
(d) Use of a small limestone deposit;
(e) Elimination of the risk of mechanical or electrical breakdown;
(f) Labour intensive operation;
(g) Flexible output.

Successful operation at this level has provided a model for the subsequent establishment of additional production units of a similar type since there has been a growing demand.

1. LIME AND ITS USES

1.1 Introduction

Lime is a mineral substance derived from limestone when it is burnt in a kiln. By virtue of its chemical and physical properties and the essential simplicity of the process by which it is made, lime has become one of the most important industrial minerals. The world's largest lime producer is the USSR, whose annual production is about 28 million tons per year. In all industrialized countries, the biggest use of lime is in steel production where it is used as a flux. But it has thousands of other uses, and indeed Boynton[1/] has claimed that literally any manufactured object has required lime or limestone in some phase of its manufacture. In the industrialized countries, lime production is a large-scale and highly mechanized industry. But most developing countries also produce lime in substantial quantities for use in agriculture, building and food processing, and because much of this lime production is in very small-scale units the total amount produced can only be estimated. Recent estimates published are that 400,000 tons of lime are produced in India and 5 million tons in Brazil. Actual production is probably higher.

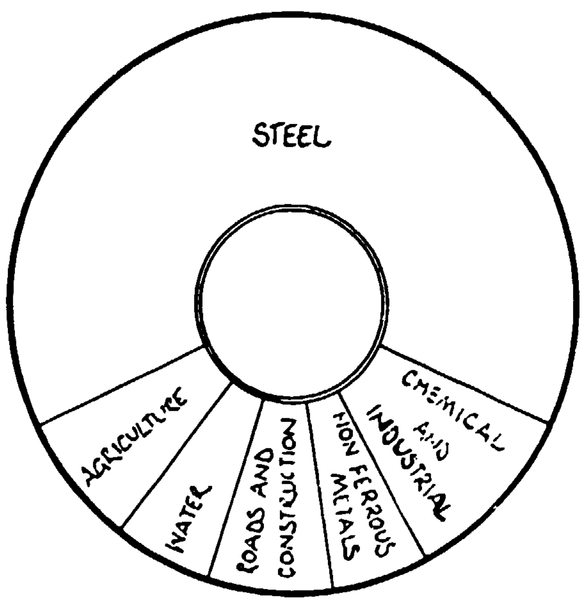
Lime is derived from limestone by burning or calcining it in a kiln. Chemically, limestones consist of calcium carbonate and magnesium carbonate and the burning expels carbon dioxide as a gas from the stone, forming calcium oxide and magnesium oxide, or quicklime. Addition of water causes a further reaction to take place, called hydration, in which the oxides are converted to hydroxides and in this form the lime is known as slaked lime or hydrated lime. The lime industry produces both quicklime and hydrated lime for sale and sometimes limestone as well. This study is, however, only concerned with the first two, the burnt products of limestone.

1/ R.S. Boynton, Chemistry and Technology of lime and limestone, Wiley Interscience, 1980, p. 1.

The first section of the report discusses the various uses of lime in industry, in agriculture and in building, and the forms in which lime is needed for these uses.

Traditionally, the building industry has been one of the major consumers of lime and this is still the case in many developing countries. But there are many other industries and services which consume large quantities of lime and in industrialized countries these industries are the major consumers, with a much smaller proportion used in the building industry. The pattern of end use varies dramatically from one country to another but figure 1.1 shows the end use in France in 1977 when a vigorous industry produced over 3.75 million tons of lime. The most significant features are the enormous consumption of the steel industry and the very wide variety of other uses. These uses will be described in the following sections.

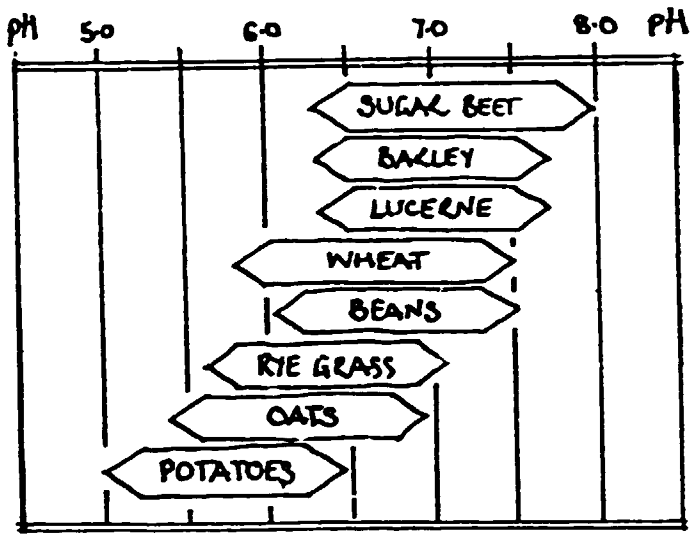
Figure 1.1. End users of French lime production in 1977



1.2 Agricultural uses of lime

The fertility of the soil is greatly improved if its acidity (pH) is reduced by liming. Different crops have slightly different ideal requirements and some of these are shown in the figure below.

Figure 1.2. Soil acidity for optimum growth



The liming may be done with quicklime, hydrated lime or powdered limestones and chalks as well as various industrial waste carbonates. Burnt limes act quickly and are especially useful for market gardening and where three crops are taken in one year. Powdered limestone or chalk is a cheaper material than lime and is a very useful byproduct of a limeworks where the quarrying operations produce undersized waste material which cannot be used in the limekilns. The waste materials from a lime hydrating plant may also be blended into agricultural limes.

Liming can benefit the soil in several ways. By reducing the acidity it enables phosphates and other nutrients from fertilizers to be released. Low acidity also improves the natural microbiclogical enhancement of the soil through the breakdown of organic matter. Lime on clay soils can improve the physical structure and thus help root growth in crops. Lime also contributes calcium to the crops and where magnesium levels are low the best way to make up the deficiency is with magnesian lime. The rate of application depends very much on the needs of the crops and the effect of leaching after rainfall. It may vary between nil and up to 5 tons/hectare and may not be necessary every year.

The sales of agricultural limes are likely to be very important for a small limeworks. The effect of transport costs makes it possible for them to compete with larger producers further afield.

1.2.1 Treatment of grassland

Liming grassland tends to encourage the growth of the more nutritious plants and the calcium and magnesium rich fodder is beneficial to livestock. There is a special advantage on wet grassland where the reduction of acidity can control the spread o. parasitic threadworm and liver flukes.

1.2.2 Incidental agricultural uses

For the same reasons that lime helps soil fertility, it is essential in the controlled composting of crop wastes. Typically the waste material is built up in layers covered alternately with lime and fertilizer.

Quicklime has been used for centuries for the safe disposal of diseased or unfit carcasses. It destroys them and prevents bacteria from growing in them.

Lime is used as a filler and reagent in the manufacture of certain pesticides. It can be used on the farm mixed with equal amounts of copper sulphate for the preparation of Bordeaux mixture, a fungicide, but newer products are easier to apply.

Limewash - a paint made with water and quicklime - is ideal for painting farm buildings. It is cheap, bright and acts as a disinfectant. Its preparation is described in section 1.8.

1.3 Uses of lime in the chemical industries

Lime is one of the most fundamental reagents for the chemical industries. It is a low cost material with powerful properties which enable it to form both organic and inorganic calcium compounds, to control acidity (pH) or to regenerate other more expensive reagents. Its use as a coagulant and flocculant allow it to remove colloidal impurities. Many of the products it makes are themselves the building blocks of the chemical industry.

The biggest chemical use is in the production of caustic soda and other alkalis by the Solvay process, but for this the carbon dioxide gas generated in the lime kilns is needed and so the lime is always burned at the chemical works.

Magnesia, made from lime and natural brines, is used for refractory materials, special cements, fertilizers and rayons. Calcium carbide, made from lime and coke, is used to make acetylene gas and calcium cyanamide fertilizers, though the demand for both of these is less than it used to be.

Much lime is used to prepare precipitated calcium carbonate which is used as a filler for papers, paints, rubber and pharmaceuticals.

Other products are calcium hypochlorite bleaches, citric acid, phosphate chemicals, glycerine and propylene oxide - a building block for organic chemicals.

1.4 Uses of lime in the food industries

The only major use of lime in the food industries is in the refining of sugar from sugar beet. Up to 250 kg of lime are needed for each ton of sugar and this is largely supplied from limekilns at the sugar factories. Sugar cane refineries also need lime, but on a much smaller scale. Consumption varies between 2 and 7 kg/ton.

In Mexico a major use of lime is for the household preparation of maize used to make tortillas.

Other minor uses are the treatment of waste products at canning factories, the reduction of acidity in canned fruits and the preparation of gelatine from waste bones and animal hides. Grape lees, the refuse product in wineries, can be treated with lime to produce tartaric acid which is used in baking powder.

The storage of apples, and some other fruits, can be improved by the controlled athmosphere method in which hydrated lime absorbs the carbon dioxide exuded by the fruit.

1.5 Uses of lime in the metallurgical industries

Steel making by the basic oxygen method requires enormous quantities of high quality lime to form the flux which carries away the impurities as a slag. A portion of dolomitic lime is sometimes used as this extends the life of furnace refractory linings. An example of the scale of this consumption can be seen in figure 1.i.

Lime is an important ingredient in the Bayer method of smelting aluminium where it is used with caustic soda (itself made with lime) to break down the bauxite ore.

Magnesium is produced from sea water or brines through the intermediate step of base exchange with lime to produce the magnesium hydroxide from which first magnesia then magnesium is made.

Very substantial amounts of lime are used in the preparation of non-ferrous metals by the flotation of their ores. In the flotation of copper, the largest use in this group, the lime acts as a settling agent and controls the acidity (pH) during the process. Other metals prepared by flotation using lime are zinc, lead, gold, silver and uranium.

The metallurgical industries are a most important outlet for the lime industry. Steel making requires the highest quality limes and flexible production methods since the highly reactive limes needed do not store well.

1.6 Environmental protection

A long established practice, which is still a major use of lime, is its use at waterworks to soften hard water. Lime, as quicklime or hydrate, will react with calcium and magnesium bicarbonate to precipitate calcium carbonate which can be filtered out. Where there are also chlorides or sulphates in the hardness, soda ash is used in a combined treatment. Lime treatment brings several other advantages. It reduces the acidity, it clears the water by settling out cloudy suspensions, it precipitates heavy metals, nitrates and phosphates and it contributes to the sterilization of bacteria. All of this helps to keep the distribution pipework in good order and free from algae.

Lime is used to prepare many industrial wastes for safe disposal. The same cleansing actions used to treat drinking water come into play. Where the waste is in the form of a sludge, as from sewage treatment and waterworks filtration, quicklime has the added advantage of drying out the excess water through hydration of the lime. The lime stabilizes organic residues in a sludge and, by preventing them from putrifying, reduces the smells. Such sludges may be suitable for use as fertilizers.

Where lakes, ponds and rivers have become severely polluted, careful treatment with lime has restored the correct level of acidity and precipitated the nitrates and phosphates which cause eutrophication. Lime also clears the water to help light penetrate. Powdered limestone may be used with the lime for its neutralizing power.

Lime has been used in large quanitities to reduce emissions of sulphur dioxide from flue gases. This may become one of the most important uses for the sale of lime in industrial countries.

1.7 Other industrial uses of lime

In many industries a little lime is used in small quanities either for effluent treatment or as part of the processes. In tanneries the hides are plumped up and de-haired in a bath of lime as the first stage of the work. Bone glue factories use lime to remove the collagen from the animal wastes. The oil industry uses lime in the special drilling muds which lubricate the drills. Lime is also used for lubrication in wire-drawing. Some types of glass need lime to fuse the silica whilst others use limestone.

One of the very large consumers is the paper industry where lime is needed to recover the alkalis used in the sulphate (Kraft) process. In large scale paper and pulp works the resulting carbonate sludges are recovered and burned back to lime in kilns on the site. Only a small amount of make-up lime is then needed to replace losses - perhaps 10 per cent. Small factories would not have their own lime kilns and would need to buy their lime on the market.

An exceptional form of lime is deadburned dolomite which is used as a refractory lining for electric steel furnaces. This is calcined at very high temperatures and has an extremely low reactivity; the tonnages would be high and dead burned dolomite would not be produced at small limeworks.

This description of the uses of lime could never be complete since small amounts are used in all sorts of industries in many different ways. Each industry will have its own special requirements and impurities which are harmless to some users may be unacceptable to others. The owner of a limeworks must know the composition and physical properties of his lime and be able to match this to potential markets.

1.8 Uses of lime in building

Lime is a building material of ancient origin, and still plays a central role in the construction methods of many cultures. It provides the binding medium which is used with sands in mortars and renders. It can also produce a paint called limewash and concretes for low stress uses such as vaults, footings and ground floor slabs. Lime is used to stabilize soil building blocks and for major earth stabilization projects in civil engineering. It is also used in the manufacture of calcium-silicate bricks, blocks and other building units.

The name lime describes a range of materials which may all be used in one way or another for building. There are no generally accepted classifications but table 1.1 shows the most useful distinctions.

Lime is produced from limestones by calcining in a limekiln. The product of a limekiln is largely quicklime (CaO) together with impurities and overburnt materials in which, in extreme cases, clay and lime fuse together. There may also be ash from the fuel. Lime is sometimes used in this quicklime form for limewashes and soil stabilization, but for most building uses it is needed in the hydrated form - that is, it must be slaked with water; this may be done at the building site as described later, but is more usually done in the limeworks.

Lime is normally delivered to building sites either in 25 kg bags of dry hydrate or as a putty - that is, a viscous mass. The use of lime as putty is rare in many countries but this is an excellent way to store lime. It allows time for slow slaking particles to hydrate harmlessly. It also allows the lime to absorb, physically, as much water as possible. This increases its sand carrying capacity and makes it exceptionally easy to use.

Normal, pure, limes take a first set by drying out and harden very slowly by absorbing carbon dioxide from the atmosphere. Hydraulic limes are so named because they can be used in hydraulic engineering works. This is because they can set underwater by the chemical hardening of the natural cements they contain. Hydraulic limes cannot be used for many of the purposes described in the previous section of this report, but they are exceptionally useful for building.

The action of hydraulic limes can be imitated by the use of pozzolanic additives - that is fine powdered materials containing active silicas. There are many natural volcanic sources notably in Indonesia, East Africa and

Table 1.1. Types of lime and their uses in building

	Source	Quicklime	Composition of hydrated limes	Uses in building
High calcium limes	Largely pure calcium carbonate chalks and limestones	Mainly CaO	Mainly $Ca(OH)_2$	For pure lime mortars, limewashes and especially for plastering
Magnesian limes	Dolomitic limestones	CaO with CaO.MgO	$Ca(OH)_2$ and $Ca(OH)_2.Mg(OH)_2$ and perhaps $Ca(OH)_2.MgO$	As above but the lime must be fully slaked to $Ca(OH)_2.Mg(OH)_2$
Hydraulic limes (a wide range of strengths)	Argillaceous (clayey) limestones and grey chalks	CaO with calcium silicates and aluminates	$Ca(OH)_2$ with natural cementitious compounds	Especially suitable for firm mortars, concretes and for work below water

Note: Lean limes containing high levels of sandy impurities are of very limited use.

Central America. In some other countries, India, for example, a pozzolanic material is made by pulverizing fired clay or bricks. Further sources are PFA - the fly ash from coal burning power stations, and rice husk ash, a common waste product in many countries, which is finding increasing use in construction.

The characteristic qualities of buildings constructed with lime are gentle surfaces which can deform rather than crack, relatively soft finishes which are warm to the touch and absorb excess moisture (such as condensation) rather than letting it run down the wall faces. If masonry constructed with lime does deform, it will often form numerous very fine cracks which, in time, can heal themselves by the formation of a new carbonate surface.

1.8.1 Lime mortars for masonry

Mortar is the jointing material used for brick, block or stone walls. A good mortar should be cohesive, should spread easily and should retain water so that it remains plastic without stiffening whilst the units are adjusted for line and level. It should bond to the units then set and develop strength quite quickly so that it can carry the weight of further work laid above it. Its final strength should be a little less than that of the masonry units but adequate to carry the required load without cracking the units. It should resist weathering by rain, wind and frost.

Well made lime mortars can achieve these complex requirements better than any other mortars. If the ingredients are carefully chosen and carefully handled lime mortars wil [illegible] ad very smoothly and will bond well to the units. Pure lime mortars [illegible] lowly and, if this is inconvenient, hydraulic limes or lime and pozzolan should be used for a quicker set. The use of a little cement (perhaps one part of cement to twenty of lime mortar) can also speed the early setting. If they are well proportioned and worked, lime mortars will set without cracking or crazing. When they have hardened they are impervious to running water but allow air and vapour to pass freely. This helps to control condensation and offers a very worthwhile protection to the masonry units themselves, since they are less likely to be damaged by the crystallization of salts moving through the wall.

If the design of a structure requires mortar of higher than usual strength, then lime-cement compo should be used. In this the lime gives the smooth working and good bonding performance whilst the cement gives the strength. Typical mixes are 1 cement : 1 lime : 6 sand and 1 cement : 2 lime : 9 sand.

A wide variety of limes can be used including pure high calcium limes, magnesian limes and hydraulic limes. Whatever is chosen, the limes should be fully hydrated to avoid damage by expansion which is caused by late hydration.

Pure lime mortars can be kept for long periods before use, provided they are not allowed to dry out. In this time the lime fattens, that is it absorbs water more intimately into its structure, plumps up and becomes still more plastic. This is the basis of the premixed lime mortar industry in which sand, lime and water are mixed in a central depot and distributed as mortar to building sites in the area. On the sites they are usually batched up with a little cement to improve the early setting. Pigments are sometimes added at the mixing plant to offer attractive colours.

To summarize, lime mortars perform very well. For an early set and for hardening throughout the mortar, a hydraulic lime should be chosen or either a pozzolan or a little cement should be added. The lime industry can promote lime-pozzolan bagged cements for masonry and also premixed lime-sand mortars. Lime for mortars forms one of the most important markets for a small-scale limeworks.

1.8.2 Lime plasters and rendering

The properties of lime - cohesiveness, plasticity, low strength - which make it suitable as a mortar material are of equal importance for plasters and renders, and mixes similar to those for masonry mortars are used. The same precautions in mixing and storing materials are needed except that even more care must be taken to allow lime putty to fatten up, not only for ease of application, but because lime plasters show damage from late hydration very clearly through the following faults:

(a) Pitting and popping - sudden explosions within the plaster leaving small craters, often with a dark spot at the centre;

(b) Unsoundness - general expansion which destroys the bond between the plaster and its backing.

In both cases the problem is eliminated by careful sieving and allowing the putty to mature fully.

Clean animal hair is sometimes added to the first coat of lime plaster for reinforcement. particularly when used on flexible backings such as wooden laths.

Only in poor quality work is a single coat of lime plaster applied. Two coats are used in better quality external work. The first has coarse sand and the second has finer sand with, perhaps, rather more lime. For best quality internal work a third coat of very fine lime plaster is gauged with a little plaster of Paris (gypsum plaster).

A mix of equal parts of lime putty and cow dung is used around the whole world for parging or plastering the inside of chimney flues. This works well, perhaps because of its exceptionally good adhesion.

1.8.3 Limewash

Limewash is a paint based on lime and water which can be used on lime plasters, soft brickwork, earth walls or other porous surfaces. It is very easy to make and looks good. As it is absorbent, it can mask the effects of occasional condensation and it allows walls to breathe freely.

The simplest way to make a limewash for internal use is to dilute a lime putty to a thin cream with fresh water and add pigments from the so-called earth colours (yellow ochre, umber, etc.). For external use it is better to make a limewash with quicklime (a good, reactive, lime, preferably high calcium) and tallow.

Thin coats of limewash can help to stabilize loose plaster surfaces and protect decaying limestone. Limewash may be prepared at a limeworks and sold sealed in airtight containers in the thick state to be thinned out on the building site.

1.8.4 Lime stabilized soil blocks

In many parts of the world there are good traditional methods of building with earth, mud or soil. But in recent years the traditions have often been lost because of commercial pressure to use other building materials. It is not easy to re-establish such traditions as considerable skill and knowledge is needed to make the best use of each particular variety of subsoil. A scientific basis must be used when earth building is reintroduced or used for the first time.

Of the various methods in which soil has been used, the one which is most easily adapted to scientific or engineering methods is the technique of building with soil blocks, sometimes known as adobe. The science of soil mechanics is well advanced and road engineering laboratories can easily identify the important features of any soil sample. The best method of producing a consistently stable building block with good weathering properties will depend on the characteristics of the soil. Cement is usually best for soils with a low clay content and lime is best for soils with higher clay contents, particularly where this includes a high alumina content. Cement stabilization depends on the ability of portland cement to form a gel which surrounds the sandy particles and sets in the usual way to form a rather crude concrete. Lime stabilization is quite different. If quicklime is used, the first stage is the hydration of the lime which absorbs water and generates heat. This is followed immediately by a drastic change in the nature of the clay through cation exchange and flocculation which changes the soil from a plastic (smoothly deformable) material into a friable state. In this state the soil can be compacted by heavy pressure to increase its density and to form a coherent block which will be good for building. But the real strength of the block develops only slowly as the lime combines with certain active clays to form natural cements. This stage requires water and is much quicker at raised temperatures. In experiments it was found that when cured in water at 50°C, soil blocks stabilized with lime achieved the same strength in seven days that they would have taken nine weeks to achieve at ambient temperatures. In small scale self-building projects this slow hardening may be acceptable, but if it does create a problem a quicker process might be developed using a mixture of cement and lime.

Experiments are essential to assess the merits of each particular combination of soil and lime and to judge the best proportions of lime to soil, the best water content and the best method of compaction.

Well judged lime stabilized soil blocks can be very cost effective, particularly for low cost housing, farm and industrial buildings. The lime content will vary from project to project but will typically be 4 to 8 per cent by weight.

1.8.5 Soil stabilization for engineering projects

Increasingly, lime is finding a very important role in stabilizing loose and clayey soils for roadmaking, airfields, car parks, railways and canals. It has even been used below house foundations on clay soils. The appropriate techniques vary widely with the local conditions and the materials to be stabilized. Some of the techniques work best in warm climates.

At the simplest level, quicklime can be spread over the ground and mixed in with the top few centimetres of soil to improve conditions for vehicles on a building site or a woodland track. As the lime slakes in the ground it absorbs water chemically and drives off further water through the heat which is generated. It alters the structure of clay in the soil and leaves the soil in a suitably friable state to be compacted. All of this happens within the first few hours. In the longer term (and very much influenced by ambient temperature) the lime can form pozzolanic cement compounds which considerably raise the loadbearing capacity of the soil. If slaked lime is used instead of quicklime there will be a safer working environment but less scope for removing moisture from the soil.

This technique can be used by mixing the soil in situ to form embankment or road foundations. Where greater quality control is needed the soil can be mixed at a central mixing area on the site. It has also been used very successfully for the water resistant lining to canals.

Where soils do not contain a suitable reactive clay, lime stabilization can be undertaken using lime with a pozzolanic material. This might be a volcanic pozzolan or an artificial material such as blast furnace slag or pulverized fuel ash (PFA).

Injection and other techniques have been developed to stabilize clay soils for depths between 1.5 metres to 3.5 metres. This has been used beneath raft foundations for buildings and for the maintenance of railway beds. A deep-lime mixing technique has been used for causeways over marshland and even out into the sea.

The scale of these civil engineering works is rather large for the output of a small-scale lime works, but small-scale lime-burning might operate on an itinerant basis burning lime on the project sites.

1.8.6 Other uses of lime in building

There is a very large market for lime for use in the production of calcium-silicate products. Some of these are produced in large factories and are not compatible with small scale production or development. There are three main groups of products. Sand-lime bricks, lightweight cellular concrete blocks and silicate-concrete components.

Sand-lime bricks (often called calcium-silicate bricks) are made by mixing between 5 and 10 per cent of hydrated lime with damp sand and compressing it into brick shapes which are then matured in a steam oven or autoclave for about seven hours. This produces a hard and white brick which requires only one fifth of the energy needed to fire a clay brick. Pigments may be added to give pastel colours.

Lightweight cellular concrete is made by various patented methods in highly automated plants. Pulverized quicklime and aluminium powder react and foam up in a graded silica sand aggregate which may include pozzolans and even portland cement. The foamed mass is cut into blocks which are cured in an autoclave. Densities vary between 0.2 and 0.9 tons/m.

In the Federal Republic of Germany and USSR high density and very strong silicate-concrete prefabricated units are produced from sand, quicklime and fine silica which, again, is cured in an autoclave. The units can include steel reinforcement for slabs and beams. Pipes, tiles, railway sleepers and even prefabricated stair flights are produced.

In recent years lime has been used as a filler, alongside powdered limestone and other minerals, in the mixes for bituminous (asphalt) concretes used for surfacing roads. Often 1 per cent of hydrated lime is incorporated in the mix to modify any clay adhering to the aggregate, to absorb water and thus improve the bonding and to contribute in various ways to a longer life. The percentage may seem small, but on large projects the tonnage can be very considerable.

On a smaller scale, lime is used in various ways in paint manufacture. Pecipitated calcium carbonate, prepared from it, is a common pigment. Lime is used in the preparation of other pigments such as satin white, red iron oxide, antimony oxide and zinc oxide.

1.8.7 Conclusion

There are thus important uses for lime in the production of building materials as well as the many uses on site. Hydraulic limes and lime-pozzolan mixes are very valuable for the building industry and form the basis for sound construction methods. Where they are used, specifications must be carefully prepared, on the basis of experiment, for the particular limes and pozzolans available. A flourishing small limeworks can offer a range of materials from quicklime, hydrate and lime-putty to pozzolanic-lime cements, stabilized blocks, premixed mortars and limewash. By-products might include pulverized limestone or chalk for agriculture and aggregates for roadmaking. Opportunities exist to sell lime in small or large quanitities to many other industries such as those referred to in 1.3-1.7.

2. CHOICE OF TECHNOLOGY FOR LIME PRODUCTION

2.1 Introduction

Although lime manufacture involves only simple chemical processes, there are an enormous number of different forms which a lime production plant can take, from very small to very large, using very simple or highly sophisticated technology, and producing either only one or a number of different products. Planning a new lime industry therefore involves making a series of separate but interconnected technological decisions, each of which will be influenced by a variety of factors.

The prospective manufacturer will need to know what raw materials are available, of what quality, where they are located, what the total quantity of available materials is, and how easily it can be quarried. He will need to know what the size and nature of the market for lime is, so that the scale of production and the type of lime to manufacture can be determined. In order to decide on the location of the plant, he will need to know about the infrastructure of the region, the availability of water and power supply and the state of roads and other transport facilities.

He will need to know the types of fuels available and their cost, in order to decide on the most efficient way of burning the lime. In order to decide on the type of kiln to use, he will need information about a variety of kiln types, and how they can be supplied or built; and he will also need to consider carefully the level of technology involved in each case. He will need to know what manpower resources are available, to be sure that employees can be recruited to match the level of technology and management skills required.

Crucial technological choices about the establishment of production plants have frequently been made without giving due consideration to all these factors, and the result has often been disastrous for the effective and profitable operation of the plant. Before any decisions regarding technology selection are made, detailed market studies and technological and economic feasibility studies should be made, in which all these factors need to be taken into consideration and appropriate recommendations are made.

In this section the technological elements of the lime manufacturing process are described and the major technical choices which will have to be made are discussed.

2.2 Types of lime

The most basic classification of limes refers to the form of the lime. The principal terms used are quicklime and hydrated lime. Quicklime is the direct production of a lime kiln and is usually in the form of lumps, and is called lump lime. Lime in this form has a great affinity for water. When water is added to quicklime a further reaction takes place between the two, and the result is hydrated or slaked lime. The form of slaked lime may be a dry powder (dry hydrated lime), or a plastic putty (lime putty) or a slurry (lime slurry or milk of lime).

Limes are also classified according to their chemical composition. The principal terms used are high calcium lime, magnesium lime and dolomitic lime. In a high calcium lime, the quicklime is primarily calcium oxide, with less than 5 per cent of magnesium oxide. If the lime contains between 5 and 20 per cent of magnesium oxide it is referred to as magnesian lime, and if it contains between 20 and 41 per cent of magnesium oxide it is called dolomitic lime.

There is a considerable degree of overlap between the uses of these three types of lime, but manufacturing techniques need to be rather different in each case.

The third way of classifying limes is according to their use. The terms most commonly used are agricultural lime, building lime, chemical lime, mason's lime. The term agricultural lime is sometimes (wrongly) used to refer to ground limestone or chalk which has not been burnt in a kiln. Hydraulic lime is a type of building lime which contains appreciable amounts of impurities (usually silica and alumina), and possesses the property of hardening in combination with water, like a cement. It is primarily used for structural purposes. The opposite term used in building is fat lime which is pure and thus able to form a plastic putty, but develops little strength.

Some other important terms used are autoclaved lime, which is a special form of highly hydrated dolomitic lime, largely used for structural purposes; dead-burnt dolomite which is a specially sintered form of dolomitic quicklime that is chemically inactive and used primarily as a refractory for lining open-hearthed steel furnaces. Some of the terms defined above may be used in combination with others, such as dolomitic quicklime, high-calcium hydrated lime, etc. The types of lime needed for different uses are described in chapter 1.

Different standards apply to different uses of lime, and these usually refer both to chemical composition and physical properties. Fineness, water retentivity, plasticity and soundness are among the physical properties defined and specified in building standards. A list of standards and specifications is given in the UNIDO Lime Directory.

2.3 Raw materials

Lime is normally produced by burning or calcining some form of limestone which consists of calcium and sometimes magnesium carbonates. The process of lime production involves the dissociation of carbon dioxide from these carbonates, which occurs at high temperatures, according to the following:

$$CaCO_3 + (MgCO_3) \xrightarrow{\text{heat}} CaO + (MgO) + CO_2$$

$CaCO_3$	$(MgCO_3)$	CaO	(MgO)	CO_2
Calcium carbonate	Magnesium carbonate	Calcium oxide (quicklime)	Magnesium oxide (magnesia)	Carbon dioxide

Some form of limestone is to be found in most countries of the world, but not all limestones are suitable for limeburning. Some knowledge of the different forms of limestone and the requirements for a suitable raw material for limeburning is thus essential for the prospective limeburner.

Three principal qualities of a limestone are of interest to the limeburner:

(a) Its chemical composition should be suitable for the type of lime which it is intended to produce.

(b) It should occur in a form in which it can be economically quarried and broken into the size and range of sizes required for the type of kiln to be used.

(c) Its behaviour during calcining should suit the type of kiln to be used.

Each of these factors will be considered separately.

2.3.1 Chemical composition

For chemical and metallurgical use, only high calcium limes are suitable, for which limestones consisting of more than 95 per cent calcium carbonate are required. Apart from magnesium carbonate, the major impurities likely to be found in limestones are silica, alumina and iron oxides, with smaller quantities of potash, soda and sulphates. Specifications for different uses limit the allowable proportions of these impurities in the lime, and thus set upper limits to their proportion of the composition of the stone. The presence of impurities also reduces the thermal efficiency of the kiln as explained below.

Lime to be used for building or road construction can be made with magnesian or dolomitic limestone; and as magnesium carbonate dissociates at a lower temperature than calcium carbonate, this can reduce the fuel requirement of the kiln. In the United States, most building lime is of the magnesian or dolomitic type. However, very close control of both the burning and the hydration are necessary if these types of lime are to be produced, otherwise delayed hydration can occur; they are more difficult to use for small-scale operations unless good kiln control can be guaranteed.

Building lime and lime for steel making can also be made with limestones having a proportion of silica (SiO_2) or alumina (Al_2O_3) in the form of clayey matter. Such argillaceous limestones can produce a hydraulic lime, with the property of developing strength in mortars which is very desirable in building work; they are commonly grey in colour. However, the quality of the lime depends on the distribution of the impurities and can be very variable.

2.3.2 Size of stone

The acceptable range of stone sizes depends on the type of kiln to be used. The larger the stone, the longer it takes to raise the temperature of the whole stone to the dissociation temperature, and hence the slower the kiln process. However, small stones leave less space between them for the passage of the hot gases which can choke the kiln and lead to uneven or incomplete burning. Both the size and the size range are therefore important. Vertical shaft kilns require the most careful selection; in a typical case acceptable stone sizes ranging from 50 mm diameter (smallest) to 100 mm diameter (largest) might be specified. Such limitations may result in the production of considerable quarry waste. Other kiln types, such as rotary, refractory hearth or inclined shaft kilns can accept smaller stone sizes down to 5 mm diameter and a larger size range as described later. Some types of batch kilns are built with larger stones, up to 250 mm diameter, at the bottom, and progressively smaller stones towards the top, in order to achieve even burning conditions through the kiln.

2.3.3 Behaviour of firing

It is important, in most kilns, that the limestone used should not disintegrate or decrepitate, during the firing process, since this will block the passage of the gases through the stone. Stones with a high shrinkage during firing are also difficult to burn evenly in shaft kilns. These effects cannot satisfactorily be predicted from the appearance or chemical composition of the stone; it is essential therefore to carry out firing trials before using a new type of limestone, using the same temperature and rate of heating as will be found in the kiln type to be used.

2.3.4 Types of limestone

Limestones occur in nature in many different forms and some idea of their potential for limeburning can often be obtained from the geological description.

Shells and coral are organic limestones, and usually very pure calcium carbonates. Although often in shallow water they can be easily accessible raw materials for small-scale limeburning operations. Shells, however, are too small to burn in a normal vertical shaft kiln and either rotary kilns or other specially designed kilns have to be employed. The removal of shells and coral may be prohibited on environmental grounds.

Fossiliferous limestones may be very pure calcium carbonates, but could disintegrate in firing; chalk is usually very pure, but may be too soft to stand the pressure of a large kiln without crushing.

Travertine and tufa are precipitated from ground water, like stalactites; they can be suitable for limeburning, but are often impure and of variable density; the deposits, though superficially extensive, may be very thin, and reserves should be carefully checked.

Dolomite or dolomitic limestones are limestones containing a mixture of calcium and magnesium carbonates; although acceptable for building and steel making, autoclave hydration is desirable for a sound lime and this may make them unacceptable for small-scale plants.

Argillaceous limestones are limestones with a proportion of clayey material; they can make a hydraulic lime for some building purposes; for other purposes the clay is an impurity that reduces the proportion of useful lime which can be produced, affects it colour and reduces kiln efficiency.

Marl is a form of calcareous mudstone which may produce a hydraulic lime, but commonly is too soft and has too little calcium carbonate to be of much use.

Marble is technically a limestone which has been recrystallized as a result of high pressures; although the term is also used for any limestone which can be polished. It is usually dense and easy to crush into suitable sizes, however, its density also makes it less easy to calcine, and it may contain undesirable impurities. Marbles have a tendency to decrepitate in firing but this is not necessarily so.

Thus, no stone should be used without first determining its chemical composition, the extent of the reserves and the variation in quality likely to be found, and investigating the ease with which it can be quarried and its likely performance in the kiln. To conduct such investigations, the assistance of the local Geological Survey, usually a branch of the Ministry of Natural Resources or Mines, should be sought.

2.4 Energy and fuels

The bulk of the energy used in lime production is consumed in the firing of the lime kiln. Dissociation takes place at temperatures over 900°C, and lime kilns are usually operated at temperatures between 1,000°C and 1,250°C. The stone has to be heated up to that temperature, which must then be maintained while dissociation takes place. The theoretical heat requirement for this process can be calculated. Much more heat is in fact required in any actual kiln, because of inevitable heat losses in the process. The main sources of heat loss are:

(a) Loss of heat in the exhaust gases from the kiln;

(b) Loss of heat from the kiln through the kiln lining through conduction, radiation and convection;

(c) Loss of heat in the quicklime discharged from the kiln;

(d) Heat required to dry the stone and the fuel.

If the stone contains impurities further heat will be required to raise these to the kiln temperature, and some of the limestone also will be heated but not completely converted into quicklime. Against these heat losses, some of the heat required to raise the temperature of the stone can be recovered by heat exchange between the exhaust gases and the burnt stone and the incoming stone and air. Thus for continuous operation, the heat required for initial preheating of the stone does not form a part of the theoretical heat requirement. The thecretical heat requirement is normally given as 770 kcal/kg for high calcium lime and 723 kcal/kg for dolomitic lime per ton of quicklime produced.

The efficiency of a lime kiln is the ratio of the theoretical to the actual heat requirement for burning a particular limestone, and one of the major objects of kiln design is to improve efficiency by reducing heat losses and increasing heat recovery. Modern lime kilns operate at anything from 30 to 85 per cent efficiency giving actual energy requirements from 905 kcal/kg to 2,570 kcal/kg of high calcium quicklime produced, according to the type of kiln used.

A wide variety of fuels may be used in lime kilns, and the choice in any particular case will depend partly on the price and availability of alternative fuels, and partly on its suitability for the type of kiln system which it is proposed to use.

Firewood is used in many traditional types of lime kiln. For batch kilns and some types of shaft kilns it is the ideal fuel since it provides a longer flame than other fuels, which penetrates further into the stone mass, and it burns at a lower temperature which lessens the danger of overburning. On the other hand, it is not very convenient in operation, especially for continuous kilns, and tends to have been replaced by oil, gas or coal where these are available. Because of the rapid depletion of timber, in many countries, firewood should only be considered as a fuel for new projects in special circumstances.

Coal and coke are very commonly used in mixed feed vertical shaft kilns, and can show good fuel economy even in small kilns. Coke is preferable because of its low volatile content, but it is harder to ignite, so a mixture of the two fuels is sometimes used. Pulverized coal is commonly used in rotary kilns.

Oil and gas are the most commonly used fuels for lime kilns and especially those of larger output. Even though often more expensive, their ease of operation and the lack of ash residue are important advantages. But to use these fuels efficiently, and without overburning the lime, requires careful design of the burning zone in the kiln, and accurate control of the fuel and stone feed. They are therefore appropriate mainly with proprietary kiln systems which are designed to operate with a particular grade of fuel.

Alternative fuels such as peat and biomass (grasses, etc.) have been used in isolated cases, but only in batch kilns and with very low efficiency.

Some electrical energy is also required in any lime plant for driving machinery, especially crushing and conveying plant.

2.5 Quarrying and preparation of stone

The preparation of stone for the lime kiln involves quarrying or extraction operations, transportation to the limeworks, reducing it to the size range required for the kiln, eliminating undersize and oversize material, and removing contaminating materials. How this is done depends on the nature of the stone, the scale of operation and the type of kiln to be used. Only a few general points will be emphasized here.

The location of the kiln should be as close as possible to, or preferably in, the limestone quarry, to reduce transportation costs. If the quarry can be designed so that the stone is extracted at a level above the top of the kiln, or incorporating a simple ramp on which vehicles can drive to the top of the kiln (or kiln feed) then much expensive conveying and hoisting equipment can be eliminated.

Excavation of the stone by hand methods is sometimes possible, but is very labour intensive, and very costly in most countries. Even if the quantities required are not large, blasting can normally be economically employed. The use of a specialist contractor to blast a large quantity of stone infrequently for subsequent use is sometimes appropriate.

For small intermittently operated kilns hand breaking and sizing can be employed, but the use of crushing and screening equipment is likely to be economical even for small levels of continuous output. If the limestone is contaminated with clay or other rocks, a washing and sorting process may be needed.

In most lime plants, a large volume of unuseable, undersized stone is produced. This can often economically be used for concrete aggregate or for agricultural lime (i.e. powdered limestone) with a small outlay on additional crushing and screening plant.

2.6 Lime kilns

The lime kiln is at the centre of a lime plant, and usually represents more than 50 per cent of the capital cost. Thus it is important to consider very carefully which, from the wide variety of kiln types available, should be chosen. The general features, advantages and disadvantages of each type and its variations will be described here, but no attempt will be made to describe individual proprietary systems in any detail. For this purpose specialist consultants, or the lime kiln manufacturers themselves, should be consulted, as listed in the UNIDO Lime Directory.

In a lime kiln, limestone is heated to a temperature at which dissociation will take place, and maintained at that temperature until all, or as much as possible, of the stone has been converted into quicklime. The quicklime is then cooled and discharged. The heat for this process is supplied by burning fuel which may be intimately mixed or layered with the limestone, may be injected from the sides of the kiln, or may be burned adjacent to the kiln and the hot gases then passed through the kiln. In any case, there is a flow of hot gas through the kiln; air and fuel enter, and exhaust gases and sometimes ash from the burnt fuel also leave the kiln.

Control of the kiln process is very important, since if the lime is either underburnt or overburnt it is useless. Underburnt material, usually the core of the stone, cannot be converted to hydrated lime. Overburning leads to hard-burnt or dead-burnt lime; the stone shrinks and water cannot enter to complete the subsequent hydration process. Either too high a temperature or too long a retention time can lead to overburning.

There are a very large number of different kiln designs available, which differ considerably according to the type and size of stone burnt, the type of fuel used, the quality of the lime produced, the scale of production, the level of technology used, the capital cost and the efficiency in terms of fuel consumption. It is commonly assumed that the cheaper kiln designs, using a lower level of technology, will produce a lower quality of lime and will have a higher fuel consumption; but this is not always true, and there are opportunities by careful plant design and operating skill to produce a good quality lime with a low fuel consumption in a small plant using relatively low levels of technology and capital cost. Larger plants, especially those using rotary kilns, are not necessarily more efficient in their use of fuel.

Lime kilns can be classified according to the following types:

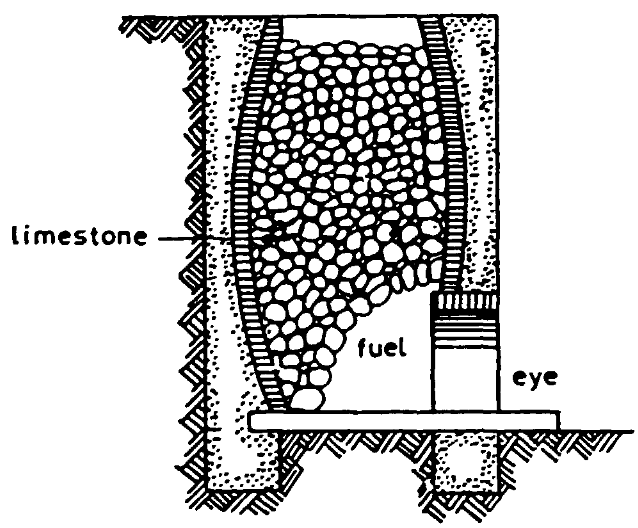
(a) Batch or intermittent kilns;
(b) Vertical shaft kilns;
(c) Rotary kilns;
(d) Other kilns.

Each type will be briefly described.

2.6.1 Batch kilns

The characteristic of batch kilns is that each separate batch of stone is placed in an empty kiln. The stone is placed manually within the kiln, and a fire is created by burning fuel below and within the stone, until it is judged that all the stone has been converted to quicklime. The quicklime is then allowed to cool and is removed. Sometimes no permanent kiln at all is used and the stone and fuel are piled up in the open. A great many kilns of this type are in use in the developing countries today, and are described by various names such as pot kilns, flare kilns, etc. An example is illustrated in figure 2.1. Their great advantage is that the kiln has extremely low or negligible capital cost and production can be intermittent or seasonal according to demand and labour availability. However, the intermittent production is very wasteful of fuel, since none of the heat used to raise the stone to dissociation temperature is recovered, and other heat losses are often considerable; and although a gradation of stone sizes is often used in order to attempt to achieve uniform burning, a high proportion of both underburnt and overburnt material is usually produced leading to a poor quality lime. There is still a place for such kilns where a large quantity of lime is required for a single job in a remote place (such as road construction), and where a very high quality of lime is not needed; but for any situation where a regular production is intended, use of a continuous type of kiln such as those described below will greatly reduce fuel consumption and the use of batch is not recommended.

Figure 2.1. Cross-section of typical batch kiln[2/]



2/ G.E. Bessey, Production and use of lime in developing countries. Overseas building notes No. 161, Building Research Establishment, April 1975.

2.6.2 Vertical shaft kilns

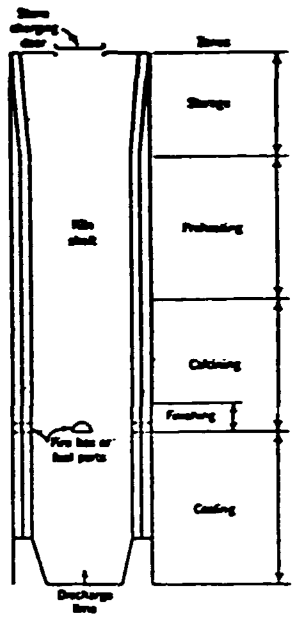
Vertical shaft kilns are kilns in which the stone falls under gravity through a vertical shaft, in which it is heated up, burnt and cooled, and from which it emerges as quicklime. The crucial feature of such kilns is the counterflow principle: stone enters from the top of the kiln and flows downwards, air enters from the bottom of the kiln and flows upwards, and exhaust gases emerge from the top. By this means heat exchange occurs at two levels. The stone in the top of the kiln gains heat from the cooling exhaust gases and is therefore preheated before entering the hottest part of the kiln; the air entering the bottom of the kiln gains heat from the cooling stone, and is therefore also preheated before entering the hottest part of the kiln. This heat exchange serves to improve the thermal efficiency of the kiln, since most of the heat used to raise the temperature of the stone and the air can be recovered.

A vertical shaft kiln can be considered to be divided into four different zones as shown in figure 2.2, known as the storage, preheating, calcining or burning and cooling zones. In practice, the boundaries of these zones are not distinct. The exact proportioning and contouring of these zones is the main problem to be solved in designing a vertical kiln and a great number of variations are used.

The storage zone serves primarily to ensure continuous operation even if the stone supply is irregular, and generally holds about two hours' or more supply of stone. Stone is charged into the storage zone by means of a skip hoist or some other device. Some vertical kilns are open at the top, but this can make draught control difficult and expose the stone to rain, so most shaft kilns are covered, and provided with special doors for charging stone and with chimneys or flues to release the exhaust gases, or at least with a metal sheet roof.

In the preheating zone, the stone is heated to the dissociation temperature by the hot gases rising upwards from the calcining zone. In some kilns part of these gases are drawn off from the top of the preheating zone and recirculated to the calcining zone; in others, they are exhausted through the storage zone. In areas where the exhaust gases may present an environmental problem, they can be passed through a dust collector; in some lime plants connected with chemical industries, the carbon dioxide can be collected for use in other processes.

Figure 2.2. The zones of the vertical shaft kiln[3/]



In the calcining zone the stone is maintained at the required temperature for dissociation. Methods of firing include mixed feed, in which the fuel is intimately mixed with the stone as it passes down the kiln, direct firing using solid fuel or oil, or indirect firing using gas or oil burners or gas producers. These methods will be described below. In the calcining zone the temperature must be as uniform as possible, and both the temperature and the retention time must be kept within limits so that the stone is neither underburnt nor overburnt. The appropriate limits depend both on the type of stone and its size.

3/ R.S. Boynton, Chemistry and technology of lime and limestone. Wiley-Interscience publication, 2nd edition, 1980.

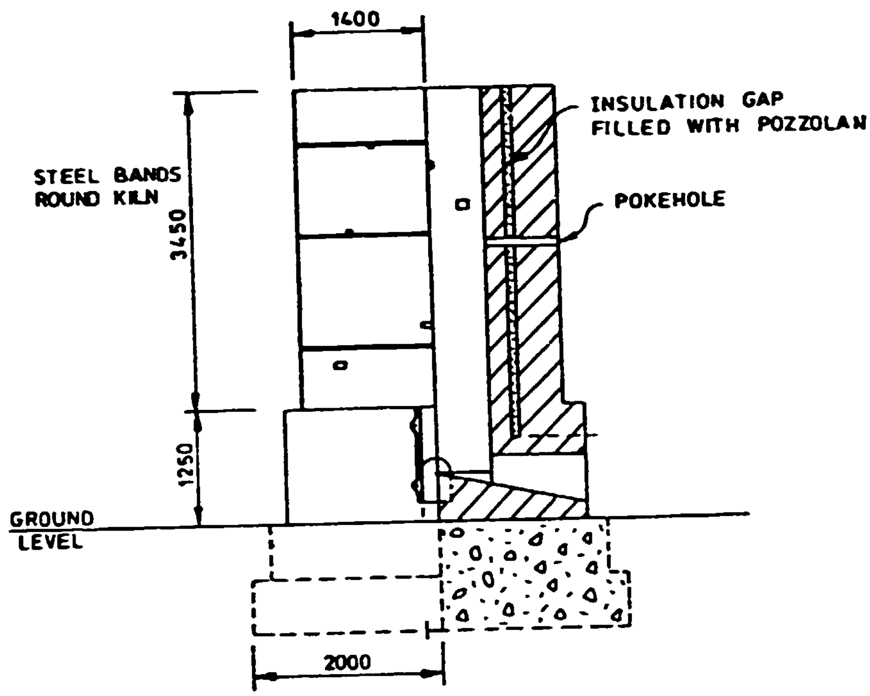
In the cooling zone, the quicklime is cooled and the air for combustion is heated simultaneously. For maximum fuel economy the quicklime at discharge should be at a temperature not higher than 50°C, at which temperature it can be held comfortably in the hand. The cooling zone may incorporate fans in order to increase the flow of air and it may be tapered to assist a more uniform discharge. At the bottom will be the discharge doors or openings through which the lime is removed either manually or by means of some automatic discharge device to a conveyor.

Most of the older types of shaft kiln use large stone, exceeding 75 mm diameter and in some cases up to 300 mm diameter. If coal or coke are available mixed feed kilns can be very efficient thermally. In the older and smaller types the limestone and coal or coke fuel are manually charged in alternate layers, but in more modern coke-fired kilns the mixing and charging of the feed is handled automatically. Capacities can vary from as little as 10 tons/day to as high as 400 tons/day. It is difficult to avoid a degree of hard-burnt and underburnt material in such kilns and there is a proportion of ash mixed with the quicklime. Designs for small-scale mixed feed kilns are available from the Khadi and Village Industries Commission in India (figure 2.3); as they are cheap to build such kilns can also be operated intermittently if necessary.

To obtain better control of burning conditions and avoid ash contamination kilns fired by oil and gas burners either outside or within the kiln are now widely used. Small-scale kiln designs using oil have been developed and published by the Ceramic Researcn Institute at Bandung in Indonesia; larger scale oil-fired kilns are the German Beckenbach ring kiln, and the British Wests kiln (figure 2.4); most United States kiln designs use natural gas, for example the Azbe and Union Carbide kilns. Some, such as the Austrian Sobek system use a mixture of fuels. A UNIDO report[4/] gives further details of these various kiln systems.

4/ F. Sobek, A manufacturing guide to the lime industry, UNIDO, 1975.

Figure 2.3. Indian small-scale vertical shaft kiln[5/]



More recent developments on shaft kiln technology have been concentrated on making possible the use of smaller diameter raw material, to reduce the quantity of waste material produced. The double-incline kiln burns a mixed feed of coke and limestone with a size of approximately 25 to 40 mm and also requires fuel oil. The kiln works by turning over the stone as it passes through the kiln so that the hot gases have access to the whole stone. Its capacity is about 150 tons per day. The parallel flow regenerative kiln has two or three parallel shafts, which are used alternately for preheating and calcining. The stone size ranges from 25 mm upwards, and the capacity can be from 100 to 600 tons/day. Normally gas is used for fuel and the kiln is said to have the best and most consistent thermal efficiency of any kiln available. Both of these last kilns produce a good quality soft burned lime; but they involve more elaborate controls than earlier shaft kiln designs and are consequently more expensive.

5/ R.J.S. Spence and D.J. Cook, Building materials in developing countries. J. Wiley, 1983.

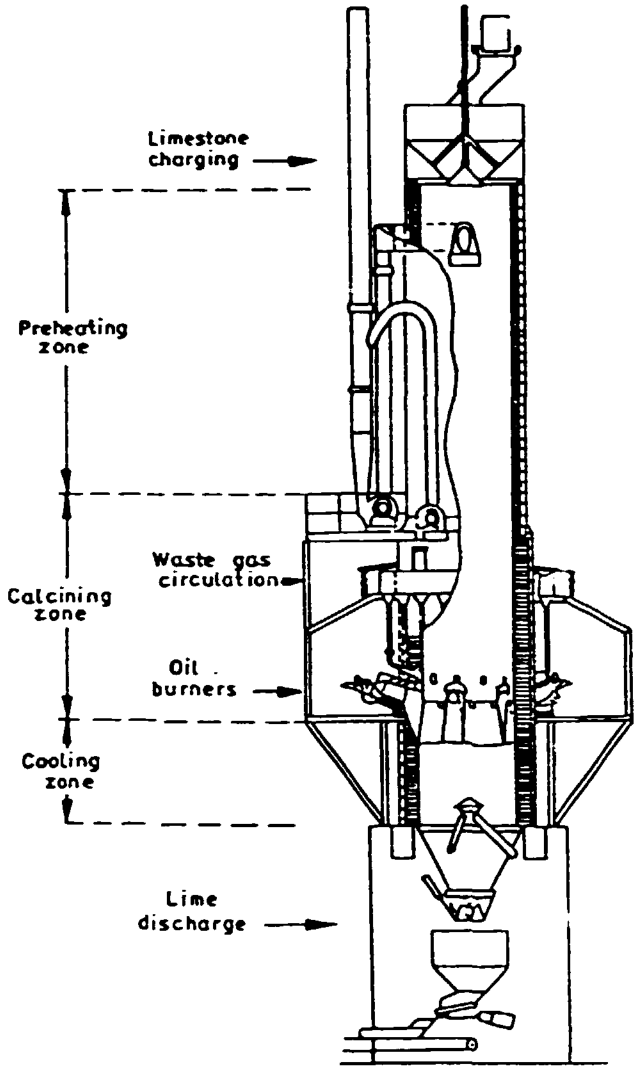


Figure 2.4. European vertical shaft kiln[6/]

Table 2.1 gives some further details of the various alternative kiln designs available.

2.6.3 Rotary

Because the height to diameter ratio of a vertical kiln needs to be large (at least 6 to 1), there is an upper size limit above which a vertical kiln ceases to be feasible. For very large scales of production rotary kilns are therefore used. A rotary kiln is a long tube of large diameter (3 m or more), lying nearly horizontal but with a slight incline and rotating slowly. The

6/ Published by courtesy of Wests Pyro Ltd.

Table 2.1. Comparison of alternative lime kilns

Type	Capacity (ton/day)	Stone size (mm)	Type of fuel	Fuel consumption	Control	Capital cost	Source of information
Batch[a]	1-3	50-100	Wood	2,250+	Low	Very low	Wingate (1985)
Continuous							
<u>Shaft kilns</u>							
KVIC mixed feed[a]	4-10	100-125	Coal	1,350	Medium	Very low	Spiropoulos (1985)
European MF	100-300	90-200	Coke	900-1,000	Medium/low	Medium	Boynton (1980)
Ring kiln	100-350	25-125	Oil or gas	1,040-1,140	High	High	Boynton (1980)
Double inclined	100-150	7-25	Varied	1,050-1,120	High	High	Boynton (1980)
Parallel-flow	100-600	25-150	Nat gas	880-920	High	High	Boynton (1980)
<u>Rotary</u>							
Simple	100-400	10-55	Varied	2,200-3,400	High	High	Boynton (1980)
Advanced	400-1,000	15-50	Varied	1,300-1,550	High	Very high	Boynton (1980)
<u>Miscellaneous</u>							
Fluosolids	100-125	0.2-0.5	Oil or gas	1,390 approx.	High	High	Boynton (1980)
Calcimatic	100-500	6-100	Oil or gas	1,570-2,100	High	High	Boynton (1980)

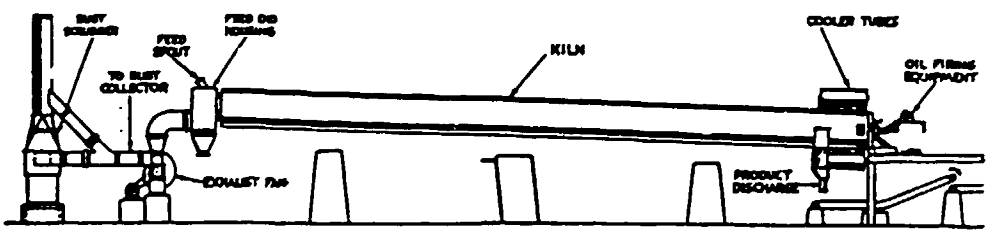
a/ The term small-scale kiln used in this report refers to kilns with capacities less than 20 tons/day.

stone is charged at the upper end of the kiln and passes slowly down and along the kiln, being tumbled by the rotating action. The fuel, oil, gas or pulverized coal, is burned at the bottom of the kiln and the hot gases pass up the kiln making contact with the stone as they pass, and are then discharged to a chimney. Most of the kiln volume is filled with the hot gases, and the area of stone exposed at any one time is relatively small, so heat exchange is relatively inefficient, and fuel consumption is high. The kilns can, however, be closely controlled, and can burn smaller sizes of stone; they are commonly used in the United States where fuel has been relatively cheap and a large productivity per worker is needed, but some very large capacity kilns are in use in other countries.

Developments of rotary kilns in recent years have been mainly concerned with improving their thermal efficiency as the cost of fuel has increased. Modern rotary kilns are shorter than older kilns, but are equipped with preheaters, coolers and miscellaneous modifications of the internal kiln shape which provide for a much more efficient heat exchange and heat recuperation. Energy consumption has dropped from the 3,300 kcal/kg typical of old kilns to less than 1,400 kcal/kg in modern kilns, though this is still 25 per cent greater than the most efficient vertical shaft kilns.

Rotary kilns have capacities up to and exceeding 1,000 tons/day. An example is shown in figure 2.5. The development of flash calciners now enables even the smallest stone (< 25 mm) to be calcined in rotary kiln plants.

Figure 2.5. Simple rotary kiln 7/



7/ R.S. Boynton and K.A. Gutschik, Building lime, its properties and manufacture, UNIDO ID/WG.20/1, 1968.

One important disadvantage, however, is that preheaters can trap sulphur, and if the lime is to be used in the steel industry the very low limit on sulphur content may be exceeded. The capital cost per unit output of rotary kiln plants is relatively high, but drops as the size increases.

2.6.4 Other kilns

Two radically different kiln types will be mentioned here. The Fluo-solids kiln is a fluidized bed calciner. The limestone is reduced to a uniform fineness of between 0.25-0.5 mm, and is calcined while held in suspension in an upward flow of air and combustion gases. Because of the fine size, the kiln operates at a relatively low temperature, 900-1,000°C, and fuel consumption is around 1,340 kcal/kg. A soft burned and highly reactive lime is produced. Most kilns of this type have a capacity of 100-125 tons/day. The kiln is particularly valuable for burning a limestone that is too soft for other kilns, or which decrepitates.

The Calcimatic kiln is a large diameter moving refractory hearth, in which the stone passes through the cycle of preheating, calcining and cooling during one complete rotation of the hearth. The stone can vary in size from ´ o 100 mm diameter and accurate speed and temperature control can be exercised to suit a particular stone type, size and degree of reactivity. These kilns can have capacities ranging from 100 up to 500 tons/day; in the United States fuel consumption (gas or oil) averages around 1,750 kcal/kg. Both this and the Fluo-solids kiln have capital costs per ton of lime produced comparable with rotary kilns.

There are other kiln types, but those described above include the main types which should be considered in establishing a new lime plant. Table 2.1 summarizes the information given above, and can be used as an initial guide to selection of kiln type. The names of a number of manufacturers and suppliers are given in the UNIDO Lime Directory.

2.7 Hydration

Some of the quicklime produced from the lime kilns may be sold in this form. A number of lime users in the chemical and building industry will prefer to do subsequent processing themselves, and take advantage of the saving in transport costs from moving the lighter quicklime rather than the hydrated lime.

Most users, however, will want to purchase hydrated lime, in one of its forms, so hydration is always an integral part of any limeworks.

Chemically, the process of hydration involves the addition of water to calcium oxide (quicklime) in order to convert it to calcium hydroxide (slaked or hydrated) lime, thus

CaO	+	$H_2O \longrightarrow$	$Ca(OH)_2$	+ heat
calcium oxide (quicklime)		water	calcium hydroxide (slaked or hydrated lime)	

Considerable heat is evolved during this reaction, which in the case of soft-burned calcium lime takes place very rapidly, almost explosively. At the same time, through the expansion of the quicklime, it disintegrates and if the hydration is properly controlled, is reduced to very fine particles. Not all limes react so vigorously, though. Impure limes such as argillaceous limes hydrate much more slowly, as do hard-burnt limes; and there are special problems associated with the hydration of magnesian or dolomitic limes which will be discussed later.

2.7.1 Forms of hydrated lime

Hydrated limes can take three forms: dry hydrate, a dry fine powder; lime putty, a plastic mixture of hydrated lime and water; and milk-of-lime which is a milky suspension of lime in water. Only limeworks which are integrated with other process industries produce milk-of-lime; lime putty is produced by some limeworks for sale as the basis of a mortar or plaster material for the building industry; but the bulk of hydrated lime is today required in the form of a dry hydrate.

Whichever of these products is to be produced, addition of the right amount of water, at the right rate, is crucial to successful hydration in order to avoid two damaging effects. If too much water is added quickly, the lime is drowned. Hydration stops or is slowed because the temperature does not rise sufficiently to disintegrate the particles. Conversely, if too little water is added, the lime is burned owing to the generation of excess heat, and incomplete penetration of water to the interior of the particles. In either case, a slaked lime of poor quality is produced which may also be unsound, because of the possibility of delayed hydration. A further condition which must be avoided is air-slaking. A quicklime exposed to air of moderate to high relative humidity will begin to hydrate slowly by combination with the moisture in the air: air slaking is also accompanied by carbonation, the absorption of carbon dioxide from the atmosphere, turning the quicklime, calcium oxide, back to calcium carbonate on the surface. Air-slaked lime is useless and to avoid air-slaking, quicklime should never be stored for any length of time in a humid atmosphere.

2.7.2 Non-mechanized hydration

In a small limeworks where capital costs must be minimized hydration can be done by hand methods, without the use of machinery. There are two techniques available: platform slaking, which produces a dry hydrate, and tank slaking, to produce lime putty.

Platform slaking involves breaking the quicklime and spreading it on a level platform in a layer of about 300 mm thickness, then adding water while the lime is turned over and over. After enough water has been added, the lime is covered and left for 24 hours and then sieved to remove impure or unslaked material; the result is a somewhat coarse dry hydrate.

Tank slaking involves adding quicklime to water in a tank and stirring while hydration occurs: the resulting milk-of-lime is then run off into a settling tank in which a lime putty is formed.

2.7.3 Mechanized hydration

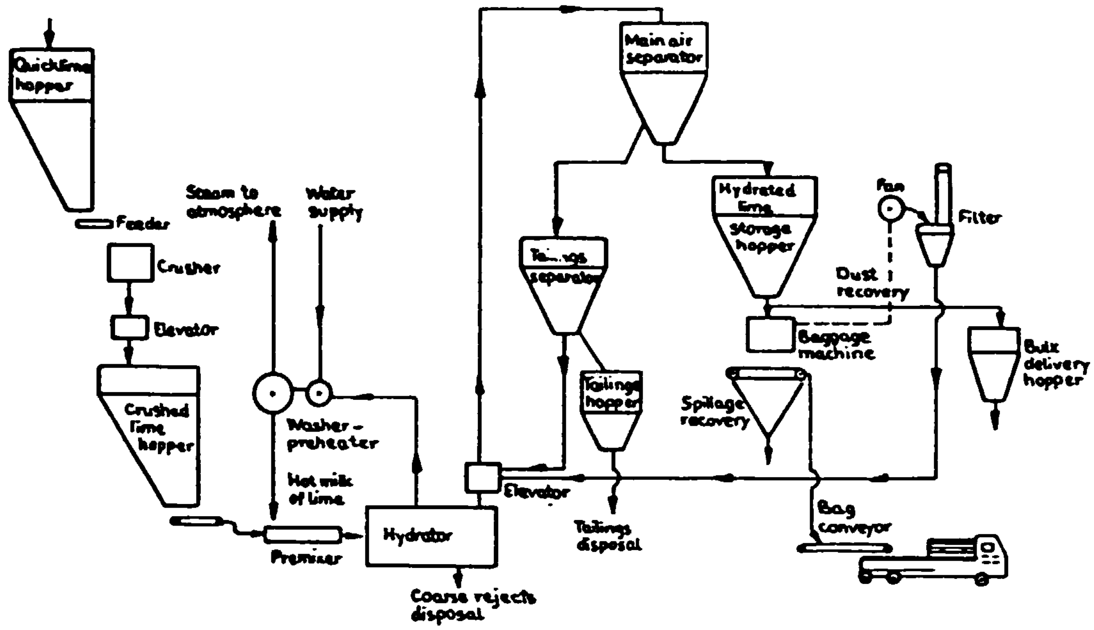
For larger scales of production a mechanical hydrator is used. There are many different types of hydrators, operating at many different scales of production. All involve the controlled addition of water or steam to quicklime while it is agitated to stimulate hydration, and the removal of the hydrated material. Most operate continuously, but for small levels of output batch hydrators are also used. A hydration plant usually involves, in addition to the hydration unit, a grinder for reducing the quicklime to pebble size, a storage bin, weighing and feeding equipment, an air separator, which rejects coarse material, and storage silos for the hydrated material. It can also be equipped with a bag-packing machine. Scales of operation can vary from 1 ton/hour to 40 tons/hour. A diagram of a typical hydration plant is shown in figure 2.6.

A special problem arises in the hydration of magnesian and dolomitic limes. These are mixtures of calcium and magnesium oxide, and normal slaking will hydrate the calcium oxide but not the magnesium oxide, which hydrates much more slowly. If any unslaked magnesium oxide remains in the lime, it can air-slake over a long period, and cause unsoundness in building work. If an autoclave hydrator is used, in which hydration occurs under pressure, complete hydration of the magnesium oxide can be achieved, and the resulting highly hydrated dolomitic lime can be used for all building purposes. An autoclave hydrator is, however, more expensive than other types.

2.7.4 Choice of hydration technique

Choice of the appropriate technique and equipment for hydration depends on the type of lime produced by the kiln, the quality and end-use of the product desired, and the intended scale of operation. Both lime industry specialists and equipment suppliers should be consulted; some names will be found in the UNIDO Lime Directory.

Figure 2.6. Diagram of a modern hydration plant[8/]



2.8 Safety and environmental protection

Although there are no diseases known to be specially associated with working in a lime production plant, there are dangers which must be considered when designing a lime production plant. The most important of these is the danger of lime burns. The rapid evolution of heat from hydrating quicklime can cause it to reach a temperature high enough to cause a burn if it comes into contact with the body and this danger can be increased by perspiration from working in a hot humid environment. Those working with quicklime should always wear protective gloves and face-masks. Other sources of danger in lime

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8/ R.J.S. Spence and D.J. Cook, Building materials in developing countries. John Wiley, 1983.

plants are more obvious - high kiln temperatures, rotating machinery, falling objects and stone, etc., and careful consideration should always be given to these dangers in considering plant layout and design.

Lime kilns and hydrators can both produce airborne dust which can be an environmental hazard, and many countries have regulations governing particulate emissions. Various control devices such as cyclones, scrubbers and electrostatic precipitators can be installed to reduce dust emission to tolerable levels. These are vital in the case of rotary kilns, but not necessarily so in the case of shaft kilns. Consideration should also be given to the control of smoke in the kiln exhaust gases, which may be unacceptable, particularly if bituminous coal is used for kiln firing.

3. FINANCIAL AND ECONOMIC ASPECTS OF LIME PRODUCTION

3.1 Market potential

The success of a new lime production enterprise depends on a combination of technical and economic factors. There can be no lime production without the appropriate raw materials and a technology for processing them, but equally there can be no lime production without a market for what is produced. Thus, once the existence of suitable raw materials for lime production has been established, the next step is to establish that a market exists.

For a new and relatively small-scale lime production enterprise, three different types of market should be examined:

(a) Import substitution;
(b) Newly developing markets;
(c) Substitution for alternative products.

Each of these topics will be briefly examined.

3.1.1 Import substitution

In most regions or countries which do not produce lime, and in some which do, there is probably a small quantity being imported for retail sale or for use by industry or public sector enterprises. The quantity of this input, the sources of supply, the end-uses and the quality required, and the price of this import should be determined and then analyzed. This will set an upper limit on the possible sales price which will be possible and a lower limit on the potential market for lime of equivalent quality. To establish this market in more detail the principal existing users should be contacted and their requirements in terms of quantity, demand fluctuation and quality should be determined. If it is likely that a lower quality lime will be produced locally at first, the effect which this might have on the potential market and price should also be established.

Principal existing users of lime imports in developing countries are likely to be in the building industry (building contractors, the Public Works Department of Government, etc.), the Roads Department, Water Authorities, and certain industries (sugar, paper, etc.). Metallurgical and chemical industries are more likely to establish their own (captive) lime plants.

3.1.2 Newly developing markets

In addition to existing markets for lime, in developing economies it is probable that some new markets for lime will emerge, and these could be a particularly suitable outlet, since existing supply arrangements will not have to be interrupted.

Most prominent among these markets are likely to be new industries and construction. Any of the industries mentioned in chapter 1 may need lime. Contact should therefore be made with officials in the Government who will know of such projects, and with those involved in planning or feasibility studies for them. Likewise the need for lime in any planned construction project, whether it involves building, roads or other civil engineering works, should be investigated. It is possible that the design of such projects could be done in such a way as to use lime if its potential availability were known to the designing engineers.

The potential for new or expanded uses in agriculture, water and waste treatment such as those described in chapter 1 should similarly be investigated.

3.1.3 Substitution for alternative products

Considerable scope for using lime as a substitute for other products probably exists in the building industry. As explained in chapter 1, mortars and plasters made with lime can have better properties than those made with cement alone. Lime can be used as a stabilizer for soil blocks. Lime-pozzolana mixtures can replace cement in a wide variety of uses. Althogether the scope for replacement of lime for cement can constitute more than 50 per cent of the total cement usage in a developing country. Given normal prices and qualities, this substitution can often (where cement is not made locally) reduce the cost of contruction also. It is possible that either public or private organizations involved in building will be willing to incorporate lime or lime-based materials into their specifications and designs if a sufficient output of sufficient quality is known to be available. This substitution may be particularly attractive where pozzolanic materials such as volcanic ash, rice husk ash or burnt clay powder are available at a low price. The potential market arising from cement substitution is often very large, and can be estimated by assessing the quantity of cement currently used for low-strength applications.

Beyond these tangible and quantifiable markets, there is a further potential market which will emerge once lime production is established. Most self-build housing construction in developing countries is at present carried out with hardly any manufactured building materials because these are not available or are too expensive. The establishment of a small lime plant locally may create a supply of lime at a price which individual houseowners can afford to buy for mortars, renders, whitewash, blockmaking etc., and which could contribute substantially to the improvement of housing conditions in the area. The size of such a market depends largely on the local economy and the amount of cash available for purchase of building materials. It could be greatly enhanced by demonstration uses at the plant, at local agricultural fairs, etc. It cannot, of course, be relied on for initial market assessment calculations, but the possibility of large later expansion of demand should be considered in the initial plant design.

3.2 Feasibility study

Once the potential market has been established, it is essential to prepare a formal feasibility study in order to assess the economic viability of the project, and as a basis for seeking finance. It may at this stage be necessary to employ the services of a consultant familiar with the preparation of such studies for the lime industry, or it may be possible to complete the study without outside help. In either case, the procedure set out in the UNIDO Manual for the Preparation of Industrial Feasbility Studies[9/] should be used. The study should also include the following elements:

(a) An account of the project background and history, and of any previous studies and investigations.

(b) An assessment of the demand for lime, its price, and the market for the output of the new project, based on the investigations above, and including the possibility of capturing a larger potential market through setting a lower price. The market assessment should be disaggregated by end use, seasonality of demand and give an assessment of the sensitivity of demand to price variations.

(c) A review of alternative marketing strategies and distribution mechanisms, including consideration of working through established merchants.

(d) A proposal for the product mix (i.e. different types of lime), and an assessment of any appropriate plant capacity, bearing in mind the potential growth of the market, but also of avoiding costly overcapacity.

(e) An account of the inputs and raw materials required, sources of supply, results of raw materials analyses where appropriate, and prices.

(f) A site location review, proposing one or more possible sites with reference to quarry location, transport accessibility, water and other inputs, and taking into account environmental impact.

(g) A preliminary design, including proposed technology for each stage of the production and possible alternatives, site layout, storage facilities, buildings and site works, with an assessment of sources of supply and costs for each item, and maintenance requirements.

9/ UNIDO Manual for the Preparation of Industrial Feasibility Studies, United Nations, New York, 1978.

(h) An assessment of staff and labour requirements and their availability, including salaries, wages and overheads.

(i) An implementation schedule setting out step by step the procedure and timing of implementation from first decision to invest until full production is reached.

(j) A financial and economic evaluation, including the following components:

(i) Fixed and working capital requirements and implementation cost schedule,

(ii) Production and operation costs (including cost of sales and overhead costs);

(iii) Cost-volume-profit analysis to determine return on investment and payback period;

(iv) Cashflow programme.

For more explanation of these various elements, the UNIDO Manual for the Preparation of Industrial Feasibility Studies[10/] should be consulted, but some additional points should be noted:

(a) For a small project, a very detailed feasibility study may not be appropriate, and the cost of such a study should be considered in relation to the total likely cost of the project. An upper limit of 3 per cent of this is suggested by the UNIDO Manual.

(b) The level of sophistication of the financial analysis should be considered in relation to the accuracy of the data available; analyses using discounted cash flow techniques for example may be inappropriate when only approximate data are available and may give a misleading impression of accuracy. Some indication of the likely margin of error should be given.

10/ *Op. cit.*

(c) When assembling the components of investment and production costs particular attention should be paid to the timing of expenditures and costs which influence both the cash flow of a project and its internal rate of return.

(d) It is important to make a realistic assessment of the time and cost of building up a market for lime in areas where this is not an accepted product, and it may be necessary to budget for a substantial level of stocks if the demand is seasonal or sporadic.

The case study described in chapter 4 gives an account of how these various factors were taken into consideration in the establishment of a particular small plant in Botswana. It may be possible to obtain information on similar case histories from local sources or from published reports. A number of such reports are listed in the UNIDO Lime Bibliography.

3.3 Sources of finance

The mix of capital employed in any kind of manufacturing business is of fundamental importance, although small, high risk enterprises are normally forced to rely heavily on owner's equity. Where it is possible to raise loan capital, the choice among possible forms of lending should be based upon a comparison of interest rates linked to the purpose for which the loan is sought.

If the purpose is to provide working capital, overdraft finance or short term borrowing is suitable. If it is for two to five year investment, such as vehicles, plant and equipment, then leasing or hire purchase (if available) or medium term loans will be appropriate. For an investment of five years or more, it will be necessary to rely on equity, debenture or long term loan capital.

Lime manufacture in developing countries could often be suitably financed through an established development finance institution such as an industrial finance corporation or an industrial development bank. In the case of industries to be set up in a rural location, favourable finance may be available through aid-financial rural development programmes. It is also worth examining the scope for reducing cash needs through securing deferred payment arrangements with equipment suppliers or advance payments from distributors.

A UNIDO publication[11/] gives further guidance on possible sources of finance appropriate to a lime manufacturing enterprise. The following points are worth particular emphasis:

(a) There are a great many potential sources of loan finance for a profitable industry such as this, but terms and conditions may vary considerably. It is essential to consider as many different sources as possible before making a decision, rather than accepting the first offer made.

(b) The period of time required to conclude the procedures for obtaining financing for the project can be unexpectedly long, particularly if any international agencies are involved. It is essential to start this process at the earliest possible opportunity to avoid not only possible financial loss but also loss of momentum on the project.

11/ UNIDO, Financial resources for industrial projects in developing countries, PI/61/Rev.1, February 1981.

4. A CASE STUDY OF SMALL-SCALE LIME PRODUCTION: MOSHANENG LIMEWORKS IN BOTSWANA

4.1 Background

The Moshaneng limeworks is one of a group of buildig materials projects initiated by the Southern Rural Development Association (SRDA) in conjunction with the local government's Production Development Committee (PDC) for the Southern District of Botswana. SRDA is an organization which was established in 1979 to assist in rural development by such means as employment creation, the establishment of production units and the training of personnel. It has its headquarters at Kanye which is the administrative centre of the Southern District.

SRDA and the PDC recognized the need for building materials production in the district, and the country as a whole, and organized an investigation of the potential. The findings of the investigation motivated SRDA to establish a subsidiary organization under the name of Mineral Holdings Trust (MHT) whose function is to develop the building materials, and small mining and quarrying industry in the district.

At the time that MHT was established (1982), the total population of Botswana was slightly under one million. None of the major towns lies within the Southern District but a relatively large proportion of the rural population live there. A large area of Botswana is arid and therefore sparsely inhabited. The most populated part of the country is the fertile south eastern section, much of which falls within the borders of the Southern District. Thus, there is a comparatively large demand for building materials in this district, as well as the nearest town, Lobatse, and the capital, Gaborone. This demand was filled almost exclusively by products from the neighbouring Republic of South Africa, which is also where many Batswana go to find employment.

The objectives for establishing local building materials production were therefore twofold: firstly to limit Botswana's almost total dependence on South African imports and secondly to create employment in the Southern District. This concurred with the Botswana National Development Plan which had as two of its major objectives import substitution and job creation.

The first projects to be undertaken by MHT were fired clay brick production, slate quarrying and the cutting of tiles, extraction and processing of mineral pigments, stone crushing for roadstone and terrazzo chips, and lime production. Users of lime in Botswana include the copper smelting works, the construction industry, the Rural Road Department, the Department of Agriculture, farmers and tanners. All the lime needed was imported from the Republic of South Africa. The Moshaneng limeworks was implemented to reduce this dependence on imported lime and to create employment locally, requiring only the skills available in Moshaneng and neighbouring villages. What follows is a description of how this project was implemented from the feasibility investigations to full production, including a preliminary financial appraisal and some recommendations based on this experience to the small producer and project planner.

4.2 Raw materials and resource assessment

4.2.1 Limestone/dolomites

The first step taken in the project investigation was to consider whether the resources for lime production did in fact exist and if so, to examine their suitability. Three possible sources or raw material were identified by the Botswana Geological Survey Department. They were analyzed and two were shown to be of adequate chemical composition for use in the construction and agricultural industries; one at Diphawana 20 km south of Kanye and one at Moshaneng, approximately 25 km west of Kanye. Both deposits were of dolomite. The Moshaneng deposit was provisionally selected for further investigation because it was in the form of a disused mine tailings dump which meant that the dolomite was already quarried and crushed. This potentially very expensive part of the lime production process could therefore be limited to selection and trimming where necessary. The chemical composition of the minedump dolomite showed a total oxide content of 88.8 per cent.

Samples of the Moshaneng dolomite were fired in a small testing kiln to establish its behaviour on firing under field conditions. Two possible effects were of interest in this instance, decrepitation on firing, and the reactivity of the quicklime produced. Limestone which decrepitates or breaks down in the kiln inhibits adequate firing by blocking the flow of hot gases through the kiln. Reactivity is the rate and ease with which the quicklime is hydrated. This effect was of particular concern since dolomite is easily overburnt, resulting in a quicklime which is slow in hydrating completely (see 2.7). Hydrated lime containing unhydrated particles is unacceptable for use in the construction industry. As will be described later, by careful firing (temperatures below 1,000°C) and screening, this condition was restricted to an extent which made the product acceptable. It was found that the dolomite did not break down on being fired and produced a fairly reactive quicklime which was buff coloured.

4.2.2 Fuels

The fuel available was a low grade coal with a calorific value of 22 MJ/kg, from Serowe. The price of the coal at the limeworks was P40 per ton (approximately $US 40), 50 per cent of which was the cost of transportation. An alternative to the coal was wood. It was, however, decided that, although its price was marginally lower than that of coal, its use would add to the already severe problem of deforestation and in addition its collection would be inconsistent and unreliable. Certainly the choice of firewood as a fuel was not a feasible long term solution.

Boynton[12/] states that the theoretical heat requirement for the calcination of high calcium lime is 3,200 MJ/ton of limestone fired. The amount of fuel used at the Moshaneng limeworks was in the region of 260 kg

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12/ R.S. Boynton, Chemistry and technology of lime and limestone. Wiley-Interscience publication, 2nd edition, 1980.

per ton of dolomite fired (305 kg per ton of hydrated lime produced), i.e. 5,720 MJ/ton of dolomite fired. This constitutes a thermal efficiency of about 40 per cent, which is good for a kiln of this size and simplicity.

4.3 Market investigation

Concurrently with testing to confirm the suitability of the raw materials, a market investigation was conducted to identify the potential markets and gauge their extent. People such as the Chief Architect and the Works Superintendent of the Public Works Department, the Principal Housing Officer of the Self Help Housing Association, local contractors and building materials suppliers were interviewed to assess the potential market for lime in the construction industry. Further, the Rural Roads Department and the Department of Agriculture were approached. Both use lime and expressed interest. In short it became apparent that a market did exist. This was supported by the 1980 import figure of 5,649 tons of lime which was likely to have increased in 1981 due to the general increase in economic activity and development. All who were interviewed expressed an interest. Their interest was almost exclusively dependent on the lime being of sufficient quality, low price and most of all, supply being consistent. During project implementation it was discovered that the local tannery used a certain amount of lime which they were prepared to consider buying from the project on condition that its colour was satisfactory. Further, a small gold mining operation in the north of the country was interested in purchasing the lime.

4.4 Site survey

A site survey followed which revealed a suitable area for the establishment of the whole production site. A general idea of the scale and nature of the operation had been formulated at this stage. The site identified was adjacent to the mine dumps, in a position where the transportation of stone from the working face to the kiln would be short and at the same time kiln feeding would be made easy. The site required a minimum of site clearance and adequate access roads were already available. An unused well was available nearby for the necessary water supply and labour was available locally from the village of Moshaneng.

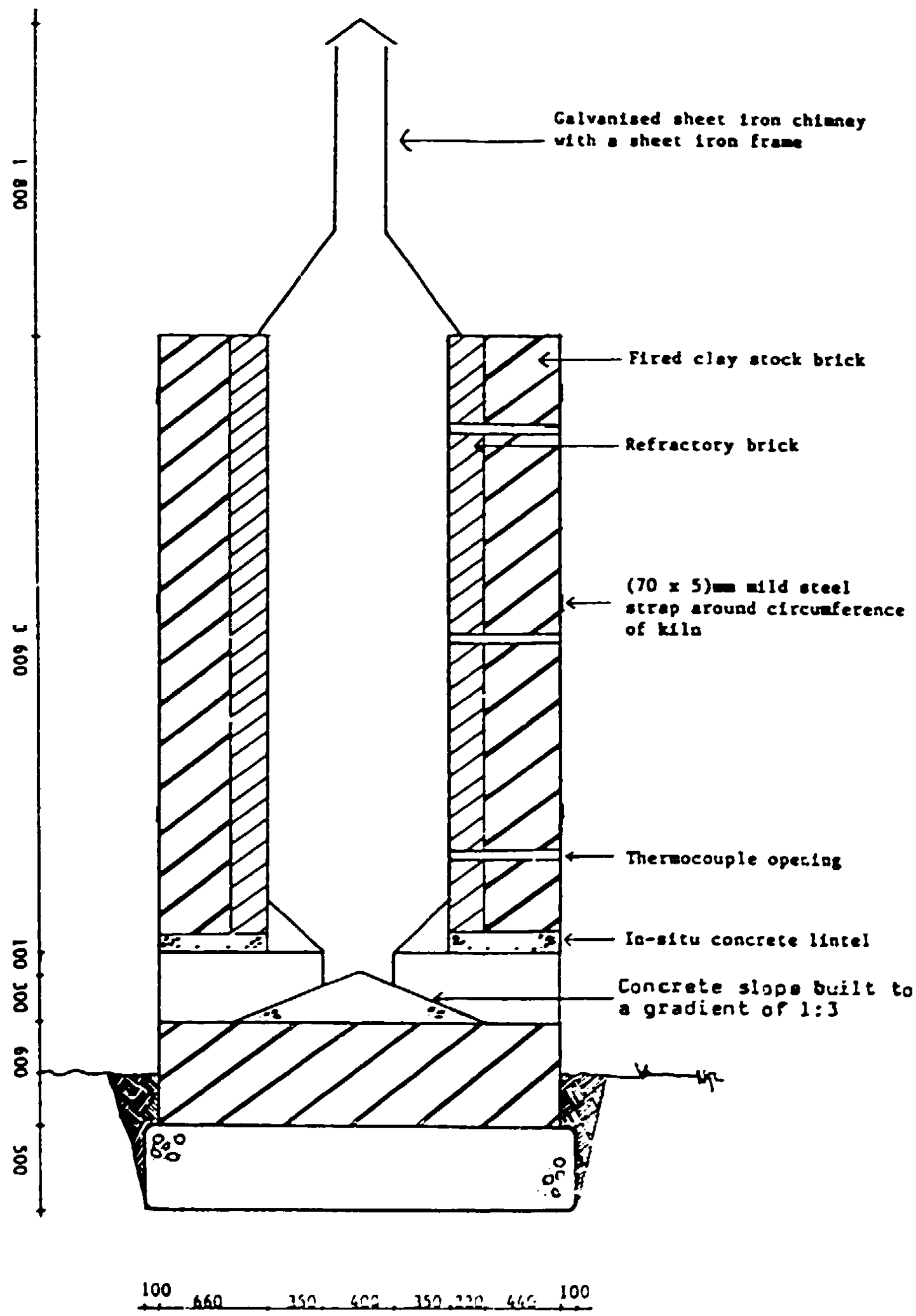
Consultations were held with the Moshaneng village council to inform them of the intention and to gain their approval for the scheme. This approach proved to be particularly successful and had unforeseen advantages. It not only served to create a degree of community participation which was useful in SRDA's later community development activities, but also made the allocation of land for the projects by the Tribal Land Authority, and the management of the lime production plant easier. The initial consultations resulted in the identification of the unused well, and the council also provided a list of villagers available for employment with details of their previous experience and skills.

4.5 Choice of technology

It was now possible to develop the design of the production plant. The operation was to have a small output, be flexible in operation, that is be convertible from a continuous to a batch operation, and also be such that production capacity could be increased with ease if required. Further, it had to be simple so as to minimize the need for skilled manpower to operate and maintain the plant.

Advice on the available simple, low output technologies (kilns and methods of slaking) had been sought from various groups, including the Intermediate Technology Development Group (ITDG) in England and the Khadi and Village Industries Commission (KVIC) in India. Various options were provided and studied. It was finally decided that the three ton per day KVIC vertical shaft kiln design was the most suitable. This kiln had been used effectively on several occasions. The basic design is such that, if necessary, it can easily be modified to suit the specific situation. Its diameter and length can be adjusted to suit the output requirements and the length can be adjusted according to the nature of the limestone and fuel used. It can be operated on a batch or continuous basis; coal, charcoal or wood can be used as fuel; and most significant of all, it is easy to construct and locally available materials can be used. In Moshaneng the fired clay bricks made locally were used to construct the kiln. The kiln was to be fed in alternate layers with dolomite lumps selected from the mine dumps and coal. Simultaneously the calcined quicklime lumps were to be withdrawn from the extraction ports at the base of the kiln. Figure 4.1 shows the kiln design used.

Figure 4.1. Design of KVIC-type vertical shaft kiln used at Moshaneng



In the building construction industry slaked lime can be used in two forms, as a putty or in powdered form. It was decided that the powdered form was the most appropriate since this is the form in which it is used in Botswana in both the agricultural and the soil stabilization applications, and also the builders were familiar with the use of powdered lime. The simplest methods of slaking is by spraying water over the quicklime lumps on a slaking floor. This was the method to be adopted in Moshaneng. The slaked lime was then to be screened by trommel screen and bagged. Figure 4.2 summarizes the production process.

On the basis of this preliminary plan for production, estimates of the labour requirement and the approximate rates of production were made for the economic calculations.

4.6 Economic feasibility study

On completion of the engineering design and the formulation of the production plan, the economic feasibility of the proposed operation was checked. Information on availability, cost and delivery time implications of the machinery and equipment and materials was collected, as were data on the cost of labour, raw materials and office supplies, as well as all other cost data necessary to carry out the economic calculations. The documents and economic calculations were prepared as follows:

(a) Capital cost schedule, including an account of the plant and equipment to be purchased and the building required.

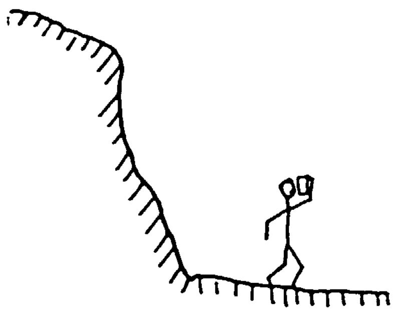
(b) Project implementation cost schedule.

(c) Production cost, cost of sales and overhead cost schedule.

(d) Projected income statements, the first year and from year one to year five.

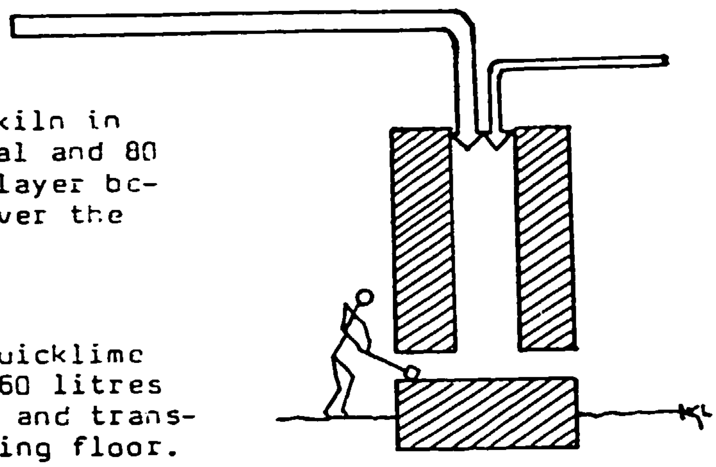
(e) Cost-volume-profit analysis to determine the breakeven sales volume.

Figure 4.2. General description of production process



Activity A

20 workers selecting and trimming dolomite lumps to the required size at an average rate of 200 litres/day. The raw feed was stockpiled at the kiln. Payment for these workers was by the bucket collected. 3 days stockpile was maintained at all times to take care of fluctuations in work attendance.

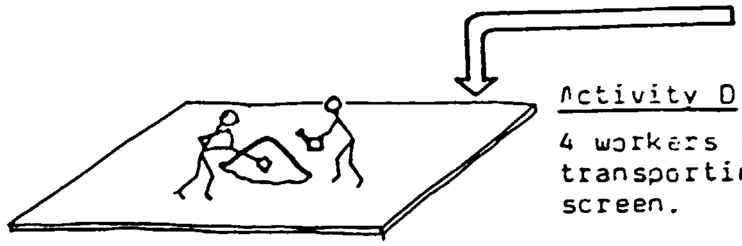


Activity B

4 workers feeding the kiln in layers of 20 litres coal and 80 litres dolomite, each layer being spread uniformly over the preceding one.

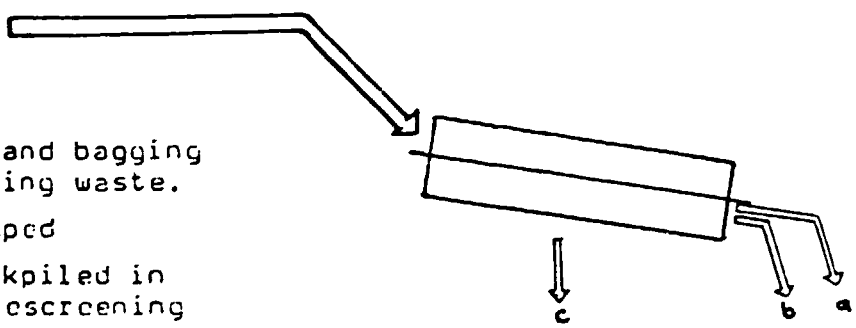
Activity C

2 workers extracting quicklime at a rate of approx. 160 litres per hour from the kiln and transporting it to the slaking floor.



Activity D

4 workers slaking quicklime and transporting it to the trommel screen.



Activity E

4 workers screening and bagging slaked lime and dumping waste.

a. +5mm fraction dumped

b. +30mesh -5mm stockpiled in mound for later rescreening

c. -30 mesh fraction bagged and weighed in 25kg bags

(f) Return on investment and payback period.

(g) Project implementation programme, manpower plan and cashflow of the first year including the implementation period, which enabled the working capital requirement to be determined.

The results of this study were evaluated by SRDA and the PDC. Once they were satisfied as to the feasibility of the project, it was agreed to commence with implementation.

4.7 Project implementation

A detailed project implementation plan was prepared, the first task of which was to follow up the funding organizations which had shown an interest in financing SRDA's proposed building materials production activities, and obtain a commitment to finance. This commitment was used to secure short term bridging finance from the local bank and the Botswana Development Corporation which enabled implementation to continue while the applications for funding were being processed.

The necessary land was then applied for from the Tribal Land Authority and was duly allocated. An order was placed for the refractory bricks at this stage since it had been established that delivery would be slow, and an agreement was made with a local builder to construct the kiln.

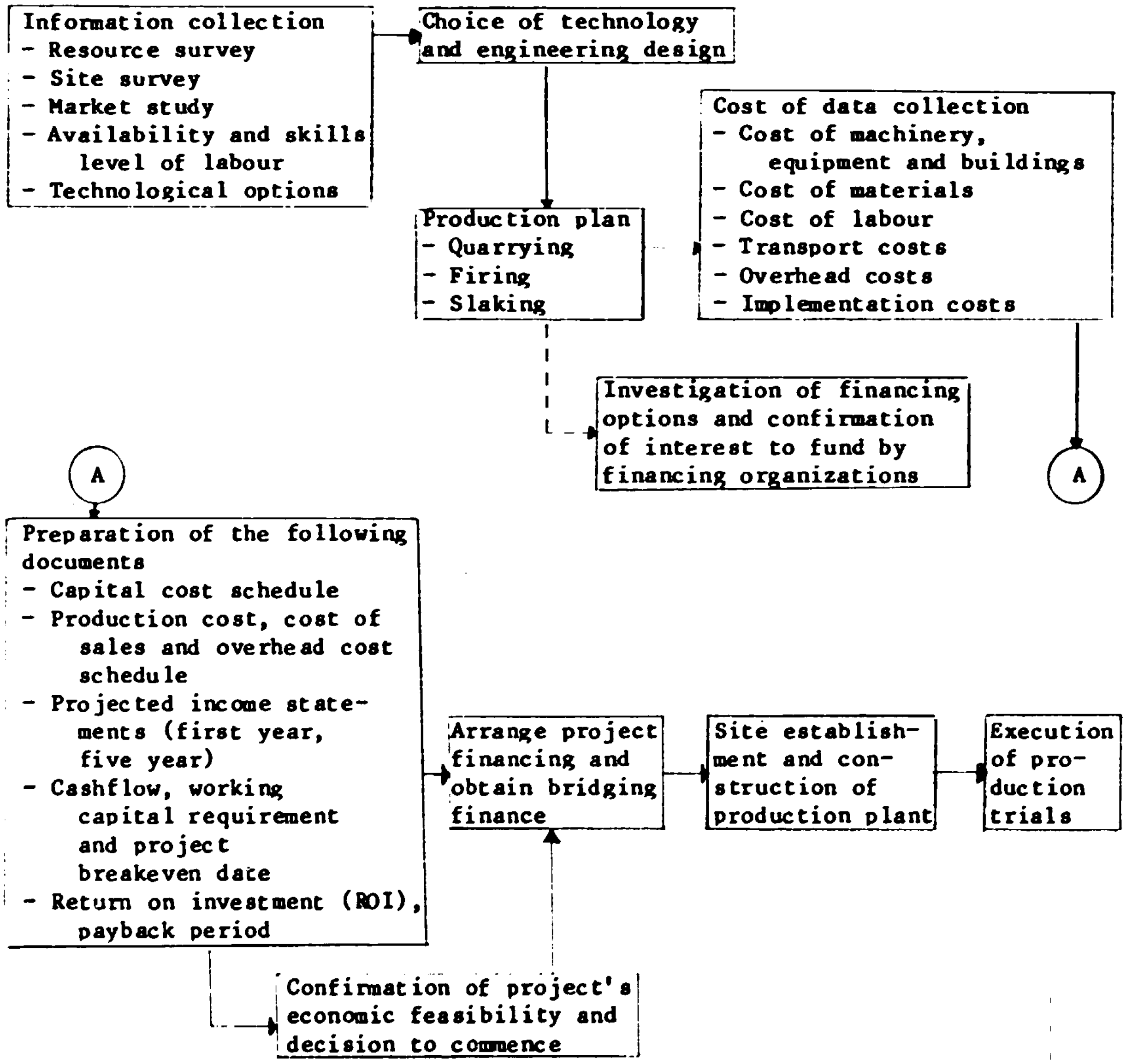
The production site took approximately 5 weeks to construct, after which a series of trials were undertaken to establish the best operating conditions.

The whole process of project investigation and implementation is illustrated schematically in figure 4.3.

4.8 Production trials

Method of execution. A series of production trials were now conducted in order to determine the optimum plant operating conditions. During these trials measure volumes of stone and fuel were fed into the kiln, and temperatures were measured at various points in the kiln. The lime produced was tested and to determine the amount of unburnt material, and samples were also sent to the Geological Survey for analysis.

Figure 4.3. Flow diagram of project investigation and implementation



Five trial runs were carried out, four on a batch and semi-continuous basis and one continuous. The experience of each successive trial run allowed adjustments to be made to the following kiln operating parameters:

(a) Proportion of coal and stone in the kiln feed;

(b) The volume of each layer;

(c) The size of the stone;

(d) Draught control;

(e) Rate of extraction.

Table 4.1 shows a quantitative comparison between the three modes of operation.

Table 4.1. Comparison of modes of operation of the kiln

Mode of operation	Labour used (manshifts/ 24 hours)	Hydrated lime output per day (kg)	Output per manday (kg)	Fuel consumption per ton produced (MJ/ton)
Continuous	30	3,900	130	5,641
Semi-continuous	20	2,300	115	6,695
Batch	4.8	530	110	8,300

The trials showed that there are definite advantages in operating the kiln continuously. The production capacity (output per day), and the production efficiency (output per manday) are higher than with the other two methods. In addition, the fuel efficiency is higher. However, the method of operation adopted initially was the semi-continuous one, to avoid the complication of a third shift.

Slaking a dolomitic lime requires care, to ensure that the lime produced does not contain unhydrated material. The method adopted involved two screening operations. The first screening took place two days after the addition of water, when material smaller than 0.5 mm was bagged. Material between 0.5 mm and 5 mm in size was stockpiled for a period of three weeks and then rescreened. A significant proportion of the material slaked during this period.

Figure 4.2 summarizes the production process adopted as a result of the production trials.

4.9 Financial analysis

Table 4.2, 4.3 and 4.4 give an account of the economics of the project soon after going into full production. The figures have been converted into 1982 $US at the rate of 1 Pula = $US 1.

The project enjoyed certain unusual economic advantages. As a non-profit organization NHT is not liable to taxation; also no allowance is made for interest or repayment of the capital, since the capital costs were met by grants from the Dutch Government, USAID and the Friedrich Ebert Foundation (Federal Republic of Germany). The establishment and the operation of the plant was also supported by UNDP and UNIDO.

This enabled the lime to be produced for the very low sales price of $US 100 per ton, only 65 per cent of that of imported lime. It should be noted however that the capital cost of the project is so low that even a 10 per cent interest on the total investment could only increase costs by $US 5 per ton produced, or about 5 per cent.

A sales price closer to the price of imported lime would have enabled the project to earn a much larger income than that shown in table 4.4, which in a non-profit organization was intended simply to provide a margin of safety in covering costs.

4.10 Marketing and prices

Sales were expectedly irregular during the early stages of full production. An extensive marketing exercise was carried out including advertising in the media, visits to the major potential buyers, such as the

Table 4.2. Moshaneng limeworks: investment costs

	Depreciation period (years)	Cost ($US)
Capital costs		
Buildings	20	6,200
Kiln	10	3,800
Office equipment and furnishings[a/]	10	1,000
Water pump and piping[a/]	5	2,000
Trommel screen	5	1,200
Bag stitching machine	5	400
Slaking floor and loading ramp	5	600
Wheelbarrows, shovels and hammers	3	800
Thermocouples	3	800
Total capital cost		16,800
Implementation costs (working capital)		
Kiln feed		400
Fuel		250
Transport		1,500
Labour		1,550
Supervisor and administration clerk		2,400
Rents and royalties		200
Total implementation costs[b/]		6,300
Total investment cost (capital + implementation)		23,100

a/ These costs were shared between several projects.

b/ The costs were incurred during 3 month immplementation period.

Table 4.3. Moshaneng limeworks: production and operation costs

	Cost ($US)
Variable costs	
Kiln feed (114 tons)	650
Fuel (22 tons)	880
Bagging (2,530 bags)	930
Water	20
Royalties	50
Labour (420 mandays)	1,920
	4,450
Fixed costs	
Supervisor's salary	320
Sales costs	240
Overheads (project administration)	570
Repairs, maintenance, replacement	100
Depreciaion costs	180
Other costs (rent, transport, equipment)	140
	1,550
Total monthly production and operation cost	6,000

Table 4.4. Moshaneng limeworks: economic performance summary

Total investment cost	$US 23,000
Annual sales (759 tons at $US 100)	$US 75,900
Annual production and sales costs[a/]	$US 69,540
Net annual income (year)	$US 6,360
Breakeven sales volume (tons/month)	52.3
Return on investment (per cent)	27.5
Payback period (years)	2.75

a/ Based on 330 days of production.

b/ Assuming production rises by 5 per cent in second year.

works departments, the Self-Help Housing Association, and the Department of Agriculture, and demonstrations in the surrounding villages. Most of the budgeted amount for advertising and promotional work was spent in these early months of operation.

The price of the lime produced in the early stages was $US 2.50 per 25 kg bag, compared with $US 3.90 for lime imported from the Republic of South Africa. The District Works Department architect agreed that the use of lime in mortars and plasters would become recommended practice in local public works contracts.

4.11 Conclusions and recommendations

The experience of the Moshaneng limeworks has shown that with careful planning this low technology option can be used successfully to produce sufficient quality lime at a comparatively low cost. The advantages of such an operation can be summarized as follows:

(a) Low capital cost;

(b) High return on investment possible with consequently short pay-back period;

(c) Easy to construct, maintain and operate, and locally available material can be used in construction;

(d) Production capacity is comparatively low, hence the reserves of limestone required during the life of the works is low. Limestone deposits of insufficient size for large scale production can therefore be utilized with economic effect;

(e) No risk of mechanical or electrical ...akdown and therefore the operation is relatively independent of the need for highly trained, expensive and often unavailable operating and maintenance personnel. This is of particular importance in the remote, and often the not so remote, areas of developing countries;

(f) Labour intensive operation (low capital cost per job created);

(g) Flexible output. It is possible to vary output in keeping with demand during the life of the limeworks by adding successive kilns which can be brought into operation as and when required.

In a high risk situation, either where the extent of the market cannot be gauged with any accuracy or where the continuity of the market is uncertain, the investment cost of bringing into operation a single kiln of this type is so low that it may be regarded as a pilot plant only, to be incorporated into a plant of the required capacity as one of a battery of kilns, if the pilot phase proves positive. In this particular case, it is understood that a further four kilns of a similar type are either planned or under construction in Southern Botswana with UNDP/UNIDO assistance.

In many developing countries large sections of the country are remote from the lime or Portland cement producing centres. In these areas the population level is generally also low and/or widely dispersed. This causes a severe shortage of cementitious material or limited availability at exorbitant prices. The appropriate solution to satisfy the demand for lime in such circumstances is clearly a level of output to suit the specific needs of the region, and a level of technology which makes for easy and reliable operation and which is as inexpensive as possible. The choice of technology adopted in Moshaneng is also particularly suited to a one-off situation such as a source of lime for the soil stabilization of a road construction project.

5. HOW TO OBTAIN ASSISTANCE

5.1 General

To bring any new manufacturing enterprise into successful operation is a complex business, which will require specialist assistance at many levels.

The first step should be to obtain whatever relevant information and advice is freely and locally available. Many governments have established organizations whose function is to assist in the development of small industries. Technical, financial and procedural advice may be freely available from such organizations, or from the Ministry of Industries. Information on raw materials availability, its quality and its potential uses may be obtained, again often freely, from the local Geological Survey. Financial advice may also be obtained from local banks and other financial institutions. At this stage, it is appropriate, too, to talk to those involved in the lime industry locally, the users of lime; the manufacturers and the traders or retailers.

If prospects for successful lime production appear encouraging, a more detailed exploration of alternative methods and uses can be made by the use of published sources of information. There are several national and international orgnizations which have published reports and manuals on lime production, and there are a number of commercially published books on the subject. Certain periodicals publish regularly articles on lime production which can be a helpful source of information. At this stage also the relevant national standards for lime for various end uses should be obtained.

At some stage, generally, it will be necessary to employ a specialist consultant to undertake a detailed feasibility study and make specific technological recommendations. The services of such consultants tend to be expensive, and can be minimized if exploration discussion and preliminary studies have been carried out beforehand. The employment of consultants should be seen as a third stage, when a fairly clear idea of the location, the type of market and the approximate scale of operation has already been established.

5.2 The UNIDO Lime Directory and Bibliography

Alongside this report, UNIDO has published a directory and a bibliography which are designed to be a guide to sources of specialist help and technical information on the lime industry, to assist in the investigations described above.

The Directory lists organizations which may be helpful, in one way or another, in the development of the lime industry, and the Bibiliography lists documents which provide more detailed technical assistance on the many aspects of lime manufacturing or use mentioned in this report, or records particular experiences of initiating new plants, processes or equipment in many parts of the world.

The Directory, which lists organizations, is subdivided into five sections. In the first section is a list of suppliers or manufacturers of the kilns, plant and equipment needed for lime manufacture, either at large or small-scale. Such firms can in many cases provide the consulting services needed to assess raw materials, conduct market surveys, and design and install the entire plant. Many of them, however, deal only with a particular type of equipment and scale of operation. It will therefore usually be appropriate, before making any commitment to any particular manufacturer or supplier, to obtain the services of an independent consultant, who can advise on matters such as raw materials, plant location, markets, and so on, as well as the appropriate scale and type of equipment to use. A list of such consultants (or organizations which can advise on consultants) is therefore given.

Another type of organization, not listed, is the national Geological Survey, which is usually a branch of the Ministry of Mines or Natural Resources in each country, which will keep full details of geological mapping and exploration which has been carried out, and also usually be equipped to conduct testing of raw materials to assess their suitability for lime manufacture.

The Directory also lists national lime manufacturers associations, which may be consulted for information on the present state of the lime industry, and many also advise on appropriate consultants to use.

Another type of organization which should be consulted is any local organization conducting research and development work in lime manufacture or use, who may give valuable information on new techniques of production or new uses for lime, or provide helpful examples of similar projects. A list of such organizations is therefore provided.

Finally, the Directory lists national organizations dealing with research and documentation in the building industry, which may be able to provide additional information on the local industry, or on the market for lime in the building industry.

None of these lists of organizations claims to be a complete list; they are provisional and partial, and UNIDO intends to update them and expand them as more information becomes available.

The Bibliography is a list of documents which may prove helpful to provide more technical detail than is available here. The first two parts contain a list of published books and technical reports on lime manufacturer and use. Some of these are old, but still valuable as sources of information. Most are produced by the organizations listed in the Directory, where addresses are given, or by commercial publishers.

The technology of lime manufacture and use is changing rapidly, and technical articles can quickly be outdated by new developments.

Important developments are reported in the technical literature, and the Bibliography therefore lists periodicals which deal partially with lime manufacture and use, recent issues of which should be consulted.

Standards and specifications appropriate to different countries and uses of lime should be consulted for information on required properties, testing procedures and so on, and a list of these is therefore given.

Finallv, the Bibliography lists a selection of technical articles which deal with either lime manufacture or use. Most of these have either been published in the periodicals listed, or in the Proceedings of the International Lime Congresses, which are held every four years. These proceedings, or copies of the papers presented at them, can be obtained either from the International Lime Association at BACMI London, or the United States National Lime Association in Washington D.C.

Again, none of these lists are complete; each of them is subject to continuous revision and updating by UNIDO.

5.3 The UNIDO lime database

As a further source of assistance to potential lime producers, UNIDO has developed a computerized database giving country-by-country information on the lime industry. For each country, the following information will be kept on file, and updated:

(a) Total national production of burnt lime during each of the preceding 5 years, and (where available) for certain earlier years.

(b) Recent import and export tonnages and prices for lime, with principal import sources and export destinations.

(c) End use distribution of lime produced divided between six principal consumer groups, and including a further nine sub-groups.

(d) Detailed prices of lime and of ordinary Portland cement.

(e) A list of the principal lime producers, their location, production or plant capacity, and summary information on the technology used.

(f) A list of organizations, other than producers, in the country engaged in the support of the lime industry, e.g. consultants, equipment suppliers, manufacturers association, etc.

(g) A list of local sources of financial assistance to lime industry development.

Information held on the UNIDO lime database will be available to potential users either in form of:

(a) Print-outs for one or more countries or a group of countries (region or economic grouping), or

(b) A diskette containing the whole database, suitable for use on standard microcomputers.

UNIDO will perform and in due course publish analyses of the international data in the database in a form which will enable potential producers to identify market trends, potential areas for development, and current price levels.

6. CONCLUSION

The purpose of this report has been to show that the lime industry is potentially of great importance to the economies of developing countries, and that its expansion and promotion could bring widespread benefits in increased production, employment, and income-generation, and often through reduction of imports. In this concluding chapter, the principal arguments in favour of the promotion of lime will be briefly restated.

(a) Lime is an industrial mireral which today has a vast range of uses, in agriculture, in the metallurgical and chemical industries, in the treatment of water and wastes, and in the building and construction industry. Producers of lime are not tied to a single market, and new markets are constantly being found for it.

(b) Lime is a material of ancient origin, already well-known in most countries, and usually already produced by traditional craft methods. Some rudimentary knowledge both of the production and uses of lime usually exists, and this can be built upon.

(c) The capital cost of establishing a lime production plant is low, permitting a high return on investment and rapid payback period.

(d) Raw materials of sufficient quantity and quality for starting lime production are very widespread; there are numerous suitable deposits or reserves in almost every country.

(e) The technology of lime production can be matched to the technological level of the region. For poor countries with a low technological infrastructure, simple kilns and processing equipment can be used, which can be fabricated locally. Dependence on imported equipment or skills can be minimized.

(f) At a simple level, lime production is labour-intensive and generates employment. Few trained or qualified people are required, and the skills required are learnt on the job. Employment in the production of lime teaches skills which can be applied to other, more sophisticated, industrial processes.

(g) Lime production can be carried out efficiently and profitably at a small scale. An investment of only a few thousand dollars is needed to start a small lime manufacturing industry. The earnings of a small initial plant can be used to pay for its expansion by adding further small production units.

(h) Availability of lime can make a big contribution to the improvement of housing standards. Lime can frequently be used in place of cement in blockmaking, mortars and renders, and road construction. Where cement is either scarce or expensive because of large transportation distances, local manufacture of lime can reduce building costs significantly.

Given the right economic environment, the lime industry can be self-promoting, and need little development finance or institutional support. Two particular acts of official support could, however, give great encouragement to the industry. The first is that a number of regional demonstration projects could be established, to show the methods of lime production, and prove that it can be profitable at a small scale. The second is that existing standards and specifications for building materials and other lime uses could be examined and if necessary rewritten to enable a greater use of locally-produced lime. Recent experience shows that if the lime industry is given a little encouragement of this sort, its growth can be very rapid.

For the guidance of our publications programme in order to assist in our publication activities, we would appreciate your completing the questionnaire below and returning it to UNIDO, Division for Industrial Studies, D-2119, P.O. Box 300, A-1400 Vienna, Austria

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QUESTIONNAIRE

Lime in industrial development: A UNIDO guide to its uses and manufacture in developing countries

	(please check appropriate box) yes	no
(1) Were the data contained in the study useful?	/_/	/_/
(2) Was the analysis sound?	/_/	/_/
(3) Was the information provided new?	/_/	/_/
(4) Did you agree with the conclusion?	/_/	/_/
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(6) Were the format and style easy to read?	/_/	/_/
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