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S.A. DEPARTMENT OF MINES.

AEOLIANITIC LIME SANDS.

PART I

CALCINATION REQUIREMENTS.

by

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LIMESAND INVESTIGATIONS

ABSTRACT

Preliminary investigations into the calcination of lime sands from Eyre Peninsula, South Australia are described in this report. The material as mined has a chemical composition suitable for lime production without prior beneficiation. Usual commercial practice is to calcine crushed limestone in a much coarser form than granular limesand. A recommendation for future work in developing equipment specifically for burning limesands is made.

1. INTRODUCTION

At the request of the South Australian Mines Department, an investigation commenced into the utilization of deposits of aeolianitic lime sands which occur in the Coffin Bay area of Eyre Peninsula, South Australia.

The extent of the deposits has been estimated (Johns 1957) at about 1,000 million tons in mobile dunes, with a greater tonnage as fixed aeolianites. There are further extensive deposits in other coastal areas of the State.

Utilization of the material for purposes other than as a flux in pyrometallurgical operations depends on its amenability to calcination, upon the ease with which the lime so produced can be hydrated, and on the properties of the hydrate.

Preliminary tests have shown that the material calcines readily, that the lime hydrates satisfactorily and that a hydrate of good quality is produced.

The fine granular nature of the lime sand prevents the use of conventional kilns for calcination on an industrial scale. The use of a novel type of fluid-bed kiln is proposed.

2. MATERIAL EXAMINED

A 500 pound sample of lime sand from dune deposits in the Coffin Bay area was supplied by the South Australian Mines Department.

Chemical analyses and screen sizings are given in Tables 1 and 2. The material contained magnesium carbonate in excess of five per cent. and in consequence was classified as a magnesian limestone. Calcium and magnesium carbonates exceeded 97 per cent. so the material was suitable for calcination as mined.

Material and bulk specific gravities have been determined as 2.63 and 1.52 respectively.

Table 1

Chemical Analysis

		Per cent.
Calcium Carbonate	$CaCO_3$	91.50
Magnesium Carbonate	$MgCO_3$	5.80
Silica	SiO_2	0.94
Aluminium Oxide	Al_2O_3	0.24
Ferric Oxide	Fe_2O_3	0.24
		98.72

Table 2

Screen Sizing

B.S.S. Screen	Weight per cent.	Cumulative Weight per cent.
+ 14	0.25	0.25
-14/ + 18	0.90	1.15
-18/ + 25	5.35	6.50
-25/ + 36	14.75	21.25
-36/ + 52	24.35	45.60
-52/ + 72	37.85	83.45
-72/ + 100	14.85	98.30
-100/ + 150	1.50	99.50
-150	0.20	0.20
	100.00	100.00

3. EXPERIMENTAL PROCEDURE AND RESULTS

Preliminary calcination tests were conducted by putting 5 g samples of lime sand into a muffle furnace held at 900°C. Chemical analysis of samples withdrawn from the furnace at regular intervals showed that calcination was complete after about 15 minutes in the furnace. A chemical analysis of lime produced in this way is given in Table 3.

Table 3

Lime: 15 minutes calcination in Muffle Furnace at 900°C.

		Weight per cent.
Total Lime	CaO	91.40
Magnesia	MgO	4.15
Residual Carbon Dioxide	CO_2	0.55
Silica	SiO_2	1.72
Alumina	Al_2O_3	0.84
Ferric Oxide	Fe_2O_3	0.20
		98.86
Available CaO (calculated)		90.7
Removal of CO_2 "		99.3

Similar tests were carried out with the muffle held at 1,000°C, and the time required for calcination was reduced to five minutes. Thermodynamic data from Kubaschewski and Evans(1958) show that one atmosphere partial pressure of carbon dioxide is in equilibrium with lime and magnesia at temperatures of 897°C and 419°C respectively. The muffle tests indicated that the rate of calcination in the muffle was controlled by the rate of heat supply to the lime sand.

From the screen analysis given in Table 2, the lime sand has a particle size distribution such that it should fluidise at relatively low fluidising gas velocities.

To determine the fluidising characteristics of the lime sand, fluid bed tests were conducted in two perspex model fluid-bed reactors, one 2.75 inches and the other 6 inches in diameter. Batch tests in both models showed that fluidisation at room temperature commenced with a superficial air velocity, (i.e. air velocity in the open tube) of about 0.2 feet per second. Beds having aspect ratios (bed height to diameter ratios) up to 2:1 were susceptible to channelling at air velocities between 0.2 and about 0.4 feet per second. However, at air flows above 0.4 feet per second, turbulent fluidisation was observed in all the fluid beds tested. At air velocities of about 3.5 feet per second dust losses became noticeable and at about 7 feet per second most of the solids were transported in the fluid.

Beds of lime sand up to 12 inches in depth can be fluidised satisfactorily at room temperature with fluidising air velocities between about 0.4 and 3.5 feet per second.

Fluidised bed calcination tests were carried out in a reactor made from a length of 3-inch bore silica tubing. The reactor was heated with two 2 KW resistance heaters wound on the tube and the whole insulated with a 4-inch thickness of refractory insulation.

Samples of 1,000 g of lime sand were fluidised in the reactor and the rise of temperature with time recorded. For the first test it was found that the temperature rise was roughly linear with time for the first 20 minutes when it reached a temperature of about 900°C. The temperature remained constant for about 20 minutes and then started to rise again. Chemical analyses of a sample taken when the temperature reached 925°C showed that calcination was 99.7 per cent. complete. The charge was weighed after the test and dust losses found to be 3 per cent.

In a second test the temperature rose in a similar manner and a sample taken when the temperature reached 1025°C showed calcination was 99.7 per cent. complete. Dust losses amounted to 5.5 per cent.

In these tests, as with the muffle tests, the rate of calcination was limited by the rate of heat supply.

The lime produced in these tests was hydrated and standard tests were carried out to determine properties of the hydrate.

It was found that the lime hydrated rapidly when little excess water was added, but in the presence of a larger excess, hydration was slow. A chemical analysis of the hydrate is given in Table 4.

Table 4

Composition of Hydrated Lime

		Weight Per cent.
Lime	CaO	69.6
Magnesia	MgO	3.90
Carbon Dioxide	CO_2	not detectable
Water at 100°C	H_2O	nil
Total water	H_2O	23.8
Silica	SiO_2	1.19
Alumina	Al_2O_3	0.28
Ferric Oxide	Fe_2O_3	0.31
		99.08

A fineness test (British Standard 890/1940) was carried out on a sample of the hydrate. This comprises wet screening 100 g on BS No.72 and BS No.170 sieves. Results which show that the sample conformed to the standard are given in Table 5.

Table 5

Fineness of Hydrated Lime

	Weight Per cent.	Permissible Maximum
+ 72	4.0	5
-72 + 170	7.2	10

A complete sizing with the Haultain Infrasizer is given in Table 6.

Table 6

Infrasizing of Dry Hydrate

Nominal size microns	Weight per cent.
+ 63	3.8
-63 + 45	1.8
-45 + 31	1.0
-31 + 22	1.6
-22 + 16	3.4
-16 + 11	0.6
-11	87.8
	100.0

In addition a test for "fluffiness" was carried out which comprised hydrating 20 g of lime with a minimum amount of water to produce a dry hydrate. This was allowed to stand for four hours and the volume measured in a graduated cylinder. A bulk specific gravity of 0.37 was obtained. This was acceptable to the specification.

4. DISCUSSION

Results reported in the previous section may be summarised as follows:

1. The lime sand as mined calcined readily and the rate of calcination under the conditions tested was dependant on the rate of heat supply.

2. Provided that no large excess of water was used, hydration of the lime proceeded readily.

3. A hydrate of good quality was produced.

4. The material fluidised well with air at velocities between about 0.5 and 3.5 feet per second at room temperature.

5. The lime sand was transported in an air stream at room temperature if the air velocity exceeded about seven feet per second.

The lime sand is suitable for calcination and it remains to select equipment for treating the material on an industrial scale.

Vertical shaft kilns are probably the most commonly used type of industrial plant in the lime burning industry (Bowles 1952). Coarse lumps of crushed ore are fed to the top of the shaft and move down through a rising stream of flue gases produced by burning fuel in the lower part of the kiln. Heat consumptions of 5,000,000 B.T.U. per ton of lime produced are common. As this type of kiln treats only coarse lump feed, it is common practice to reject 25 per cent. of the stone as fines (Bowles and Arundale 1956). A further consequence of the coarse nature of the feed is that it is necessary to calcine for prolonged periods at high temperatures to avoid large unburnt cores of limestone. A certain amount of overburning and underburning is therefore unavoidable.

Rotating shaft kilns are also commonly used for burning limestone (Holme 1949). Capital costs are higher than for vertical kilns with equivalent capacities, and fuel consumptions of 8,000,000 B.T.U. per ton of lime are common. The size of stone fed to rotating kilns is usually between about 1/8 inch and 1-1/2 inches, so lime of better quality than that from shaft kilns is produced. Dust losses usually amount to about 10 per cent. of the feed.

These are the two types of industrial equipment commonly used for lime calcination. The fine particle size of the lime sand makes it unsuitable as feed for either type of equipment. If fed to a vertical shaft kiln voidage would not be sufficient to allow the upward flow of flue gases through the charge and the kiln would be inoperable. If fed to a rotary kiln, kiln capacity would have to be reduced by a factor of about six to prevent the charge being swept from the kiln with the flue gases.

A fluid-bed calciner for treating fine crushed material is in operation in Massachusetts U.S.A. Crushed limestone at minus 6 mesh is burnt in a five stage fluo-solids reactor (see Figure 1). with a fuel economy of 5,000,000 B.T.U. per ton of lime and dust losses of 25 per cent. (White and Kinsella, 1952).

Such a reactor could be used to treat lime sands, probably with a fuel consumption of about 5,000,000 B.T.U. per ton similar to plant mentioned above. However plant capacity would be lower by an estimated 50 per cent., this estimate being based on terminal velocities at calcining temperatures which have been calculated from velocity measurements taken at room temperature.

The West Australian Department of Industry is at present investigating the use of a multiple stage fluid-transport system (see Figure 2) for calcining lime sands which are somewhat similar to those occurring at Coffin Bay (Feakes, unpublished date 1958). Lime sands flow co-currently with combustion gases and are separated with cyclones in each stage of the equipment. The overall flow of solids and gases is countercurrent. Some difficulty is being experienced in separating quick lime from flue gases, due mostly to lime adhering to the walls of the cyclone. Developments will be watched with interest.

Fluid-bed reactors are in general characterised by a high degree of internal circulation of solids and gases, resulting in uniformity of temperature and chemical composition throughout the bed. Various types of baffled fluid beds have been proposed by Orochko, Melik-Aknazarov and Poluboiarinov (1957) as a means of reducing internal circulation and so maintaining concentration gradients, mainly to improve reactor performance when high yield is required. A baffled fluid bed reactor of the type shown in Figure 3 could be used for calcination of lime sands.

In the scheme proposed, lime sands flow down through the reactor against a rising stream of gases as in a conventional shaft kiln. By restricting longitudinal circulation with suitably arranged baffles, temperature gradients could be established along the length of the kiln. High thermal efficiencies could result, which would reduce fuel consumption. This in turn would reduce the volume of flue gases produced per unit weight of stone burnt and so increase kiln capacity.

Data from Kelley (1949) and Kubaschewski and Evans (1957) indicate that the maximum thermal efficiency which could be expected from a countercurrent system of this type is about 3,900,000 B.T.U. per ton of lime. Flue gases comprise the bulk of the gases flowing through the kiln, so capacity could be up to 20 per cent. greater in a high efficiency kiln than for a conventional five stage fluid-bed kiln with a heat consumption of 5,000,000 B.T.U. per ton.

Such a reactor would be simple to construct and capital costs should not be high. Labour and fuel costs, two major items in the overall cost of producing lime, should be about the same as for a conventional shaft kiln.

Dust losses of 3 to 5 per cent. have been found when calcining 1000 g charges of lime sand in a small fluid-bed reactor. Losses which would be experienced in a large plant cannot be prodicted. However the lime sand is composed of closely sized, dense, rounded particles, as opposed to the wide range of fractured irregular shapes such as the crushed stone fed to the American fluid-bed kiln. There is therefore a strong possibility that dust losses would be considerably less than the 25 per cent. experienced in America.

In view of the small particle size of the lime sand, calcination temperatures need not exceed about 900°C. Calcination times at this temperature for similar lime sands have been estimated (Feakes, unpublished data 1958) at about one second. Holding times at the calcining temperature in the reactor would be governed by the geometry of the reactor and would probably exceed that necessary for complete calcination. At a temperature of 900°C the result would be complete calcination without overburning.

It is therefore recommended that future work on the project be directed to developing a suitable baffled fluid-bed reactor.

The fuel used would be fuel oil, although it is probable that a suitable grade of coal or coke in pulverised form would be satisfactory.

The suggested investigation would involve determining suitable baffle designs and the optimum shape, size, and number of reactor stages. These data will in turn determine the overall kiln dimensions. Initial tests would be conducted with a reactor about 12 inches in diameter.

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FIGURE.— 1.

FIVE STAGE FLUID BED LIME KILN

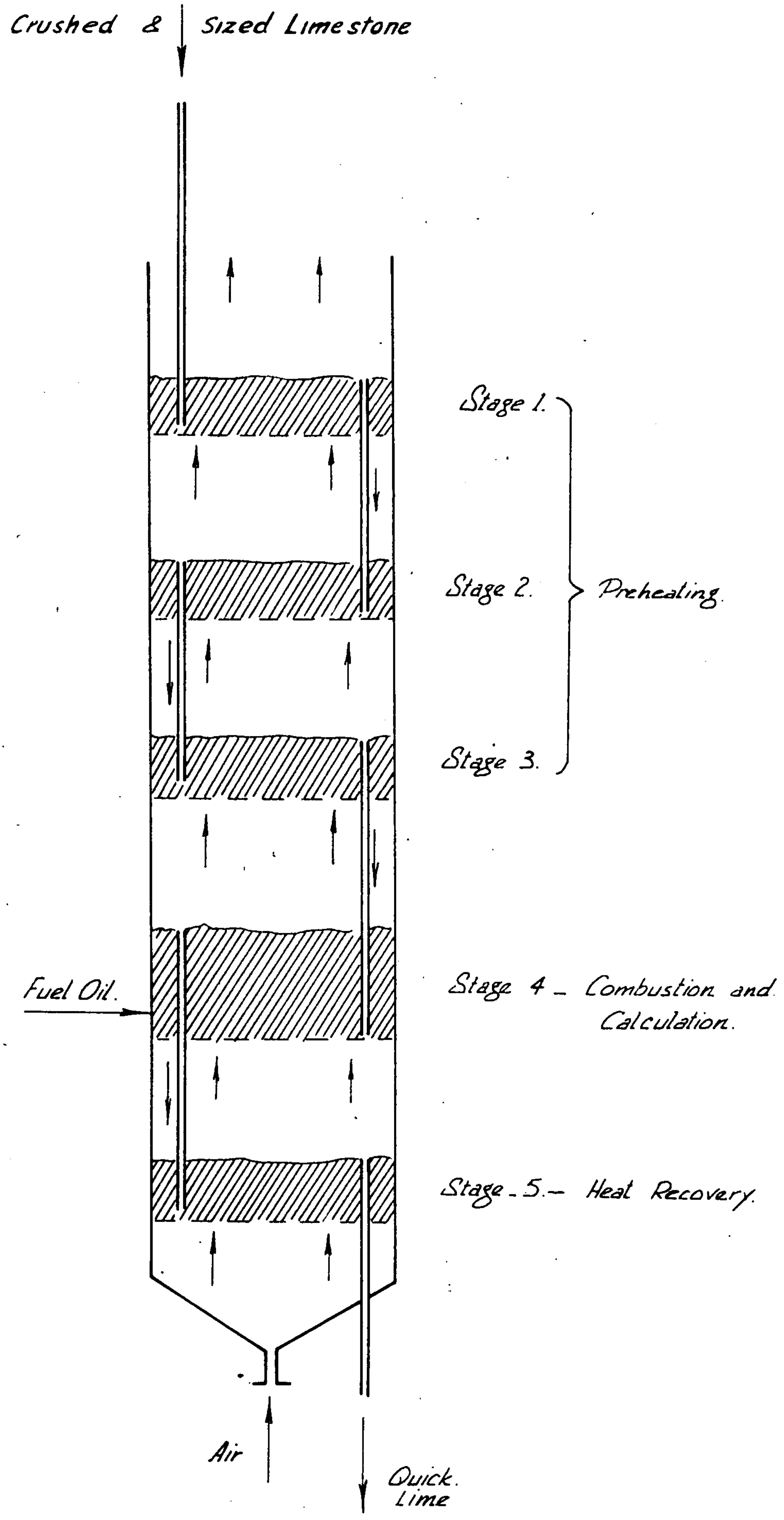

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FIGURE. – 2.

FIVE STAGE FLUID TRANSPORT LIME CALCINATION. SYSTEM

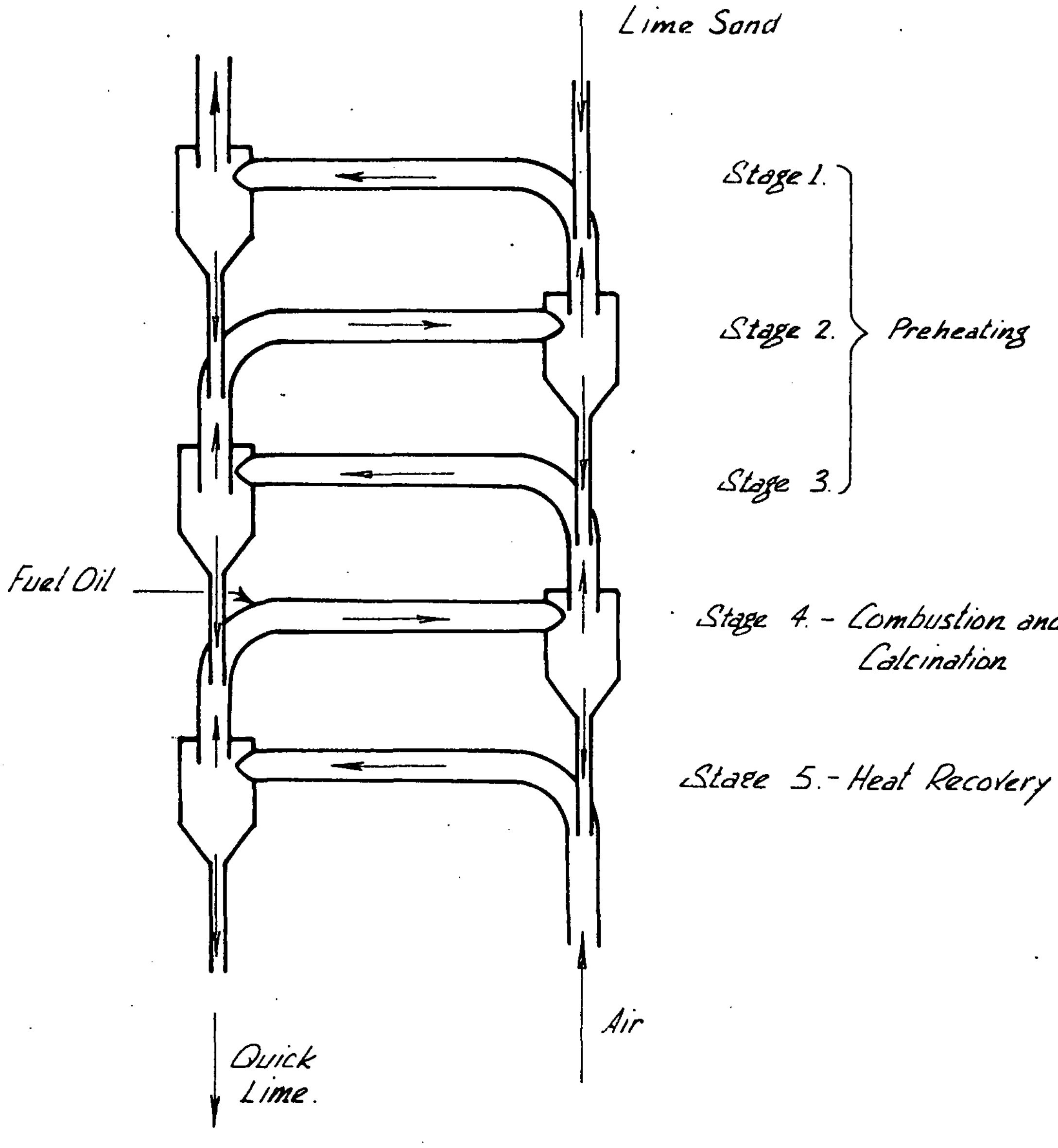

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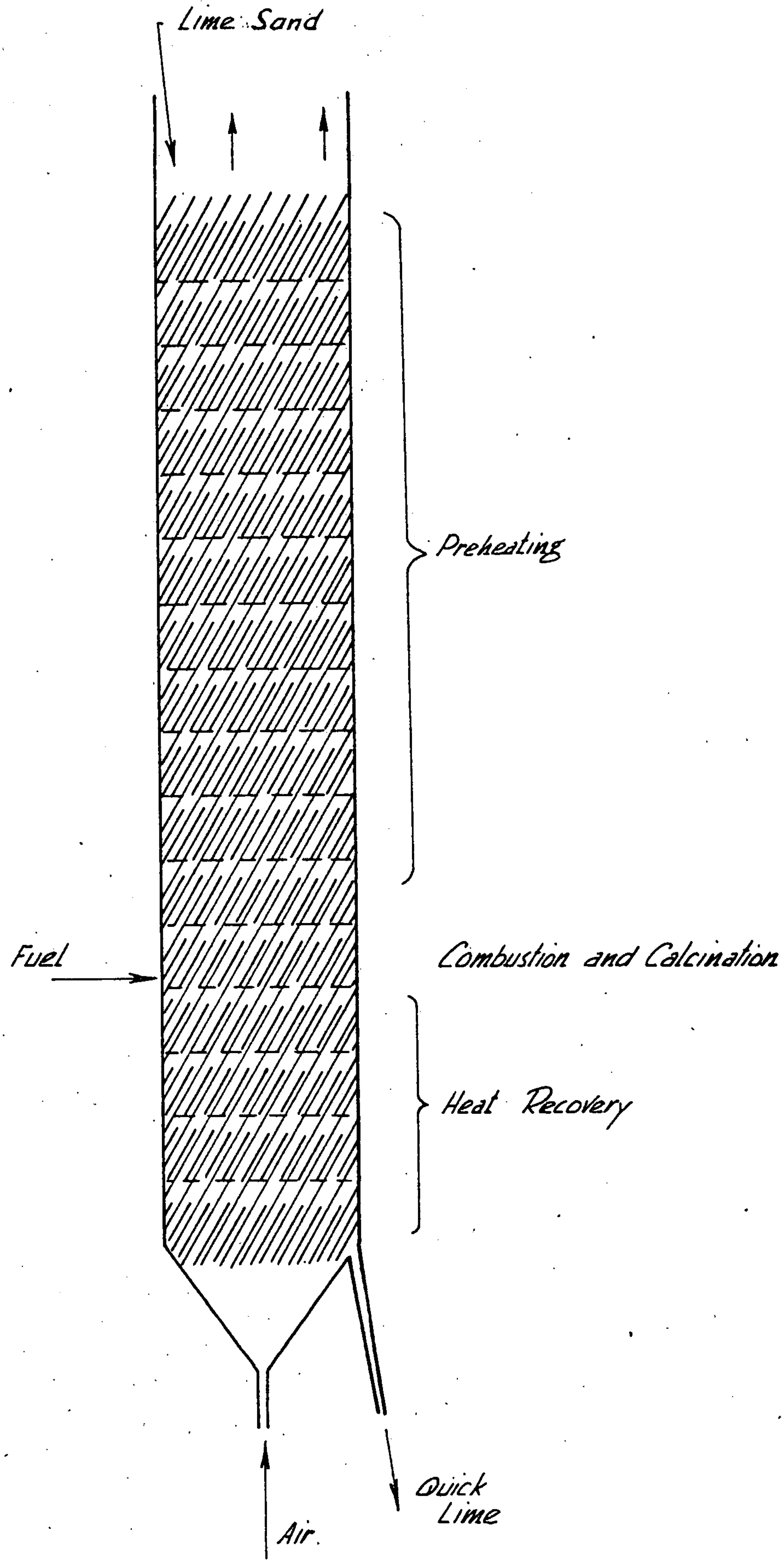
FIGURE.— 3.

BAFFLED FLUID BED LIME KILN



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