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UNITED NATIONS
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ENGLISH

LIME INDUSTRY

XP/GAM/86/039/11-01

THE GAMBIA

Terminal report

Prepared for the Government of the Gambia
by the United Nations Industrial Development Organization

Based on the work of F. Sobek, expert in lime production

Backstopping officer: C. Rydeng, Chemical Industries Branch

V.86-63160
3517T

Explanatory notes

The monetary unit in the Gambia is the dalasi (D).

References to tonnes (t) are to metric tonnes.

ABSTRACT

Following a request by the Government of the Gambia for assistance in the elaboration of a technical study for the establishment of a lime industry, the United Nations Industrial Development Organization (UNIDO) approved the project "Lime industry" (XP/GAM/86/039) in January 1986.

The objective of the mission of the expert in lime production, who was assigned to the project for a total of six weeks, was to establish the technical feasibility of the project and to propose a technology permitting the industrial production of quick lime and hydrated lime using cockle and oyster shells as a raw material.

Once he had ascertained through various prospecting trips that suitable raw material was available in sufficient quantities, the expert elaborated two detailed proposals, one for the immediate setting-up of a small-scale pilot plant equipped with a single-batch kiln and a second for a wood-fired induced-draught shaft kiln with a capacity of 5 t/day, which should be erected as soon as some experience has been gained in the collection of cockle shells, in lime burning on a semi-industrial scale and the selling and distribution of quick lime and hydrated lime, which are expected to substitute to some extent the presently imported cement. According to the expert's calculations, the production cost for one tonne of lime (excluding capital costs) would be about one third of the present retail price for one tonne of cement, a fact which, one may assume with certainty, will lead to a partial substitution of imported cement by locally produced lime.

CONTENTS

INTRODUCTION

The Gambia has no limestone deposits. The local production of lime from oyster shells at an estimated 200 to 300 t/year is insignificant, so that about 20,000 t/year of cement must be imported.

According to a very detailed study of the Canadian Lavalin International, published in October 1983, the country has about 355,000 m^3 of cockle shell reserves from the Nouakchottian transgression which constitute a suitable raw material for the production of quick lime. Although the shells are being used for road construction and for other purposes, the Government is willing to release an appropriate quantity for lime production. The maximum quantity of cockle shells required for road construction and repairs over the next 10 years was estimated at a total of 200,000 m^3.

In view of the availability of the necessary raw material, the establishment of a lime industry, in several stages, could therefore be undertaken, especially since lime could replace cement to a large extent, except where the latter is used for building load-bearing structures. Furthermore, limestone is much healthier than cement for the construction of dwellings for people and animals due to its air-exchanging property.

Following a request by the Government of the Gambia, dated 10 October 1985, for assistance in the elaboration of a study for the establishment of a lime industry, the project "Lime industry" (XP/GAM/86/039) was approved by the United Nations Industrial Development Organization (UNIDO) in January 1986. The lime expert took up his assignment at Banjul on 12 June 1986.

The objective of his mission was, apart from providing evidence of the technical feasibility of the project, to suggest a technology permitting the industrial production of quick lime and hydrated lime from the available cockle shells. The total duration of the expert's assignment was six weeks, part of which was spent on the elaboration of the present detailed technical proposals.

RECOMMENDATIONS

1. The erection of the singl[illegible] pilot kiln, according to the specifications laid down by the expert[illegible] be completed.

2. Subsequently, pilot tests [illegible] cockle shells should be carried out, preferably under the supervis[illegible] of the lime expert who designed the kiln.

3. Should the test results [illegible]cessitate modifications in the kiln technology, these should be conceived a[illegible] implemented, particularly with a view to examine the possibility of a continu[illegible]s operation of that type of kiln.

4. Finally, the proposed [illegible]sign for the 5 tonne/day shaft kiln should be reviewed, and the total inv[illegible]ment cost, including working capital and necessary spare parts, estab[illegible]hed.

I. ASSESSMENT OF COCKLE SHELL RESERVES

To evaluate and assess the cockle shell reserves, and their suitability for lime production, a total of three prospections was undertaken. The district chosen was the area of Dubong, near the town of Bwiam, approximately 100 km from the capital Banjul on the national highway south of the river Gambia.

This district was chosen firstly because the future operator of the lime plant has exploitation rights in that area, and secondly because of the little overburden, the relative thickness of the shell deposit as well as the yield figures of generally 25 to 50 per cent for the dead material surrounding the shells.

A. Prospection in the Dubong area, first section

After visiting a deposit that has already been almost exhausted by the local population and preparing a temporary test pit, as well as inspecting how lime burning is done from oyster shells at two locations set up for the free-burning process, the designated district was visited.

The district of Dubong was localized according to information and maps contained in the report by Lavalin International of October 1983 (volume 2, appendix I, pp. 1 and 2).

It was decided to prepare some new test pits, at locations which correspond to test pits previously prepared by Lavalin. All new test pits were dug in the south-north direction. However, as the north arrow on the Lavalin test pit map (reproduced in figure I) deviates approximately 40° east from the actual north, it was difficult to identify the exact location of some old test pits, as can be seen in the following table.

Location of new and old test pits

New test pit No.	Lavalin test pit No.	Depth a/ (m)	Overburden a/ (m)	Shell stratum a/ (m)	Yield a/ (per cent)
1	26	1.4	0.3	0.6	25
2	35	1.8	0.3	1.2	35
3	36	1.5	0.2	1.2	30
4	49	1.6	0.2	1.2	50
5	50	1.6	0.9	0.3	50
-	48	-	-	-	-
6	52	1.5	0.3/0.6	0.6/1.2	-
-	47	-	-	-	-

a/ Data from the report of Lavalin International.

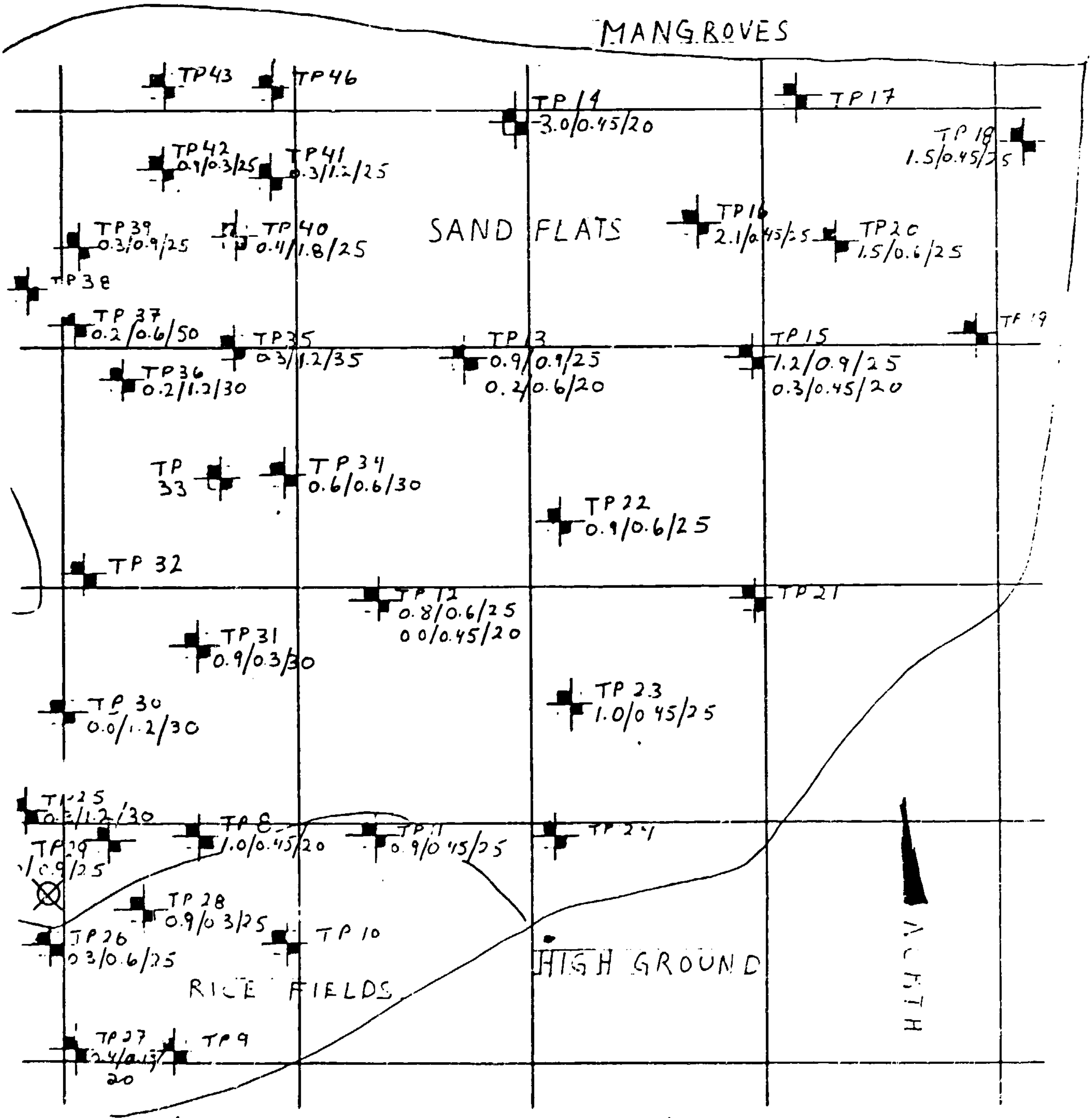
The result of the prospecting was as follows:

(a) New test pit No. 1 was dug to a depth of 1.5 m; the yield corresponds to Lavalin's figure of about 25 per cent. No samples were taken;

Figure I. Test pit map, Dubong

LAVALIN INTERNATIONAL INC.
RECORD OF FIELD EXPLORATION
ASPHALT AGGREGATE SEARCH
THE GAMBIA FIRST HIGHWAY MAINTENANCE PROJECT

SITE: Dubong - 1st section



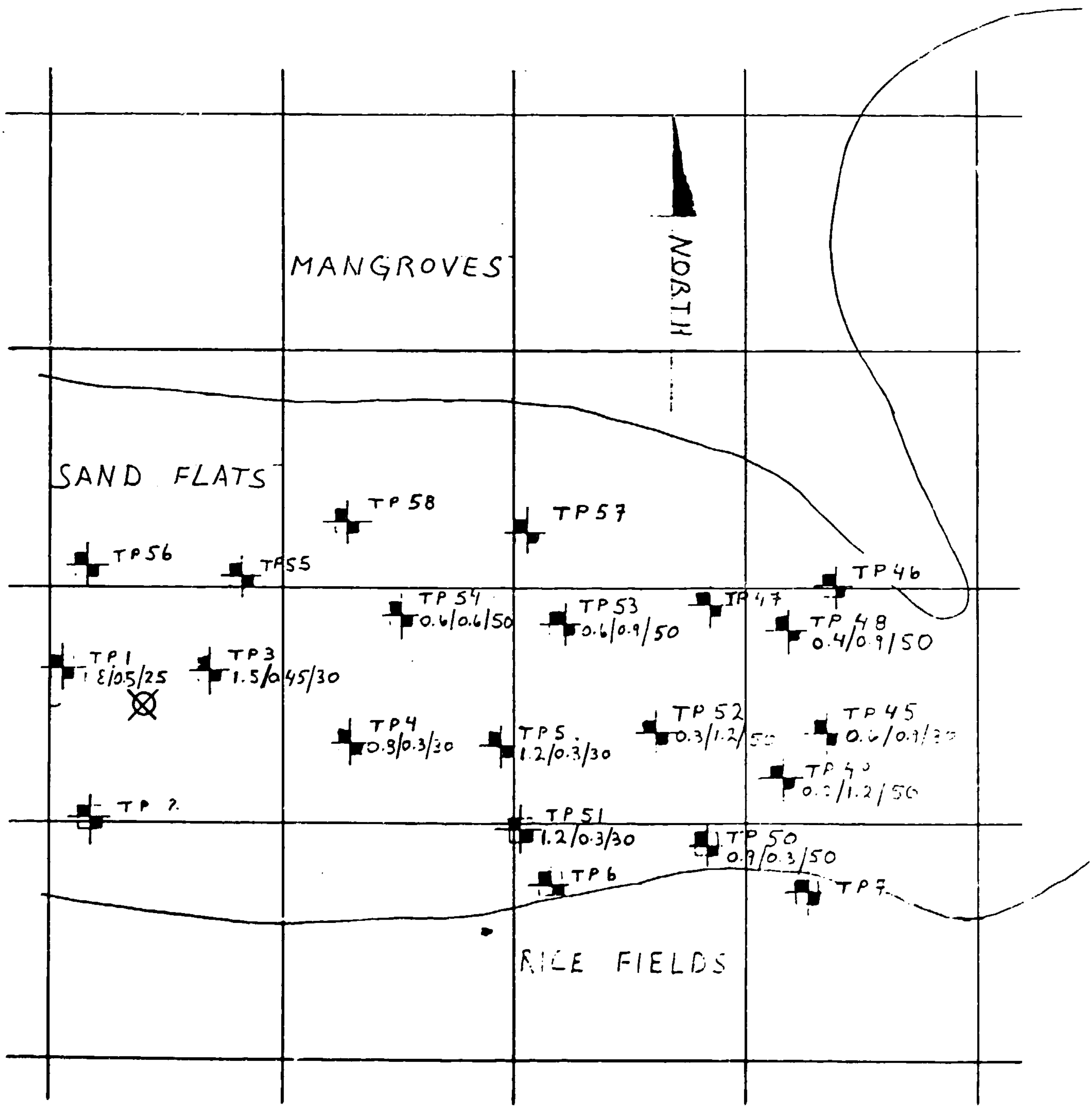
LEGEND: TEST PIT
AUGER HOLE
REF. POINT

EXAMPLE: TP 213 — TEST PIT #213
0.9/0.5/20
% YIELD
THICKNESS OF SHELL STRATUM
THICKNESS OF OVERBURDEN

Figure I (<u>continued</u>)

LAVALIN INTERNATIONAL INC.
RECORD OF FIELD EXPLORATION
ASPHALT AGGREGATE SEARCH
THE GAMBIA FIRST HIGHWAY MAINTENANCE PROJECT

SITE: Dubong - 1st section



LEGEND: TEST PIT
AUGER HOLE
REF. POINT

EXAMPLE: TP 213 — TEST PIT #213
0.9/0.5/20
% YIELD
THICKNESS OF SHELL STRATUM
THICKNESS OF OVERBURDEN

(b) New test pit No. 2 was to be dug to a depth of 1.8 m, but then stopped at 1.2 m. It can therefore be assumed that the shell stratum is still deeper. As opposed to Lavalin, the thickness of the overburden is not 0.3 but 0.6 m. The shells are embedded in sandy clay. A sample was taken;

(c) New test pit No. 3 was dug to 1.5 m as specified. Contrary to Lavalin, the overburden layer is not 0.2 but 1.2 m. The shell stratum was not dug under and thus its thickness not determined. A sample was taken;

(d) New test pit No. 4 was dug to 1.6 m as specified. The shell stratum starts directly under the surface and is about 1 m thick. Lavalin's details could be verified. The yield of 50 per cent according to Lavalin is also correct;

(e) New test pit No. 5 was dug to about 1.5 m. All details of Lavalin could be confirmed. A sample was taken;

(f) New test pit No. 6. The identification of Lavalin test pit No. 52 proved difficult. The pit was dug to a depth of 1.8 m, but no shell stratum was found.

In order to obtain a representative sample (quality and piece size), the yield of the single-test diggings was subjected to a flotation process and then brought back to the locality.

A series of photographs showing the new test pits in the Dubong area are reproduced in figure II.

Résumé of the prospections in the Dubong district

There is no doubt that there are cockle shell deposits in this district. In contrast with the usual deposits of natural (settled) rock strata in moraine, nappe etc., these deposits show a more heterogeneous structure.

The former ocean bed does not indicate larger agglomerations, because in the district concerned, soil elevations and saggings have disappeared through erosion. The search for localities can therefore only be accomplished by systematically laying out a network of test pits.

B. Prospection in Jiffet and Mbangkama

Jiffet was described by Lavalin International in volume II, appendix I. A total of 27 test pits was registered, which are indicated on the test pit map, reproduced as figure III. This district is considered a "man-made cockle shell deposit" (see Lavalin report, volume I, section 1.1.1.2).

During the prospecting work it was possible to visit well-kept test pits, and it was ascertained that the Lavalin details correspond fully to the actual situation. The shell stratum is 1 to 1.5 m thick, is immediately at the surface and ought to give a yield of 60 per cent. The deposit has evidently been manually collected (see figures IV and V). The cockle shells are generally smaller than in the Dubong area, i.e. of a size of 1.5 to 3 cm (see figure VI). The traditional method of free-burning of lime is shown in figure VII.

The shells can be transported via goods-carrying barges on the river Bolon.

Figure II. New test pits, Dubong

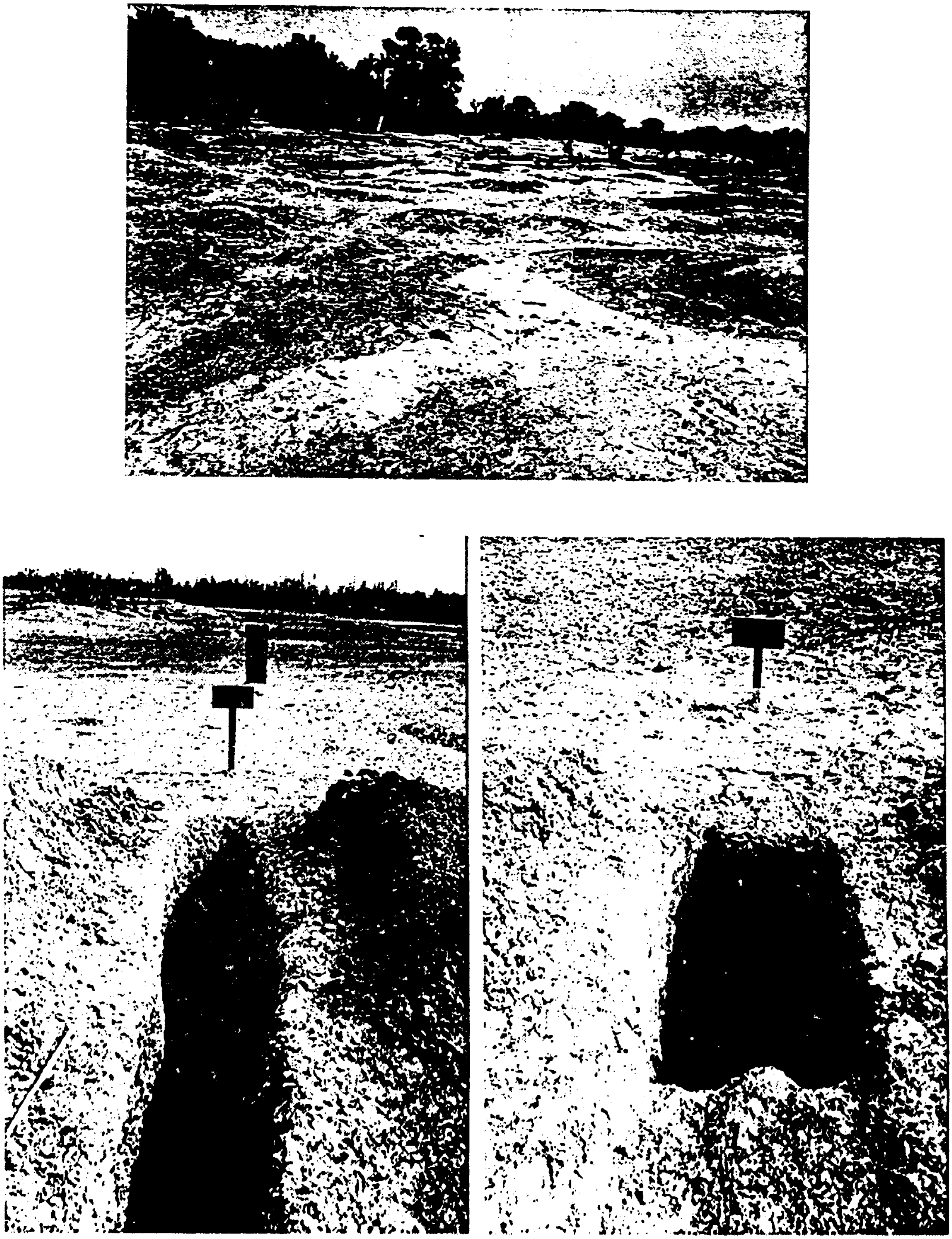


Figure II (continued)

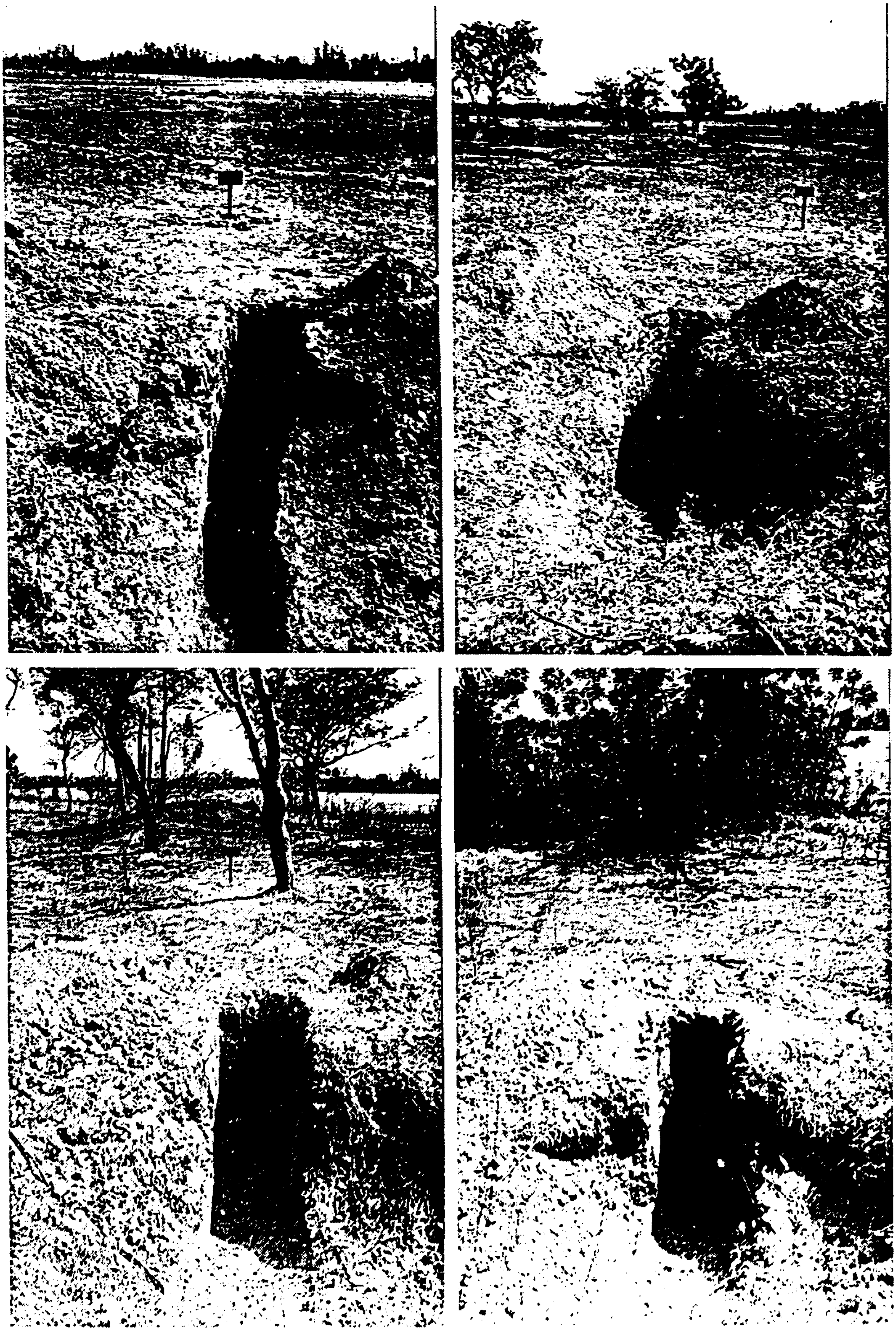
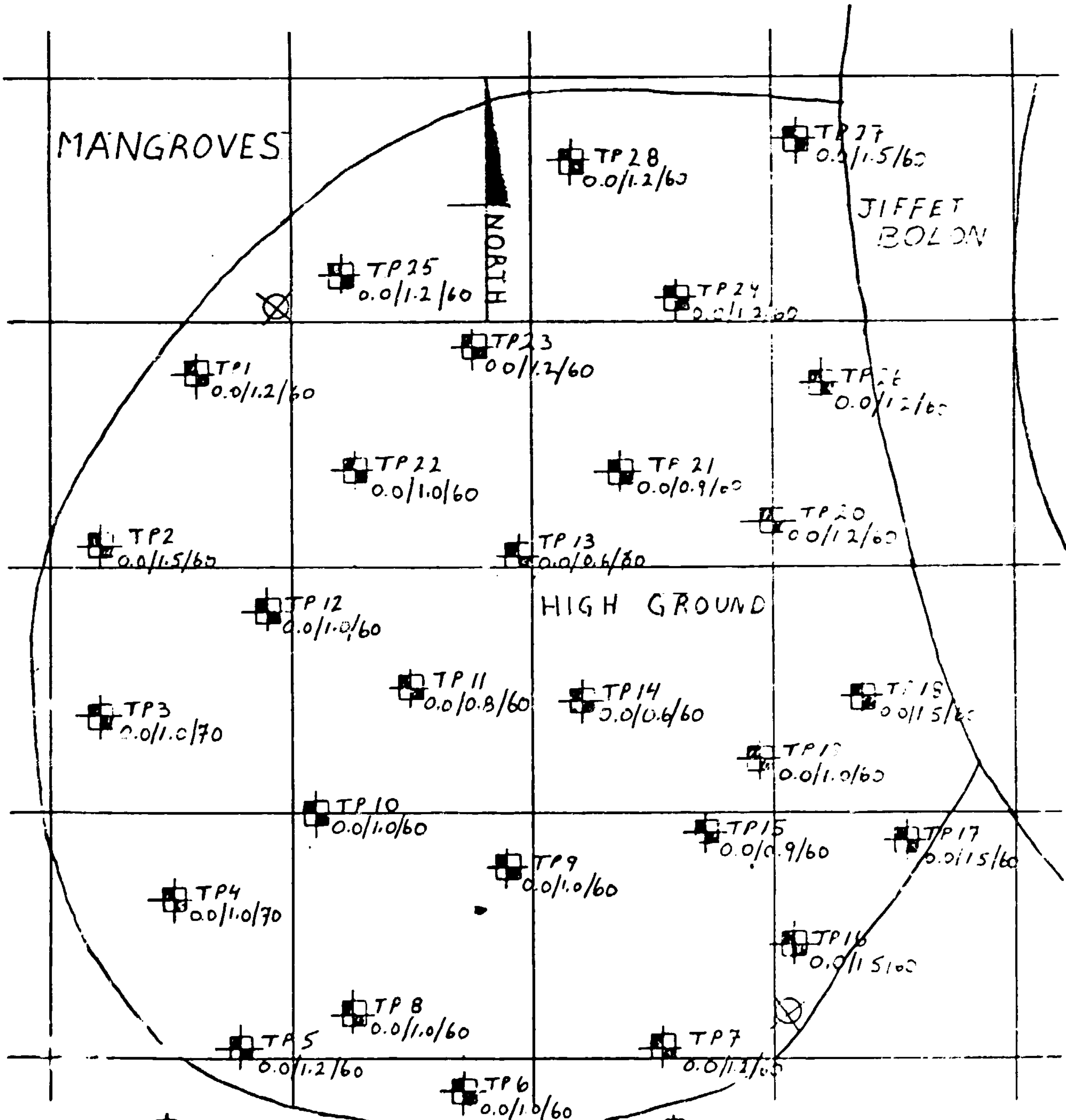


Figure III. Test pit map, Jiffet

LAVALIN INTERNATIONAL INC.
RECORD OF FIELD EXPLORATION
ASPHALT AGGREGATE SEARCH
THE GAMBIA FIRST HIGHWAY MAINTENANCE PROJECT

SITE: JIFFET



LEGEND: TEST PIT
AUGER HOLE
REF. POINT

EXAMPLE: TP 213 — TEST PIT #213
0.9/0.5/20
└ % YIELD
THICKNESS OF SHELL STRATUM
THICKNESS OF OVERBURDEN

Figure IV. Typical man-made pile of oyster and cockle shells, Jiffet

Figure V. Oyster and cockle shells, Jiffet

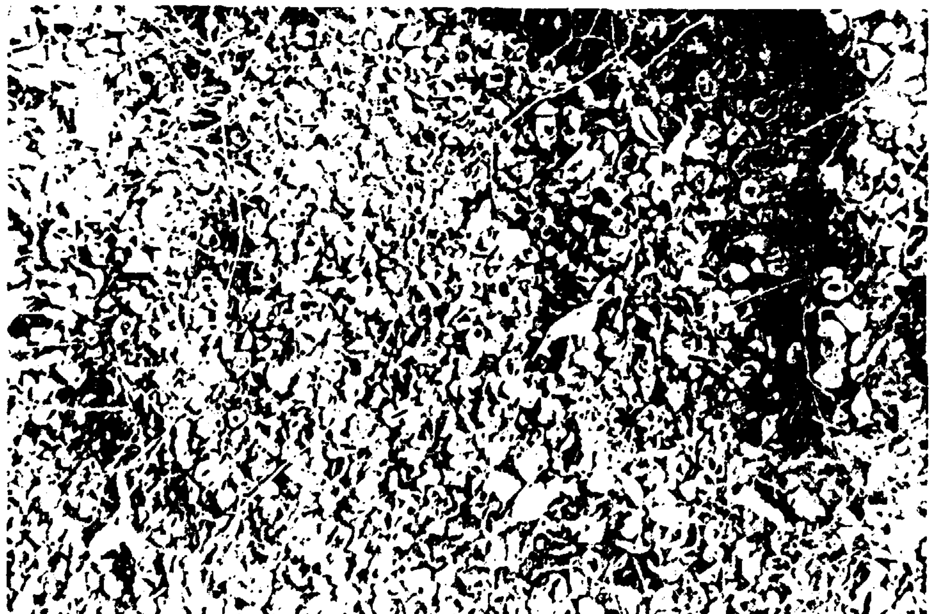


Figure VI. Washed cockle shells

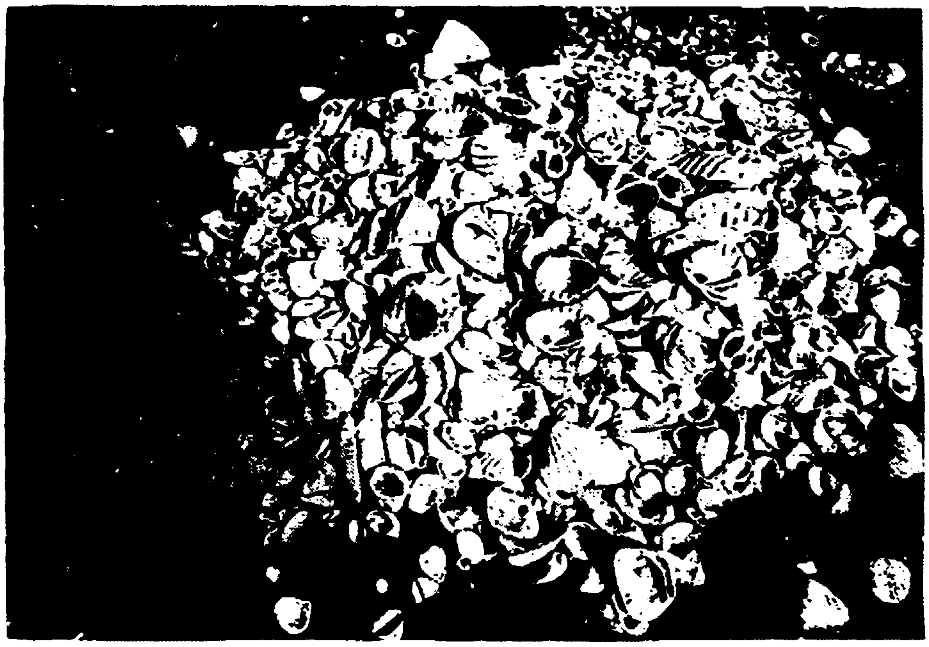


Figure VII. Lime burning from oyster shells

Lavalin did no prospecting work in Mbangkama, which is about 5 km as the crow flies north/north-east of Barra, located directly on a navigable river branch. This is evidently also an artificial deposit with similar characteristics as that in Jiffet.

In both deposits the percentage of oyster shells was overestimated at 30 per cent.

II. PROCESSING OF COCKLE SHELLS INTO QUICK LIME AND HYDRATED LIME

A. Determination of the bulk specific gravity and percentage of voids in the cockle shell fill

The assumption that the shape of the cockle shells would give rise to aerating problems in a conventional shaft kiln proved to be erroneous. The fact that the cockle shells are not only stacked in shell form, i.e. dish in dish, in the kiln, but also in their original form, i.e. shell edge on shell edge, and frequently also back to back, gives a free space-to-solid ratio of 1.55 : 1 or 64 per cent voids in the fill, as determined by a test.

For the purpose of designing the calcining kilns and for reasons of calculation, the bulk specific gravity and percentage of voids of the samples was exactly determined by the expert in the laboratory of Citroproducts (Gambia) Ltd.

Determination of bulk specific gravity

$$\frac{\text{Weight of cockle shells}}{\text{Volume of full vessel}} = \frac{13.695\ \text{kg}}{14.00\ \text{l}} = 0.978$$

Thus, the weight of one cubic metre of cockle shells is about 1,000 kg.

Determination of the percentage of voids

The test was carried out in a vessel having a capacity of 14 l, by filling the vessel to the rim with shells of representative average size and then filling it to the rim with water, the quantity of which was measured and related to the volume of the cockle shells.

14 l cockle shells : 9 l water = 1.55 : 1
or 64.28 per cent.

The percentage of voids in the fill is therefore 64 per cent.

B. Determination of a suitable kiln

In view of the average thickness of the shells of 4 to 10 mm and their hardness, they would lend themselves for processing in a conventional shaft kiln of adequate dimensions.

The original idea of proposing a batch-type (zig-zag) calcining kiln (see figure VIII) was dropped, because that kiln cannot be fired with wood, whilst in a conventional shaft kiln firewood, which is advantageous in the calcining process and easily available at a reasonable price, can be used as a fuel.

Various sizes of the proposed shaft kiln have been successfully tried several times, with a different number of furnaces and fuel material. However, the use of cockle shells in such a kiln, in conjunction with a just under-stoichiometric combustion of wood for firing, is an innovation, and only a pilot project should it be implemented in the first instance in order to determine the efficiency of the technology.

Apart from the injector chimney system which produces an induced draught, the fireproof material for the shaft and the furnaces and a small number of simple measuring instruments, all of the other material required to construct the kiln could be purchased and assembled locally.

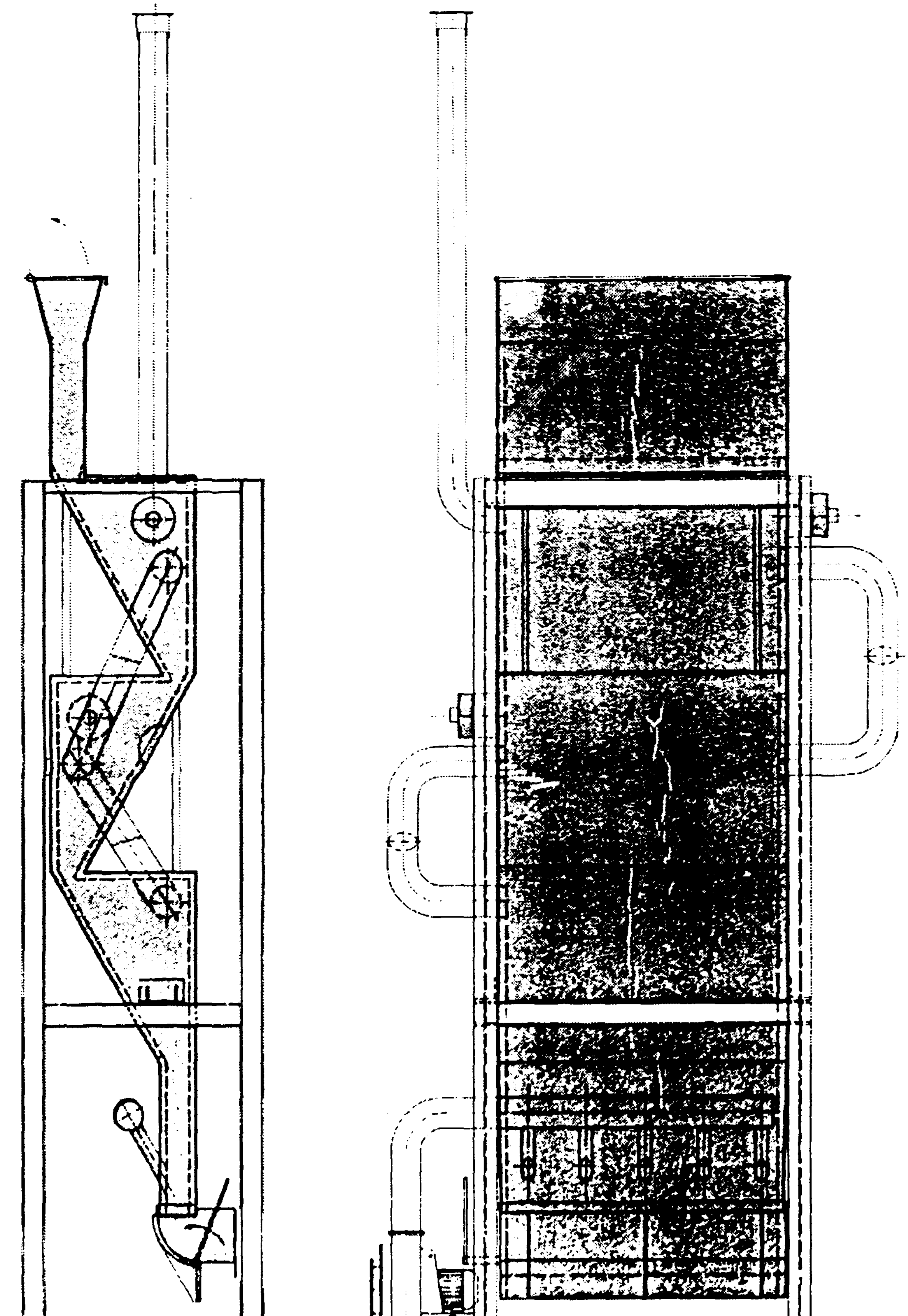


Figure VIII. Batch-type (zig-zag) calcining kiln

Although lime is already being produced from oyster shells in various places in the Gambia by a free-burning process using wood, and the method is thus familiar, one cannot consider that lime as a substitute for cement. Therefore, the site of the kiln to be erected after the efficiency of the technology has been established in pilot tests, has been carefully adapted to the existing conditions, i.e. with an output of 1,500 t/year during the first stage of the project, the kiln would produce 5 t/day during 300 working days per year. A detailed description of that kiln is given in chapter IV.

According to his job description, the expert was also required to present drawings and specifications for a small-scale pilot plant for the production of lime.

In co-operation with the Industrial Development Unit of the Ministry of Economic Planning and Industrial Development, it was decided to set up a single-batch pilot kiln with a volume of 1 m^3. The possibility of erecting and operating such a kiln immediately constitutes a technological development which closes the gap between the customary free-burning of oyster shells in the Gambia and an industrial lime production.

This kiln already features industrial characteristics and was laid out according to the expert's calculations. Detailed specifications and drawings are given in chapter III. Apart from the injector blower, the kiln can be completely manufactured from local materials.

C. Market requirements for locally produced lime

It was ascertained that the lime produced locally from oyster shells by the free-burning process has virtually no significance for building purposes, i.e. for the manufacture of masonry and plaster mortar.

The lime which is sold in 50-kg jute or plastic bags by private manufacturers directly to private customers is being produced by manual dry slaking and costs D 12 per bag, or about D 240 per tonne. It is mainly used for the white-washing of walls and as a disinfectant.

There is a large number of private firms who handle medium-sized and larger buildings, either independently or for third parties, and it should be easy to convince them to replace cement by lime, in view of the fact that the retail price of cement is D 700 to 800 per tonne.

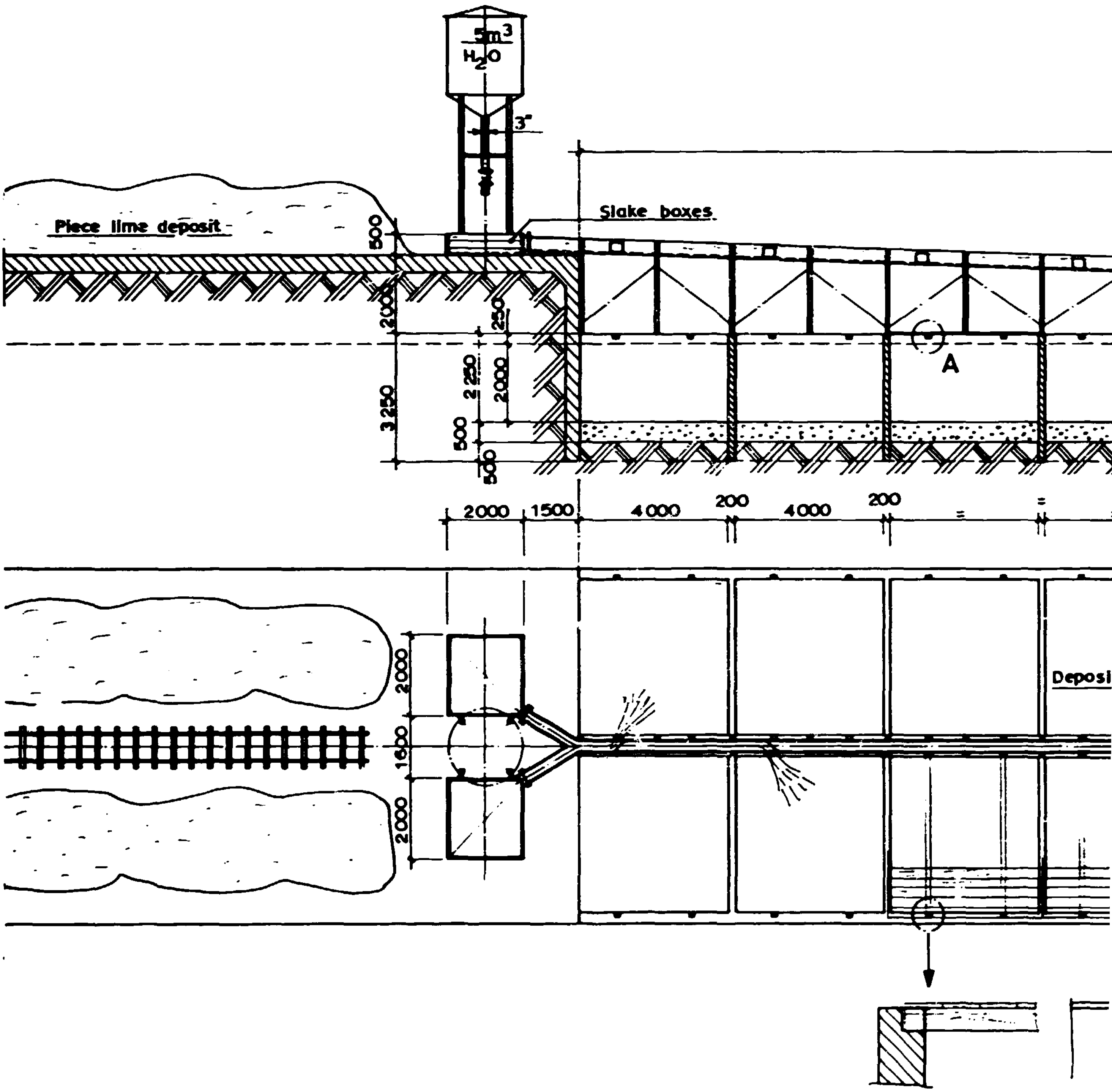
The production cost of D 217.56 per tonne, excluding capital costs, determined in chapter IV, can be regarded as being so low that, even in the case of unfavourable financing conditions and considering the high interest rates for loans in the Gambia, a successive substitution of imported cement by lime for non-supporting masonry can be anticipated.

D. Proposals for the further processing of quick lime

The production of dry-slaked hydrated lime (hand-slaking process) is well known in the Gambia.

The advantages of wet-slaked "Vienna" lime were explained in detail to all involved as well as the conditions for the construction of slaking pits.

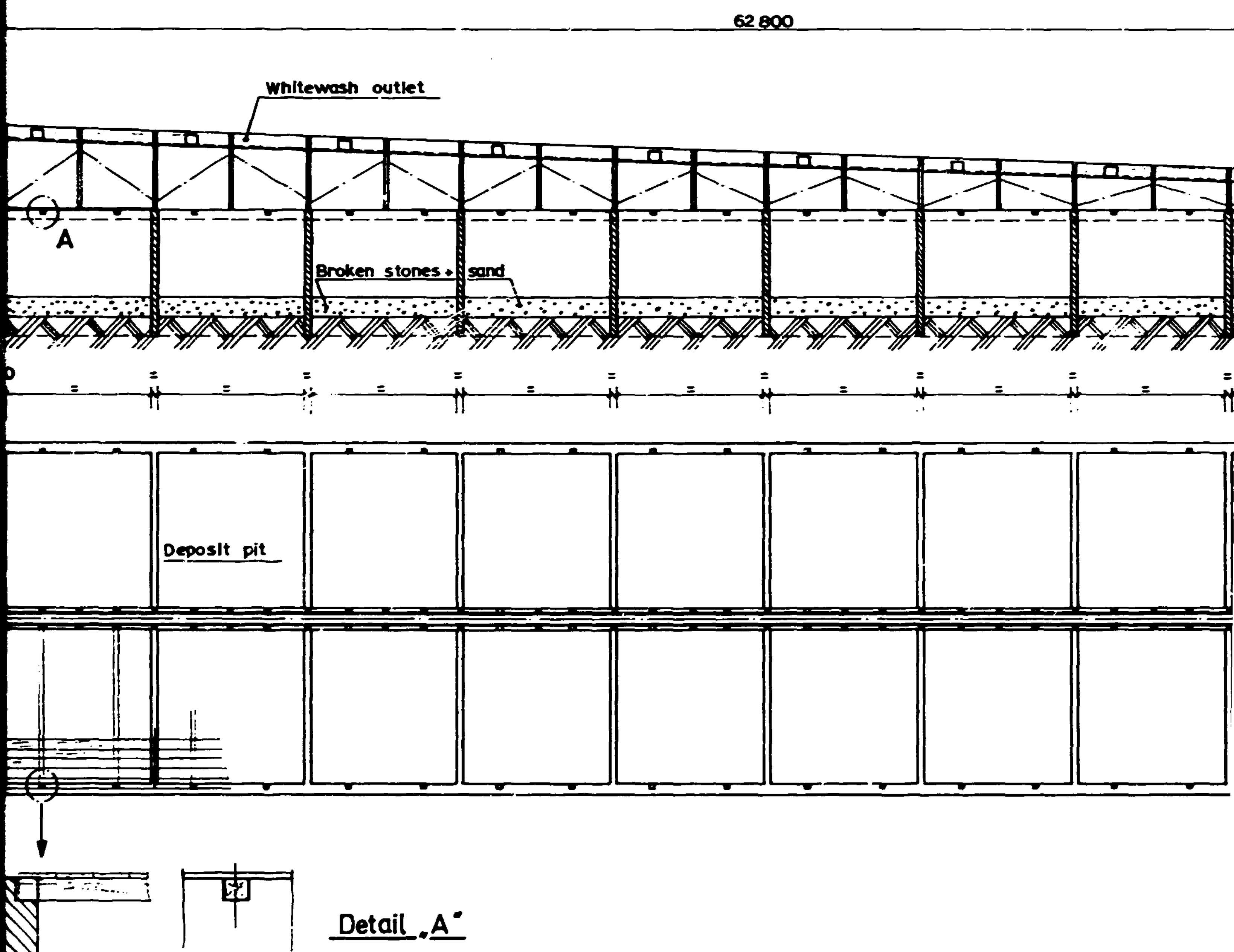
The lay-out of a wet-slaking plant, which can certainly be set up in the Gambia, is shown in figure IX.



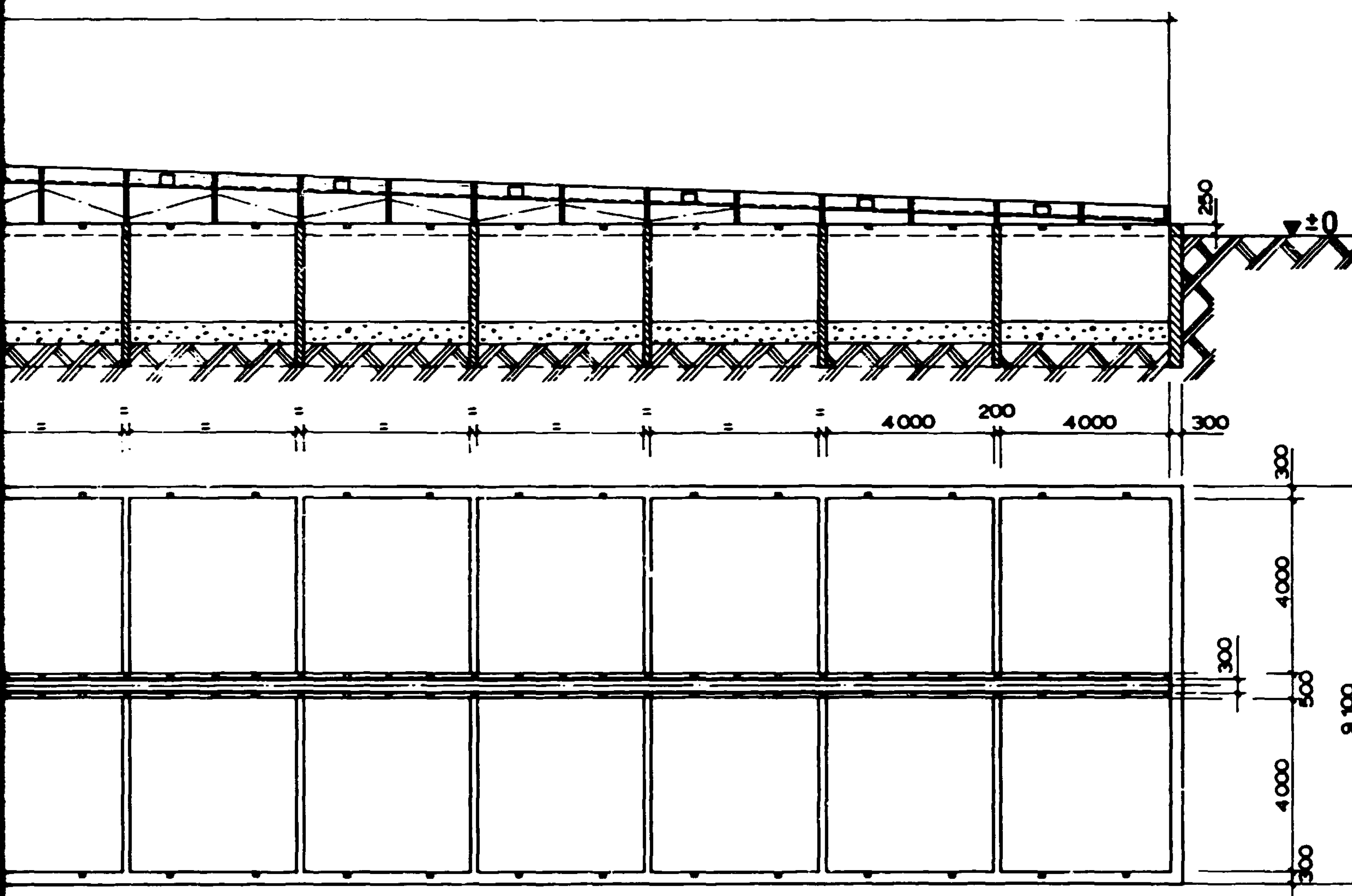
5m3
H2O
3"
Piece lime deposit
Slake boxes
A
500
2000
250
2250
2000
3250
500
500
2000
1500
4000
200
4000
200
2000
1600
2000
Deposi

SECTION 1

Figure IX. Wet-slaking plant for lime



SECTION 2



SECTION 3

III. SINGLE-BATCH PILOT KILN

A. Technical specifications

Diameter	$\phi = 0.8$ m
Section	$S = 0.5$ m^2
Height	$H = 4.0$ m
Volume	$V = 1.0$ m^3
Specific weight	$\gamma = 1.0$ t/m^3
Content	$C = 1.0$ t
Fire wood	3,700 kcal/kg
CO_2 max.	20.5%
λ	1.8
Nm^3/kg	8.5
Fuel consumption	2,000 kcal/kg

Fuel consumption $\dfrac{1{,}400 \text{ kg x } 2{,}000 \text{ kcal}}{3{,}700 \text{ kcal}}$ = 757 kg wood

Exhaust gas from burning process
8.5 Nm^3/kg   8.5 x 757   = 6,435 Nm^3

Exhaust gas from deacidification process

$$\frac{1{,}400 \text{ kg shells x } 40\%}{100} = \frac{560 \text{ kg } CO_2}{1.97} = \frac{284 \text{ Nm}^3}{6{,}719 \text{ Nm}^3} =$$

$$= \frac{6{,}719 \text{ Nm}^3}{11 \text{ h}} = 610 \text{ Nm}^3$$

$$\frac{273 \text{ K} + 180 \text{ °C x } 610 \text{ Nm}^3}{273 \text{ K}} = \frac{1{,}012 \text{ Bm}^3\text{/h}}{3{,}600 \text{ sec.}} = 0.28 \text{ Bm}^3\text{/sec.}$$

Capacity of blower motor:

$$P = \frac{Q \times \Delta p}{102_n}$$

$$P = \frac{0.28 \times 250 \text{ mm WC}}{120 \times 0.4} = \frac{70}{40.8} = 1.71 \text{ kW}$$

Burning time compared with sinking speed in the shaft kiln:

$$\frac{5{,}000 \text{ kg/24 h}}{24 \text{ h}} = 208 \text{ kg/h} \approx 200 \text{ kg} = 0.20 \text{ m}^3$$

$$\frac{7 \text{ m}}{3 \text{ zones}} = 2.3 \text{ m x } 0.5 \text{ m}^2 = \frac{1.15 \text{ m}^3}{0.20 \text{ m}^3} = 5.75 \text{ h}$$

Burning time	$\approx$ 6 h
Estimated preheating time	$\approx$ 5 h
Duration of charge without cooling time	$\approx$ 11 h
Speed of exhaust gas	0.42 m/s

Speed of exhaust gas in annular gap	2.6 m/s
Speed of injected air	35.8 m/s

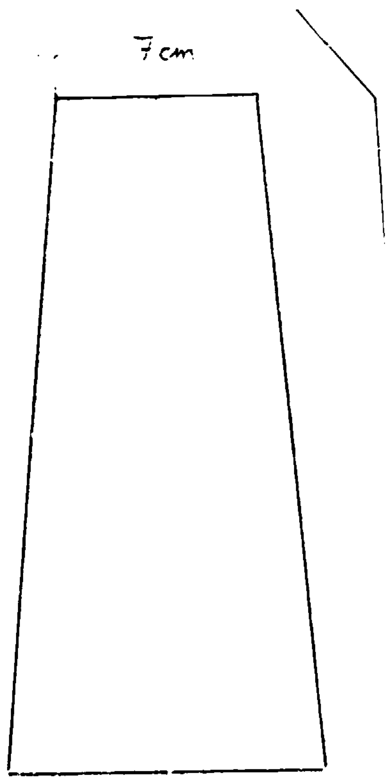
Calculation of arch-bricks (11 x 5 x 23 cm) for the lining of the batch kiln, consisting of locally produced red bricks

U_i = ϕ 0.80 m
D x π 0.80 x 3.14 = 2.513 m

U_a = ϕ 0.80
0.23
0.23
1.26 1.26 x 3.14 = 3.958 m

$\frac{3.958\ m}{0.11}$ = 35.98 = 36 pieces

$\frac{2.513\ m}{36}$ = 0.0698 m = 7 cm



1 : 25

Calculation of arch-bricks (11 x 5 x 23 cm) for the outer wall of the batch kiln, consisting of locally produced red bricks

U_i = ϕ 1.66 m

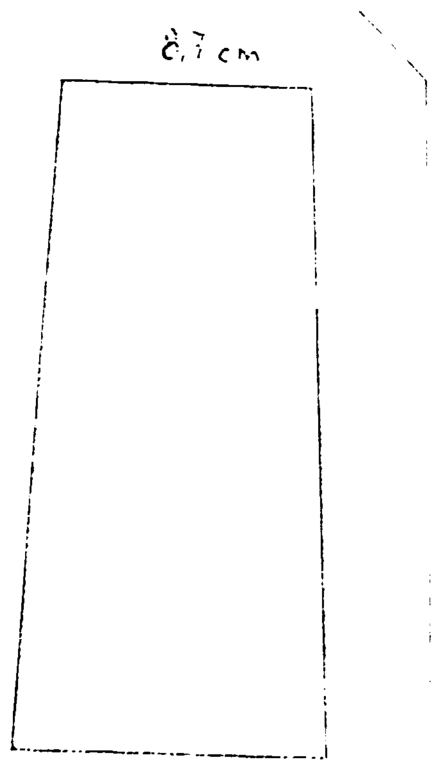
D x π 1.66 x 3.14 = 5.215 m

U_a = ϕ 2.12

2.12 x 3.14 = 6.660 m

$$\frac{6.660\ m}{0.11} = 60.54 = 60 \text{ pieces}$$

$$\frac{5.215\ m}{60} = 0.0869\ m = 8.7\ cm$$



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Detailed technical drawings showing a cross section of the batch kiln, details of its labyrinth and the waste gas equipment are reproduced as figures X, XI and XII.

Figure I. Cross section of batch kiln

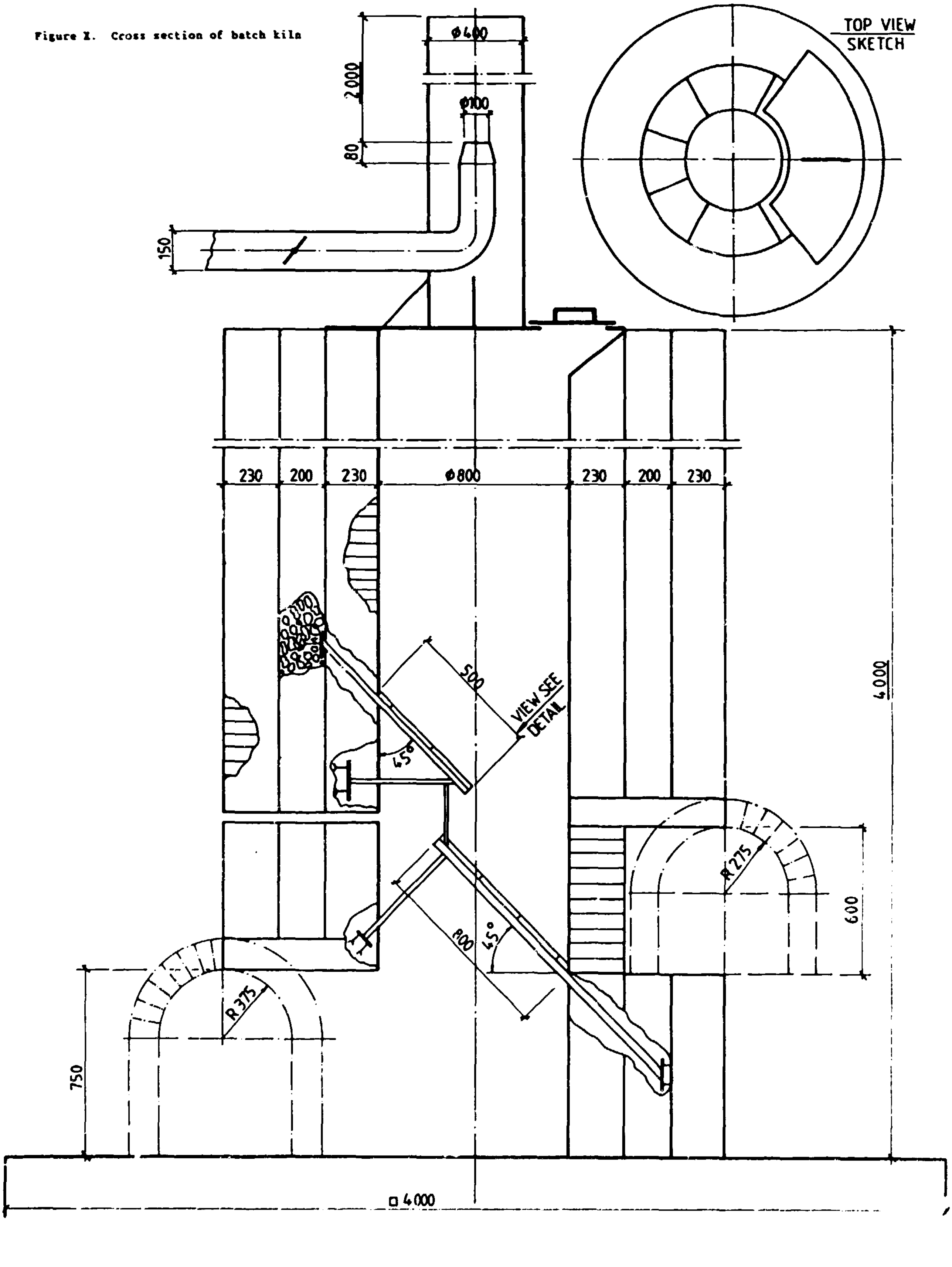
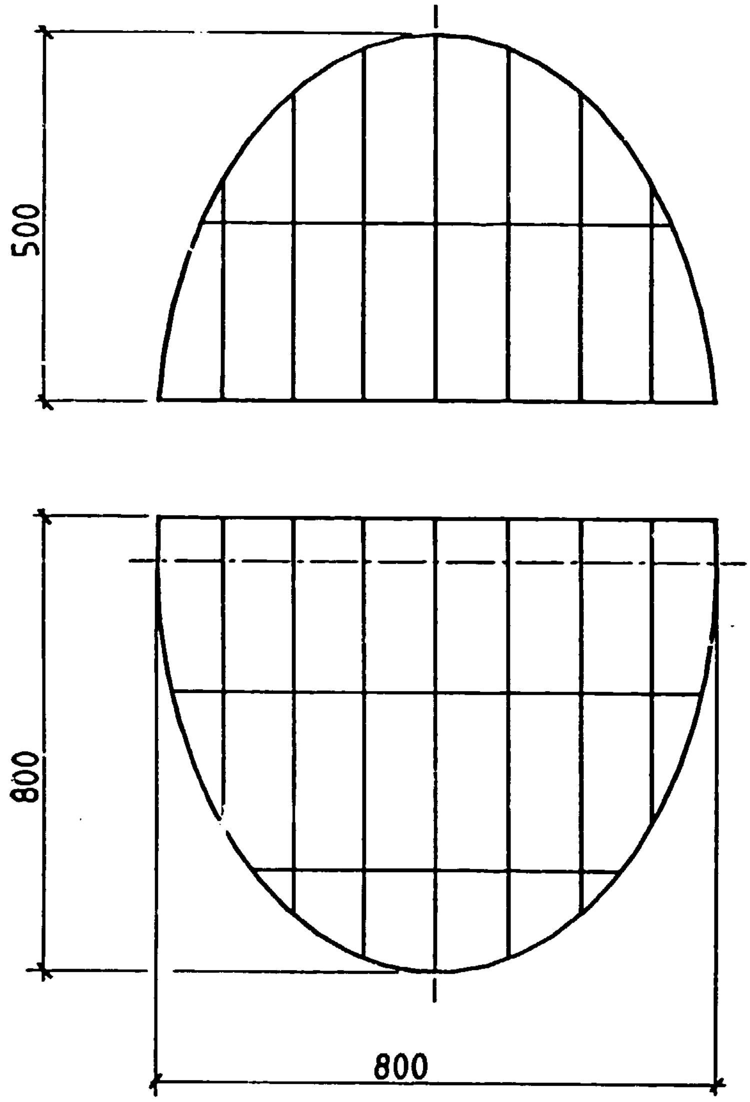
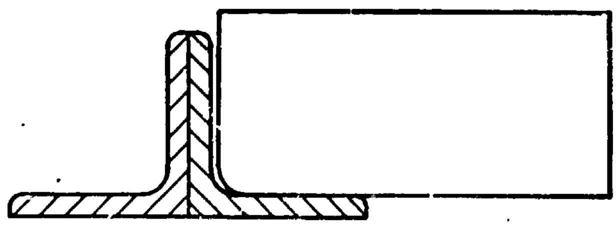


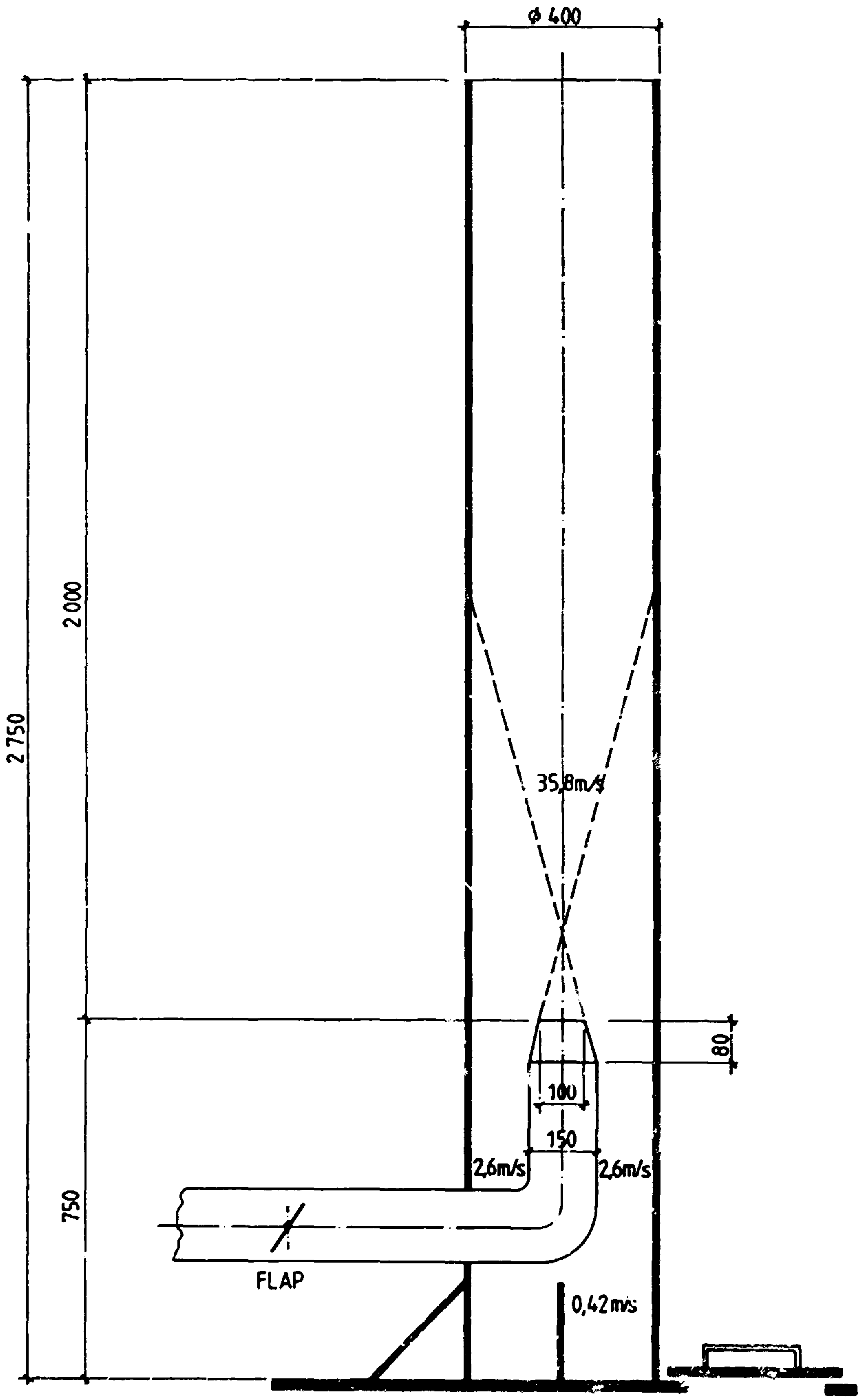
Figure XI. Details of labyrinth of batch kiln





TYPICAL SECTION

Figure XII. Exhaust-gas equipment (injection system) for batch kiln



B. Material requirements

Foundation

Round, diameter 4 m, height 1.2 m = 15 m^3 concrete, consisting of
1 part Portland cement 225 and 3 parts clean ballast (cockle shells)
Total dry weight about 4,000 kg
Reinforcement in upper half:
Main braces, 20 mm ϕ
Connecting braces, 10 mm ϕ, lashed with 3-mm iron wire
Total weight about 800 kg reinforced steel

Arch-bricks for outer wall

80 layers of 60 bricks each = 4,800 bricks (11 x 8.7 x 5 x 23)

Arch-bricks for lining

80 layers of 36 bricks each = 2,880 bricks (11 x 7 x 5 x 23)

Outer wall to be built with cement mortar.
Lining to be built only with clay.
Insulation of crushed bricks, plus 1/3 cement and 2/3 clay.

Structural steel components made from sheet steel

Chimney plate, 10 mm
Charging cover, 10 mm
Gusset plates, 10 mm
Chimney, 3 mm
Injector line and nozzle 2-3 mm

Angle iron, 50 x 50 x 5 mm, with 20 mm grate to receive bricks
T or U iron, 50 x 50 x 5 mm 5 m anchors
Hoop iron for shaft bonding
Flat iron, 5 x 50 mm (better 7 x 70 mm)

C. Construction costs

The estimated costs for the construction of the pilot kiln according to material lists, current local prices and European prices for the imported part are given below.

	Dalasis
Foundation	18,000
Bricks	2,400
Insulation	500
Masonry work	700
Grate framework	1,100
Injector system and chimney	1,500
Blower, imported, CIF	8,250
Cables, plugs etc.	850
Boom with buckets and rope	200
	33,500

IV. WOOD-FIRED INDUCED-DRAUGHT SHAFT KILN FOR FIVE TONNES/DAY

A. Technical specifications

Inside shaft diameter	0.8 m
Usable shaft height	7.0 m
Cross section of shaft	0.5 m^2
Specific cross section output	10 t/m^2 in 24 h
Effective kiln capacity	5 t/day

Kiln design

The foundation work will consist of a steel-reinforced concrete slab laid out to suit the existing ground structure.

The shaft will be made of locally produced bricks with insulating material consisting of a mixture of crushed bricks, clay and cement. The working lining consisting of refractory arch bricks, having an Al_2O_3-content of 40 to 60 per cent, will be imported as will be the working lining of the two furnace chambers facing each other.

In order to prevent penetration of secondary or additional air, the kiln will be provided with a 2-mm sheet-steel jacket; the same applies to the two furnace chambers resting on a supporting structure.

The furnace platform, located on a special supporting structure, will consist of sectional steel with grid or bulb plates placed on top.

The charging platform, of the same structure as the furnace platform, will carry the pulley block for the charging winch as well as the injector air-blower with drive motor, chimney and charging funnel with cover.

At ground level (+/-0) two discharging holes for manual discharge will be provided. In the centre of the shaft, on the floor slab, a ferroclad distribution cone will be provided, the lower part of which is interconnected with the lining by means of two hopper saddles.

Between level +/-0 and the furnace platform and the charging platform, caged ladders will be installed.

The layout calculation for the foundation slab should be done by an authorized civil engineer in accordance with the construction regulations in effect in the country.

View, section and detail drawings of the shaft kiln are reproduced in figure XIII (A) and (B).

Kiln equipment

2 Grates, preferably of fire-proof steel

2 Furnace doors, made of sheet steel, with frame and internal insulation

2 Ash boxes, made of sheet steel, fitted with bottom flaps and counter-weights

2 Adjustable air inlets

Injector chimney system

1	Medium-pressure air blower with drive motor and adjustable regulating (control) valve
1	Injection air nozzle
1	Adjustable displacement assembly with steel-wire rope, return pulleys and nail board with index scale
1	Chimney
1	Charging funnel with hinged cover
1	Construction winch with drive motor to be installed on level +/-0, together with rope and return pulley

Layout

Capacity	5 t/day
Granulometry	50-100 mm
Fuel	firewood > 3,000 kcal/kg
Shaft dimensions:	
Effective shaft height	7.0 m
Usable shaft diameter	0.8 m
Shaft form	cylindrical
Number of firing holes	2
Number of firing levels	1
Height of the cooling zone from $\pm$ 0 until the lower edge of the firing holes	2.80 m
Specific fuel consumption	1,500-2,000 kcal/kg lime

Sinking speed

Capacity 210 kg/h or 0.21 m^3/h
For 1 m shaft height = 0.5 m^3

$$\frac{0.5\ m^3}{0.21\ m^3/h} = 2.38\ h$$

$$\frac{1\ m}{2.38\ h} = 0.42\ m/h$$

Burning time

Coefficient of thermal conductivity = 0.84 kcal/m/h/°C

Specific kiln capacity = 10 $t/m^2/24$ h

Altered value of the heat transfer figure with specific capacity = 40 $kcal/m^2/h/°C$

Firing time according to Balazsovics 1/ 5 h

Calculation of height of firing zone 1/

Firing time x sinking speed = 5 h x 0.42 m/h =
= 2.1 m necessary height of firing zone

Calculation of the necessary amount of cooling air

At 1,000 °C entering temperature of the lime into the cooling zone and 80 °C lime temperature in the discharging part

(1,000 - 80 °C) x 0.214 (cpm lime) = 196 kcal/kg lime

$$\frac{196}{920 \times 0.32 \text{ (cpm air)}} = 0.666 \text{ Nm}^3 \qquad = 0.7 \text{ Nm}^3\text{/kg lime}$$

Comparison of the necessary minimum cooling air with the amount of combustion air

(a) Cooling air

0.7 Nm^3/kg lime x 210 kg/h lime = 147 Nm^3/h

(b) Combustion air

$$\frac{210 \text{ kg/h} \times 2{,}000 \text{ kcal/kg}}{3{,}000 \text{ kcal/kg wood}} = 140 \text{ kg/h wood}$$

140 kg x 5.3 Nm^3 air (excess air 50%) = 742 Nm^3/h

The available volume of cooling air is, therefore, at least five times higher than necessary.

Dimensions of the cooling zone	Metres
Post firing zone	1.0
Cooling zone	1.0
	2.0
Discharge cone height	0.8
Total cooling zone (i.e. height from ± 0 to the lower edge of the firing holes)	2.8

1/ "Influence of the loss of ignition of burnt lime on the dimension and construction of the lime shaft kiln", G. Balazsovics. Budapest, 324 Radex Rundschau. 1970. 5th issue.

<u>Dimensions of the pre-heating zone</u>	<u>Metres</u>
Height of burning zone	2.1
Height of cooling zone	<u>2.8</u>
	4.9
Pre-heating zone	<u>2.1</u>
Total shaft height	7.0

<u>Amount of exhaust gas</u>

(a) <u>From the combustion</u>

With a specific fuel demand of 2,000 kcal/kg lime the following quantity of wood is needed:

$$\frac{210 \text{ kg} \times 2{,}000 \text{ kcal/kg}}{3{,}000 \text{ kcal}} = 140 \text{ kg of wood}$$

With stoichoimetrical combustion of 1 kg of wood (according to Boie), the theoretical gas quantity is:

$$vgo = 0.89 \times \frac{3{,}000}{1{,}000} + 1.65 = 4.32 \text{ Nm}^3\text{/kg}$$

The theoretical air quantity is:

$$vlo = 1.01 \times \frac{3{,}000}{1{,}000} + 0.5 = 3.53 \text{ Nm}^3\text{/kg}$$

With an access air of 50 per cent, the real gas quantity is:

$$vg = 4.32 \text{ Nm}^3 + 0.5 \times 3.53 = 6.08 \text{ Nm}^3\text{/kg wood}$$
$$140 \text{ kg/h wood} \times 6.08 \text{ Nm}^3 = 851.2 \text{ Nm}^3\text{/h}$$

(b) <u>From de-acidification</u>

Stone quantity $\frac{210 \text{ kg/h lime}}{58} \times 100 = 362$ kg of stone
(with a loss of ignition of 42 per cent).

CO_2 from lime stone

$$\frac{362 \times 0.42\% \text{ loss of ignition}}{1.976\ (\gamma \text{ of } CO_2)} = 77 \text{ Nm}^3\text{/h}$$

2% H_2O from stone

$$\frac{362 \times 0.02}{0.804} = \frac{9 \text{ NM}^3\text{/h}}{86 \text{ Nm}^3\text{/h}}$$

Total amount of exhaust gas, (a)+(b) $= 937.2 \text{ Nm}^3\text{/h} \approx 940 \text{ Nm}^3\text{/h}$

Calculation of the operating cubic metres at an exhaust gas temperature of 200 °C

$$\frac{273 + 200}{273} \times 940 = 1{,}628.6 \ m^3/h \approx 1{,}630 \ m^3/h$$

For the operation of the injector, the same quantity of fresh air will be needed (in m^3/h) as is represented by the amount of exhaust gas, i.e. 1,630 Nm^3/h.

Layout of the chimney

With an exhaust gas quantity of 1,630 m^3/h or 0.45 m^3/s, and an entrance speed of the exhaust gas of 6.36 m/s into the chimney, a tube with an inner diameter of 300 mm is chosen.

$S = 0.07068 \ m^2$

$$v = \frac{0.45 \ m^3/s}{0.07068 \ m^2} = 6.36 \ m/s$$

Inner diameter of tube	300 mm
Wall thickness	4 mm

Layout of the injector tube

With a quantity of pressure air of 1,630 Nm^3/h or 0.45 m^3/s and a discharge speed of 57.3 m/s, a tube with an inner diameter of 100 mm is chosen.

$S = 0.00785 \ m^2$

$$v = \frac{0.45 \ m^3/s}{0.00785 \ m^2} = 57.3 \ m/s$$

Inner diameter of tube	100 mm
Wall thickness	3 mm

Exhaust pipe of the chimney

An exhaust pipe with an inner diameter of 275 mm is connected to a narrower intermediate part of 150 mm diameter.

$S = 0.05939 \ m^2$

Wall thickness 4 mm

The medium speed resulting in the exhaust pipe, prior to the mixing of the waste gas with the combustion air, is:

$$v = \frac{3{,}260 \ m^3}{3{,}600 \times 0.05939 \ m^2} = 15.24 \ m/s$$

In addition to the quantity regulation of the combustion air by means of adjustable flaps, a streamlined corpus (double cone) is installed which is placed axially in the tube. By alternation of that cone, the kiln draft can be regulated.

Layout of the blower

$Q = 1,630\ Nm^3/h = 0.452\ Nm^3/min$

$p = 400$ mm WC

$T = 20$ °C

rev/min = 3,000

Power consumption

$$P = \frac{Q \times \Delta p}{102 \times \eta} = \frac{0.452 \times 400}{102 \times 0.5} = 3.5 \text{ kW}$$

$\eta = 0.5$

B. Production cost for burned lime

The production cost, although excluding capital costs, may serve as a basis for the calculation of a marketable price. The capital cost will depend on the form of project financing.

In order to calculate the production cost, the general production costs have to be established. In the absence of a similar calculation, an annual bill of costs has been simulated, based on the ascertained data.

Assuming a continuous operation in three shifts during 300 days per year, the theoretical output at maximum efficiency of the furnace of 5 t/day is 1,500 t/year.

The following costs for wages, raw material and auxiliaries are actual market prices and have been ascertained in the Gambia in June 1986:

Wages (including local benefit factor)

1 Unskilled worker	D 10/day or D 1.25/h
1 Skilled worker (mechanic, electrician, chief of burning)	D 12/day or D 1.50/h
1 Engineer	D 500/month

Materials

(a) Raw shells, trated and charged (1 t = 1 m^3)
D 23/m^3, plus transportation D 43/m^3 = D 66/m^3 or D 66/t

(b) Fuel
Fire wood, 4,000 kcal/kg, including transportation D 40/t

(c) Electricity
Three-phase current, 380 V D 0.71/kWh

1. Annual direct costs

Wages

Per eight-hours shift operation:

4 Unskilled workers (D 1.25/h)	D 40
1 Furnace specialist (D 1.50/h)	D 12
	D 52

Annual total, 300 days of three shifts, i.e. 900 shifts at D 52	D 46,800

Materials

(a) Raw shells, trated and charged

$$\frac{\text{5 t/day of burned lime}}{\text{58 t loss of ignition}} \times 100 = 8.62 \text{ t/day}$$

Annual total: 8.62 x 300 = 2,586 t at D 66/t =	D 170,676

(b) Fuel

$$\frac{\text{2,000 kcal/kg lime}}{\text{4,000 kcal/kg wood}} = 0.5 \text{ kg wood/kg lime}$$

For 1,500 t/year of lime 750 t of wood are needed.

At a price of D 40/t this gives	D 30,000
Transportation and charging D 5/t	
For 1,500 t/year the cost is	D 7,500
Annual total	D 37,500

(c) Electricity

Drive	Nominal load (kW)	Actual input Per cent	Actual input kW
Exhaust gas fan	6	100	6
Elevation machine	1.5	60	0.9
Total			6.9

2/3 of 6.9 kW = 4.6 kW for 300 days x 24 h = 7,200 h at D 0.71/kWh	D 5,112

2. Annual operating costs

(a) Operation and auxiliary materials	D 3,000
(b) Management (1 engineer for D 500/month)	D 6,000
(c) Storage fees (D 1.60 x 1,500 t)	D 2,400
(d) Maintenance (3 per cent of the plant value of D 840,000)	D 25,200

3. Annual production cost

		Dalasis	
Wages		46,800	
Materials		213,288	
Raw shells	170,676		
Fuel	37,500		
Electricity	5,112		
Total direct costs			260,088
Operation and auxiliaries		3,000	
Management		6,000	
Storage fees		2,400	
Maintenance		25,200	
Total operating costs			36,600
Production costs			296,688
To those production costs 10 per cent have to be added for administrative costs:			29,668
The total production costs are therefore			326,356

The operating costs expressed as a percentage of the total direct costs are:

$$\frac{\text{Operating costs}}{\text{Wages + Materials}} \times 100 = \frac{36{,}600}{46{,}800 + 213{,}288} \times 100 = 14.07\%$$

4. Cost per tonne of lime

		Dalasis/t
Wages	$\frac{46{,}800}{1{,}500}$	31.20
Materials		
Raw shells	$\frac{170{,}676}{1{,}500}$	113.78
Fuel	$\frac{37{,}500}{1{,}500}$	25.00
Electricity	$\frac{5{,}112}{1{,}500}$	3.41
Total direct costs		173.39
Operating costs (14.07% of direct costs)		24.40
Production costs		197.79
Administrative costs (10% of production costs)		18.77
		217.56

The production cost for one tonne of lime is therefore D 217.56.

It is pointed out again that the amount of D 217.56 does not include capital costs since the total investment for the 5 t/day kiln was not calculated during the expert's mission. Should the expert return to the Gambia to assist in completing the pilot kiln and to advise during the pilot tests, he would also be expected to assist in calculating the investment costs and the total production costs (fixed and variable costs), anticipating a successful pilot operation.

Annex

JOB DESCRIPTION

Post title:	Lime expert
Duration:	Six weeks
Date required:	As soon as possible
Duty station:	Banjul, with travel in the country
Purpose of project:	The immediate objective of the project is to assist in determining the techno-economic viability of producing lime from the local cockle shell deposits.

Duties:

The lime expert will be delegated to the Government of the Gambia to advise and assist in evaluating the techno-economic possibilities for establishing a local lime industry processing cockle shells into commercial lime. Particularly the expert will be expected to:

(a) Evaluate and assess the cockle shell reserves, and their suitability for lime production (raw material verification);

(b) Advise on if, and in the affirmative how, the cockle shells can be processed into quick lime and hydrated lime;

(c) Prepare a technical study for a small-scale lime kiln in balance with requirements;

(d) Present drawings and specifications for a small-scale lime plant;

(e) Give estimates of material requirements and building costs considering maximum use of local resources;

(f) Estimate the market requirements for locally produced lime;

(g) Calculate production requirements and costs and make a summary analysis of the feasibility of the project.

The expert will also prepare a final report presenting his findings, conclusion and recommendations for further action which might be taken.

Qualifications:	Engineer with extensive experience in the evaluation of lime raw materials and the design of small-scale lime plants.
Language:	English