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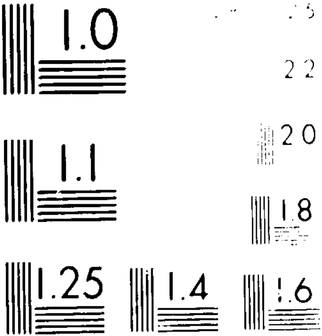
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Small Scale Cement Technology*

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based on

information received from

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Explanatory notes

Reference to dollars are to United States dollars.

A full stop (.) is used to indicate decimals.

A comma (,) is used to distinguish thousands.

References to tons are to metric tons:

t	ton(s)
t/a	tons per annum
t/d	tons per day
WG	refers to water guage

ABSTRACT

Increasing transport costs and modest cement consumption have emphasized the demand for small cement plants in some developing countries including the least developed countries and regions. In the past small cement plants have been represented both by rotary kiln and shaft kiln plants, but the cement from the latter was seldom of uniform quality.

The development of dry process technology, however, has resulted in an improved homogenization technique from which also shaft kiln plants can benefit. In the meantime also the shaft kiln technology has been significantly improved compared to the situation 25 years ago. The result is that small cement plants can be established with both the rotary kiln and the shaft kiln technology with the only difference that small rotary kiln plants may cost more to establish and operate than small shaft kiln plants. The only problem with the shaft kiln is that the technology cannot be used unless the raw materials are suited for it.

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INTRODUCTION

Recently increasing transport costs have created a demand for decentralization of cement plants in various developing countries, particularly in the least developed countries and regions.

In order to produce low-cost cement it is common to build up big units as close as possible to the raw materials and either close to the market or to means of inexpensive transport.

The alternative to large productions units is decentralization with small scale cement plants developed in such a way that capital investment can be kept low in order to keep down the fixed cost. One way to reduce costs is to reduce the need for heavy casted parts and establish a high degree of standardization in equipment design and production. Complex and sophisticated equipment and factory lay-outs should be avoided.

High investment costs for large-scale rotary kilns have resulted in the development of improved technology of interest for small-and medium-scale cement plants, including shaft kiln plants. (Pre-blending and homogenization).

Particular experience in building and operating small scale cement plants has been established by China, where about 3,400 shaft kiln plants are in operation in the ranges of 3,000-7,000 t/a and 10,000-50,000 t/a. as well as 50,000-100,000 t/a. Of a total production of 74 million tons of cement in 1979, approximately 50 million were produced by shaft kilns.

European experience in building and operating shaft kilns is as old as cement production, but only one supplier is still offering complete plants.

This supplier is still actively involved in building new plants and the technology (black meal process) is appreciated by its users.

Besides small scale shaft kiln plants also small scale rotary kiln technology is in the offering from several companies. We have no up to date experience regarding the investment costs of the new so called compact plants. Some companies however claim that they can be built at costs similar to shaft kiln installations.

Until that is proved we may anticipate higher initial costs as for instance indicated in Annex III.

I. BACKGROUND INFORMATION

As the investment cost in the cement industry is normally very high, it is important to determine the most economical and suitable size for small-scale factories in order to make savings through standardization. This seems to be in the range of a production of 60,000-120,000 t/a from two conventional shaft kilns.

For the conventional shaft kiln, low volatile fossil fuel, with less than 20% volatile matter will have to be used. If not available the problem may be solved by charring high volatile fuel; the volatile gases emitted could be burned and used for drying of raw materials. Such a system has worked successfully since 1965 at the Gippsland Cement Plant in Taralgou, Vic Australia. The plant is using charred brown coal briquettes as fuel for the 2 shaft kilns.

For the above-mentioned shaft kiln system, it is necessary to produce pellets or nodules, which are small, one-half inch (12 mm) diameter balls, of uniform quality and high strength, consisting of ground raw materials and 12-18% water. If formation of nodules of sufficient strength and heat resistance is not possible, a rotary kiln process is mandatory.

A small-scale cement plant producing 120,000 t/a would be the ideal size. The cost of machinery for the shaft kilns incorporating cooler would amount to approximately 4-6% of the total investment cost, whereas that of a rotary kiln plant would be approximately 8-10%. The advantages of a shaft kiln installation would be:

(a) Substantial savings in space;
(b) Simple construction with no heavy castings;
(c) Few problems with starting and stopping;
(d) High degree of reliability due to the durability of refractory bricks;
(e) The kiln and the cooler is an integrated unit;
(f) Low-alkali clinker could be produced;
(g) A high degree of do-it-yourself construction could be developed which is important in order to bring down the total investment cost.

There are various processes for feeding the fuel to the shaft kiln. The most simple, and perhaps the most common is to feed the fuel (anthracite or petrol coke, coke breeze, blast-furnace coke or similar), separately in sizes of 1.5-2.5 mm, directly to the pan pellertizer together with the raw mix. Other processes such as black meal, shell (black meal with white meal coating), and coke slurry should be considered depending on the type of fuel, especially if high content of ash occurs.

Small-scale shaft kiln cement plants may meet with opposition from large-scale cement producers as a network of shaft kilns in some areas could create competition for their markets.

On the other hand it should not be forgotten that the rotary kiln technology is very reliable and that a small rotary kiln plant despite high costs help to familiarize operators with a technology that sooner or later may be applied in the expansion of the plant when the cement market has been developed with the first cement plant installation.

The quality of the cement depend on the quality of the Portland clinker produced. Therefore continuous and regular operation is important. Efficient operation of a shaft kiln require a good distribution of air in the burning zone. This can be facilitated with a good discharge grate. It has been proved that the so-called step grate works satisfactorily with low maintenance costs.

Highly-developed equipment for the preparation of raw material also helps to produce good quality low alkali clinker in a shaft kiln (semi-dry process). Pre-blending of the limestone is highly recommended whether a rotary kiln or a shaft kiln is considered.

II. CAPITAL INVESTMENT FOR NEW CEMENT PLANTS

Investment efficiency (production capacity per unit invested) is extremely important for all factories because it is difficult to find the necessary financial support unless the feasibility of the project is proven beyond doubt.

Once financing is secured, the fixed costs required for amortization will influence the price of the final product. Here the shaft kiln technology still appear to have an edge over the rotary kiln technology. See Annex III, where the costs of "Verticle kiln plants" are compared with rotary kiln plants.

Manufacturers of rotary kiln plants with preheaters and calciners prefer not to use kilns of a capacity below 800 tons per day (t/D). The reason are :

(a) Cyclones are small and jamming might reduce the efficiency of the plant;

(b) In case of frequent stops, because of blocking of cyclones, fuel consumption might come out higher than anticipated.

(c) By-pass installations might be necessary in order to control the quality and additional investments might make the factory proposed less feasible.

(d) Bricklayers are reluctant to make repairs in the preheater and calciner because there is very little working space.

Never-the-less it is technically possible to produce small reliable dry process cement plants also without preheaters, the important points for a promotor is to have accurate information about investment and operating costs and compare different solutions before a final decision is taken.

III. ROTARY KILN WITH PREHEATER AND CALCINER

The present trend of building up large-scale cement plants will certainly continue.

The "run factor" for a rotary kiln mainly depends on its diameter. With diameters up to 5 m, the amount of refractory bricks used is still at an acceptable level of 0.5-0.8 kg/ton clinker.

Operations and maintenance experience have shown that conventional high-economy dry-process kilns with a four-stage suspension preheater are most reliable in the size range of 1,250-2,000 t/d, corresponding to a kiln diameter of 4.15-4.75 m or less if precalziner technique is applied.

It should however not be forgotten that small scale rotary kilns, as they were seen up to the fifties, still are technically possible to build. The only obstacle is that they are relatively expensive (investment costs per ton capacity) to build today.

Therefore some companies have started to examine the possibilities for simplifying the technique of small rotary kiln plants with present days know-how in order to be able to offer economic solutions to promotors of small cement factories.

IV. COMPACT SHAFT KILN CEMENT PLANTS

Many developing countries, particularly the least developed countries, have not developed their cement industry sufficiently. In many cases they have difficulties in identifying a balanced approach which will yield the necessary financial support.

The cement demand is often too little and to thinly spread over a large area to justify a medium or a large scale plant and increasing transport costs also works against centralized production.

When therefore both production and transportation costs are analysed, the conclusion is often that decentralized production in small scale plants is advantageous.

Also the Socio-economic factor in creating employment centers in rural areas should not be underestimated.

Conventional Shaft Kilns.

The shaft kiln technology has been used for nearly a century, but especially in the early 1960s the layout and design of a shaft kiln plants reached a very high level. This however coincided with the introduction of the dry-process four-stage suspension preheater kiln that made it possible to avoid drastically increasing cement prices by the use of big and economical production units. The shaft kiln then started to loose popularity, particularly as transport costs were still relatively low.

There are however still cases where a shaft kiln is the best and the most economic solution. Quality wise clinker produced by a shaft kiln can be as good as clinker produced by a rotary kiln provided the same care is taken in the preparation of the raw material. In order to produce good shaft kiln clinker the following conditions will have to be fulfilled:

(a) Plasticity of the raw materials particularly the clay in order to make pellets of sufficiently high strength also at elevated temperatures. Without this, it is impossible to operate a shaft kiln.

(b) A kiln diameter exceeding 3 m is inadvisable. Air distribution may become irregular and result in an unstable operation.

A common and effective kiln size is 180-200 t/d. Such a kiln would have an inside effective diameter of 2.4 m and a total height of approximately 8 m. Smaller kilns work even better because of improved air distribution inside kiln cross section.

The vertical shaft kiln is very simple. The upper part of the shaft (approximately 15-20% of the total height) is conical to correct for shrinkage of the nodules through drying, calcining and sintering. The rest of the shaft is cylindrical and this part serves as a collar and heat exchanger as the heat from the clinker preheats the air moving in counter flow from the bottom of the cooler up to the burning zone in the kiln.

The raw mix and solid fuel fed to the kiln are agglomerated in a nodulizer where 12-14% of water is added, and nodules of one half-inch diameter (12 mm) are produced. These nodules are fed to the top of the kiln and distributed equally over the material surface by means of an rotating chute.

The feeding to the kiln is regulated according to the flue gas temperature, which should be kept at 80-90°C. The material flow should be regulated to move downward with a velocity of approximately 1.5 m/h. At the bottom, the kiln is equipped with a grate of different designs. Clinker is discharged through hydraulically-operated air-lock discharge gates/or through other discharge systems.

Combustion air is blown in counterflow to the kiln and the pressure needed is about 1200-2000 mm WG; this is best obtained with a Roots blower.

Current air pollution regulations call for an electrostatic precipitator for the dedusting of the flue gas. Dust production of a shaft kiln is very low, about 2% of the clinker production, but it looks worse due to evaporated water. The low temperature of flue gas makes it necessary to preheat the gas before the filter to about 90° - 100° C, which is the most suitable temperature for an electrostatic precipitator,30-35° above the due point of the kiln gases.

V. FINDINGS AND RECOMMENDATIONS

Findings and recommendations should be considered as indicative as it is impossible to make general recommendations covering the entire world. However, it is hoped that they will be useful to promotors and Governments examining the availability of technology for small scale cement production in remote areas as well as in the least developed countries.

How to reduce capital investment

The total investment cost is divided among the following items:

	Fraction of total investment costs (%)
Mechanical and Electrical equipment	45-55
Civil Works	25-30
Transport (cif - fob)	3 - 5
Erection	12-15
Miscellaneous	4 - 5

The above-mentioned figures show where savings can be made. Civil works account for very high percentage of the cost. Considerable savings can be made here, for instance by reducing storage capacities, However, such savings depend to a large extent upon local conditions, and advice should be sought from an experienced consultant.

The following recommendations are made for the erection of mechanical and electrical equipment:

1. A perfect layout will be necessary
2. Intensive PERT (programme, evaluation and review technique) planning.
3. Intensive standardization should be made
4. The site should be provided with a well-equipped workshop especially for steel-plate work and welding.

5. Machinery manufacture and erection should be combined if possible.
6. All steel-plate work up to, say, a 25-mm thickness should be done at the site, if possible.
7. The latest welding techniques should be applied.
8. Considerable time can be saved by co-ordinating the civil work and the erection of mechanical and electrical equipment.

Implementation time.

In a plant, for example, of 120,000 t/a capacity, the civil works may involve about 8-10,000 m^3 of concrete and about 1,800 tons of mechanical and electrical equipment. The erection of civil works and the mechanical and electrical equipment would amount to approximately 120,000 and 140,000 man-hours respectively. Even on extremely difficult sites it should not take more than 10 to 13 months to erect a compact cement plant.

Economic size of plant - Annex III.

As shown in Annex III Shaft kiln plants producing 120,000 or 180,000 t/a would be the most economic size. For larger capacities normally the rotary kiln technology would be preferred. Particularly if low volatile coal is not available, but also the availability of good plastic clay is important to secure strong and heat resistant nodules for the shaft kiln process.

In order to give some more information about the relatively unknown shaft kiln process the following process or equipment details are given.

Nodulizer (pan pelletizer)

The production of suitable nodules (mechanically strong and heat resistant) is indispensable for a shaft kiln or any other kiln working on semi-dry process. The nodulizer for production of nodules was introduced in 1950 by the cement industry. Millions of tons of nodules have been produced by means of the nodulizer, especially after introduction of the semi-dry Lepol kiln. It is due to the development of the nodulizer and preblending and homogenization technique that the shaft kilns can produce clinker of high quality.

Irrespective of how the fuel is added in a black meal, shell or coal slurry process, the final nodules should consist of raw meal ground to a fineness of 10-15 percent retained on 4,900 meshes/cm^2 and less than 1,0 percent on 900 meshes/cm^2 in order to keep the free lime content below 3%. Nodule size should be kept at 10-16 mm diameter for a shaft kiln with a diameter of 2.4.

The water content depends on the raw materials (plasticity) and should be in the range of 12-18%. (wet base)

Burning Process.

Burning processes for shaft kilns are as follows :

Conventional

Black meal (Intergrate fuel process)

Shell

Coal Slurry

In the conventional process, which is the simplest, the fuel, for instance, coke, petrol coke crushed down to size 1.5-2 mm, is fed directly to the nodulizer together with the raw meal. The size of the fuel is important. Small sizes decrease and large sizes increase the height of the burning zone and thus the active cooling zone which will be respectively increased and decreased. A short burning zone results in a good thermal efficiency.

Black meal, shell and coal slurry processes require more equipment than the conventional one. These processes should only be considered in order to ensure uniform and good quality of the clinker if the fuel has a high-ash content or high reactivity. Determination of fuel content in the black meal every 2 hours as well as good mixing of the raw mix is essential for the conventional and for the coal slurry process.

Discharge grate.

Good air distribution is very important in a shaft kiln and a discharge grate is required to cope with irregular clinker formation. (lumps)

Some shaft kilns are equipped with a step grate which has proven its reliability satisfactorily for more than 20 years by securing a continuous discharge of Portland clinker up to 200 t/d.

The advantages of the step grate are :

Simple and robust construction

Low wear due to very low revolutions of the discharge grate (5RPH)

Low maintenance cost

Another grate construction is the discharge crusher grid, also called the rocker grate.

It consists of six water-cooled heavy shafts on which casted toothed sections, similar to toothed roller crushers. The rocker grate is turned every two years to distribute the wear evenly. The distance between the shaft centres allows for the passage of clinker between the toothed sections.

When the shafts are in motion by rocking from one side to another and back again they crush oversize lumps and discharge clinker as well as it secures a good air distribution even when clinker aggregation occur. The rocking movements are performed hydraulically and are activated from both sides. (Manstedt grate)

Other grates are the Wiege-rost (steinbüchl-grate) and
The Flat-grate (Grueber-grate)

As example of shaft kiln performance the attached table in Annex I presents a production record covering several years.

Annex II compare fuel and refractory consumption for shaft kiln and rotary kiln operation.

Annex III compare investment costs.

ANNEX I

SHAFT KILN PERFORMANCE (1972-1975)

Bamburi Portland Cement Company Limited, Kenya

Month	1972 Production rate (t/h)	1972 Energy consumption kcal/kg	1972 Energy consumption kWh/t	1973 Production rate (t/h)	1973 Energy consumption kcal/kg	1973 Energy consumption kWh/t	1974 Production rate (t/h)	1974 Energy consumption kcal/kg	1974 Energy consumption kWh/t	1975 Production rate (t/h)	1975 Energy consumption kcal/kg	1975 Energy consumption kWh/t	1976 Production rate (t/h)	1976 Energy consumption kcal/kg	1976 Energy consumption kWh/t
January	7.25	1 201		7.54	1 117		7.35	1 010		7.36	1.029		7.40	975	
February	6.75	1 173		7.37	1 110		7.26	1 004		7.24	968a/		7.06	971	
March	7.41	1 189		7.50	1 126		7.14	1 052		7.13	975		7.09	967	
April	7.33	1 186		7.42	1 129		7.56	1 025		7.02	986		7.14	961	
May	7.23	1 188		7.56	1 100		7.25	1 044		6.97	987				
June	7.18	1 209		7.65	1 098		7.47	1 049		7.16	986				
Average	7.20	1 191	17.27	7.51	1 113	16.08	7.34	1 031	15.61	7.15	989	22.59			
July	7.36	1 174		7.45	1 098		7.30	1 058		7.25	995				
August	7.21	1 181		7.34	1 112		7.25	1 049		7.22	981				
September	6.85	1 186		7.32	1 090		7.38	1 084		7.37	981				
October	6.91	1 182		7.54	1 064		7.14	1 084		6.77	991				
November	7.15	1 184		7.62	1 039		7.02	1 057		6.87	923				
December	7.35	1 186		7.38	995		7.06	1 047		7.22	968				
Average	7.15	1 182	15.39	7.44	1 068	14.63	7.15	1 064	18.27b/	7.12	973	...			

a/ Drop in fuel consumption due to new type of fuel.

b/ Electrostatic precipitator installed.

ANNEX II.

CUMULATIVE COSTS AT THE BAMBURI PORTLAND CEMENT
COMPANY LIMITED, KENYA

A. Refractory Costs
(US cents/ton clinker a/)

	Shaft kilns	Rotary kiln I
1973	32.8	240.9
1974	48.4	333.4
1975	52.5	254.7
1976 up to April	3.1	365.1

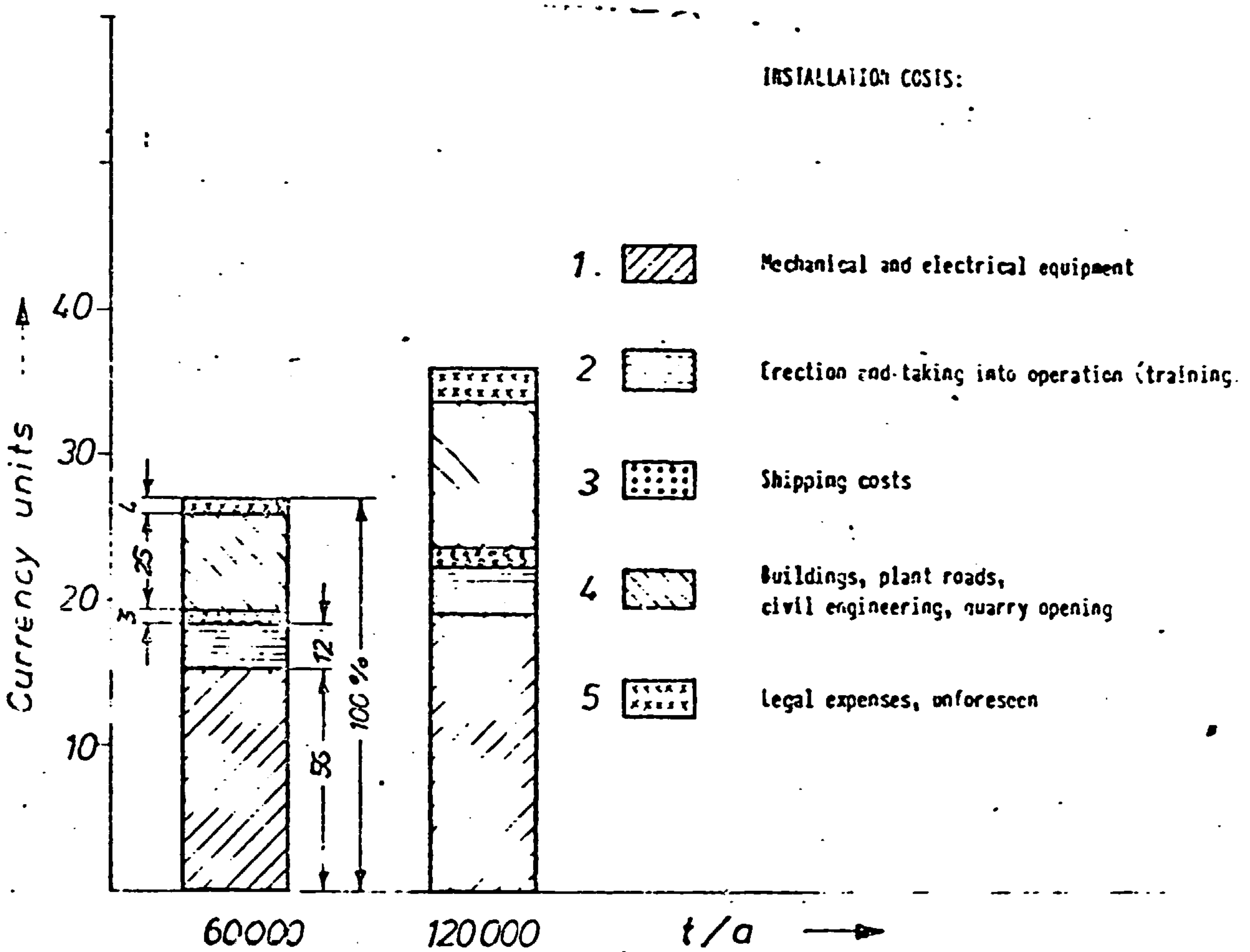
Refractory price: approximately $US 325/ton

B. Fuel costs
(KSh/ton clinker a/)

	Shaft kilns Coal	Rotary kiln I Fuel oil
1973	21.69	11.27
1974	29.84	39.33
1975	37.50	48.11

a/ The monetary unit in Kenya is the shilling (KSh). In June 1976, at the time of the expert's visit, the value of the shilling in relation to the United States dollar was $US 1 = KSh 8.35.

COMPACT CEMENT PLANTS



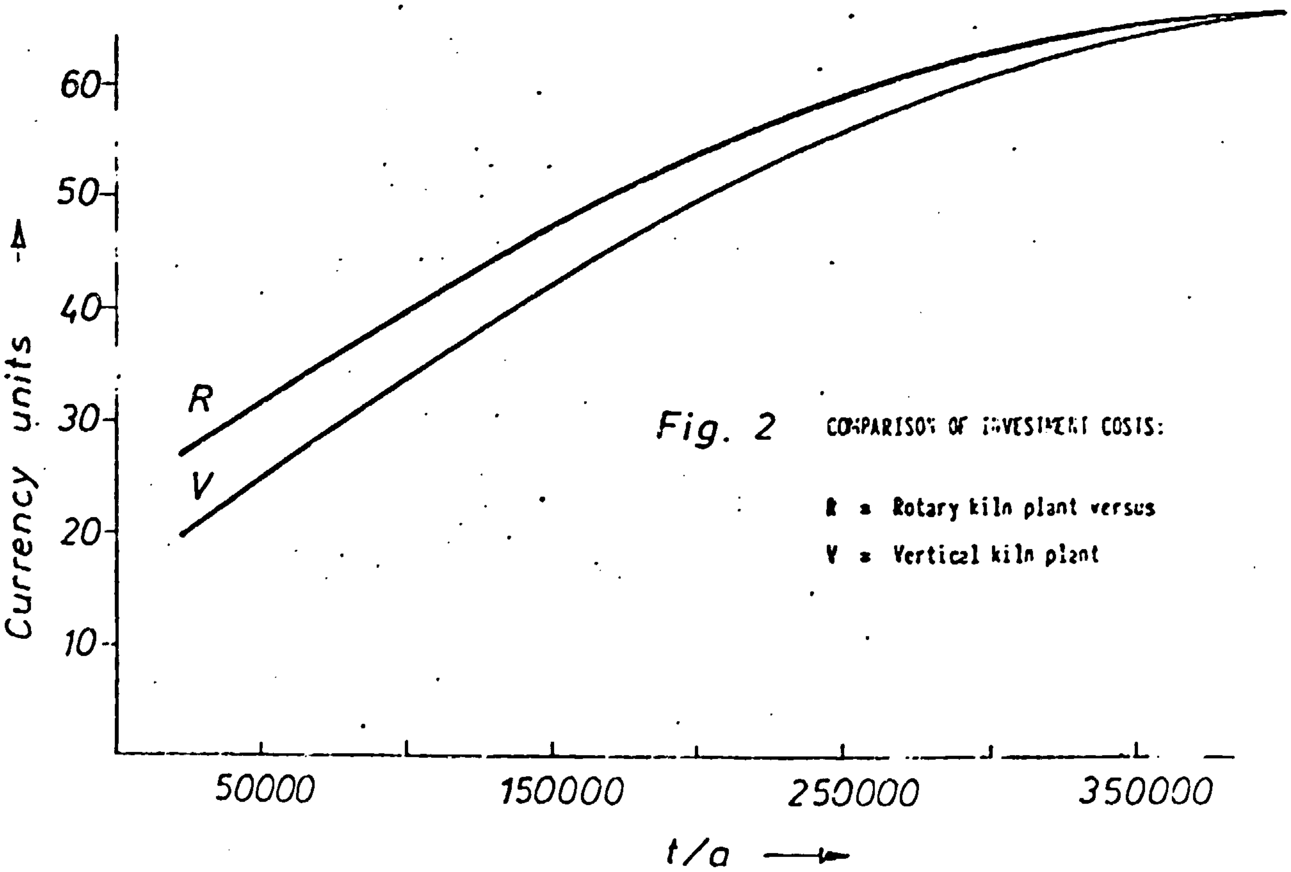


Fig. 2 COMPARISON OF INVESTMENT COSTS:

Annex IV

PARTICULARS OF SHAFT KILNS

	Units	Bamburi Plant (Kenya)	Himal Plant (Nepal) Black meal Process	CRI, India	Deggan Plant Austria Black meal Process
Inside effective diameter conical section	m	2.9	2.8	1.77	2.9
Inside effective diameter cylindrical section	m	2.4	2.5/2.6	1.18	2.6
Total height	m	8.25	8.0	8.2	8.55
Conical section height	m	1.35	1.2	2.1	1.7
Nodule diameter	mm	10-30	10-15	8-10	10-15
Nodule moisture content	%	15-18	12-13	12-13	14
Refractory thickness	mm	200-220	220	150	200
Air volume	m^3/h	30,000	10,000	4,800	12-000
Air pressure	mm WG	1,200	1300-1800	600-800	15-00
Exit gas temperature	°C	70-95	80-100	150	75-85
Clinker temperature	°C	390	80-200	60-100	80-150
Type of fuel		Anthracite coal (Swaziland)	Coke breeze (India)	Coke Breeze (India)	
Calorific value	kcal/kg	6,400	5,200	5,200	68-00
Volatile matter	%	-	1-3	1-3	4
Ash content	%	20.5	28-35	27	7
Heat consumption	kcal/kg	970	950-1,050	1,050	960
Normal output	t/h	7.40	6,7	1.25	7,7
Maximum output	t/h	8.60	7,5	1.3	8,8
Limestone (L) or coral (Co)	%	83.3 Co	80 L	70 L	70 L
Clay (Cl) or shale (S)	%	16.0 S	10 Cl		22 CL
Coal addition or interground	%	9.2-10.0	9-10	-	8,0

LIST OF DOCUMENTS

SYMBOL NO.	TITLE	AUTHOR(S)+ORGANIZATION(S)
ID/WG.326/1 CHINESE ENGLISH	Methods of Evaluation and Prospects of Utilization of Waste and Brown Coal as Fuel and Raw Materials in the Cement Industry.	Qin Zhigang, Jiang Zhigan, and Wang Yiguing The Division of Cement, Research Institute of Building Materials, China
ID/WG.326/2 CHINESE ENGLISH	Structure and Nature of Pozzolanas and Their Application in the Cement Industry in China	Fang Derui and Tong Sanduo China
ID/WG.326/3 CHINESE ENGLISH	The Burning Process of Cement Shaft Kilns	Huang Jinyang, Wang Xiangming, and Wang Yiguang The Institute of Cement Material China
ID/WG.326/4 CHINESE ENGLISH	Heat Economy of Cement Rotary Kiln	Zhu Zupei China
ID/WG.326/5 CHINESE	Background Information for Seminar on Cement Technology	Fang Run China
ID/WG.326/6 CHINESE ENGLISH	Discharge and Sealing Technique for Cement Shaft Kilns	Yang Dahua China
ID/WG.326/7 CHINESE ENGLISH	Precalcination with Coal	Huang Nabyue and Xu Bingde China
ID/WG.326/8 CHINESE ENGLISH	Technique and Economy for the Use of Lignite in Cement Rotary Kilns	Engineers from Kay Yuan Cement Plant Sichuan Institute of Cement Industry, Ministry of Building Materials Industry China
ID/WG.326/9 ENGLISH	Conservation of Energy in Cement Manufacture- Fuel and Power Consumption	T. Enkegaard F.L.Smidth and Co., A/S Copenhagen, Denmark
ID/WG.326/10 ENGLISH	Economical Aspects of Loesche-Vertical-Kiln for Compact Cement Plants of Small Capacity	H. Klatt LOESCHE GmbH Düsseldorf, FRG

SYNBOL NO.	TITLE	AUTHOR(S)+ORGANIZATION(S)
ID/WG.326/11 CHINESE ENGLISH	List of Documents	
ID/WG.326/12 ENGLISH	Cost of new Cement Plants and Conversions	Oliver Jensen F.L. Smidth and Co.,A/S. Copenhagen, Denmark
ID/WG.326/13 ENGLISH	Pollution Control in Shaft Kiln Factories	P.F. Janssens UNIDO Consultant
ID/WG.326/14 ENGLISH	Utilization of Coal in Cement Manufature	Villy Egesø F.L. Smidth and Co.,A/S Copenhagen, Denmark
ID/WG.326/15 ENGLISH	Applied Research in Process Control	G. oed UNIDO Consultant
ID/WG.326/16 + Corr.1 ENGLISH/FRENCH	Atmospheric Pollution in Cement Plants International Point of View	Jean-Claude Hillenmeyer Canada Ciment Lafarge Limited Montréal, Canada Lafarge Conseils et Etudes Paris, France
ID/WG.326/17 ENGLISH	History of PFA Use in France	J. P. Meric Centre Technique Industriel Paris, France
ID/WG.326/18 ENGLISH	Kiln Control	Villy Egesø F.L. Smidth and Co.,A/S Copenhagen, Denmark
ID/WG.326/19	LD Steel Slag-Zeolite Cement	Yang Yongqi Guo Jingxiong Chang Shifeng Shu Mingdi Li Rui Engineers,Beijing Steel Slag Cement Plant, Beijing, China
ID/WG.326/20	Report of the Interregional Seminar on Cement Technology.	Paul F. Janssens Gjerløf Poed. UNIDO Consultants UNIDO Consultants