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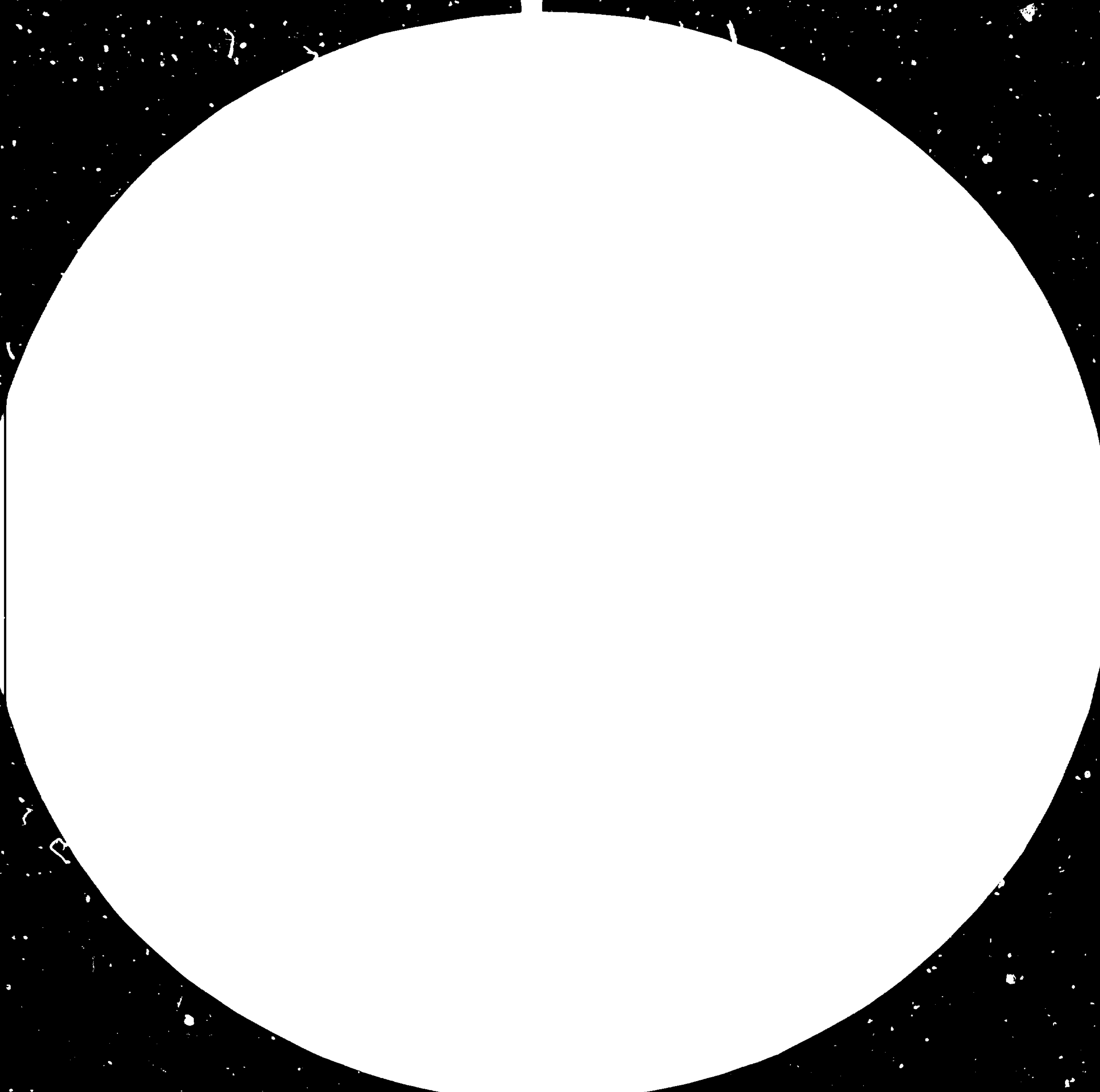

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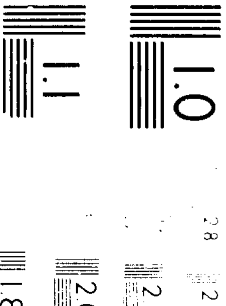
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COST OF NEW CEMENT PLANTS AND CONVERSIONS *

by

Oliver Jensen **

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Preamble

The intention of this paper is briefly to outline the aspects of installing new dry-process cement plants, focussing on comparable costs of plants of various outputs. Furthermore it will deal in general terms with questions regarding conversion of plants from wet to dry process and finally give a few comments on replacement and modernising of old plants.

A. Installation of New Plants

The general trend today, based on the last few years' world market developments, is to build a dry-process plant with a capacity of 2000-3000 tonnes per day. Clinker burning is based on the precalciner principle, and the cement plant has a centralized control room, featuring a high degree of process automation.

It is, of course, possible to install plants with larger outputs, and quite a number of plants of 4000-5000 tpd capacity have been installed throughout the world.

In fact the present level of technology permits the establishment of one precalciner kiln unit with a capacity up to 10,000 tpd.

At the lower end of the range we nowadays seldom see the establishment of cement plants with capacities below 1000 tpd. The reason for this trend is best explained by evaluating the installation cost of the different capacities, as shown in Annex 1.

If for example the total cost of a 2500 tpd plant is 100, the total cost of a 1000 tpd plant is approximately 57, and that of a 500 tpd plant approximately 44.

Similar relations between the production costs are indicated by the following figures. If again we assume the production costs of one unit of cement to be 100 for a 2500 tpd plant, the production costs of a 1000 tpd plant are approximately 122 and those of a 500 tpd plant 152.

Although the above figures are approximate, the picture is clear and gives a reasonable explanation why contracts for plants below 1000 tpd are seldom concluded on today's world market.

The greater the capacity of the production units, the lower the initial and production costs per tonne of cement, as shown in Annexes 1 and 2. These curves are based on European conditions, and show the costs in relation to capacity. In Annex 3 you will see the relative investment costs based on four different capacities.

At the lower end of the capacity range it will be noted from Annex 1 that there is a sharp rise in production costs for kiln capacities below 1200-1500 tpd. A new plant should therefore be larger than 1200-1500 tpd, provided the market can absorb the production.

The upper limit for a new production unit is mainly determined by practical parameters. First of all the infrastructure; are rail and road systems capable of distributing the output from the plant? Another limiting factor is transport of the large diameter equipment to the factory site. Lining problems with large diameter kiln will also restrict the diameter of a kiln. However, it is quite common today to install kilns of 5-6 m dia., as the leading suppliers of brick lining master the technology and are able to provide lining for 5-6 m dia. kilns without their causing operational problems. It may be mentioned that a kiln with a diameter of 6 m and furnished with precalciner will have a capacity of more than 8000 tpd.

We can then conclude that a new unit should have a capacity between 1500 and 8000 TPD in order to ensure reasonable production costs per tonne and in order to comply with well-known technology.

Today's price for "Cement Making Machinery", f.o.b., for a 1m tonnes per year plant is around 45m US$. According to the curve, Annex 2, the total cost of the plant is approx. 150m US$, which means an investment of approx. 150 US$ per year-tonne.

The price for the equipment is much the same in different parts of the world. Differences will occur due to import duties in some countries and varying transport costs. However, the major difference from one country to another is due to variations in the price for civil work and erection. We have seen total costs as low as 120 US$ per tonne capacity for a one million tonnes per year plant and as high as 250 US$ per tonne. However, we estimate that in most countries today's price for such a plant is within 130 to 150 US$ per tonne per year.

B. Conversion Wet to Dry Process

During the last few years, the possibility of changing from the wet to the dry process has been studied at many plants. A general solution does not exist, and in many cases the wet process is favoured due to special conditions prevailing, such as high moisture content of raw materials, washable raw materials hardly requiring any grinding, wet dressing of a low-grade raw material or excessive amounts of impuritites, such as alkalis or chlorides - problems which can be solved also in a dry plant, but at a higher cost.

In general, the fuel saving alone is insufficient to compensate for the capital cost of the conversion. In some cases a conversion is carried out anyway, the philosophy being to invest now and save later, when inflation has paid off the investment; but in general conversion today is only economical if both an increased output and an improved fuel economy is achieved. Future development in energy prices may, however, change the picture and accelerate the decision-making process.

The major factors which decide whether or not a conversion will be a financial success can be listed as follows (Fig. 1):

Capital needed for conversion
Cost of capital (interest, depreciation, etc.)
Additional power required
Additional staff
Price of fuel
Fuel efficiency of old installation
Fuel efficiency of new installation
Price of electric power
Water content in present slurry
Water content in natural raw materials
Water content in filter cake (if used)

All these variables have an impact on the financial viability of the conversion.

For a conversion to be feasible, it is not enough to aim at the system which promises the lowest fuel consumption. The cost of the extra capital investment, the fuel price, the cost of stopping plant production during the conversion, the additional cost of electric power and possibly extra staff, etc., are just as important factors.

For a converted plant to be just as profitable as the existing wet plant these additional operating costs plus the new fuel costs must be equal to or lower than the fuel costs of the existing plant. Expressed as an equation we see that (Fig. 2):

1) Additional operation costs + new fuel costs $\leq$ old fuel cost.

If we know the fuel price ($/Gcal), this equation can be expressed as

2) $\dfrac{\text{Additional operating cost}}{10^{-3} \times \text{fuel price}}$ + new fuel eff. $\leq$ old fuel eff.

The additional operating costs are converted to an equivalent, needed fuel saving per kg clinker, as shown in the last equation. By adding the fuel efficiency of the new system, the sum must be equal to or lower than the existing fuel efficiency before the conversion is profitable.

Extensive research has been carried out to determine how the most important cost factors influence this equation for each of a great number of possible conversion methods. The main conclusion of this research is that simple conversions with low capital investment are more likely to be profitable than complicated conversions, and that an increase of plant output is essential for the overall profitability of a conversion. In the case of a specific plant the production increase will not only be a question of kiln capacity but also of the raw mix processing capacity, internal transport capacities etc., and it can only be evaluated by a detailed study of the plant.

The main objective of a coversion is, of course, heat saving. The graph (Fig. 3) shows the heat consumption to be expected with varying amounts of moisture to be evaporated and varying exhaust gas temperatures. The graph indicates heat balances, independent of the type of equipment used, and therefore applies regardless of wheter drying is performed in the kiln system or in the raw mill system. The graph goes down to 18% moisture in raw materials or kiln feed. If the moisture content is lower, we are dealing with the heat consumption of dry-process kilns with additional heat for drying raw materials if they contain more water than can be evaporated by the kiln exhaust gases.

With the present emphasis on energy, it is necessary also to take power consumption into consideration. Physically, 1 kWh/t clinker is equivalent to 0.86 kcal/kg clinker, but it is expensive, also in terms of fuel, to produce electrical energy so that in terms of price 1 kWh/t often turns out to be equivalent to 5-6 kcal/kg. Considering overall energy conservation, it is better to use basic thermal fuel as an energy source, the cost being only 20-30% of the cost of producing the same energy in form of electric power. This reflects, of course, that our industry has a much better thermal efficiency than power stations.

In a coversion there are two main procedures to adopt; one is to maintain the slurry processing and dewater the slurry mechanically prior to the burning process. The other is to convert to full dry process with drying of the raw materials before or during raw grinding.

There are a number of good reasons for maintaining the existing wet raw material processing. The process is uncomplicated and the existing installation may operate very smoothly. Abandoning slurry production may involve extensive alterations in raw material handling and in transport equipment within the plant. In some cases, there are solid impurities in the raw materials, which can only be removed by wet processing.

From an energy point of view the moisture content of the raw materials is decisive; a high moisture content which in any case has to be evaporated, provides a good case for maintaining the slurry processing.

The only feasible way of dewatering slurry is a filtering process. High-moisture raw materials are generally plastic, also requiring a high moisture content in the slurry, and such slurry requires pressure filters to obtain an acceptable moisture content, 18-20%, in the filter cake. Pressure filters have in recent years been developed to ensure reliable performance and are fully acceptable from an operational point of view. Unfortunately, the investment is considerable and the running costs of power, labour and maintenance, specially filter cloth, are high. The cheaper solution, suction filters, might be good enough for unplastic, low-moisture slurry, but rarely reduces the moisture content sufficiently in the types of slurry to which filtration is relevant.

Fig. 4 shows three simple kiln conversions for handling filter cake. The running costs of the filter installation is here expressed as being equivalent to heat consumption, 100-150 kcal/kg clinker, but the range may be much wider, depending on the actual conditions. This figure does not include the capital cost of the filter installation, which is often higher than the running costs.

The expected heat consumption is based on 18-20% moisture in the cake. Even without detailed calculations it can be seen that conversion will only pay, if the existing kiln has a very high heat consumption.

Our evaluation of these three possibilities shows that Scheme B is the most economical, provided of course that the slurry processing equipment, the clinker cooler, the clinker handling equipment, etc. can cope with the increased output.

A flow sheet for an installation according to Scheme B is shown in Fig. 5. The drier crusher is a specially designed hammer mill with flash-drying which is sufficiently reliable to operate in-line with the kiln. The dried raw meal from the cyclone can be divided between direct kiln feed and feed to the riser pipe to the one-stage cyclone preheater, and in this way the heat input to the drier can be adjusted. All internal fittings in the kiln are omitted.

Another approach to a similar conversion is shown in Fig. 5A.

This method is also based on using all the kiln gases for drying the filter cake in a drier-crusher. The dried and pulverised raw meal is fed directly to the kiln from a small silo. This method can be used with kiln exit gas temperatures at around 300°C. With such high exit gas temperatures, it is hardly advisable to use internal fittings in the kiln.

The gases after the drier-crusher are down to only 150°C and the fuel consumption at the installation is around 1025 kcal/kg clinker.

Installation of the drier-crusher represents about half of the cost of the filter installation and requires one worker per shift. It also requires approximately 5 kWh/t clinker and 5 kWh/t clinker extra at the draft fan, or a total of 10 kWh/t clinker. This power cost is estimated at 50-60 kcal/kg clinker as mentioned previously. The total extra operating cost can be estimated at $5.88/t clinker. This method will not permit any significant increase in production.

In the diagram it is shown how the break-even point between the original wet plant and the conversion is dependent on:-

a) The additional operating costs ($/t clinker) corresponding to a required fuel saving (Gcal/kg clinker)

b) The fuel consumption of the converted system (Gcal/kg clinker)

c) The price of fuel ($/Gcal)

d) The fuel consumption of the present wet kiln (Gcal/kg clinker)

Based on fuel cost of $18.00/Gcal, this conversion will only be profitable if the existing wet kiln uses more than 1350 kcal/kg clinker.

The diagram also shows how the higher fuel costs make it more doubtful whether this conversion will be profitable. If the fuel price in this example was $12.00/Gcal, the fuel saving required will raise to 430 kcal/kg clinker and the conversion will only be profitable if the present wet kiln uses more than 1515 kcal/kg clinker.

More complicated conversions, maintaining the slurry processing, can also be considered (Fig. 6). It applies to all these solutions that, apart from the slurry processing estimated to have adequate capacity, they involve practically new kiln installations, only a small part of the existing kiln tube being used. Such solutions must be compared with the cost of a completely new line. The value of the re-used parts is geneally lower than the cost of the production loss. Further, the use of part of the existing kiln often results in a plant with an unsuitable layout and an imbalance between the capacities of the individual departments.

During recent years we have prepared several similar projects, but so far the conclusions have been that such a conversion is not feasible from a financial point of view. This is because the value of the parts you can use from an old wet kiln is much less than the value of the production of the wet kiln during the downtime required for the conversion.

It must also be considered that the value of the kiln shell proper is relatively insignificant compared with the total investment cost of a new installation. To illustrate this we shall indicated the relative prices for the mechanical equipment for a precalciner installation with a 100% by-pass of the kiln gases as follows:

Raw mill department	approx.	25.4%
Raw meal homogenising	approx.	4.6%
Kiln feed	approx.	4.8%
Kiln department	approx.	44.4%
Kiln shell	approx.	2.8%
By-pass, kiln gases	approx.	18.0%
		100.0%

If we estimate that the mechanical equipment is 1/3 of the total investment (the other 2/3 being electrical equipment, civil work, erection etc.), the result is that the kiln shell represents less than 1% of the total investment.

The above-mentioned figures are from an actual case (4500 tpd) where we studied the possibility of converting a 5.25 m dia. kiln from wet process to dry calciner process. The outcome was in this case that the client preferred a completely new kiln.

However, in a number of cases we have concluded contracts for conversion of wet-process kilns to dry-process precalciner installations where local conditions justified such a measure.

The number of parameters to be taken into consideration for such conversions may be of the same magnitude as for completely new cement plants and can only be dealt with on the basis of a detailed study. - Such a study would be outside the scope of this paper.

With a low moisture content in the raw materials the most economical solution is usually a conversion to dry process (Fig. 7), at least when the moisture is so low (6-8%) that the kiln gases suffice for drying. Such a conversion is often combined with a new dry line, so that the costs of raw material handling and raw meal processing can be shared. The existing kiln is then converted according to Schemes F or G, where a maximum of existing equipment is re-used. The more complex conversions, Scheme H and Scheme J, re-use only a small part of the existing equipment and in comparison with a completely new line the conversion is unattractive.

A practical example of a conversion to dry process at a plant with two existing kilns is shown in Fig. 8. First a new dry line was installed, in this case a kiln with two-stage preheater. With this line in operation a wet kiln was converted to a two-stage preheater kiln without loss of total plant output and using raw meal from the new plant. The small wet kiln is occasionally used for raw meal feed without any alterations, not operating econimically but valuable as a stand-by.

Fig. 8A shows the conversion comprising the addition of a two-stage cyclone preheater, with no other significant changes to the kiln except the removal of chains. The kiln will consume 900 to 950 kcal/kg clinker and will permit a 25% production increase due to the relatively large kiln tube.

If this is utilised it will require increased cooler capacity and increased clinker handling capacity. The whole plant will have to be adjusted in proportion to the higher production.

As for the conversion to filter cake installation the break-even point can be found. Apparently, this type of conversion will be profitable if the existing kiln uses more than 1215 kcal/kg clinker and provided the cost of fuel is $18.00 Gcal.

In general terms the simplest possible method is to remove the internal kiln fittings and add a two-stage preheater. The cyclone tower can be constructed with the kiln still operating. For example, no shortening of the kiln is required.

We believe this approach to be superior as we use as much as possible of what already exists. The problem with the two-stage kiln is that the temperature of the smoke gases is between 400 and 500°C, as against 350° with the four-stage kiln. Today, many are even considering adding a fifth cyclone stage to reduce smoke temperature to around 300°C. Adding a third stage to the two-stage kiln reduces temperature by between 75 and 100°C, thus permitting a saving of 40-50 kcal/kg of clinker. This is equivalent to around 0.3 million dollars per year for a 1000 tpd kiln. There is a great deal to be said for building three-stage instead of two-stage preheaters. The cost of the extra stage is returned in a short time.

When evaluating the future development of a plant, there seems to be little doubt that conversion to complete dry process is a better solution than adopting the procedure of semi-wet systems with slurry filtration, unless there are very special reasons for maintaining slurry production.

Although the study of a wet-to-dry conversion usually starts with the kiln, it will appear that the largest share of the total cost of a conversion is invested in the raw meal processing. The transformation of the kiln as such is usually a minor part of the whole conversion.

C. Replacement and Modernising of Old Plants

Efforts in this direction should mainly be concentrated on saving fuel, power and manpower, and each case requires a separate study. I shall limit my comments to mention that in many cases one may obtain savings in the range of 5-10% in the fuel consumption only by optimizing the process, keeping the chain system in the kiln in good condition, ensuring a constant quality of the slurry feed and trying to introduce a preventive maintenance system, thus avoiding the extra fuel consumption due to unstable kiln operation.

Equal savings may in many cases be obtained in the slurry and cement mills by adjusting the mill charge and keeping the lining and diaphragms in good condition. On the world market you will today find several suppliers of special mill charges and lining materials, which help you to maintain the mills in optimal condition during long operational periods.

The investments for such improvements are very limited and are always paid back fast with the present fuel and power costs.

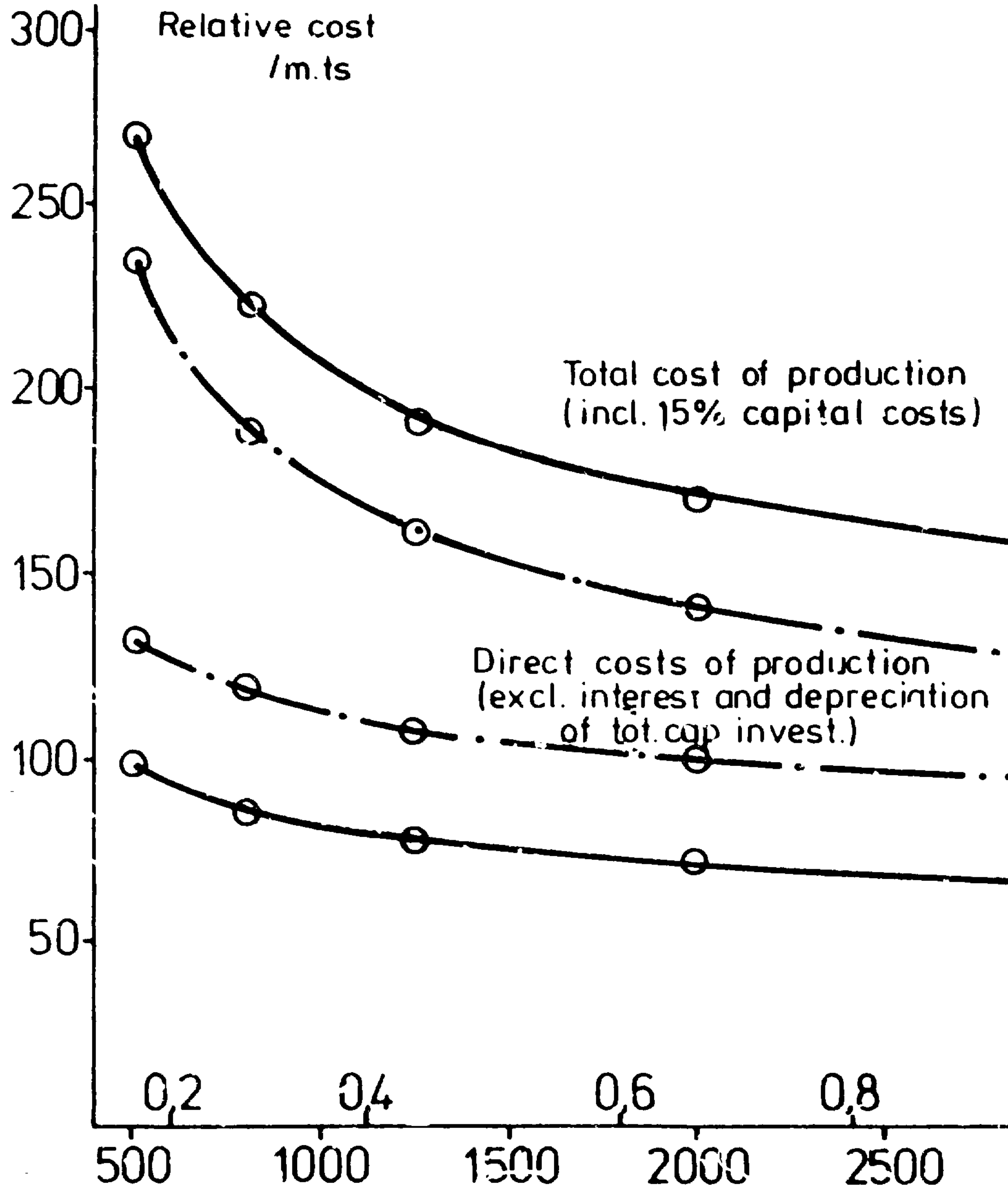
Conclusion

This paper reflects some of the most common questions put by cement people all over the world to cement machinery producers or firms of internaltional consulting engineering almost every day.

The complexity and the magnitude of the variable parameters clearly make it difficult to give specific advice on the problems briefly outlined here.

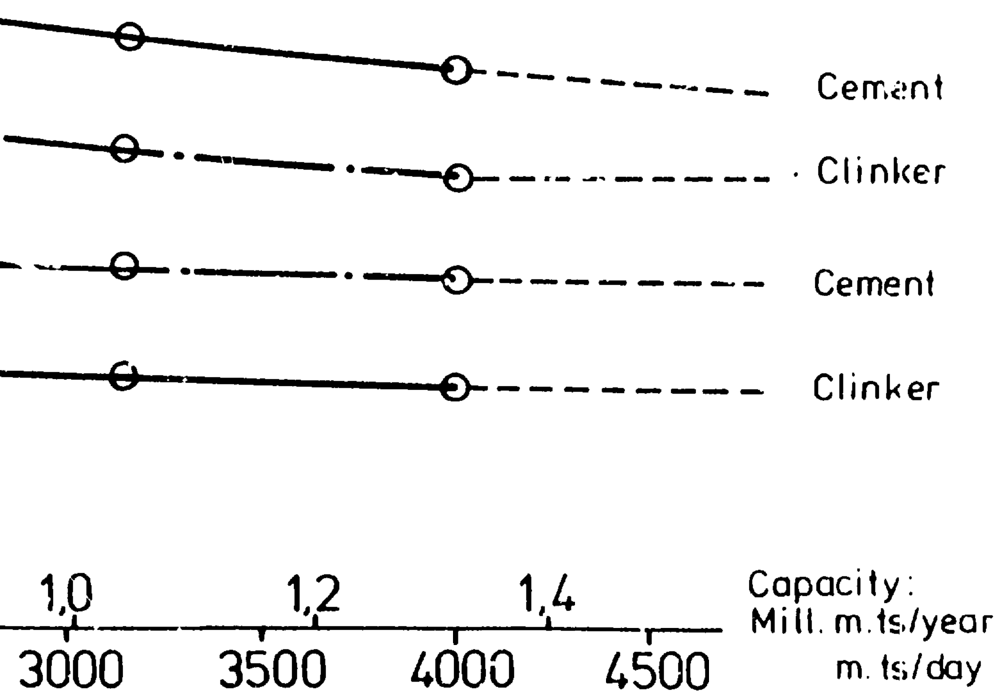
Only a thoroughly prepared project, taking individual local conditions into account, will give firm answers to these questions.

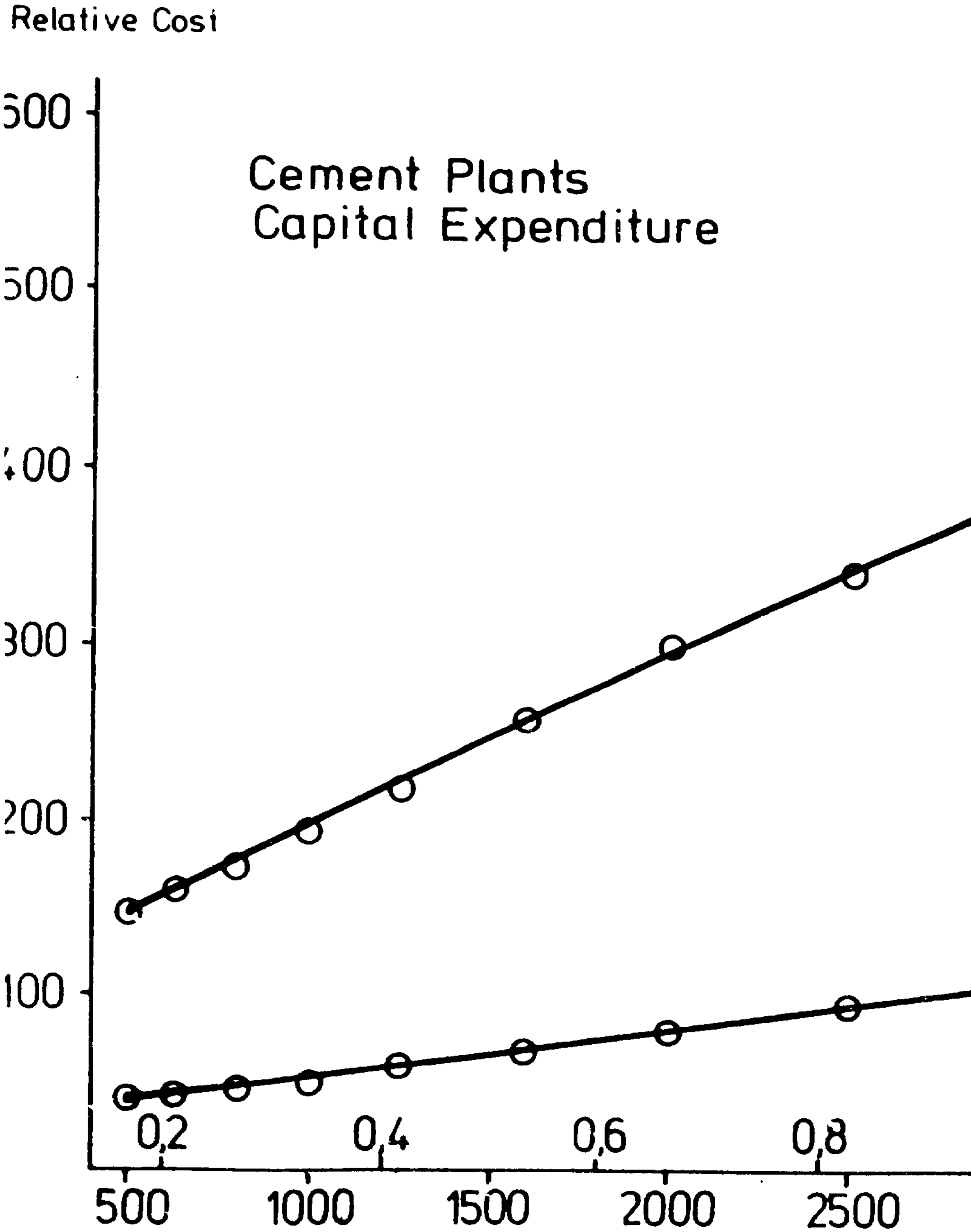
Relative Cost/m.ts



Annex 1

Production Cost of Clinker and Cement

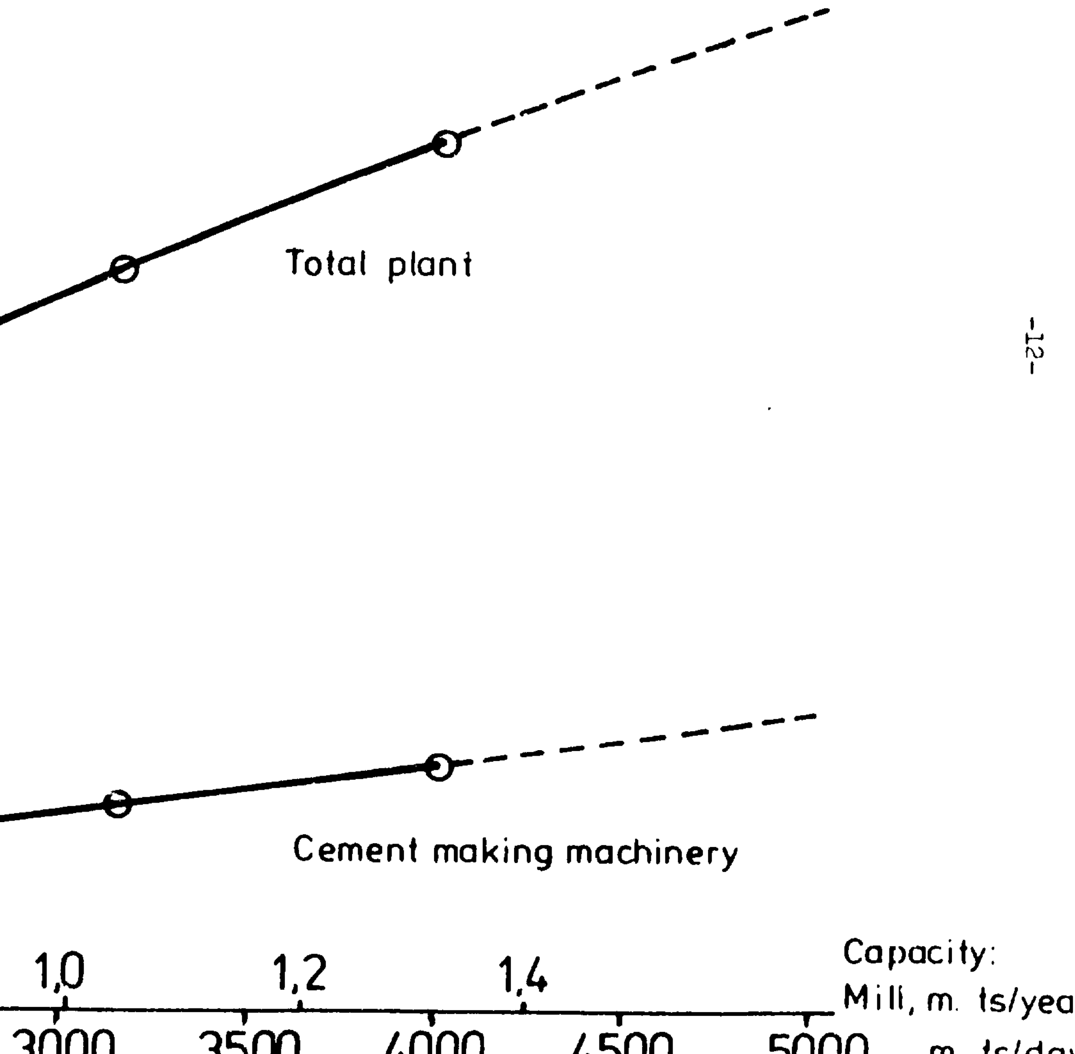




Relative Cost
Cement Plants
Capital Expenditure
500
500
400
300
200
100
0,2
0,4
0,6
0,8
500
1000
1500
2000
2500

Annex 2

Total Cost and Cost of Machinery



Comparative Costs of a Cement Plant, Dry Process, 4-stage Preheater, exclusive Feasibility Study, Cost of Land, Housing for Employees, Working Capital and Financing Costs.

Annex 3

Capacity ts/24hrs ts/year/330 days	1,600 528,000	2,000 660,000	2,500 825,000	3,150 1,040,000
1. Cement Making Machinery	27.2	27.7	28.4	28.7
2. Auxiliary Equipment (Kiln Lining, Pipes, Grinding Media, etc.)	4.1	4.2	4.3	4.3
3. Spare Parts, Mechanical	2.7	2.8	2.8	2.9
4. Electrical Equipment	7.7	7.6	7.4	7.3
5. Spare Parts, Electrical	0.6	0.6	0.6	0.6
6. Process Control Equipment	1.4	1.2	1.0	0.9
7. Erection and Administration	8.7	8.8	8.9	9.0
8. Civil Engineering	32.6	32.0	31.5	31.0
9. Roads and Fences	1.1	1.1	1.1	1.1
10. Water Supply Plant	0.5	0.6	0.6	0.6
11. Quarry Equipment, etc.	2.7	2.8	2.8	2.9
12. Opening Quarry	0.5	0.6	0.6	0.6
13. Offices, Laboratory, Repair Shops	0.8	0.8	0.8	0.8
14. Freight and Insurance	2.7	2.8	2.8	2.9
15. Consulting Engineers Fee	1.7	1.7	1.7	1.7
16. Contingencies	5.0	4.7	4.7	4.7
TOTAL %	100 %	100 %	100 %	100 %

Capital needed for conversion
Cost of capital (interest, depreciation, etc.)
Additional power requirement
Additional staff
Price of fuel
Fuel efficiency of old installation
Fuel efficiency of new installation
Price of electric power
Water content in present slurry
Water content in natural raw materials
Water content in filtercake (if used)

FIG 1

1) Additional operation cost + new fuel cost $\leqq$ old fuel cost.

2) $$\frac{\overset{(\$/\text{t. cl.})}{\text{Additional operation cost}}}{10^{-3} \times \underset{(\$/\text{Gcal})}{\text{Fuel price}}} + \overset{(\text{Gcal/kg cl.})}{\text{new fuel eff.}} \leqq \overset{(\text{Gcal/kg cl.})}{\text{old fuel eff.}}$$

FIG 2

Wet- and Semi-wet Kilns

Heat Consumption Dependence on Smoke-gas Temperature, Moisture & False Air
(Basis Titr 78 %, L.O.I. 36 %, Dust 0, Feed + Air + Fuel ambient temperature)

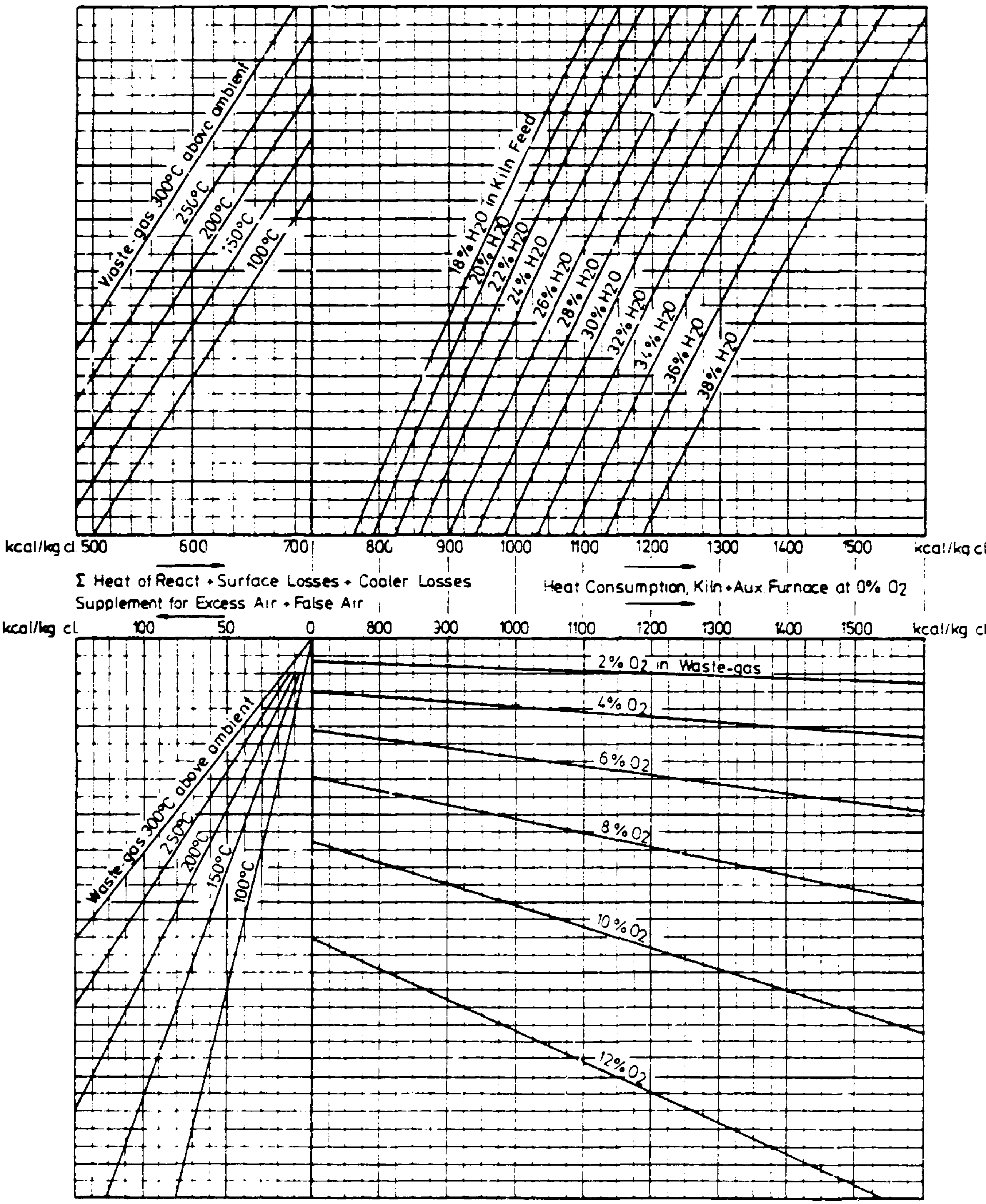


FIG 3

Conversion Wet to Dry.

High quarry moisture (>15%). Simple conversions.

Raw materials ↓ Slurry	Existing installation
↓ Pressure filters ↓ Filter cake handling and feeding	New installation. Operation costs (power, man-power, maintenance (cloth)) equal to 100-150 kcal/kg clinker.

Kiln Department	Scheme A	Scheme B	Scheme C
Kiln	Unchanged	Unchanged	Shortened
Additional equipment	Chain system	1-stage preheater Drier-crusher I.D.-fan	Grate preheater Cooler modification I.D.-fan
Expected heat consumption (kcal/kg)	1200	1050	950
Additional power consump. (kWh/t)	0	7	15
Production increase (%)	0	15	25
Cost of conversion	cheap	medium	expensive
Prod. loss during conversion	small	small	large

FIG 4

Conversion Wet to Dry

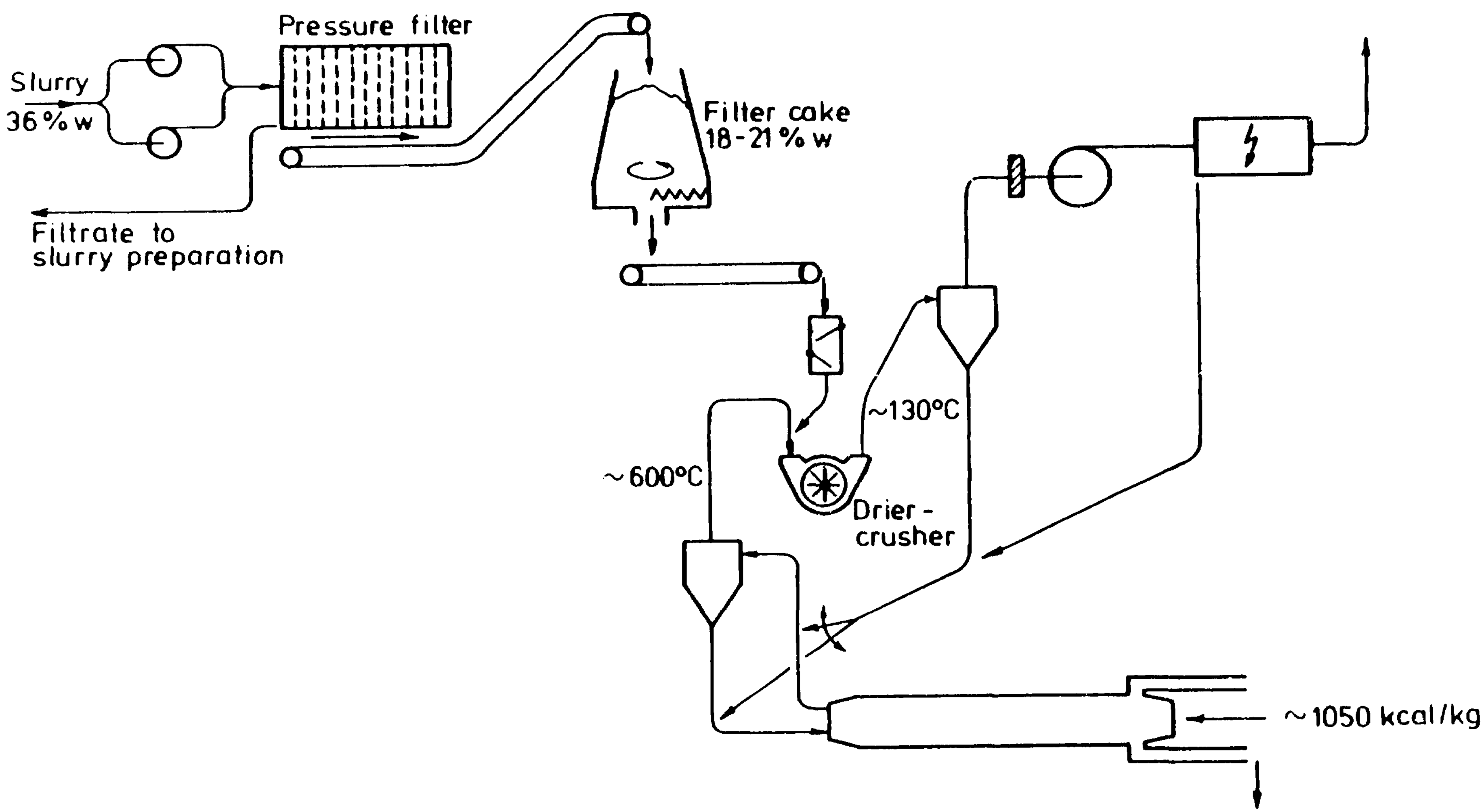
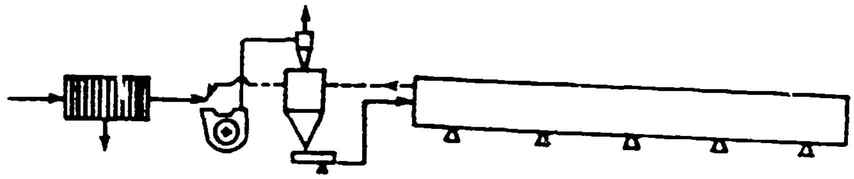


FIG 5

INTERREGIONAL SEMINAR, PEKING. OCT. 1980 | FIG. 5A

Conversion to filtercake installation

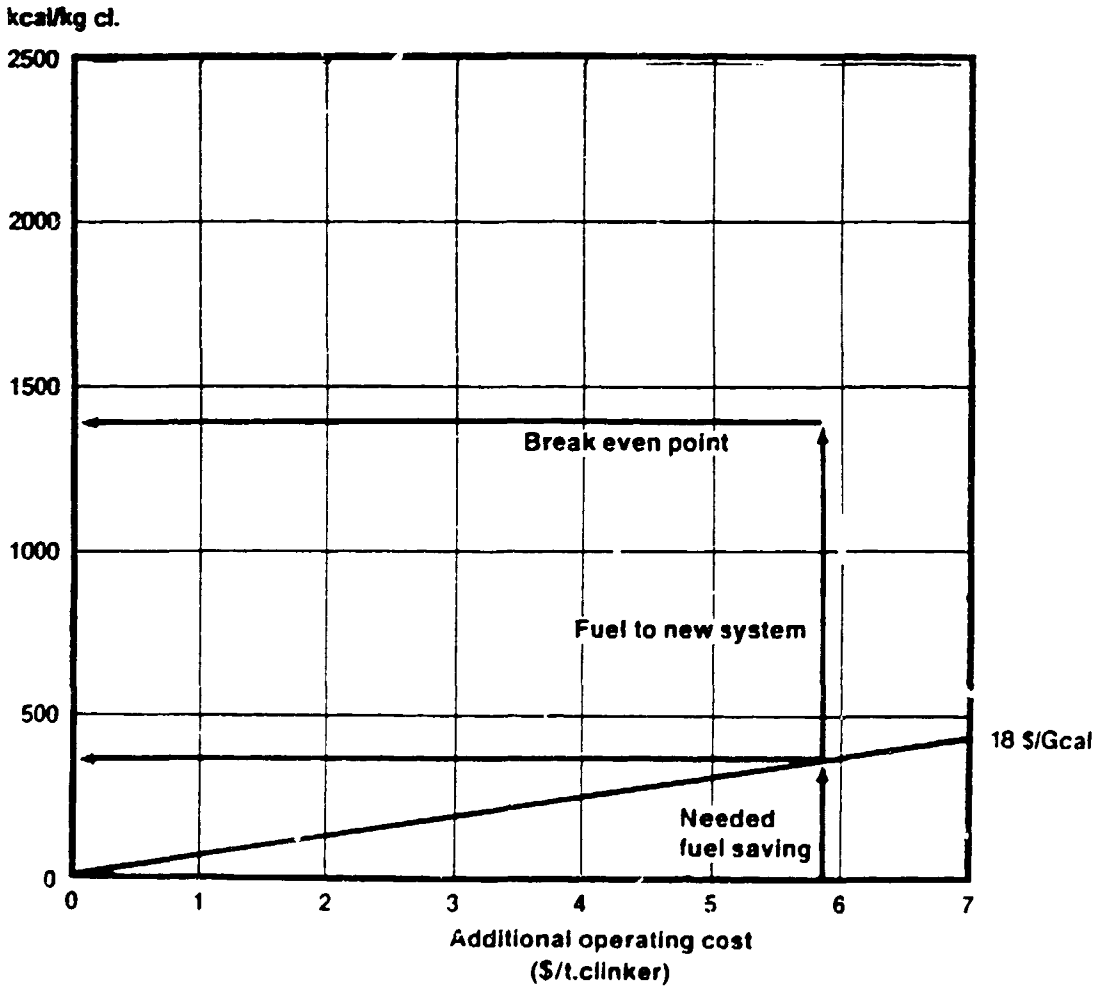


Slurry to filters, filtercake to dryer-crusher.
Raw meal to long kiln with chains removed.

Fuel to new system, 1025 kcal/kg cl.
Potential production increase, 0%
Conversion stop, 1 month
Equivalent production loss, 1 month

INSTALLATION COSTS	
Slurry filters	11.25
Dryer-crusher	7.13
Modification of kiln	0.50
Production loss	1.13
Total ($/annual t.cl.)	20.01

OPERATION COSTS	
Interest + Depreciation (20%)	4.00
Slurry filtering	1.25
Dryer-crusher	0.63
Total ($/t. clinker)	5.88



Conversion Wet to Dry

High quarry moisture (> 15%). Complex conversions

Raw materials	
↓ Slurry	
↓ Pressure filters:	operation costs ~ 100-150 kcal/kg
↓ Drier (drier-crusher, rotary d., flash d.) + furnace:	suppl. heat = 200 - 250 kcal/kg
↓ Raw meal homo. and feeding	

Kiln Department	Scheme D	Scheme E
Kiln	shortened	shortened + increased speed
Additional equipment	4-stage preheater Fan + precipitator Cooler modification	4-stage preheater Calciner + hot air duct Fan + precipitator Cooler + clinker transport
Expected heat consump. (kcal/kg)	780	800
Additional power consump. (kWh/t)	7	15 - 20
Production increase (%)	30 - 50	150 - 200 (if suff. slurry)
Cost of conversion	expensive	expensive
Prod. loss during conversion	large	large

FIG 6

Conversion Wet to Dry

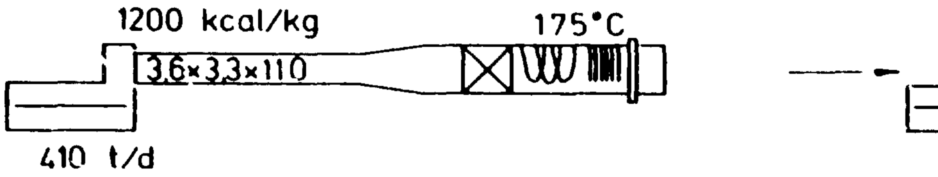
Low quarry moisture (<15%)

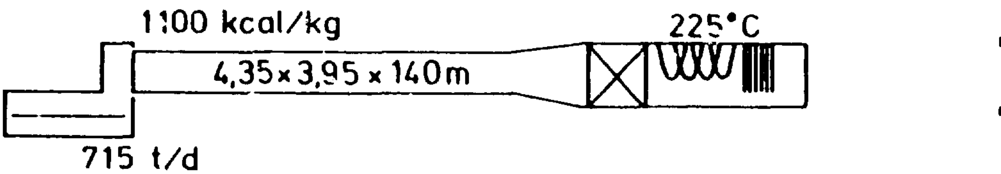
Raw materials
↓
Material stores
↓
Dry raw mill (+furnace dep. on moisture): old slurry mill for cement grinding
↓
Raw meal homo. and feeding

Kiln Department	Scheme F	Scheme G	Scheme H	Scheme J
Kiln	unchanged	unchanged	shortened	short+k. speed
Additional equipment	chain system	2-st. preheat. fan	4-st. preheat. fan, precip. cooler etc.	calc. air duct. fan, precip. cooler etc.
Expected heat consump. (kcal/kg)	1100	950	780	800
Additional power consump (kWh/t)	0	2	7	15-20
Production increase (%)	0	15-25	30-50	150-200
Cost of conversion	cheap	faily cheap	expensive	expensive
Prod. loss during conversion	small	small	large	large

FIG 7

Conversion from Wet





to Dry Process

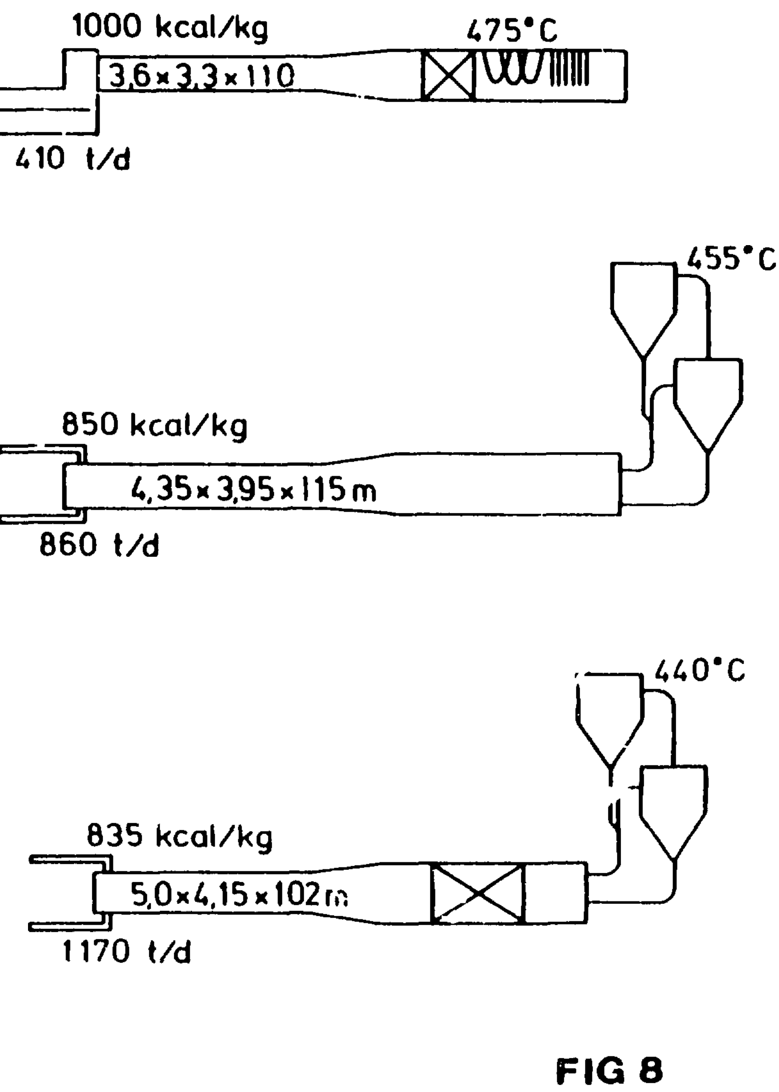
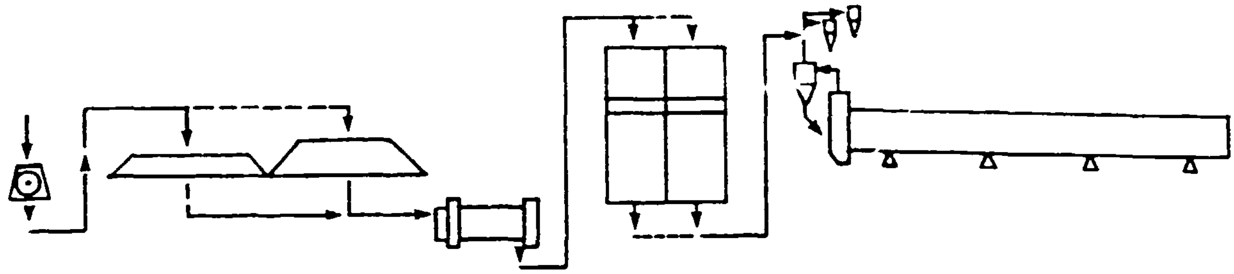


FIG 8

INTERREGIONAL SEMINAR, PEKING. OCT. 1980 | FIG. 8 A

Conversion to 2-stage preheater kiln



Raw materials to crusher, to storage and blending to new or converted raw milling.
Raw meal to homogenizing to kiln with 2-stage preheater.

Fuel to new system, 950 kcal/kg cl.
Potential production increase, 25%
Conversion stop, 3 months
Equivalent production loss, 2.4 months

INSTALLATION COSTS	
Lime + clay storage + blending	6.75
Raw mill new/converted	5.13
Raw meal homogenizing	5.63
Kiln modification + preheater + cooler	2.00
Production loss	2.75
Total ($/annual t.cl.)	22.26

OPERATION COSTS	
Interest + Depreciation (20%)	4.50
Extra power, men and maintenance	0.25
Total ($/t. clinker)	4.75