ALKALI REDUCTION IN CEMENT KILNS

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ABSTRACT

Comparison is made between the wet and dry processing plants for cement manufacture. Typical alkali reduction capabilities for various kiln systems are given and dry process kilns with energy efficient preheater systems are seen to produce clinker with higher alkali contents than normal for older systems wet or dry. Modern calcining technology has made construction of efficient bypass systems possible which allow alkali reduction. These systems may be used in combination with energy efficient dry process kilns.

Alkalies in Cement Raw Materials, Production Processes and Alkali Reduction Systems

Introduction

Alkalies in Portland Cement have drawn attention over the last two decades due to a combination of factors:-

1. Changes in cement plant technology
2. Energy Conservation
3. Environmental compatability
4. Alkali-silica reactions in concrete

The development in cement plant technology has been a continuous change from wet to dry process owing to the superior energy efficiency of modern dry process kilns. Steeply increasing fuel prices over the past couple of years has accentuated this trend.

Calls for pollution control by the modern society are being met by installation of dust precipitators with collection efficiencies exceeding 99.5 %. As a consequence, the alkalies from cement raw materials increasingly tend to end up in the cement. Due to their volatility at sintering temperature, they circulate in the process, particularly in the kiln system, and may cause clogging problems in gas ducts and cyclones.

In the same two decades it has been established that harmfull reactions occur between cement alkalies and certain types of aggregate. Fortunately these types of aggregate though widespread are not encountered everywhere.

Alkalies in cement do, however, offer some advantages, viz.

1. Improved nodulization of clinker in the kiln
2. Higher earlier strength of the cement

Both are of some importance for the cement manufacturer.

Production Processes

Although the greater part of new cement plants to-day are employing the dry process, many wet plants are still in operation and will be in production for years ahead. Typical flow-sheets are seen on fig. 1 and 2.

When a reduction of the alkali content of the cement is required, this must generally be performed by modifying the kiln section of the plant. That is apart from the fairly rare cases where supply of alternative low-alkali raw materials can be obtained.

Fig. 3 shows the principal types of traditional cement kilns. The capacity of FLS-kilns sold between 1960 and 1974, divided up according to kiln type, is given on fig. 4. The trend has clearly been towards the energy efficient dry process, which since 1974 constitutes more than 90 % of our sale of kiln capacity. A continuation of this trend (see also fig. 5) is likely to result in a world production capacity distribution approaching one quarter wet and 3 quarters dry process by 1985 (see fig. 6).

However the consumer must pay attention to the existing plants, as they supply the cement he is using to-day. In the U.S.A. some 60 % of all kilns are of the wet type and 30 % are more than 40 years old. The dry process plants in the U.S.A. are dominated by long kilns (85 %) and 20 % are 40 years old or more. This picture will change as 90 % of the planned dry process installations will be of the cyclone preheater type.

Alkali Reduction in Kiln Systems

A sizeable portion of the alkalies are evaporated in the kiln owing to their relatively high vapor pressure at the sintering temperature (see fig. 7). Part of the alkalies is caught and recycled from the colder parts of the kiln, preheater, filtre and raw mill - if the smoke gasses are utilized for drying of raw materials. Repeated evaporation and condensation results in an increasing internal circulation, until equilibrium is reached, whereby the system gives off the same quantity of alkalies as contained in the kiln feed.

The kiln systems vary with regard to alkali trapping efficiency, depending on the preheater and heat exchanger type (see fig. 8). In short when conserving energy - alkalies are conserved as well.

The smoke gasses are dedusted in filtres, mainly electrostatic precipitators. The composition of dust from these installations may be fairly rich in alkali for certain 'open' kiln systems, and the content of alkali in the clinker may be lowered by discard of a fine fraction of the dust.

Unfortunately this method is only effective in wet process plants, due to the dust composition (see fig. 9). Even for the wet process it is only kilns operating as so-called nodule kilns, which can employ this principle of alkali reduction. Large-diametre kilns usually operates as 'dust' kilns yielding precipitator dust with moderate contents of K_2O.

The concentration of alkali in the dust depends on whether the vapors of alkali are condensed as individual droplets or on the surface of solid particles. The latter is normal in dust-operated wet kilns, long dry kilns, and particularly in cyclone preheater kilns.

Consequently, only some (small capacity) wet plants can reduce the alkali content of clinker by rejecting precipitator dust. And filter dust disposal to-day is no easy matter due to restrictions from anti-pollution authorities. One way to overcome this problem is to leach the dust with water and recycle the alkali-free slurry to the kiln. The dissolved alkalies in the effluent from such a plant (see fig. 10) gives a strongly alkaline reaction and may require neutralization with acid before disposal. Also a leaching plant costs money to construct and operate, and the leached slurry, when added to the kiln slurry, often results in a higher overall water content in the kiln feed.

In the 4-stage preheater kiln a certain reduction of the alkali content can be made by means of a so-called by-pass (see fig. 11). The by-pass is unfortunately a capital demanding installation, and it increases the fuel expenditure. Actually most by-pass installations are made for chloride reduction. This is due to the limited effect on the alkali content of the clinker (see fig. 12). Mainly K_2O is reduced (see fig. 13 and 14).

The heat penalty incurred due to the alkali by-pass is quite heavy (see fig. 15) and the producers are generally not tempted to install such equipment unless compelled to for production reasons, viz. serious clogging problems arising when the clinker alkali content exceeds approx. 2 %. Disposal of dust is again a problem with by-pass operation.

Advanced Kiln Systems

The development of calcining systems in recent years has been directed towards 3 main objects, viz.

1. Reduction of the installation cost of kilns compared with the 4-stage preheater system

2. Production capacities up to 10 000 mtpd on moderate diametre kilns

3. Improved by-pass efficiency combined with an energy efficient dry process kiln

The new kiln systems we have developed (see enclosures No. 1, 2 and 3) and their application with regard to cost, capacity and alkali reduction is shown on fig. 16.

For outputs up to approx. 4500 mtpd. integral calcining kilns (see fig. 17), with calcining in suspension at the kiln inlet, are the most inexpensive of all commercial rotary kiln systems. A special scooping device at the kiln inlet raises the degree of calcination from a maximum of 30 % in the conventional 4-stage preheater kiln to about 50 - 60 %. The length of the kiln is consequently some 40% shorter than a 4-stage kiln. An efficient by-pass cannot be established on this kiln system, as the alkalies are extensively condensed on particulate surfaces before the kiln gasses leave the kiln.

For outputs ranging from 4500 - 10 000 mtpd the calcining kiln with separate calciner and hot air pipe from the clinker cooler is the only system that will will give a reasonable kiln diametre. This kiln system employs a supply of only 30 % of the fuel in the kiln proper, compared with 100 % in the 4-stage kiln. Hence alkalies evaporated in the sintering zone are concentrated in a much smaller volume of gasses, and a by-pass will be 3 times as efficient compared with systems where all gasses are drawn through the kiln. Or - the heat penalty will be considerably less. (See fig. 18)

We have developed a special version of this system (see fig. 19) for raw materials with high contents of volatile matter or for maximum alkali reduction. In this system all gasses leaving the kiln are extracted from the system, whereby the biggest possible alkali drain is established. The heat penalty is 100 - 150 kcal/kg clinker, including the heat of evaporation of alkali compounds, which could for example amount to 40 kcal/kg clinker. The heat loss is also dependent on the dust lost from the by-pass, which is quite low due to the relatively low gas velocity at the kiln inlet and the high degree of calcination of the raw meal.

In cases where a large and variable by-pass is required, for example 0 - 100 %, the gas ducts are arranged as indicated on fig. 20. A large kiln of this type produces ordinary Portland clinker at approx. 750 kcal/kg and low-alkali clinker at 850 - 900 kcal/kg clinker, with a 100 % by-pass.

Conclusion

Typical alkali reduction capabilities for various kiln systems are given on fig. 21. It is clearly seen that conventional dry process kilns with energy efficient preheater systems produce clinker with higher alkali contents than normal for older systems, wet or dry. By-pass installations may be used for alkali reduction, but are not normal to-day due to extra costs of installation, higher fuel consumption and relatively low efficiency. Modern calcining technology, however, has made construction of highly efficient, low-energy-loss by-pass systems possible in combination with energy efficient dry process kilns.

The trend, however, will undoubtedly continue towards higher alkali contents in cement due to the gradual close-down of small scale factories wet or dry, operating with inferior economy compared with large dry process facilities. (See fig. 22). The potential alkali reducers, viz. operators of small wet kilns are generally not in a position to accept additional operating expenses for alkali reduction unless they can be passed on to the consumer.

Fig. 1

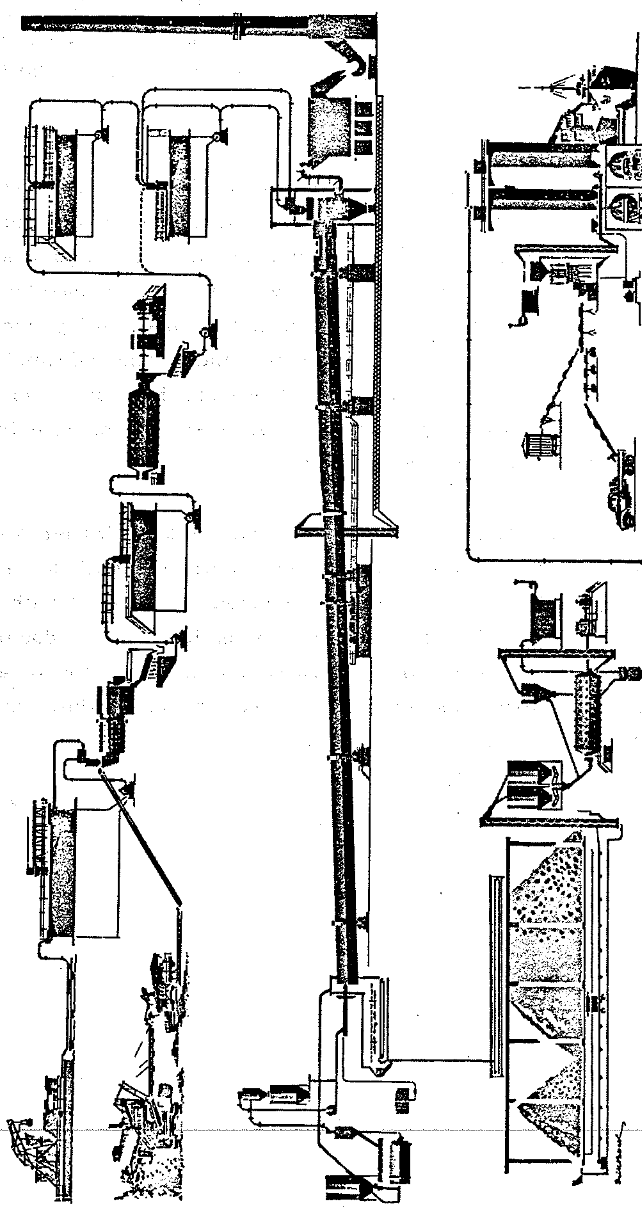


Fig. 2

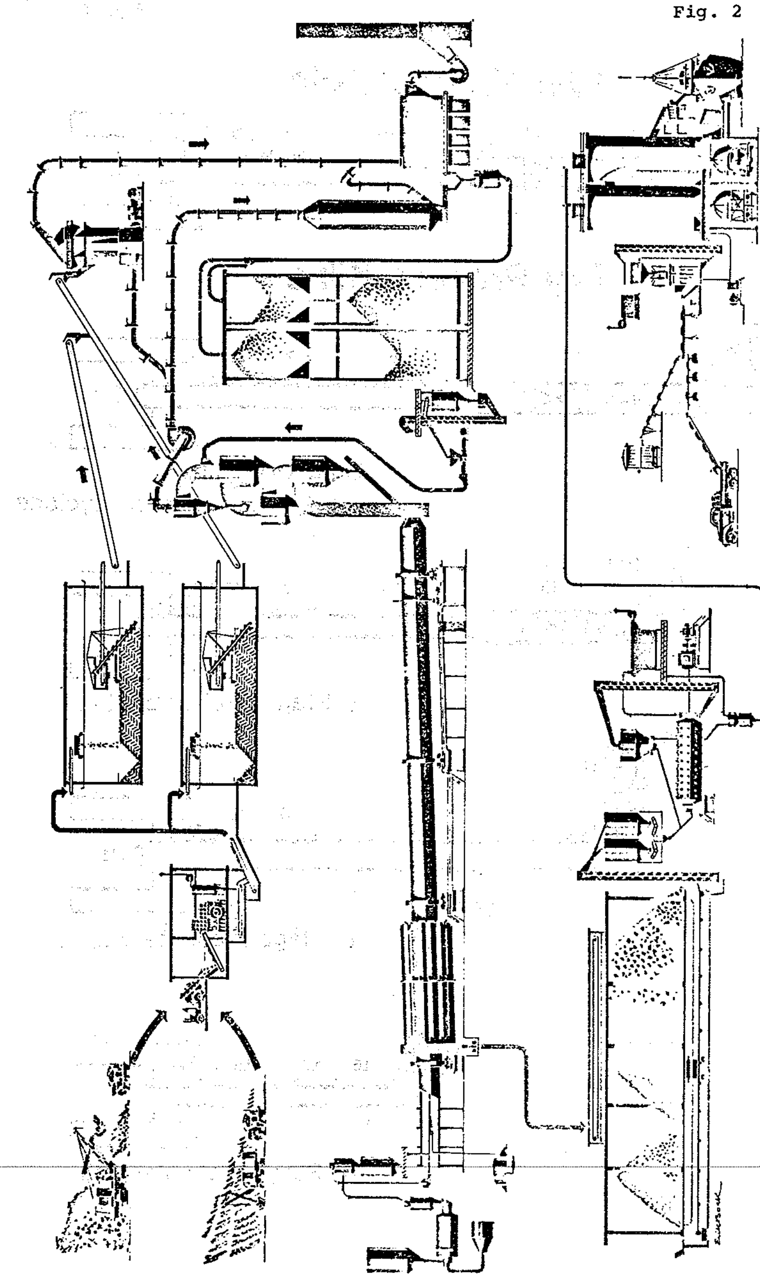


Fig. 3

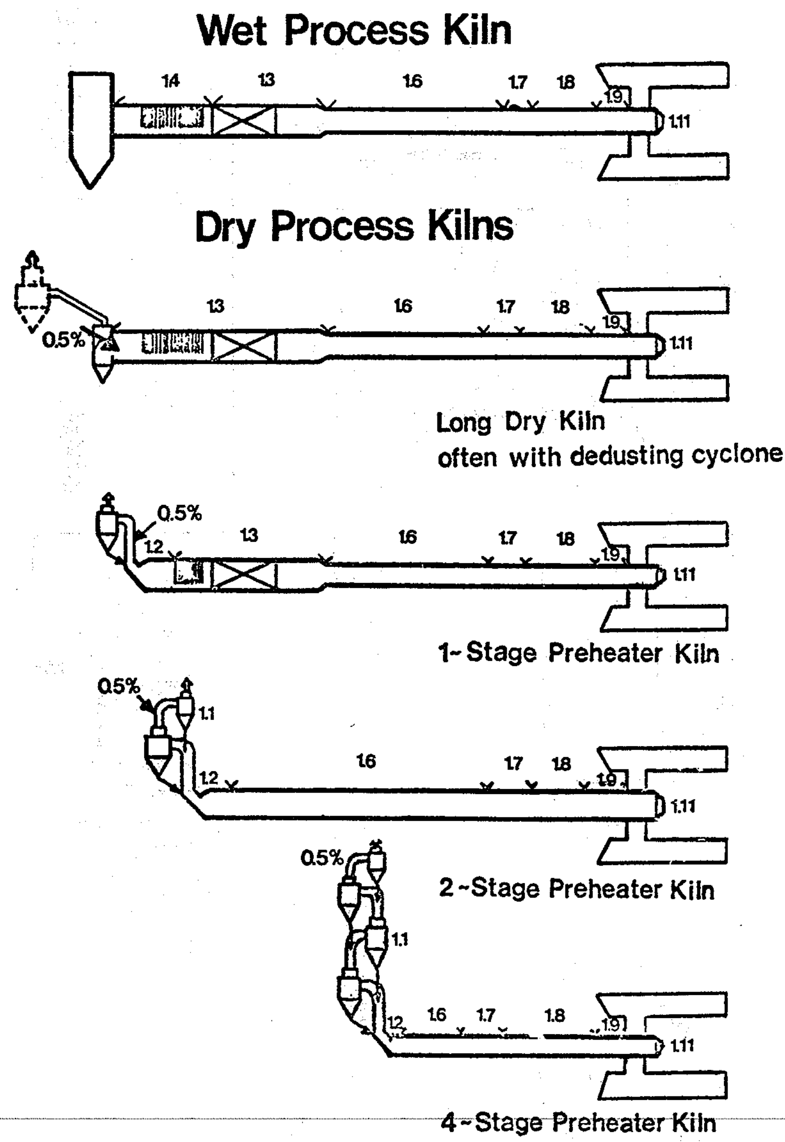

Wet Process Kiln
1.4
1.3
1.6
1.7
1.8
1.9
1.11
Dry Process Kilns
0.5%
1.3
1.6
1.7
1.8
1.9
1.11
Long Dry Kiln
often with dedusting cyclone
0.5%
1.2
1.3
1.6
1.7
1.8
1.9
1.11
1-Stage Preheater Kiln
0.5%
1.1
1.2
1.6
1.7
1.8
1.9
1.11
2-Stage Preheater Kiln
0.5%
1.1
1.2
1.6
1.7
1.8
1.9
1.11
4-Stage Preheater Kiln

Fig. 4

F. L. SMIDTH KILN CAPACITY SOLD 1960 - 1974
% - DISTRIBUTION ON PROCESS

	1960 - 64	1965 - 69	1970 - 74	1975 -
LONG DRY KILN	31.7	12.3	3.1	
1-STAGE PREHEATER	0.5	18.0	3.8	
2-STAGE PREHEATER	1.9	8.5	2.1	
4-STAGE PREHEATER	0	15.7	75.6	
TOTAL DRY PROCESS	34.1	54.5	84.6	90 +
WET PROCESS	65.9	45.5	15.4	
AVERAGE KCAL/KG CL.	1250	1120	890	

Fig. 5

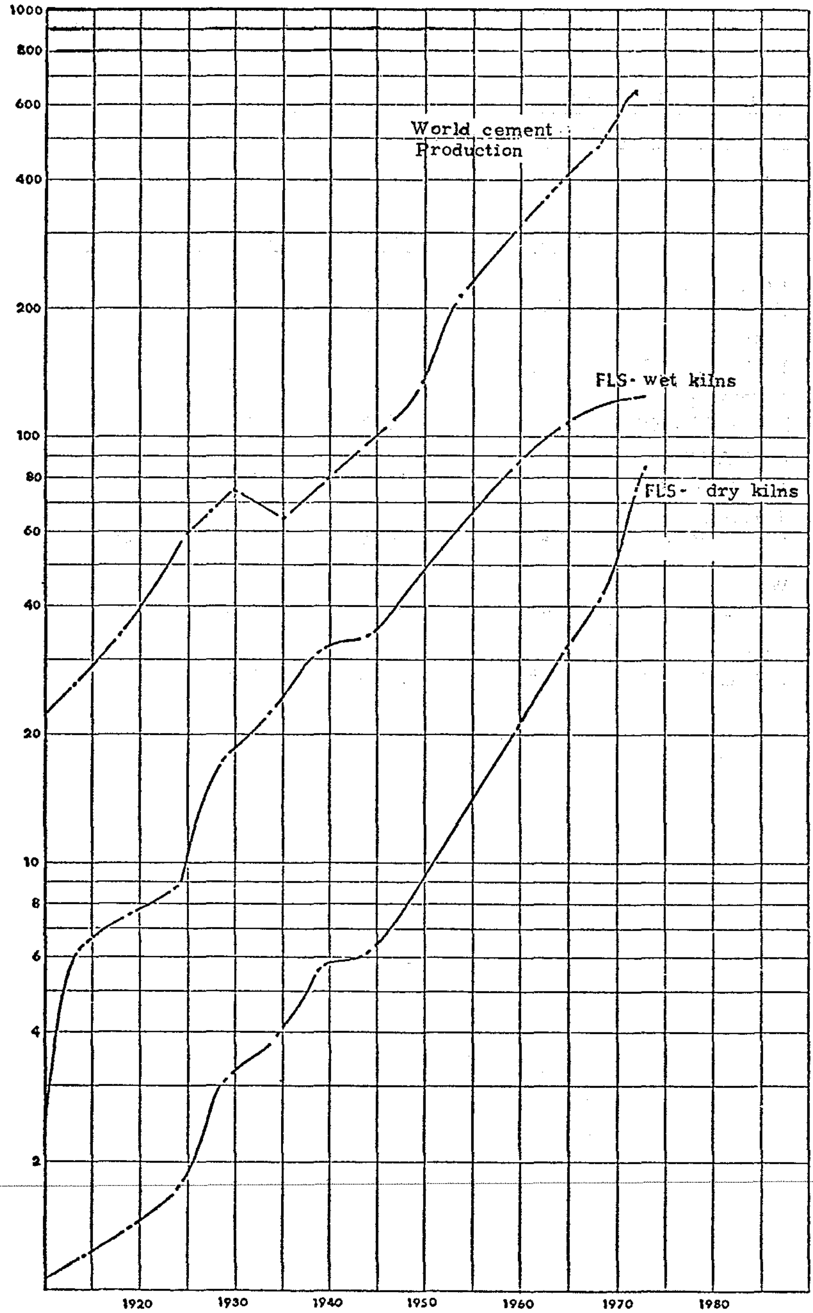

1000
800
600
400
200
100
80
60
40
20
10
8
6
4
2
1920
1930
1940
1950
1960
1970
1980
World cement Production
FLS- wet kilns
FLS- dry kilns

Fig. 6

CEMENT PRODUCTION FORECAST TILL 1985

	World Production	Capacity Distribution % Wet	% Dry	Kcal/kg Cement Average
1970	573	50	50	1272
1975	700	43	57	1225
1980	840	35	65	1184
1985	1008	28	72	1138

Fig. 7

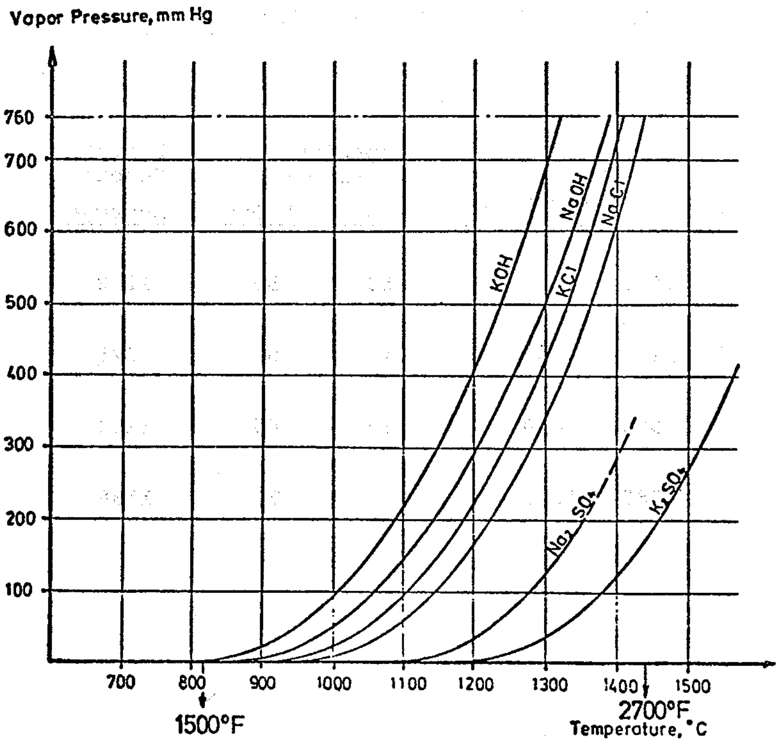

Vapor Pressure, mm Hg
760
700
600
500
400
300
200
100
700
800
900
1000
1100
1200
1300
1400
1500
1500°F
2700°F
Temperature, °C
KOH
NaOH
KCl
NaCl
Na2 SO4
K2 SO4

Fig. 8

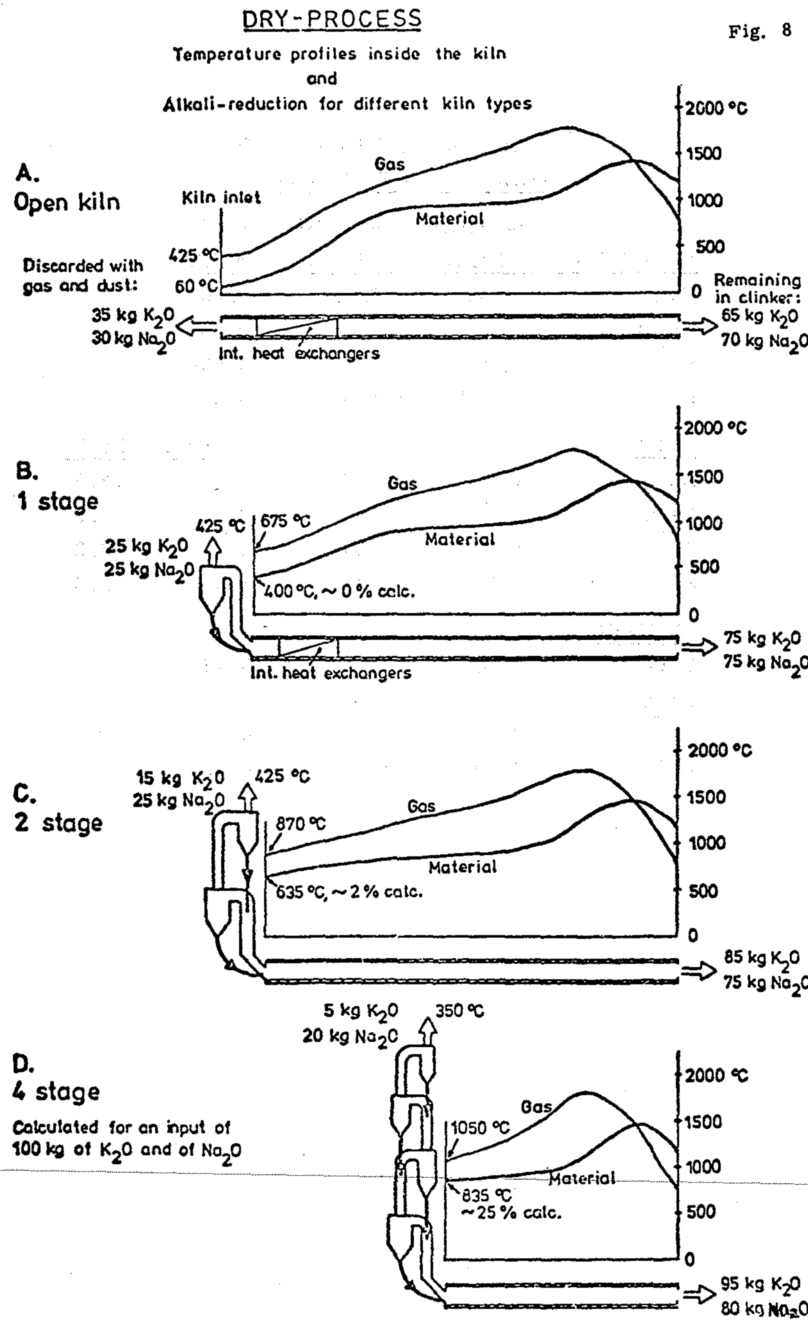

DRY-PROCESS
Temperature profiles inside the kiln
and
Alkali-reduction for different kiln types
A.
Open kiln
Kiln inlet
Gas
Material
425 °C
60 °C
Discarded with
gas and dust:
35 kg K2O
30 kg Na2O
Int. heat exchangers
Remaining
in clinker:
65 kg K2O
70 kg Na2O
2000 °C
1500
1000
500
0
B.
1 stage
425 °C
675 °C
400 °C, ~ 0 % calc.
25 kg K2O
25 kg Na2O
Int. heat exchangers
75 kg K2O
75 kg Na2O
C.
2 stage
15 kg K2O
25 kg Na2O
425 °C
870 °C
635 °C, ~ 2 % calc.
85 kg K2O
75 kg Na2O
D.
4 stage
Calculated for an input of
100 kg of K2O and of Na2O
5 kg K2O
20 kg Na2O
350 °C
1050 °C
835 °C
~25 % calc.
95 kg K2O
80 kg Na2O

Fig. 9

ANALYSES OF DUST FROM ELECTROFILTRES ETC.

	2-STAGE KILN	4-STAGE KILN	WET KILN	
RAW MEAL				
K_2O	0.53	0.30	0.46	
Na_2O	-	-	0.25	
S	0.00	-	0.030	
Cl^-	0.004	0.008	0.025	
DUST			COARSE	FINE
K_2O	0.93	0.40	10.5	22.3
Na_2O	-	-	0.65	1.9
S	0.15	0.10	4.2	7.2
Cl^-	0.12	0.05	1.5	2.5
CLINKER				
K_2O	0.84	0.51	0.43	
Na_2O	-	-	0.31	
S	0.19	-	0.10	
Cl^-	0.001	0.005	0,003	

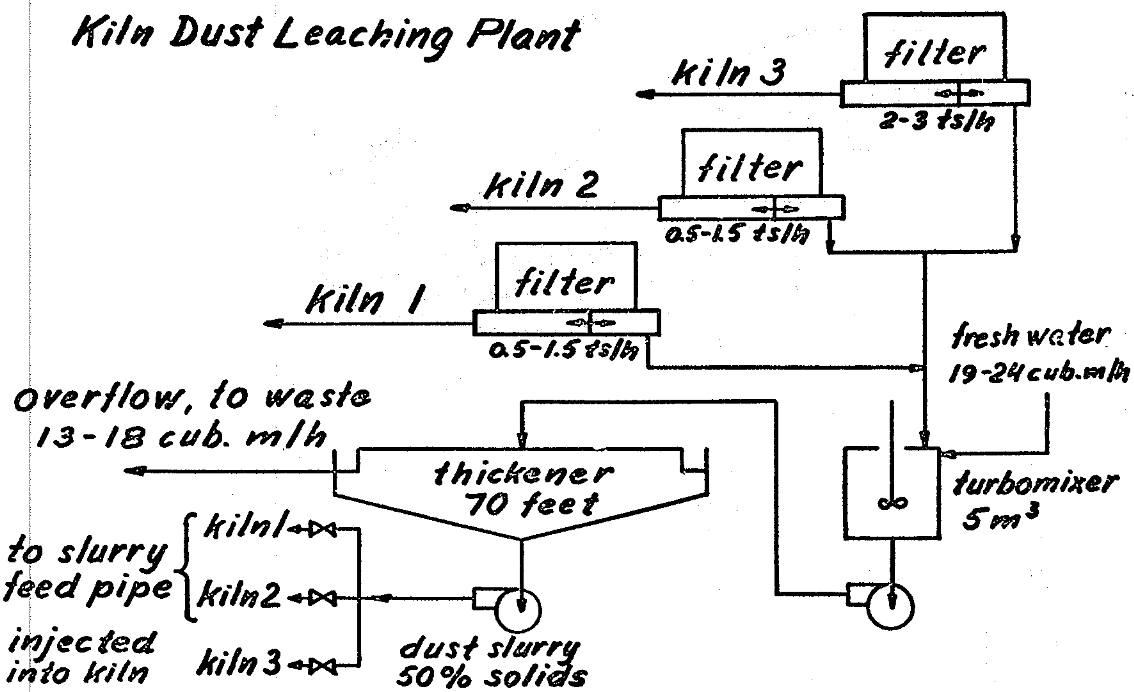

Kiln Dust Leaching Plant
filter
kiln 3
2-3 ts/h
filter
kiln 2
0.5-1.5 ts/h
filter
kiln 1
0.5-1.5 ts/h
fresh water
19-24 cub.m/h
overflow, to waste
13-18 cub. m/h
thickener
70 feet
turbomixer
5 m³
to slurry feed pipe
kiln1
kiln2
kiln3
injected into kiln
dust slurry
50% solids

Fig. 10

Fig. 11

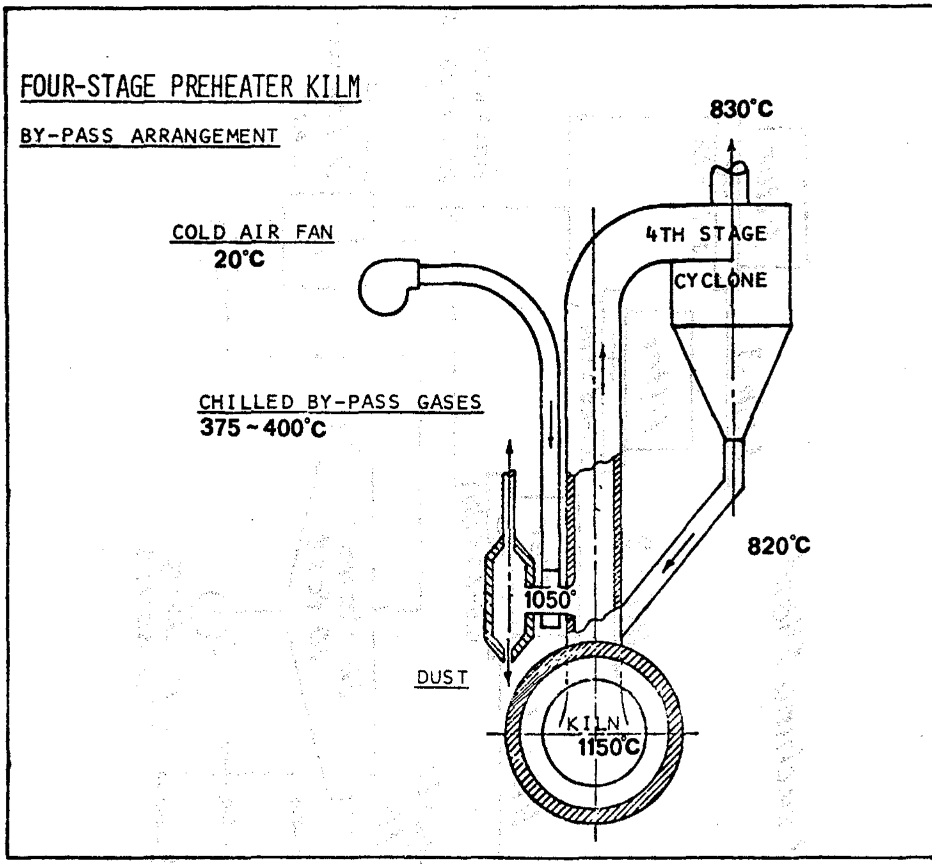
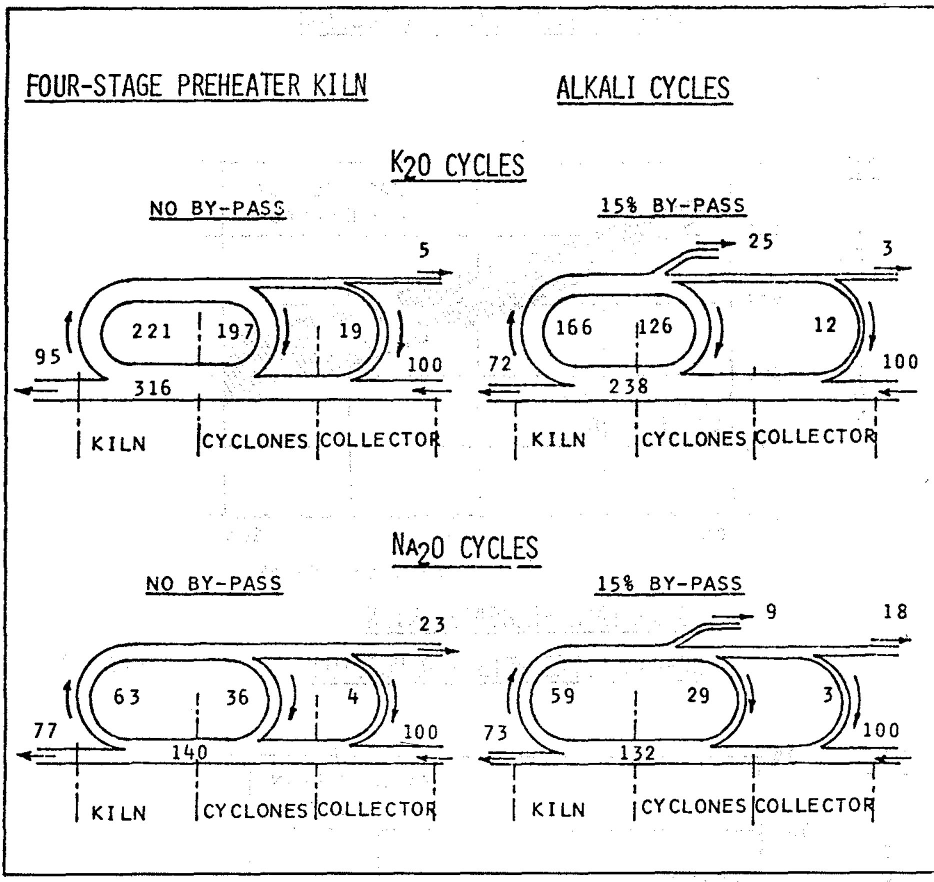
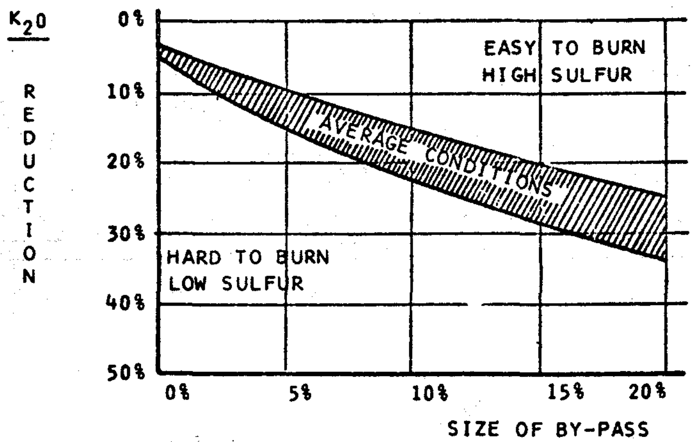

FOUR-STAGE PREHEATER KILM
BY-PASS ARRANGEMENT
COLD AIR FAN
20°C
CHILLED BY-PASS GASES
375 ~ 400°C
830°C
4TH STAGE
CYCLONE
820°C
1050°
DUST
KILN
1150°C

Fig. 12


FOUR-STAGE PREHEATER KILN
ALKALI CYCLES
K2O CYCLES
NO BY-PASS
5
221
197
19
95
100
316
KILN
CYCLONES
COLLECTOR
15% BY-PASS
25
3
166
126
12
72
100
238
KILN
CYCLONES
COLLECTOR
NA2O CYCLES
NO BY-PASS
23
63
36
4
77
100
140
KILN
CYCLONES
COLLECTOR
15% BY-PASS
9
18
59
29
3
73
100
132
KILN
CYCLONES
COLLECTOR

FOUR-STAGE PREHEATER KILN
BY-PASS SIZE VERSUS REDUCTION

Fig. 13



FOUR-STAGE PREHEATER KILN
BY-PASS SIZE VERSUS REDUCTION

Fig. 14

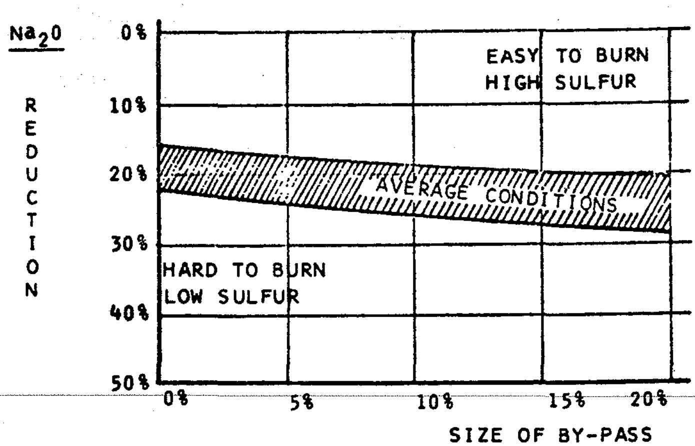


Fig. 15

FOUR STAGE PREHEATER KILN

K_2O-REDUCTION VERSUS EXTRA FUEL EXPENSES

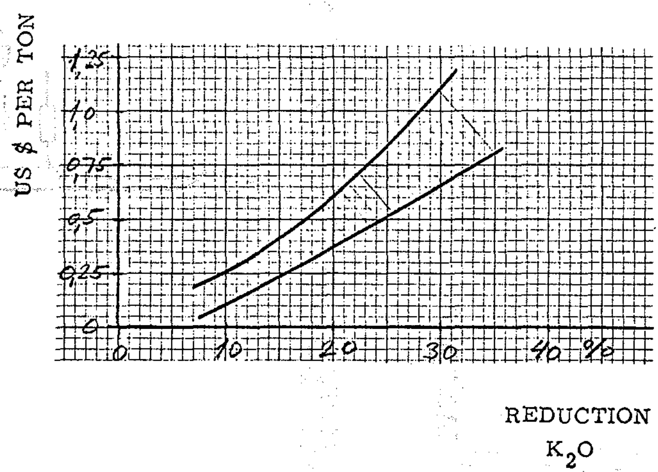
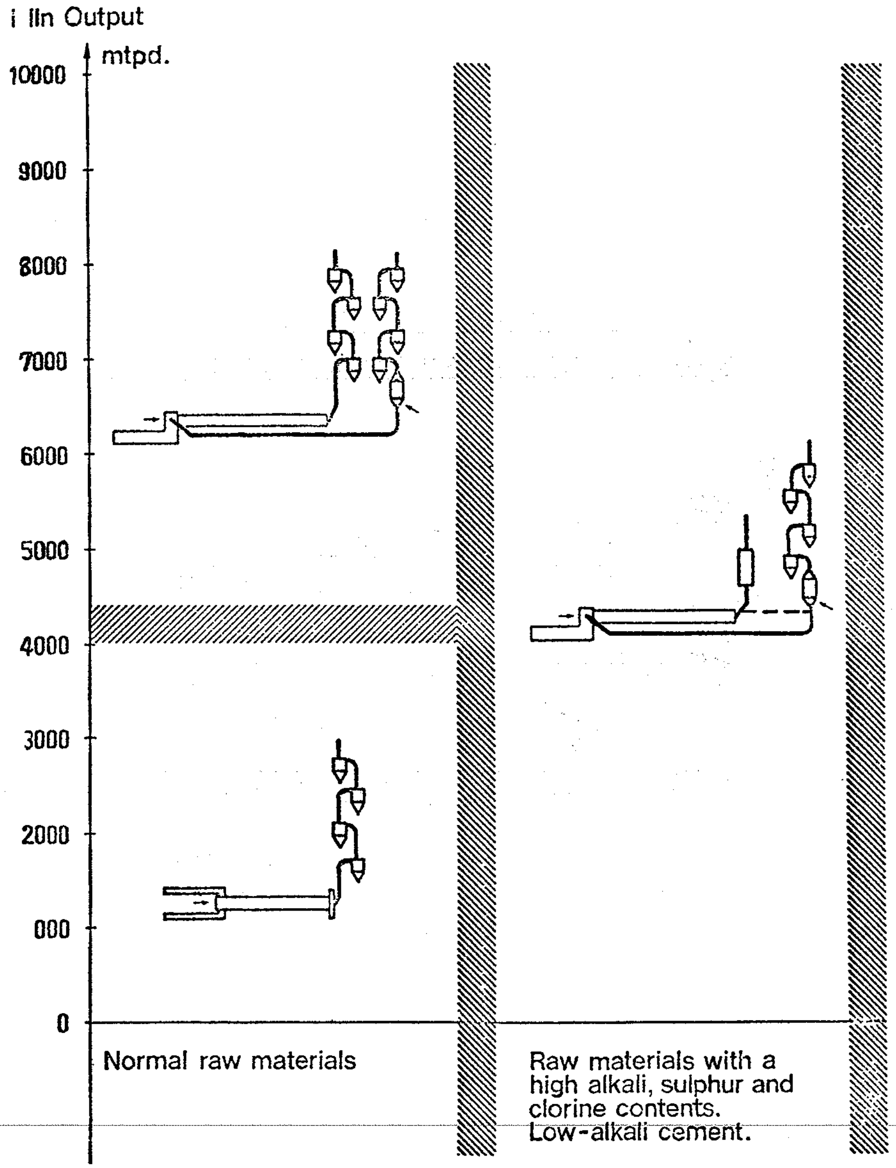
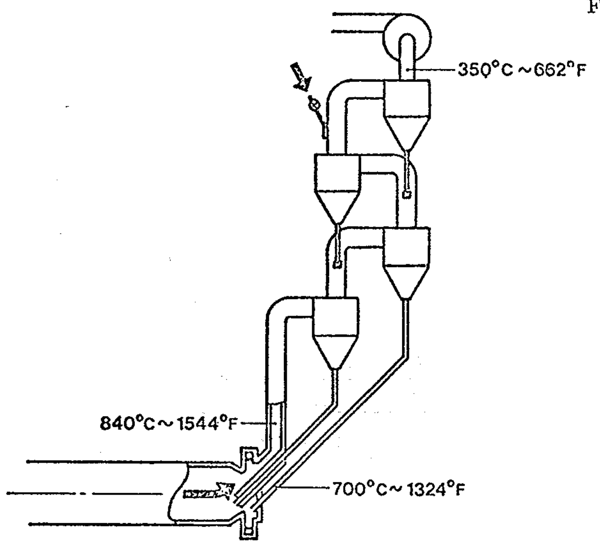


Fig. 16



i lln Output
mtpd.
10000
9000
8000
7000
6000
5000
4000
3000
2000
000
0
Normal raw materials
Raw materials with a high alkali, sulphur and clorine contents. Low-alkali cement.

Fig. 17



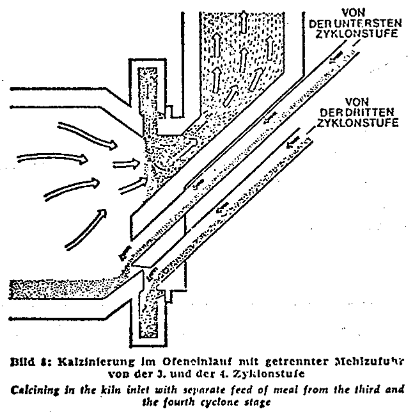


Bild 8: Kalzinierung im Ofeneinlauf mit getrennter Mehlzufuhr von der 3. und der 4. Zyklonstufe

Calcining in the kiln inlet with separate feed of meal from the third and the fourth cyclone stage

Fig. 18

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CALCINER KILN BYPASS

% K_2O REDUCTION IN CLINKER.

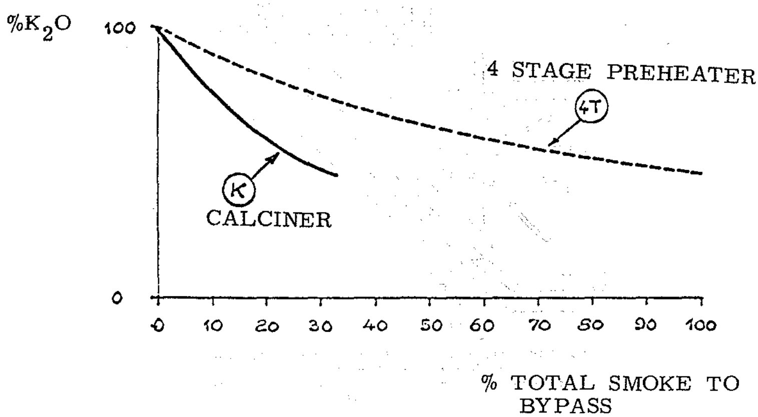


Fig. 19

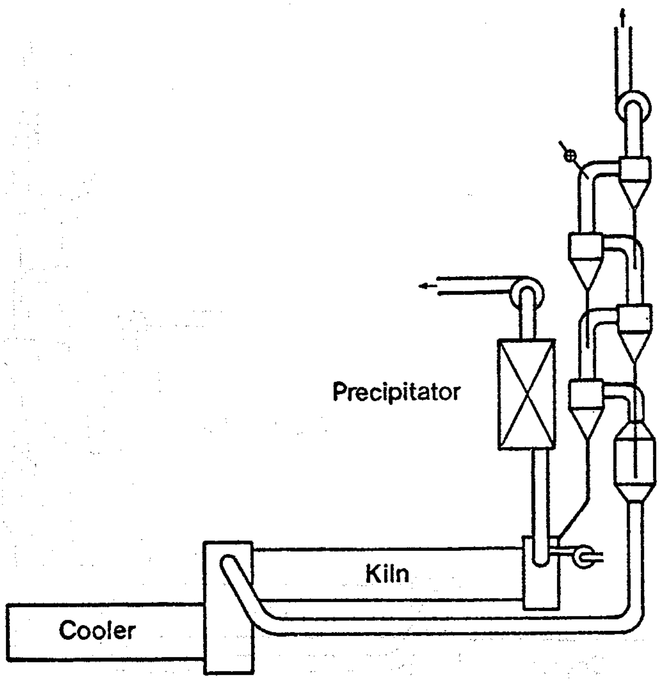


Fig. 20

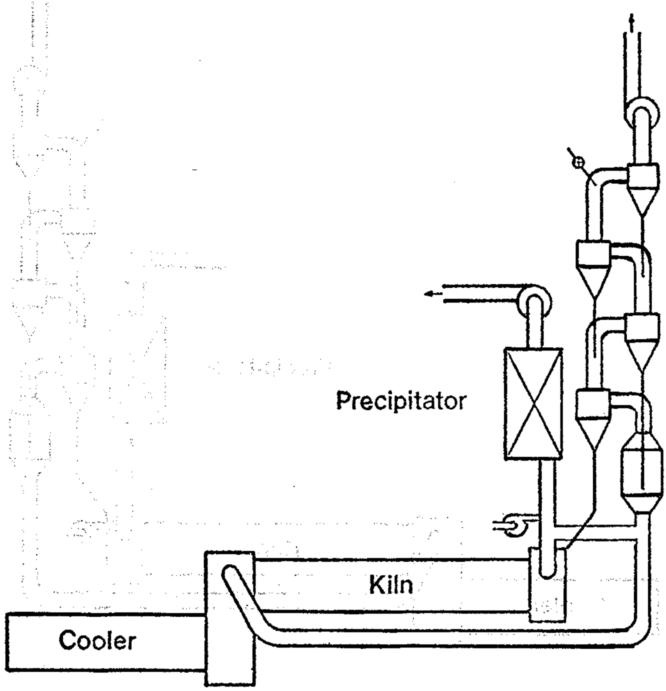


Fig. 21

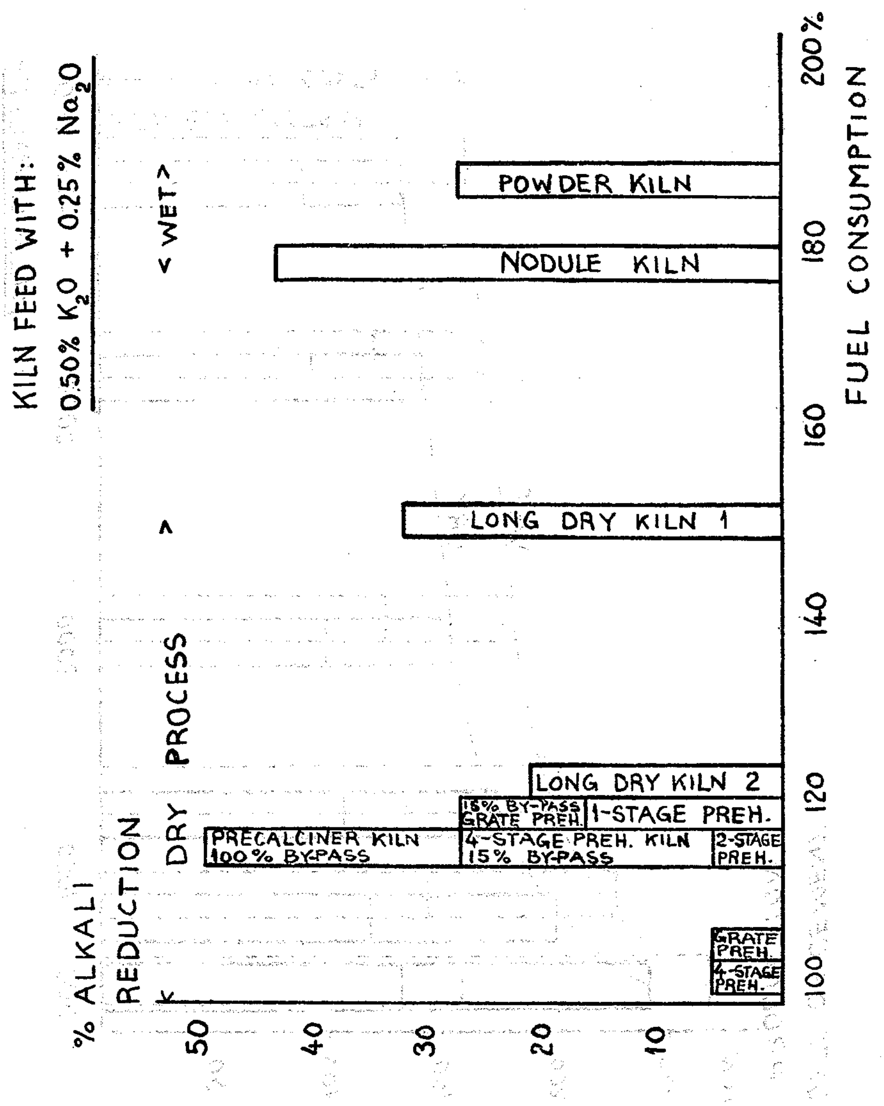
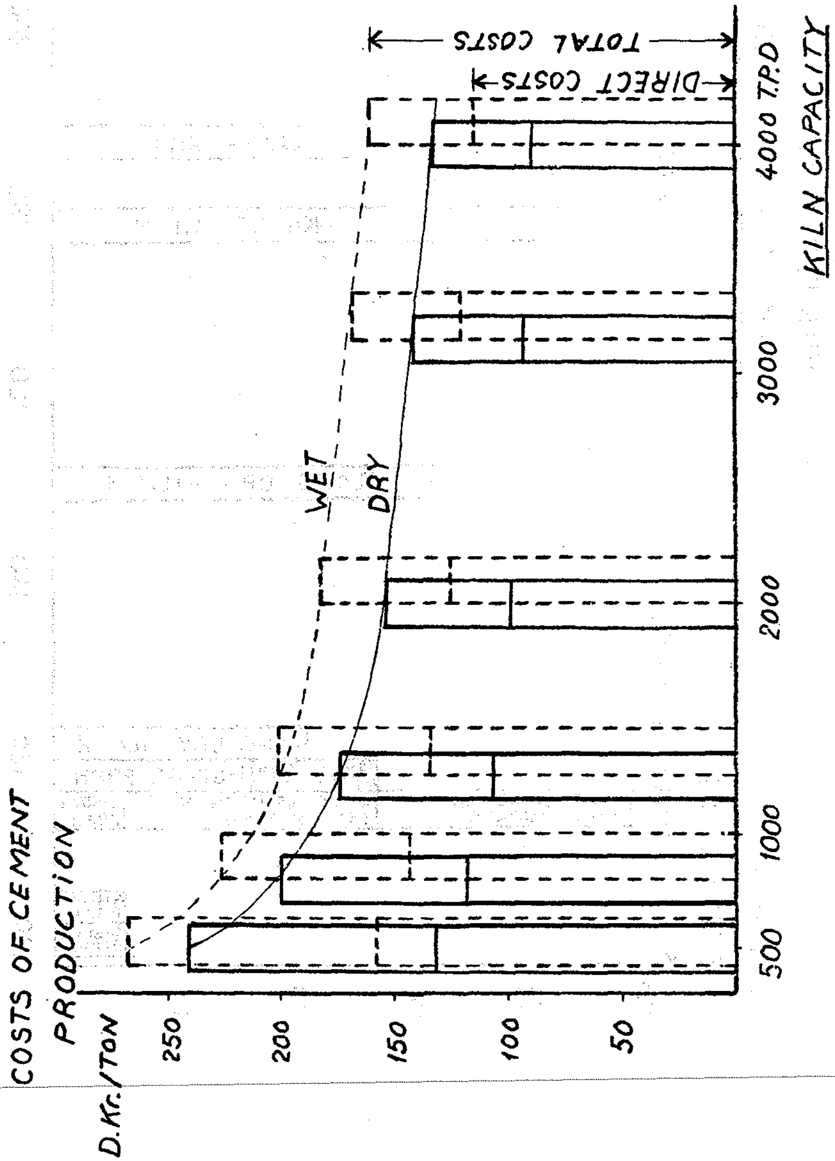

KILN FEED WITH:
0.50% K_2O + 0.25% Na_2O
< WET >
< DRY PROCESS >
POWDER KILN
NODULE KILN
LONG DRY KILN 1
LONG DRY KILN 2
15% BY-PASS GRATE PREH.
1-STAGE PREH.
PRECALCINER KILN 100% BY-PASS
4-STAGE PREH. KILN 15% BY-PASS
2-STAGE PREH.
GRATE PREH.
4-STAGE PREH.
% ALKALI REDUCTION
50
40
30
20
10
FUEL CONSUMPTION
100
120
140
160
180
200%

Fig. 22


COSTS OF CEMENT
PRODUCTION
D.Kr./TON
250
200
150
100
50
WET
DRY
TOTAL COSTS
DIRECT COSTS
500
1000
2000
3000
4000 T.P.D
KILN CAPACITY

CONTRIBUTION TO DISCUSSION

Dr. G.M. Idorn

It is interesting to observe that the alkali contents in cements can now be rather precisely assessed according to the nature of the cement materials (the "impact" of alkalies) and the type of cement processing equipment. Since any establishment of a cement manufacturing unit is a long-term investment it should therefore be possible to identify the alkali-contents for all cements over the world, and also to foresee any short term changes which may occur when a new unit is decided upon, or long term changes by means of forecasting technique modifications.

It is also interesting to observe that the cement industry equipment maker is a long-term planner. There are less than 10 major cement manufacturer-equipment making firms in the World, managing less than 10 billion dollars of sales per year. There are more than 4 thousand cement manufacturers and hundreds of thousands of cement using companies. These latter partners in the game, and especially the cement consumers (comprising a 2-300 billion dollar annual business over the World) have hardly any coherent long term planning for their technology development. It would seem to be desirable that some body or business agglomeration should work out a framework for forecasting the wanted and possible technology development, also involving the social aspects, and the resource and energy problems. Such a forecast ought to be made available for computation with the expected development of cement manufacture and of cement manufacture equipment so as to gain a more complete pattern of future possibilities to choose among.