Advanced Dry Process Kiln Systems

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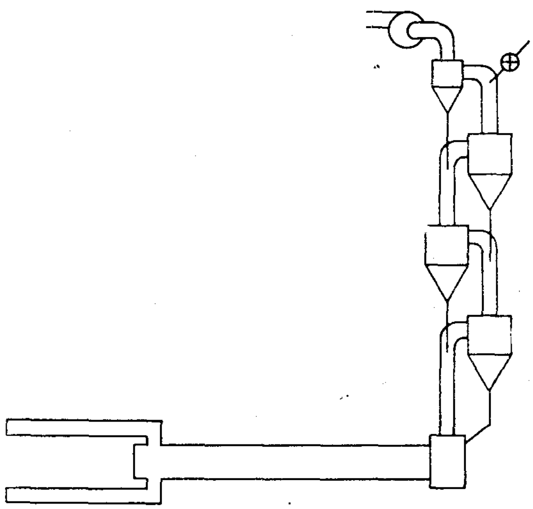
Introduction

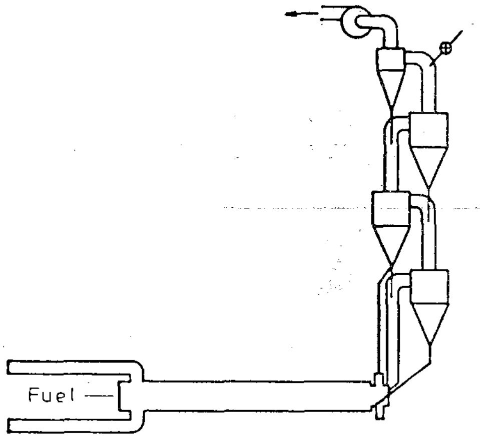
As you know, the trend in the development of modern dry process kiln systems within the cement industry has involved that the conventional 4-stage cyclone preheater kiln is the most commonly used kiln type in most plants under construction today (Fig.1).

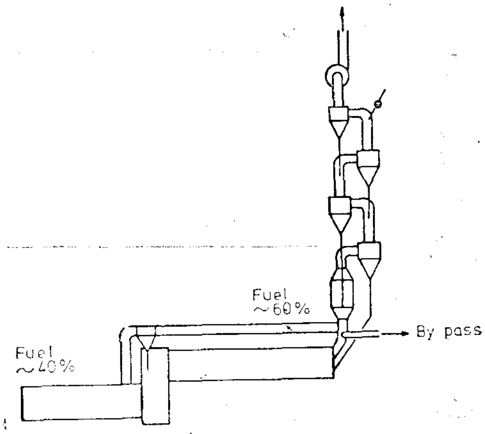
The 4-stage kiln has, however, various limitations-primarily the fact that all smoke gas produced during calcining and sintering is passing through the kiln tube, which calls for a relatively large kiln diameter. Secondly, the smoke gas temperature at the transitional stage from kiln to preheater should not exceed a maximum of about 1,200°C, owing to the risk of the formation of crust, for which reason the degree of calcination at the kiln inlet is usually not more than 30%. This results in a fairly long kiln compared to systems according to which calcination takes place in suspension. Thirdly, the heat economy of 4-stage kilns with by-pass is not very favourable, because the vapours of volatile matter from the calcining zone are combined in an unnecessarily large volume of smoke gas, viz. all the combustion products as well as CO_2 from 70% of the calcining process.



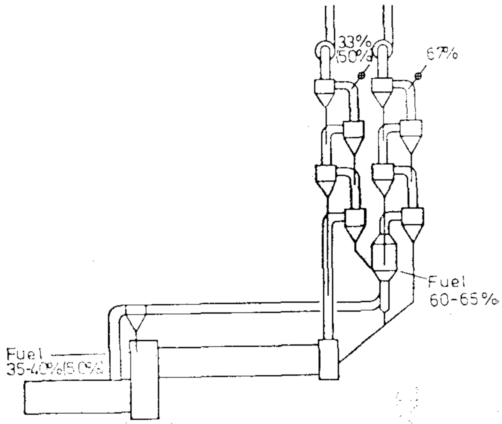
<Fig. 1>

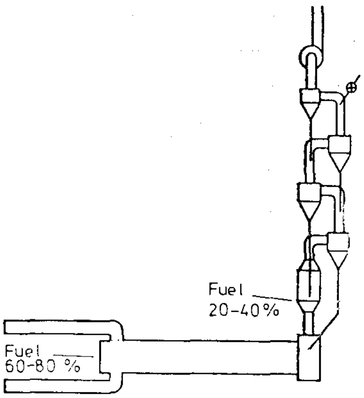
If we assume a specific capacity of 1.6–2.0 mtpd/m^3 - corresponding to a 30% degree of calcination in the kiln inlet - and a maximum kiln diameter of ab. 6 metres with a view to the lining life, the capacity of 4-stage kilns is limited to ab. 4,500-5,000 mtpd. It

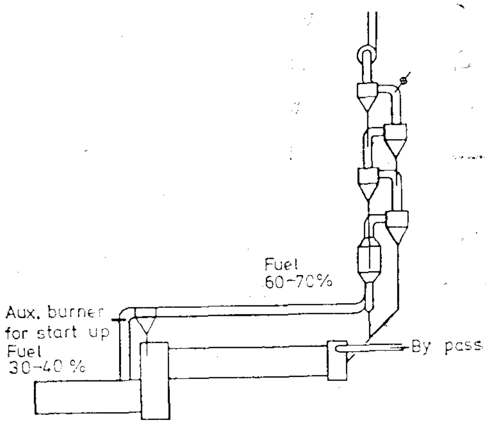




<Fig. 2- I >







<Fig. 2- II -1>

<Fig. 2- II -2>

should also be taken into consideration that the combined calcining and sintering in the kiln in principle will give an operation which is not quite as stable compared to kiln systems, in which these processes are separate and may be adjusted in dependently.

These conditions have during the past few years resulted in the development of kiln systems, according to which the calcining and sintering processes are more or less separate operations. The main result of this development is that in comparison to the 4-stage kiln it is today possible to obtain:

1) Reduced installation costs for kiln units up to 4,500 mtpd by using *Integral calcining* (i.e. calcination in the kiln inlet).
2) A kiln capacity of up to 10,000 mtpd by calcination in a separate precalciner.
3) Production of low-alkali clinker at an extra heat consumption of max. 150 kcal/kg clinker in special systems.

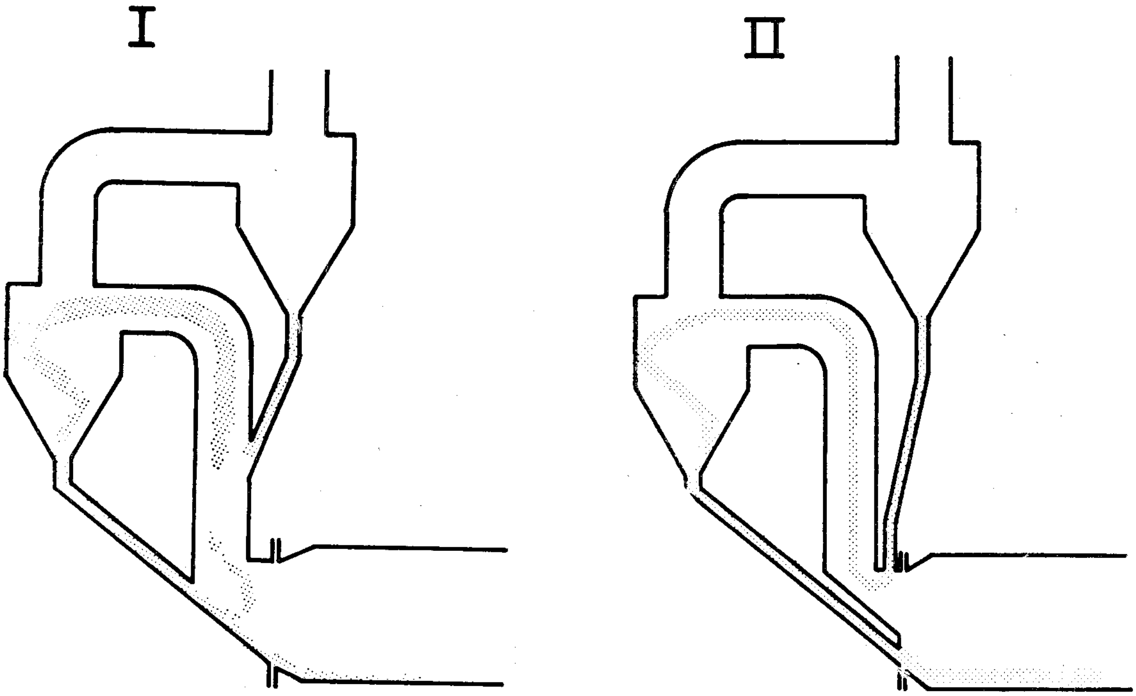
Precalcination systems

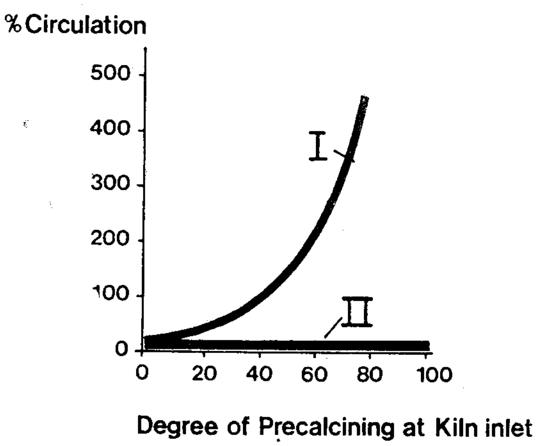
In the precalcination systems marketed today the calcining process takes place as illustrated in Fig. 2, either in the kiln inlet (System I) or in a separate calcinator with separate fuel supply (System II).

Calcination in the kiln inlet, or *integral calcining,* could in principle be made in two ways as shown in Fig. 3. According to Principle I, the material is whirled up at the bottom of the riser pipe to the lowermost cyclone stage and is put in circulation through this stage. To obtain a high degree of calcination a considerable circulation is essential, which, however, is difficult to maintain constant, and which involves a heavy pressure loss.

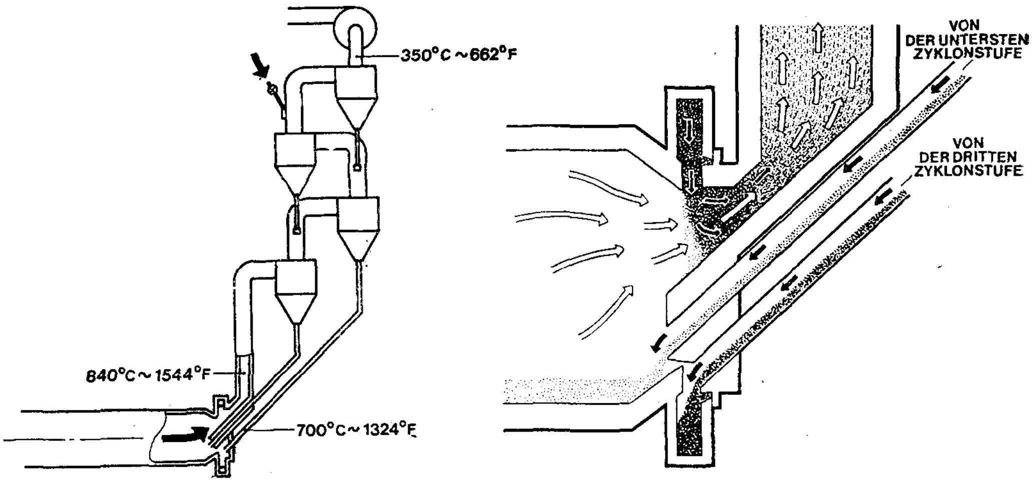
We have, therefore, decided to develop Principle II, working without circulation. According to the latter system the raw meal is transported from the lowermost cyclone stage but one to the kiln inlet of the kiln tube and by means of a scooping device it is introduced into the smoke gas from the kiln, then calcined, and through the lowermost cyclone stage by-passing the scooping device and fed into the kiln tube.

As shown in Fig. 4, the raw meal is preheated to ab. 700°C in the three upper cyclone steps of the integral kiln. The calcining in suspension takes place in the scooping chamber in the course of 2–3 seconds at the contact of raw meal and smoke gas with the result that the temperature in the riser pipe to the preheater will be ab. 840°C. When applylng this system, the smoke gas temperature at the kiln inlet will no longer


I
II


% Circulation
500
400
300
200
100
0
0
20
40
60
80
100
I
II
Degree of Precalcining at Kiln inlet

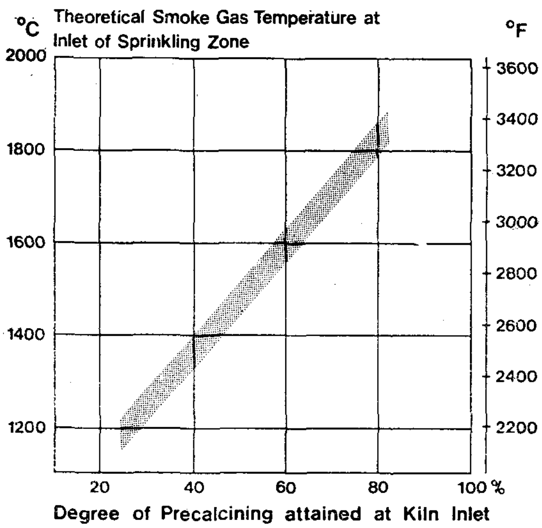
<Fig. 3>



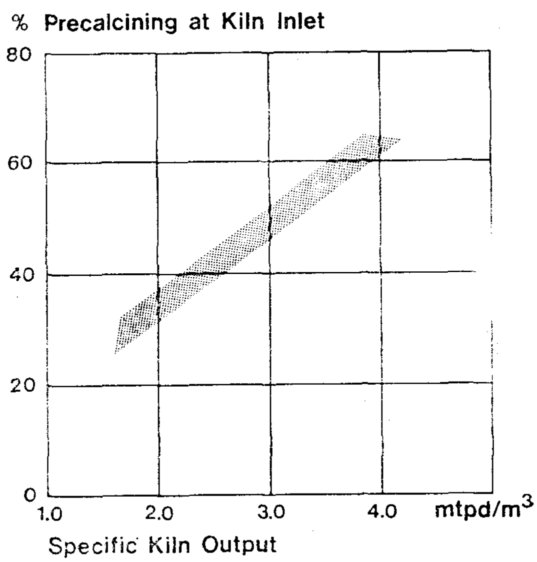
<Fig. 4> *Calcining in the kiln inlet with separate feed of meal from the third and the fourth cyclone stage*

have to be limited to ab. 1,200°C. It is thus possible to increase the degree of calcination by increasing the smoke gas temperature without the risk that problems of crust formation occur in the riser pipe.

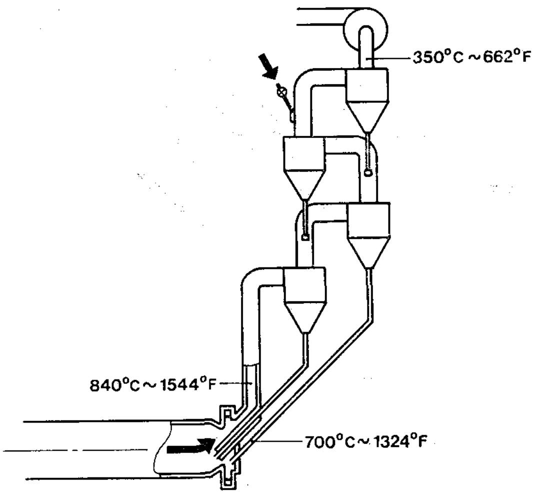
The correlation between smoke gas temperature and degree of calcination is shown in Fig. 5. In practice the temperatures are slightly lower than those shown on account of some dust contained in the smoke gas. Fig. 6 shows the correlation between specific



<Fig. 5>



<Fig. 6>



<Fig. 7>

kiln output and degree of calcination at the kiln inlet. In practice a specific kiln output of 3.5 mtpd/m³ has been obtained at a 50–60% degree of calcination.

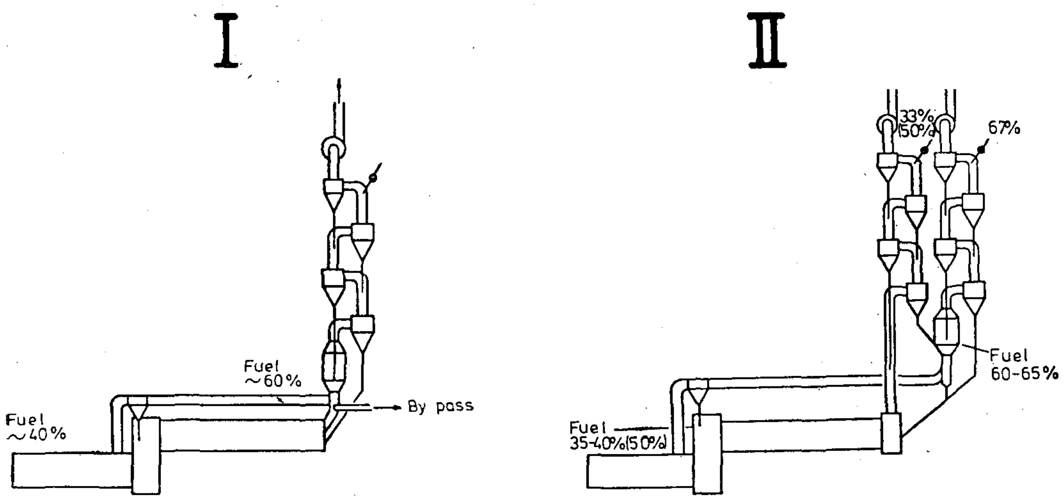
By increasing the smoke gas temperature before the scooping chamber the difference in temperature between smoke gas and charge in the kiln is increased, and in this way the heat transmission is improved and the kiln length may be reduced. The diameter is not changed compared to 4-stage kilns. In principle, as illustrated in Fig. 7, it is possible to obtain an almost complete calcining by means of secondary burners but in practice the degree of calcination should preferably be limited in order that the sintering zone should not advance too far up in the kiln.

The short integral kiln has a somewhat lower radiation loss and power consumption of the kiln motor than the 4-stage kiln. The kiln may be equipped with planetary cooler as well as other traditional cooler types. On account of its reduced length the installation costs for the integral kiln are lower than for other kiln types.

High-capacity precalciner kilns

In the case of kilns of capacities larger than ab. 4,500 mtpd a kiln system with separate precalciner and secondary air supply from the clinker cooler should be chosen out of regard to the life of the kiln lining, ref. Fig. 8. For such installations up to 60–70% of the fuel is introduced into the precalciner so as to obtain the greatest possible reduction of the amount of smoke gas in the kiln tube. In this way the kiln diameter could be kept below ab. 6 metres for capacities up to 10,000 mtpd.

Most precalciners of this type are based upon one of the two air distribution principles shown in Fig. 8. In System I the secondary air from the clinker cooler is distributed between kiln and calciner by means of a damper placed in the air duct between cooler and precalciner, combined with a contraction in the smoke gas duct after the kiln. Combustion air and kiln exhaust gas are mixed at the inlet to the calciner, which results in a

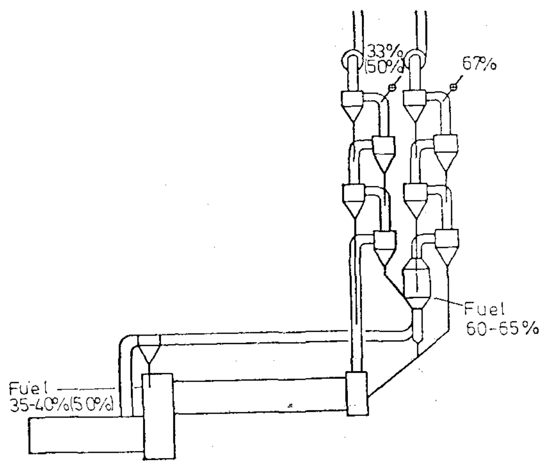


<Fg. 8>

reduction in the oxygen content in the precalciner inlet to ab. 14%.

According to System II the smoke gases from kiln and precalciner are divided into separate cyclone preheater strings, and the combustion air is distributed between kiln and precalciner by the fans of the preheater strings. This simple principle of gas distribution in connection with operating the precalciner with pure preheated cooling air has been the decisive factor for our choice of developing a kiln system along these lines.

The system is shown in Fig. 9 from which it appears that during normal operation the precalciner is fed with preheated raw meal partly from the 4th cyclone in the kiln string, partly from the 3rd cyclone in the precalciner string. The calcined material is precipitated into the 4th stage in the precalciner string and proceeds from there to the kiln. On start-up of the plant the precalciner is by-passed, and it is not started until hot air can be extracted from the clinker cooler; then raw meal is fed to the precalciner string.



<Fig. 9>

At a 90% degree of calcination of the

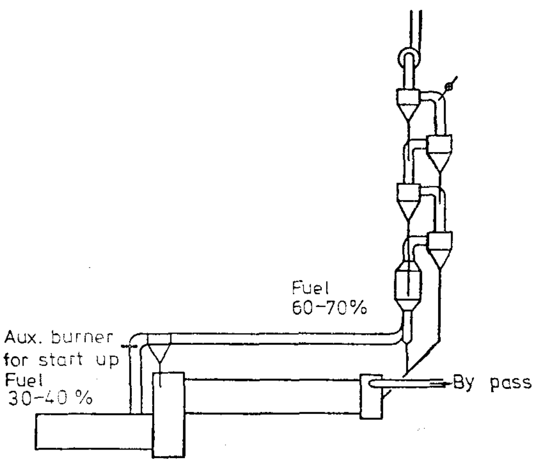
raw meal the specific output of the kiln will generally amount to ab. 3.6 mtpd/m^3, or approximately twice the output of the 4-stage kiln. Compared to a 4-stage kiln, both diameter and length of the precalciner kiln could be reduced by about 20%; it could be provided with a rotary cooler or grate cooler. The costs of installation and operation correspond fairly well to that of a 4-stage kiln of the same capacity.

When using low-calorie fuel that has an ash content too large to permit firing into the kiln tupe itself, kilns with separate precalciner could be used with advantage. In practice it has been experienced that this type of fuel can be burnt off quantitatively in the precalciner, possibly adding a high-grade fuel firing to avoid a too low lime saturation factor of the clinker.

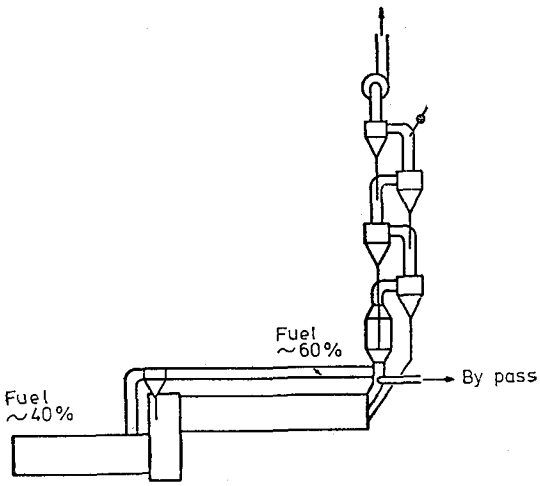
Precalciner kilns with by-pass

A major improvement compared to a 4-stage kiln is a kiln with separate precalciner, in cases when there is a need for making a by-pass for volatile matter at the lowest possible heat loss. If that is the case, the plant could be equipped with a 100% by-pass as shown in Fig. 10, or with a variable by-pass as shown in Fig. 11. In both cases the smoke gas from the kiln is first cooled and then dedusted in a separate electro filter.

In order to minimize the heat loss from the by-pass, the greatest possible degree of calcination should be aimed at in the precalciner, thus minimizing the amount of smoke gas in the kiln. At a 90% degree of calcination in the precalciner the amount of smoke



<Fig. 10>



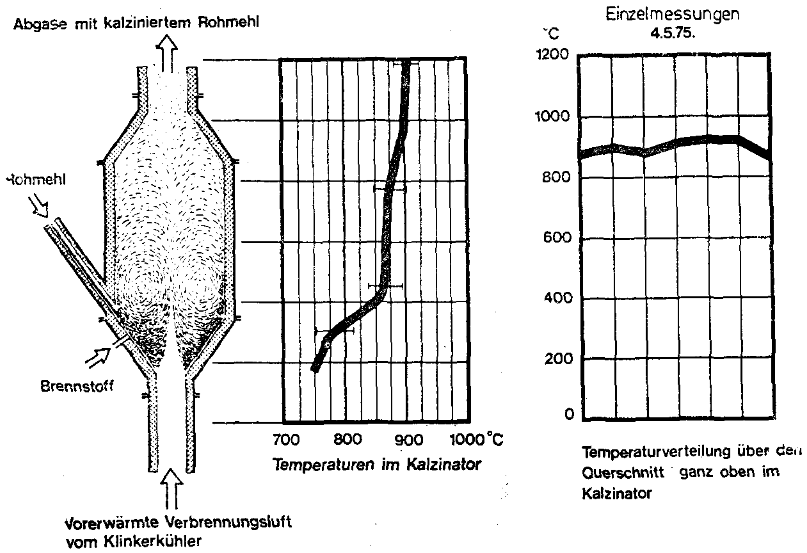
<Fig. 11>

in the kiln is reduced to ab. 30% compared to a 4-stage kiln, and the heat loss from a 100% by-pass will, depending on the dust loss, amount to 100–150 kcal/kg clinker, a substantial part of which (say 40kcal/kg clinker) arises from the unavoidable loss of evaporation heat from the alkali compounds. The dust loss from the by-pass will generally be limited as the smoke velocity in this kiln type is considerably lower than in the 4-stage kiln. As already mentioned, the amount of smoke is reduced by 60–70%, whereas the cross section of the kiln is only reduced by 30–40%.

This type of kiln is thus extremely well suited for production of low-alkali clinker.

The Calcining process

The design of the precalciner takes into account that it is essential to avoid coating originating from overheating and, consequently, the initial formation of clinker, as well as from re-carbonation of calcined material. Overheating may originate from an inhomogeneous distribution of fuel in the raw meal. We have solved this problem by blending the fuel into the ring-shaped material whirl, forming at the bottom of the precalciner, before actual combustion conditions are present, ref. Fig. 12. The density of material is at this point so great that the fuel is blending homogeneously with the material without special atomizing of the oil etc. The oil evaporates instantly and combustion takes place regularly and completely through the precalciner, as will appear from the temperature curves in Fig. 12.



<Fig. 12> *Material motion and temperatures in the calciner.*

It is seen that the process terminates at ab. 900°C, and also that the CO-content of the smoke gas after the preheater can easily be kept below 0.1%.

On account of the even temperature distribution in the precalciner the experience from practice shows no tendency to formation of coating as a consequence of re-carbonation of material according to the equation.

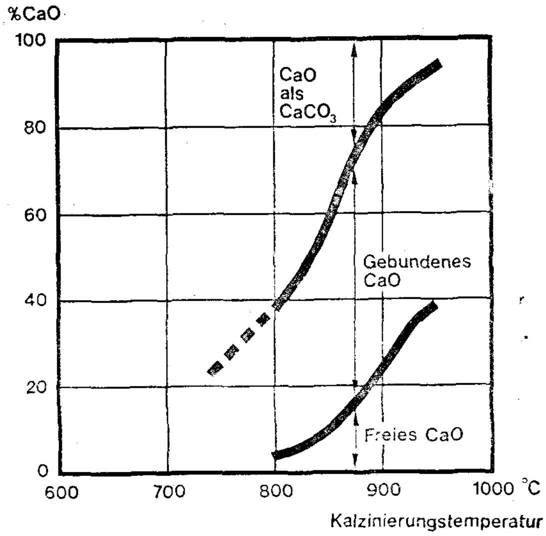
$$CaO + CO_2 \rightleftarrows CaCO_3$$

The reaction is reversible and moves towards the right if a partial cooling of the material-gas-mixture occurs at the precalciner walls, in which case the re-formed $CaCO_3$ settles there.

Counteracting re-carbonation, which is a process that has no particular significance for the heat economy of the kiln system, is the fact that the new-formed CaO quickly combines chemically with other oxides and thus avoids re-combining with CO_2. Fig. 13 illustrated this process.

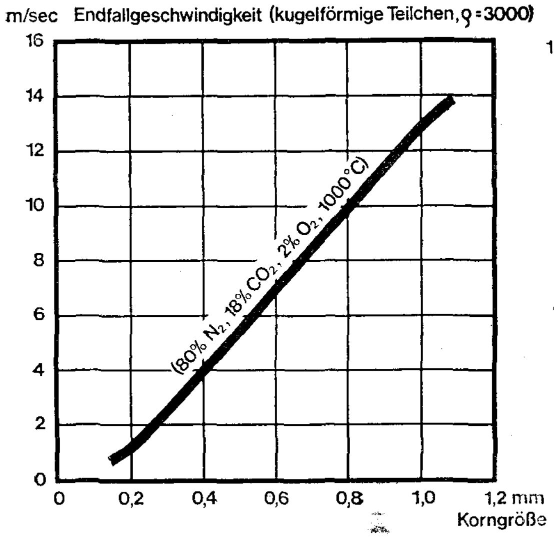
It appears that only a minor part of the CaO-content of the material is present as free CaO, while the major part is combined chemically. Increasing calcining temperature increases the amount of free CaO, which again increase the tendency to re-carbonation. For this reason it is preferable that the precalciner is designed with a view to the lowest possible calcining temperature and a quick separation of material from smoke gas.

In order to obtain a high degree of calcination at a low temperature the precalciner should be designed in such a way that the retention time of the individual particle sizes is adapted to the calcining period required, which increases with increasing particle diameter. As the calcination as shown in Fig. 12 takes place in a rising air stream, the large particles will naturally have a longer retention time than small particles since the velocity of fall increases with increasing particle diameter, ref. Fig. 14.

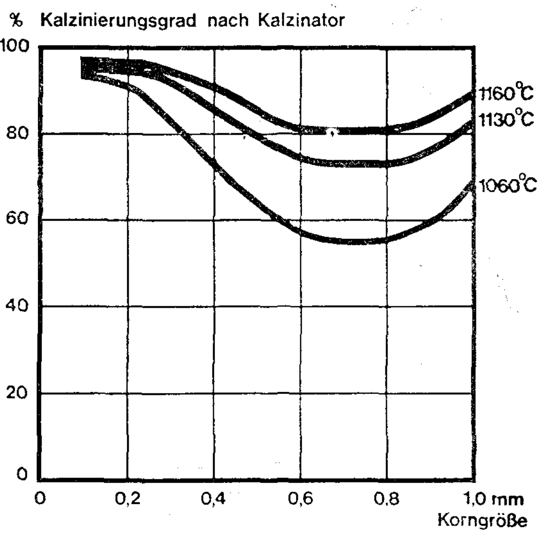


<Fig. 13> *Combining of CaO with the other consituents during suspension calcining*

To prevent coarse particles from falling through the air stream and thus excape the



<Fig. 14> *Velocity of fall of spherical particles in exit gas of 1000°C as a function of particle size*

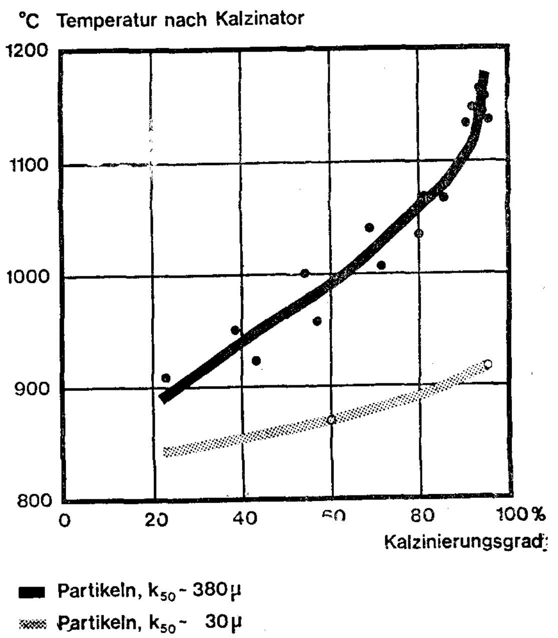


<Fig. 15> *Degree of calcination plotted against particle size in a rising air stream (material withou taddition of clay)*

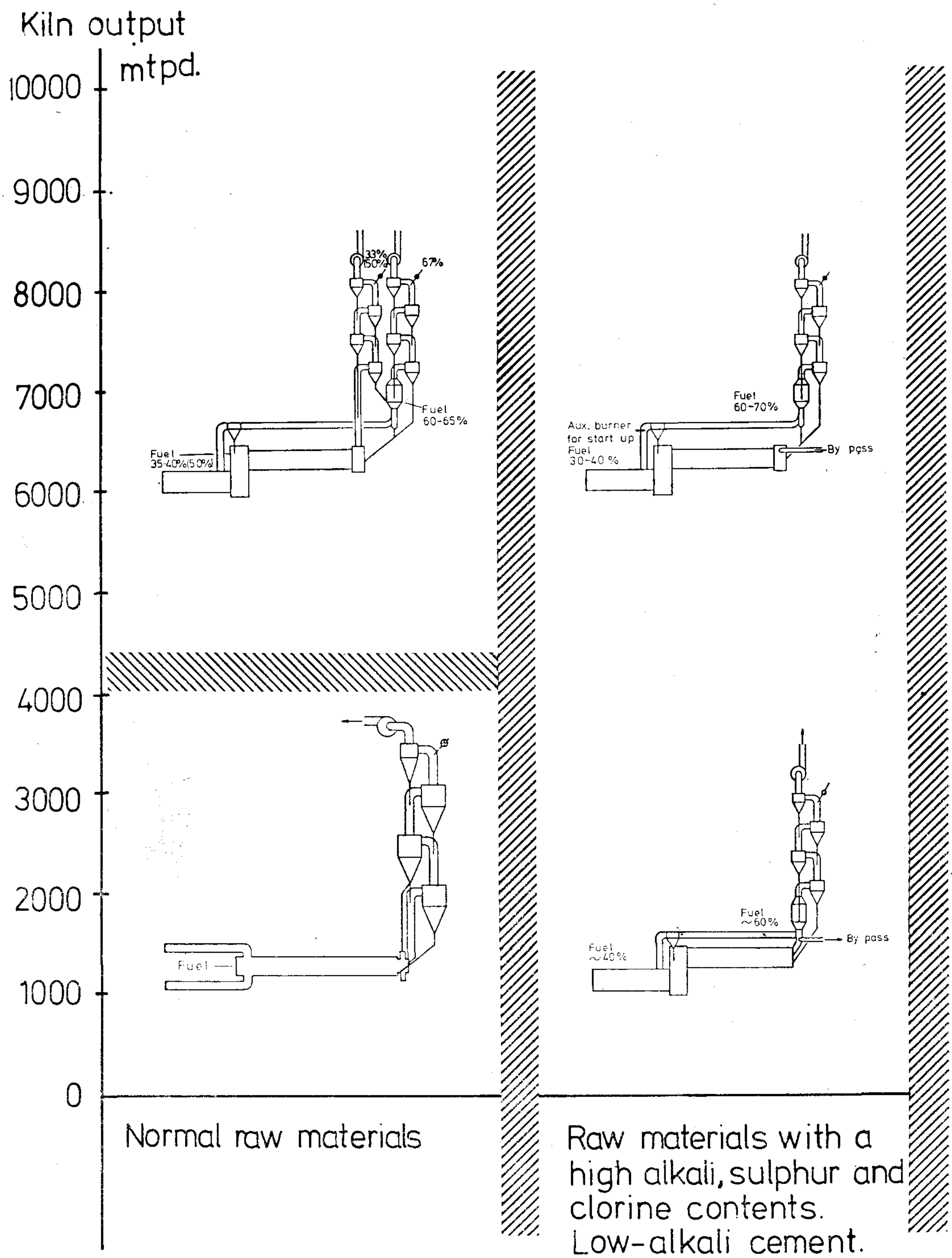
process it is essential to maintain a high gas velocity at the inlet. A suitable velocity profile in the precalciner aids in preventing an unnecessary accumulation of large particles.

Fig. 15 shows how the degree of calcination of various particle sizes is distributed against different temperatures. It appears that even coarse particles can, in fact, be almost completely calcined. Under normal conditions the majority of the particles of a cement raw mix are smaller than 0.1mm, and it appears that a measurable decline in the degree of calcination is first noticed at about 0.2mm particle size.

For raw meal with a normal particle size distribution a high degree of calcination is already obtained at ab. 900°C as



<Fig. 16> *Degree of calcination of fine and coarse raw meal plotted against temperature*


Kiln output
mtpd.
10000
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
33%
(50%)
67%
Fuel
60-65%
Fuel
35-40%(50%)
Fuel
60-70%
Aux. burner
for start up
Fuel
30-40 %
By pass
Fuel
Fuel
~60%
Fuel
~40%
By pass
Normal raw materials
Raw materials with a
high alkali, sulphur and
clorine contents.
Low-alkali cement.

<Fig. 17>

shown in Fig. 16. Coarse raw meal requires a considerably higher temperature which, as mentioned, might give rise to coating in the installation.

The precalciner design shown in Fig. 12 has been thoroughly tested, applying various types of fuel such as oil, coal, gas, and oil shale, and in all instances with a good result.

Conclusion

With a view to choice of precalciner kiln system, considering capacity, installation costs, and raw material properties, our experience—as shown in Fig. 17, can be summarized as follows:-

For outputs up to approximately 4,500 mtpd integral calcining kilns with calcining in the inlet of the kiln tube, are the cheapest of all kiln types. With a special scooping device fitted to the kiln inlet the degree of calcination is raised from a maximum of 30% in the conventional 4-stage preheater kiln to about 50-60%. Heat and power consumption only differs slightly from the 4-stage kiln, but smoother kiln operation is achieved through increased degree of precalcining which allows of a substantial reduction of the kiln length. Consequently, the lining life can be extended and the overall run factor improved. Grate or planetary coolers can be employed on these kilns.

For outputs ranging from 4,500 to 10,000 mtpd, the precalcining kiln with a separate precalciner, hot air pipe from the clinker cooler, and separate preheater strings for kiln and calciner is the only kiln type that will give a reasonable kiln diameter and control of the supply of combustion air to the system. Initial costs and heat and power consumption differ only slightly from a normal 4-stage kiln, while the smoother operation of the kiln contributes to extending the life of the lining.

The latter type of precalciner kiln is very suitable for raw materials with high contaminations with chlorine, alkalies and sulphur. A 100% by-pass of kiln gases makes manufacture of low alkali clinker possible at the expense of maximum 150 kcal/kg clinker more than used in a conventional 4-stage preheater kiln without by-pass.