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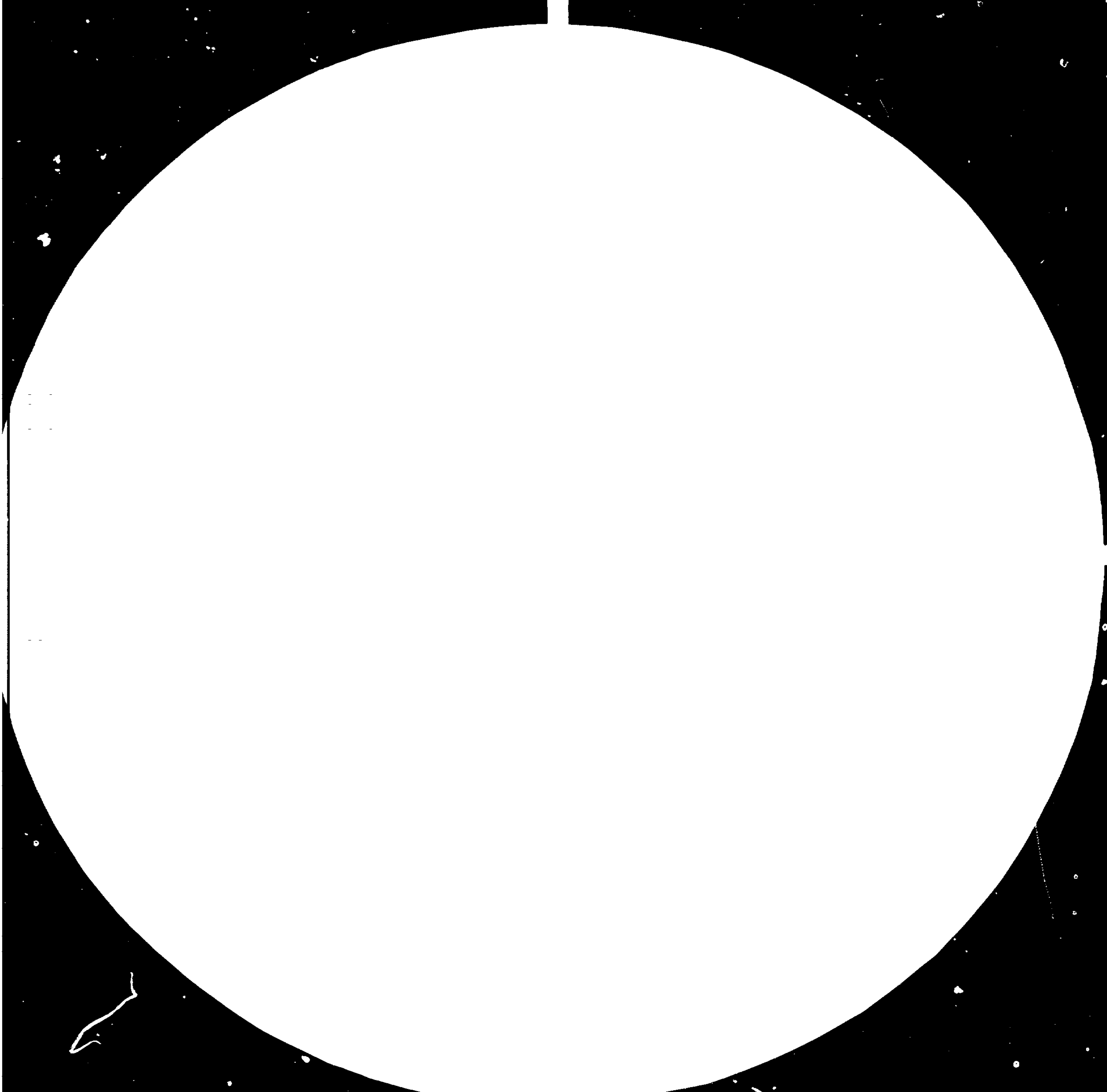

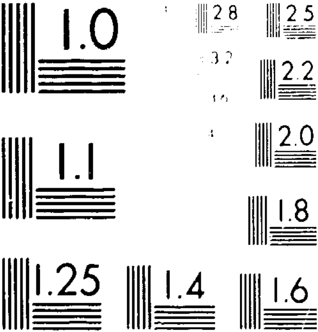

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PRECALCINATION WITH COAL *

by

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INTRODUCTION

In the world cement industry, oil is mainly used as fuel for the new technique of precalcining. In recent years, under the hitting of the oil crisis, many countries have been investigating the conversion from oil to coal as a substitute fuel.

In 1975, on the basis of successful investigation of oil fired in precalcining process, we considered the actual conditions that coal is used mainly in our cement industry and began investigating the use of coal as a substitute fuel in the precalcining process. Since 1978, a kiln line of industrial scale has been operating.

The success in investigating coal fired precalcining can not only utilize the coal resources everywhere in China to develop cement industry, but also decrease the reliance on the oil fuel. It is advantageous for expanding the precalcining technique and for using the limited oil resources in suitable places, such as petrochemical industry. This is a matter to kill several birds with one stone. Consequently, the new technique of coal fired precalcining has a great significance in the world.

According to the experience in the practical production, the output, quality and heat consumption of oil fired precalcining are similar to those of coal fired precalcining. There are no great differencee in total economical efficiency.

Since pulverised coal has a lower burning rate and higher fire point, its ignition in the precalciner is more complicated than oil. And the demand for technological control is so high that the fly ash will be prevented from cohering on the wall of furnace and incomplete combustion of coal from causing preheater super temperature.

There are no differences between coal fired and oil fired precalcining processes but the fuel. The technology is almost the same. Therefore, the extent of NO_x produced is similar. In the conventional kilns, the total fuels burn at high temperature and produce more NO_x. The exhaust gases from suspension preheater, for example, contain approx. 800 to 1000 PPM Nox. However in the precalcining process as more than 50% of overall fuel burns in the precalciner at a relatively low temperature (900^oc), there is little generation of NO_x. And the NO_x produced in the kiln is partly reduced by carbon monooxide.

The NO_x concentration measured by Japan is only 100 PPM which is under the allowing range of 250 PPM.

<u>The choice of technical flowsheet</u> :

1. The choice of firing processes

There are several firing processes which can use pulverised coal as fuel. The coal must be distributed uniformly in the precalciner and burnt in a stable condition at approx. 900^oc.

(1) Pulverised coal prefires first and then mixes with raw meal and goes on burning in a precalciner—this process of combustion and heat transfer has more advantages:

a). The pulverised coal is directly fed into the furnace to turn and a burner is unnecessary.

b). The pulverised coal prefires first and then continues to burn. The combustion is stable.

c). The pulverised coal transfers heat to the raw meal while it burns. The loss of heat is less and the efficiency of thermal transmition is higher.

d). The temperature distribution in the furnace is uniform and the temperature is easy to be controlled. This is advantageous for decarbonizing calcium carbonate.

For this kind of process, all the fly ash gets into kiln feed. Therefore the content of coal ash should not be too high.

(2) Coal burns alone in a burner and produces hot gas entering a precalciner and then heat transfer occurs between materials and gas. In this process, the coal combustion is stable and easy to be controlled. When low grade coal containing high ash content is used as fuel, this process is adoptable, because it is necessary to remove most or part of the ash which exceeds the amount reqiured by trimming. But it has the following limitations:

a) The plants, flowsheet and production control are complicated. The loss of heat is high and uneconomical.

b) high gas temperature is reqiured and the temperature is difficult to be even in the furnace. The temperature of hot gas is higher at the inlet and too low at the outlet. This affects the decarborization degree of calcium carbonate. The furnace is not sufficiently and rationally used. If adopting several inlets for hot gas to enter the furnace, the much uniform temperature distribution can be obtained in the precalciner. But difficulties in operation increase as the gas ratio at all inlets needs to be adjusted. Consequently, this process is suitable when using low grade coal as fuel and requiring ash discharge. Otherwise it is not ideal.

(3) The "black-meal " process

This process is only utilized for refuse or low grade coâl which contains volatile matter below 10%, ash above 50% and calorific value less than 3000 Kcal/kg.

Owing to the high ash, the low grade coal can basically replace clay component in the raw meal, and it is not easy to take fire. If the pulverised coal passes through three stage cyclones together with the raw meal to be preheated, it is good for the low grade coal to burn completely. As the volatile matter contained in the coal may be burnt at 400 to 500°C, the calorific of this part can not be concentrated in the furnace. As a result, the temperature of exhaust gas discharged from the preheater rises.

In order to avoid the pulverised coal to burn before it enters the furnace, the following process can be adopted in which the pulverised coal mixes with the raw meal from the third stage cyclone and enter the furnace together. Thus the pulverised coal is at the situation of a high dust concentration when it enters the furnace. It is of no advantage for the coal to contact with the combustion air. This makes the coal difficult to light and affects the combustion velocity. If the dispersivity is not good and the combustion is unstable, the fire is easy to extinguish. Therefore, this is not an ideal process either.

In summation, the combustion process should be decided according to concrete conditions. Under the general conditions, the process in which pulverised coal prefires first in the furnace and then mixes with raw meal and goes on burning and transfering heat to the meal is more rational.

2. The factor of coal quality

Fuel quality is an important factor in adopting what kind of flowsheet for the coal fired precalcining.

(1). General soft coal —— volatile matter more than 20%, ash below 30%, net calorific value above 5000 kcal/kg.

Soft coal contains higher content of volatile matter. It has close relation to the coal fire temperature. The higher content of volatile matter, the easier ignition. The soft coal containing volatile matter over 20% can ignite at about 600°C, and the temperature of furnace can be maintained at approx. 850°C. And the combustion is stable. The pulverised coal can ignite when it is fed into the furnace directly by mechanism and blown over by furnace gas.(air also can be used to blow the coal into the furnace).

The coal containing less than 20% volatile matter needs higher ignition temperature. In order to overcome this disadvantageous factor, besides the coal should be ground finer, intimate mixing pulverised coal with air should be enhanced and a primary air is used to convey the coal to the furnace. When the coal fire is specially difficult, screwed plates also can be installed at the outlet of primary air and secondary air so that the coal and air thoroughly mixed. This is good for coal to fire.

(2). Refuse or low grade coal —— volatile matter approx. 10%, net calorific value below 3000 kcal/kg, ash over 50%.

This kind of refuse or low grade coal cannot be used as fuel in rotary kilns, but can be used in precalciners. The coal is difficult to catch fire and the combustion is unstable. In addition, high ash content will affect the clinker quality as it entirely enters the raw meal.

To cope with the above mentioned difficulties, three measures are adopted as follows:

a). According to the amount of ash which is allowed by mix design, the refuse and raw meal mix to become black raw meal.

b). A portion of refuse is prepared to be black raw meal, an ordinary soft coal is injected to the precalciner to help refuse ignite and adjust the temperature.

c). A fluidised burner is installed which produces high temperature gasses to supply the precalciner. The ash is discharged to be used as admixture or trimmings. This process has a little higher heat consumption .

In the coal fired precalcining, both kiln and precalciner are required to burn pulverised coal. The process in which the coal is concentrically supplied to the kiln and precalciner in a pulverised coal shop is more suitable.

When the low grade coal is used in the precalciner, the pulverised coal must be prepared respectively owing to different kind of coal used by kiln and precalciner.

Technical conditions of coal fired precalciner.

1. The oxygen concentration in gasses

As it is more difficult for pulverised coal to fire as compared to oil ---- higher ignition point, lower combustion velocity and the presence of ashes, some advantageous conditions must be created for a stable burning of coal in the precalciner. The larger areas pulverised coal and oxygen contact, the faster reaction they have. Besides the mixing between them should be enhanced, the oxygen concentration and the fineness of coal are very important. The more molecules of oxygen the gasses contain, the more chances the coal and oxygen contact. In the furnace there is not only a large quantity of raw meal powder, but also fired exhaust gasses. The oxygen concentration is lower, the furnace structure should ensure that the place where the pulverised coal fed in has a higher oxygen concentration so that the coal is ignited easily. The coal in this place is ignited first to ensure stable combustion in the furnace. Therefore coal fired precalciner had better possess a special structure to cause the coal to light in fresh air.

Moreover, the exit gas from the precalciner should maintain a little higher excess air efficiency (about 1.25) so that the basically complete combustion of pulverised coal can be abtained in the furnace

2. Fineness of coal

The fineness of coal shows a significant role for combustion. The firing temperature of the coal decreases as its fineness increases. It is also connected with volatile matter. The less volatile matter the coal contains, the more finer its fineness is required. In our country, a plant uses the coal containg volatile matter approx. 25%, its fineness is controlled at 10 to 15% residue on 88 micron sieve. In another plant, the coal contains approx. 13% volatile matter, the fineness is required to be controlled below 6%. The coarse coal, which is uneasy to catch fire and has a lower combustion velocity, will not effect combustion stability of precalciner only the incompleted burned coarse particles in the furnace will be drawn from the precalciner together with the gasses and enter the preheater. A portion is collected by the preheater and then enters the kiln together with the raw meal and goes on burning. The other portion continues to burn in the fourth and third stage cyclones. This will cause a super-temperature in the preheater and result in increasing exit gas temperature and heat consumption. Meanwhile, it is possible that super-temperature of preheater would cause the material sticky and result in coating and blocking. Consequently, fineness of coal is one of the necessary conditions to ensure the normal operation of coal fired precalcining process. When using general soft coal as fuel, the fineness of coal should be strictly controlled below 15%.

3. The required time for coal combustion in the furnace

The size of a precalciner depends on the required retention time of the material and fuel combustion and should permit tnat the material can reach the required degree of precalcining and the fuel can basically burn out. The required time for decarbonizing reaction of calcium carbonate in raw meal is connected with the temperature and separated pressure of CO_2. According to Vosteen's experience calculation, when the temperature is approx. 900°C and the separated pressure of CO_2 is 0.2 atm., it needs 2 to 3 seconds to accomplish to 85% degree of precalcining. However, laboratory tests have shown that it only needs 0.8 seconds to accomplish to 85% degree of precalcining since the raw meal is preheated more than 600°C first and then enters the precalciner and decarbonisation is effected under the conditions of suspension and minus pressure and constant temperature. As coal combustion is affected by many factors, so far there have not been any practical formular for calculating the required combustion time.

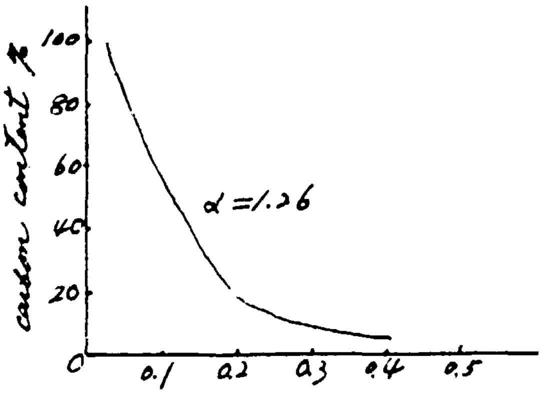

Fig. 1 time second

Fig. 1 demonstrates the relationship found between the combustion time of coal particles and the carbon burn-out in percentage. As shown in Fig.1 when burning in the precalciner, carbon cannot accomplish in 0.4 seconds owing to high concentration of dust, lower ambient temperature (900°C) and worse firing conditions. The tests of the precalciner in our laboratory have indicated that pulverised coal suspending in the furnace for 0.3 seconds still cannot burn out at 900°C and 25% volatile matter and 9% fineness. As seen, the decarbonizing reaction of calcium carbonate needs less time than that of coal combustion. It is not a problem for the required calcination rate if the coal basically burns out. In industrial precalciner, the retention time needs 1.5 to 2 seconds for the coal to basically burn out, when the furnace temperature is 850 to 900°C, coal contains 25% volatile matter and the fineness is below 15%.

4. Temperature control

The precalciner temperature is closely connected with each parameter of production control and an important technological condition for coal fired precalciner.

The grounds of temperature control not only permits stable combustion and accomplish the required calcination rate of material, but also avoid coating growing in the furnace and super-temperature in the preheater.

In the furnace the material is heated to the precalcining temperature and goes on decarbonizing. The higher calcination rate the material has, the more the kiln output increases. When the size of the precalciner is given, the retention time of the material in the furnace is basically decided. The way which raise calcination rate of material is only to increase furnace temperature. But the furnace temperature cannot be too high, otherwise it will cause operating difficulties. Because of a lower fusion point of ash (1000 to 1100°C), if the furnace temperature is higher than 1000°C, the fly ash would fuse and adhere to the furnace wall to form coating. This will seriously affect the furnace operation. It is impossible for the temperature of each part of the furnace to be absolutely uniform, thereby, the furnace temperature should be generally controlled at 850 to 900°C so that it does not surpass 1000°C. If the furnace temperature is too high, the hot gas takes away more heat, the whole preheater system will have higher temperature and the material become sticky, and coating and blocking will also be easy to form. At the same time, it is uneconomical for a preheater system to have too high temperature of exhaust gas.

Experience in actual operation has shown that the above-mentioned value of temperature is more economical and rational which can ensure the calcination rate of kiln feed to be controlled at 85 to 90%.

The type and operation of coal fired precalciner

1. Serveral sorts of existing coal fired precalciners in our country

(1). Fluid-cyclonic type of precalciner

In this kind of precalciner (Fig. 2), the material and fuel are blown up by the secondary air from the clinker cooler and then turn upwards with the gases.

The kiln exit gas entering the middle portion of pre-calciner in tangent direction blows over the material fed into it first and then makes the inner furnace gas swirl. This has advantage of mixing material with fuel.

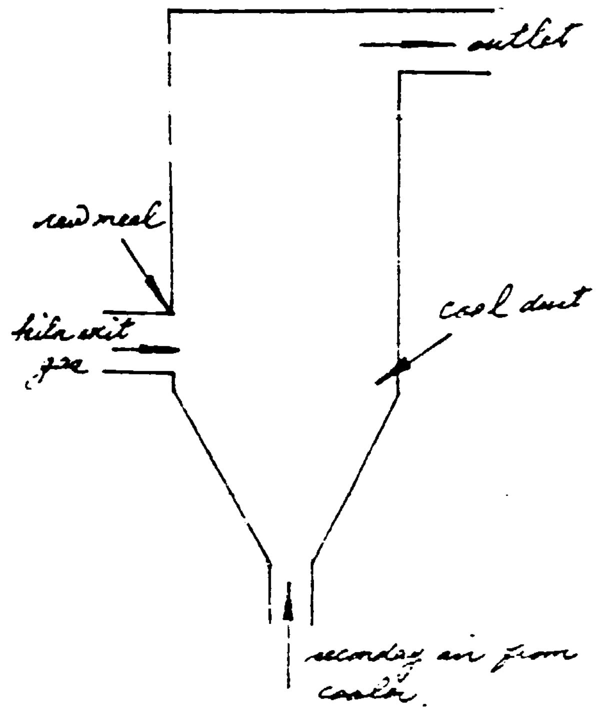

Fig 2. Fluid-cyclonic type of precalciner.

As the kiln exit gas enters the furnace in the waste, the gas of bottom part is the secondary air mainly coming from cooler at 600 to 700°C which contains higher concentration of oxygen which is good for the coal to ignite. After the catching fire, the coal mixed with material and then with swirling kiln exit gas. The coal transfers heat over its combustion. In the furnace the temperature distribution is uniform.

Generally, the gas velocity of inner furnace is 5 to 8 M/s. The blowing velocity at the furnace base must be over 20 M/s, in order to ensure the material against dropping through the base of furnace. According to the different kinds of coal, the pulverised coal may be fed into the furnace by mechanic or blowing method.

(2). A furnace with prefiring-mixing chamber

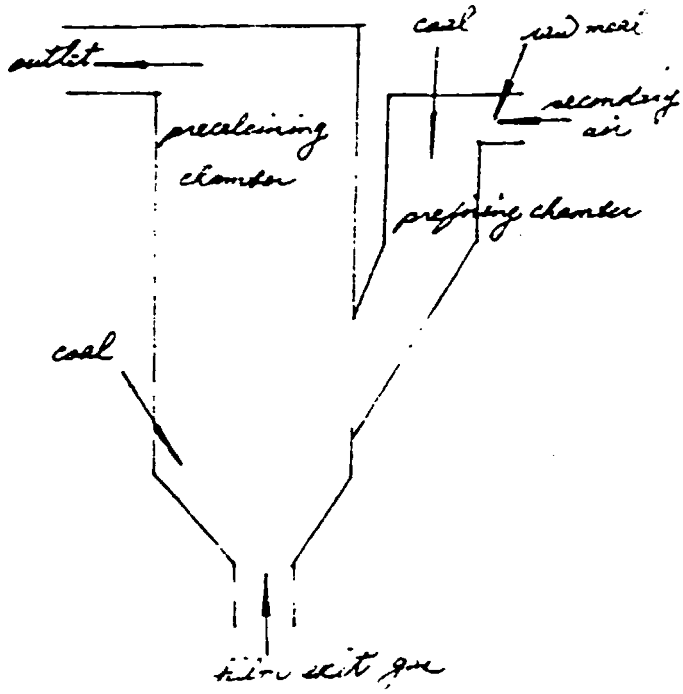

Fig 3. A furnace with prefiring-mixing chamber.

In this sort of precalciner (Fig. 3), the secondary air at 600 to 700°C coming from cooler is introduced into a prefiring-mixing chamber in tangent direction. The gas here contain higher content of oxygen and is good for the coal to light.

Owing to the less volume of chamber, it is easy for the chamber to take superhigh temperature and cause coating and blocking if all the pulverised coal is fed into it.

In case where a suitable temperature is controlled, the temperature of precalcining chamber is so low that the calcination rate of raw meal cannot be sufficient for the required level. Consequently, only a partion of the coal is fed into prefiring mixing chamber to ignite first, and then mixes with the material and enters the precalcining chamber. The other portion of the coal is directly fed into the base of the precalcining chamber and mixed with the material from prefiring-mixing chamber. The coal transfers heat to the raw meal as it burns.

Kiln exit gas is introduced through the base of the precalcining chamber. Thus, the precalcining chamber can be located at the kiln back end housing for the convenient technological arrangement. Generally, the gas velocity of inner precalciner is 5 to 8 m/s.

Because the precalciner has a prefiring-mixing chamber and the retention time of the material in the precalciner is longer, it is advantageous for increasing the calculation rate of calcium carbonate. But the resistance of precalcining system is correspondingly higher.

(3). A precalciner with a burner (Fig. 4)

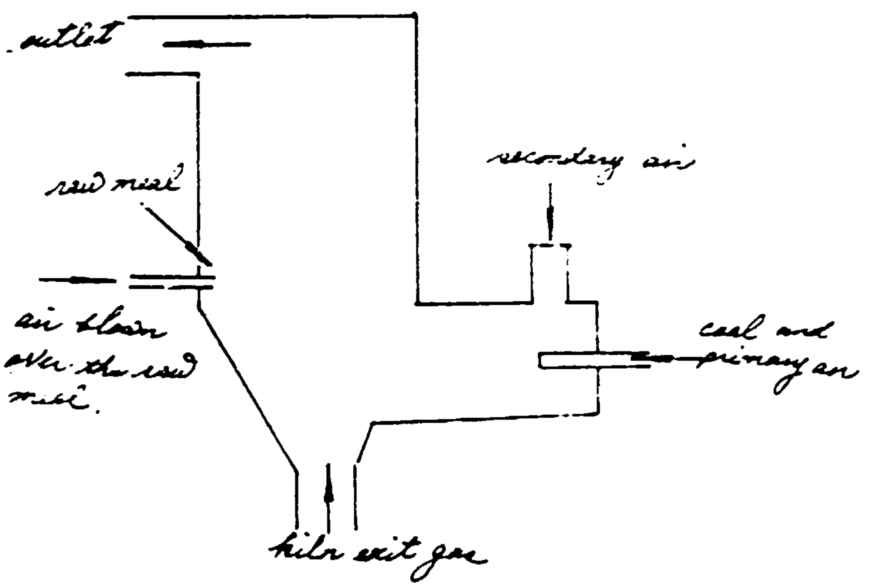

Fig 4. A precalciner with a burner.

The pulverised coal prefires in the burner and then enters the furnace and meet with the material and continues to transfer heat over its combustion. Both primary and secondary air for the burner is vented from clinker cooler. The entire coal is blown to the prefiring chamber to burn. Adjustable screw impeller are fixed in both primary and secondary injection pipes. According to different sorts of coal the number and angles of screw impeller are so regulated that the coal and the air are enhanced to mix and have advantageous for igniting.

The kiln exit gas enters the precalciner in the base. The furnace can be also located at the kiln back end housing for the convenient technological arrangement. The inner furnace velocity is 5 to 6 m/s. Low grade coal containing less volatile matter is suitable for this kind of furnace. The similar burners are also used for shaft-type preheater with precalcinings in our country.

(4). A furnace with a waste chamber (Fig. 5)

This precalciner uses refuse or low grade coal as fuel and can remove more ash out of the process.

A stable combustion of the low grade coal can be achieved when it burns singly in a burner.

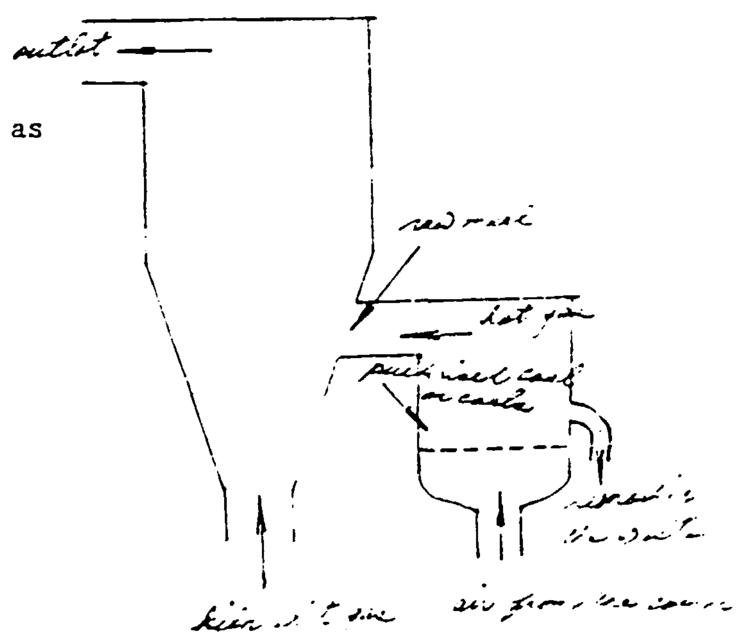

Fig. 5. A furnace with waste chamber

Since a boiling furnace is more suitable for burning of low grade coal, so it can be used as a waste chamber. The combustion air used in the boiling furnace is partly vented from clinker cooler, others taken from ambient atmosphere. Thus, the heat utilization of cooler is not sufficient.

The kiln exit gas enters the precalciner from the bottom, thereby the precalciner also can be located at the kiln back end housing.

All the four types of precalciners mentioned above have the oil ignition installed near the coal ignition.

2. The operation of the coal fired precalciner

(1). Precalciner ignition

At the beginning of operation, oil must be used to ignite since the coal ignition is not so easy.

When the temperature of kiln exit gas rises to 800°C, a temperature in the range of 600°C can be obtained in the furnace and the oil fires immediately while it is injected. If the furnace temperature is lower than 600°C, first igniting the oil burner, after that adding the pulverised coal and then the oil and coal burn at the same time. The oil is provided until the desired temperature 900°C is obtained. After 3 to 5 minutes, raw meal can be fed to the system and the process is running normally.

During the whole igniting process, a control should be required to avoid super temperature, because the furnace temperature changes rapidly while the mixing burning with coal and oil.

Every ignition needs about 50 to 60 kg oil when soft coal is used as fuel. During the operating process, when an irregularly scheduled shutdown takes place it is all right to add the coal directly without any need to inject oil for ignition, so far the furnace temperature is remained over 650°C. The lower volatile matter the coal contains, the more oil the ignition needs. After untimely shutdown, oil is needed to ignite again.

(2). The temperature control of the furnace

For the stability of production, besides the control of the kiln itself, the operation of the precalcining preheater system also must be stable. The key for a stable calcination rate of the kiln feed is to control the furnace temperature. In our country, automatic temperature adjusters called DTL type adjuster and speed controller are used to control the temperature automatically with the changes of the furnace temperature to adjust the speed of the screw feeder. It occupies proportional-plus-integral-plus-differential action. This set of installation can efficiently stabilize the furnace temperature.

In order to control the temperature automatically, rational set points of temperature must be choosen. The temperature of the section where the coal is ignited cannot represent the true temperature of inner furnace. The middle portion of the furnace is just a place where the coal transfers heat over its combustion. The temperature distribution is evener too. It is a suitable place as a set point of temperature.

Sometimes, more coarse coal dust cannot burn until it reaches the outlet when the fineness or amount of the feeding coal is unsuitable.

This causes the outlet to have higher temperature. In that case, rather lower temperature should be controlled in the middle furnace by decreasing the amount of the feeding coal. On the contrary, when the coal is easy to fire, it burns very quickly in the middle part of the furnace and nearly burns out at the outlet. The outlet temperature is relatively lower. Thus, a slight higher temperature should be controled by increasing coal feed rate.

Owing to the reason mentioned above, besides the temperature point at the middle part of the furnace, the outlet temperature point is also needed to be controlled. Therefore a multiparameter adjusting system should be used.

(3). Notice:

Although automatic temperature adjusters are used for precalciners, the conditions of raw materials and fuels are often changeful. Operators should govern timely. Besides helming the furnace operation, they must know per hour's calcination ra e of calcium carbonate, coal composition, fineness, kiln operating and temperature changes of every part of the preheater. They must have a head for figures and be always ready to adjust the operation and the temperature control to ensure the stable production.

Conclusion:

1. Coal fired precalcining is a successful technique. It is feasible to repalce oil by pulverised coal burning in the furnace and the similar economical effects can be achieved.

2. Coal fired precalciner can use not only general soft coal, but also low grade coal or refuse as fuel. This has opened up a new way to save energy source and make full use of fuel resources all over the country to produce cement.

3. Different quality of coal can be used by different technical process to guarantee the normal operation of coal fired precalciner.