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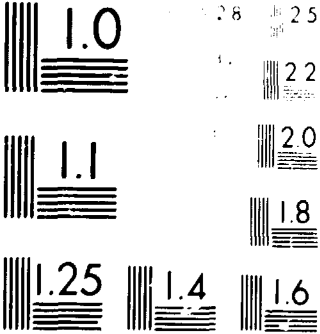
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MODERN CLINKER BURNING SYSTEMS*

by

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1.) Introduction

Independent of the cyclical fluctuations of the cement market in the different countries, the production outputs of rotary kilns have marked a sharp increase, as can be seen from the first picture.

This increase in production per kiln unit has become possible by the change from the wet process to the dry process during the fifties using meal preheaters. The specific throughput capacity of the kilns was thereby increased 4- to 5-fold. A kiln working on wet process for a daily output of 2,800 tons of clinker would e. g. the dimensions 6,3 m dia by 200 m long, with an inside kiln volume of 5,650 m^3 (0.5 tpd/m^3). For a preheater kiln working on dry process, the dimensions 5.0 m dia by 80 m long with an inside volume of 1,330 m^3 (2.1 tpd/m^3) would be adequate for the same output.

In recent years the tendency towards large production units has continued by the development of the precalcining process. Specific kiln loads increased up to 5.0 tpd/m^3, so that units with outputs of 5,000 tpd and more are no longer a rarity in these days.

78 precalciner systems have been sold by the Polysius group to this date. This figure includes 26 system-conversions besides the 52 new plants, but does not include plants which our customers have themselves converted into precalciner systems.

Over 40 of these plants have so far been successfully commissioned.

Table 15 302 is a survey of Polysius precalciner systems by type of system selected (i.e. AT or AS) and type of clinker cooler used for the three output ranges: up to 2,000 t/d; 2,000 to 3,000 t/d and over 3,000 t/d clinker production.

It can be seen that all known types of clinker cooler are in use. Although a comparison of the figures for the AT and AS systems shows that more than twice as many AT kiln systems have been sold than AS systems, the relationship shifts in favour of the AS systems for production capacities above 3,000 t/d.

The successful use of all types of precalciner and clinker cooler proves that no single, particular process represents the optimal solution for all requirements. Consequently, we must compare the different characteristics of the various systems in order to reach a conclusion on the most suitable burning process for any individual instance.

2.) Comparison of the precalcination processes.

PREPOL-AS System:

In the PREPOL-AS system, the combustion air (tertiary air) does not flow through the rotary kiln from the clinker cooler to the calciner, but is led through a separate duct. Only the flue-gas from the sinter-zone firing passes through the kiln. The quantity of gas at the kiln inlet is therefore only 60 %, in comparison with that of the PREPOL-AT system, in which the combustion air for the calciner is also led through the kiln.

The precalcining burners are located in the transition section between the tertiary air duct and the calciner. This position offers optimal conditions for ignition and burning, because the fuel is ignited in pure air and the combustion is stabilized by the heat of the calciner walls and the kiln exhaust gas. Additional ignition burners are therefore not required.

The raw meal coming from the vortex chamber (stage II) is divided into separate streams, which are fed into each train of the tertiary air duct immediately before its point of entry into the calciner. This ensures that the combustion heat of the calciner burner is directly transmitted to the raw meal.

The calcined raw meal is entrained in the flow of gas, separated from the gas in the cyclone stage I and fed into the kiln inlet.

In the PREPOL-AS system, the temperature of the tertiary air from the cooler is approx. 250° C cooler than the temperature of the gases from the rotary kiln. To balance this difference and to achieve a 90 % calcination of the raw meal, approx. 60 % of the total fuel quantity is introduced into the calciner.

Fig.13353 shows in detail the entry point of the raw meal into the tertiary air duct and also the arrangement of the burners. Fig.14774 shows the design with oil burner, and Fig.15143 is a photograph of a coal-fired precalciner.

PREPOL-AT System: (14180)

In this system, the combustion air for the precalcining burners is led through the kiln to the calciner. This produces an air relationship figure of approx. 1.8 for the sinter zone firing.

The combustion process in the sinter zone is thus faster and more complete than would be the case with a smaller excess air quantity. Because of the lower concentration of pollutants in the kiln exhaust air, higher raw material contents of alkali, chlorine and sulphur are permissible without a bypass being necessary.

(13355) The kiln exhaust gases enter the calciner via the kiln inlet housing. The calciner is so dimensioned that all the introduced fuel is completely burned before the gas enters the 1st cyclone stage. The material from the vortex chamber (stage II) is so introduced into the calciner that the combustion heat produced by the PREPOL burners is immediately used for increasing the degree of raw meal calcination.

This system permits the use of grate coolers or of planetary coolers.

At the calciner there is no temperature difference between the flue gases from the sinter zone and the combustion air for the precalcining burners. For this reason, only 40 % of the total fuel quantity is required for a calcination rate of 90 % in the PREPOL-AT system.

As it is not easy to understand why the PREPOL-AT system achieves the same degree of raw meal calcination as the AS system while using 20 % less fuel in the precalciner, a comparison of the heat balance figures of both systems is shown in Fig. 15142.

One can see that the total quantity of heat introduced into the precalciner is the same in both systems; the difference in the heat input from fuel combustion is balanced in the case of the AT process by its larger heat intake from kiln flue gases and kiln dust.

3.) Fuels

High grade and correspondingly expensive fuels, such as oil and natural gas, are being increasingly replaced by coal. The types of coal used range from lignite, with only 4 % ash content and 45 % volatiles to waste coals with approx. 65 % ash and only 4 % volatile component.

Furthermore, new types of low grade fuel are being constantly utilized. These include oil-shale, charcoal, old tyres, rice chaff, fullers earth etc..

4.) Selection Criteria

4.1 Process technological criteria

As we have already seen, the kiln flue gas quantity in the AS system is only approx. 40 % in comparison with that of the AT system. If the concentration level of pollutants necessitates the installation of a bypass, this means that the removal of a proportion of the gases will lead to lower heat losses in the case of the AS system than would be the case with the AT system.

We have also seen that in the case of the AS system, the amount of heat introduced into the precalciner by fuel combustion is approx. 20 % greater than in the case of the AT system, for the same rate of raw meal calcination.

The two following marginal conditions therefore speak for the selection of the AS system:

a.) the need to divert a considerable quantity of kiln exhaust gases through a bypass in order to reduce the concentrations of alkalis, sulphur or chlorides.

b.) the ability to burn the maximum possible amount of low grade fuels. The two kiln systems are equally suited for all other cases of need, even with regard to their specific fuel and electrical energy-consumption.

Thus, the optimal choice of kiln system cannot only be made by comparing preheater, precalciner and kiln; the clinker cooler also has to be taken into consideration.

4.2 Investment Costs

For this purpose, Table 15141 shows the specific investment costs (i.e. investment costs in US $ per t.p.d. of clinker production) for rotary kilns with planetary, drum, RECUPOL and thrust-grate coolers for the outputs 1,200, 2,000 and 3,000 t/d.

The comparison includes the following:
mechanical equipment, electrical equipment, refractory lining material as well as erection. Furthermore, in the case of systems with the grate cooler, the dedusting of the cooler's exhaust air by gravel bed filter has also been taken into account.

The percentage comparison of the investment costs shows on the one hand that specific investment costs generally decrease as production capacity increases, and on the other hand that, particularly in the case of small production capacities, the kiln with planetary cooler requires the least investment costs.
At a capacity of 3,000 t/d, th[illegible]cific investment costs of a kiln equipped with grate c[illegible] are 6 - 8 % lower than those of a kiln with planetary cooler. However, practical experience has shown that this cost advantage is generally balanced by the civil engineering costs involved.

For the 3,000 t/d capacity level, the drum cooler has not been considered, as this cooler's specific shell area decreases with increasing unit size. Despite completely fitting the unit with stirrers, lifting scoops etc., and additional cooling by water spraying, clinker temperatures of below 300° C cannot be achieved with this type of cooler - as has been shown by operating experience with considerably smaller drum coolers.

4.3 Production Costs

Besides the investment costs, the production costs have to be especially taken into consideration in order to make the correct selection of the most cost-favourable kiln system. Fig.15140 shows the operating costs for the four kiln systems already described, at a production capacity of 2,000 t/d of clinker.

The figures shown refer to plants in Europe and were calculated on the basis of several years of plant operation.

As shown by the comparison of total costs for electrical energy, fuel, maintenance and repairs and personnel, the production costs for kiln systems equipped with planetary cooler are the lowest. The RECUPOL cooler has the second lowest figure - which, by the way, is corroborated by test results obtained by one of the large cement firms. However, as shown by the above-mentioned comparison, this type of plant has the highest investment costs.

5.) Firing engineering criteria

Having discussed the most important criteria for the choice of the optimal, i.e. the most favourable kiln sytem in terms of cost, the question arises now what fuels are available at low costs, in order to be able to make a choice of kiln system in terms of process engineering.

In this connection, it is not the heat consumption as such which is of decisive importance, but the costs to be invested for fuels.

As mentioned before, PREPOL precalcining kiln systems are fired with the most diversified low-quality fuels.

However in order to keep production costs as low as possible, with equally high clinker or cement quality, the following points of view should be observed for the use of low-quality fuels.

5.1 Ash content and chemical composition

For the addition into the precalciner, there is principally no limit at all. However, the not burnable content has an influence on the exit gas temperature and naturally also on the heat consumption.

The not burnable substances must naturally be regarded as component of the raw meal. If a coal having a high content of unburnable substances is fed to the precalciner, this content has not participated in the preheating of the raw meal in the preheater. See also Fig. 13719.

The increase in the specific fuel consumption with increased precalcining is clearly visible. The influence of the calorific value on the specific consumption is the greater, the lower the calorific value figure becomes. This difference must, of course, be justified by a more favourable price.

In case of low-quality coals, an excessive chlorine and/or sulphur content is frequently established.

It is a well-known fact that the alkali, sulphur and chlorine circulations may provoke disturbing coatings in the kiln system. When using low-quality coals, the use of a bypass system becomes therefore necessary, if the raw material has already an excessive content of these constituents.

Precondition for the use of the above-mentioned fuels is, of course, that their not burnable constituent can be chemically bonded in the raw material mix, i.e. that the formation of clinker mineral continues to be possible. The raw material mix must be adapted to the respective fuel.

What influence the composition of the not burnable components has on the clinker composition may be elucidated by an example: For a raw meal, consisting of limestone and clay having a lime standard of 97, the theoretic composition of the clinker was calculated in each case. 13709.

Considered in each case was a coal having a calorific value of 7,500 (Type A) and/or 5,300 kcal/kg coal (Type B) When using the high-quality coal A, without correcting the limestone/clay mix, the result would only be an insignificant lowering for the lime standard in the clinker down to 95.8. The other moduli and the liquid phase according to Lea would hardly change at all. Due to the high chlorine content in the coal of 0.75 percent, the chlorine content in the clinker will be about 3 times as high. When using the coal B, it would even be 4.5 times as high. In addition, the moduli will change here, too, in particular the lime standard (fr.97.0 to 86.5) and the liquid phase, to a considerable extent.

Owing to the high chlorine content and to the high sulphur content particularly in the case of mix 2, a gas bypass would be required to reduce the coating-forming circulations and the concentration in the clinker.

When looking at the profitability, it should be taken into account that both the heat consumption and the investment costs will go up by the bypass.

5.2 Reactivity

For the use of low-quality fuels in the precalciner, their reactivity is of decisive importance, since combustion takes place here without flame formation. An incomplete combustion of the fuel in the precalciner will result in an excessive heat consumption due to CO losses. For this reason, the reactivity should be determined before the conversion to low-quality fuels.

5.3 Particle fineness

The particle size of the fuel is of essential importance for the speed of complete combustion. The burning time of a coal cube increases roughly with the square of its edge length. For sintering zone firing, the fineness should be set in accordance with the rule-of-the-thumb formula:

Residue 90 (percent) = 0.7 times volatiles (%wa:

In principle, the coal may be coarser for the precalciner. How coarse it may be depends largely on its reactivity. It is e.g. standard practice to deliver lignite (100 percent $<$ 6 mm; 40 percent $<$ 1 mm) into the lower

gas duct. If this is done, the fine particles will burn before getting into the cyclone, the coarser particles will be precipitated in the cyclone, passing together with the largest grainsizes, which fall through against the gas current, into the rotary kiln to be burned there.
Similarily, coarse coal (16 percent <11.2 mm, 39 percent between 11.2 and 22.4 mm, 45 percent < 22.4 mm) will be fed at the same place.

Such practices will however result only in an insignificant discharge of the rotary tube in terms of heat engineering, but they are very interesting in many cases in terms of profitableness.

6.) Firing systems

We characterize the different coal firing systems in accordance with their gas duct - the coal dust route not being considered in this respect - and we distinguish the following three basic types:

Fig. 13711 shows the "direct firing system".
The total amount of mill exhaust air is fed to the kiln as primary air. In the case of "suction operation", a higher hot air temperature can be admitted than in the case of pressure operation, so that the primary air

quantity is reduced to a minor extent, but the fan, which is exposed to coal dust, is subjected to extensive wear.

The "semi-direct firing" shown in Fig.13712 offers the possibility to reduce the primary air quantity of the kiln firing system, to the extent as permitted by the coal moisture, - without falling short of the dew point.

The excessive mill exhaust air is returned to the mill.

Unlike the "direct firing system", the additional primary air fan allows for the desired high primary air pressure of 1,200 to 1,500 mm WG (abt. 120 to 150 mbar).

The coal dust can be fed from the precipitating cyclone into a small surge bin, so that a precise flow regulation with short dead times is possible.

In the case of "indirect firing", Fig.13713 the total amount of mill exhaust air is dedusted and evacuated into the open air.

For the central coal grinding system for the supply of several kilns at a time, this would constitute the best possible solution.

We shall now attempt to select the right type of firing system for different applications.

The choice of mill type is made in accordance with the criteria of grindability, wear behavior and moisture of the raw coal.

6.1 Choice of the optimal firing system

Fig.15139 shows the most important connections for the selection of the firing system. On the abscissa the raw coal moisture has been plotted, and the ordinate shows the primary air quantity which results if, e.g. when using a direct firing system, the total amount of mill exhaust air is fed to the rotary kiln. As a parameter for this, the hot gas temperature fed to the grinding system is indicated with 250 deg C, 400 deg C and 550 deg C.

On the right side of the picture, the extra consumpt of fuel can be read off, which results due to a higher primary air quantity as compared to a firing system with 10 percent primary air.

The carrier air required for the grinding system of abt. 1.7 Nm^3/kg coal corresponds for direct firing to a primary air quantity of abt. 20 percent.

With low coal moistures and high hot gas temperature, the exhaust air quantity resulting from drying is smaller than the necessary amount of carrier air. With direct firing, the primary air quantity of the kiln firing system must be increased to the minimum amount of carrier air required for the coal mill. The fuel consumption of the kiln is increased accordingly.

The use of the semi-direct firing system with partial return of the of the mill circulation air results in this case in a reduction of the primary air quantity and fuel consumption.

If, on the other hand, high coal moistures must be evacuated with low-temperature hot air, then a larger exhaust gas quantity will result from drying than the necessary amount of carrier air.

In this case, the semi-direct firing system will not result in a reduction of the primary air quantity. Instead, in these special cases the primary air quantity can be reduced only when using an indirect firing system.

For the example entered in the diagram (1) with a coal moisture of 8 percent and a hot gas temperature of 250 deg C, the exhaust air from the firing procedure is equal to the carrier air.

The direct firing system is therefore possible for this example. The extra fuel consumption as compared to indirect firing is 30 kcal/kg clinker.

An increase of the hot gas temperature of 400 deg C allows in this example for the decision in favour of a semi-direct firing system, with the aid of which the primary air quantity can be reduced to 12 percent, and the extra fuel consumption to abt. 5 kcal/kg clinker, as compared to direct firing.

In the example (2) with a coal moisture of 5 percent, the semi-direct firing system, as compared to direct firing, leads with a hot gas temperature of 250 deg C to a reduction of the primary air quantity from 20 to 15 percent, the fuel consumption being improved at the same time by 15 kcal/kg clinker.

Example (3) shows finally an extreme case with 16 percent coal moisture. For the hot gas temperature of 250 deg C, the primary air quantity increases to abt. 38 percent, with a fuel consumption of abt. 85 cal/kg clinker.

With a coal price of US $ 80 per ton, this corresponds to extra costs of US $ 0.95 per ton of clinker, as compared to a firing system using 10 percent primary air. In this case, an indirect firing system is therefore recommended, or a coal drying with higher hot gas temperature.

The majority of applications are within the range up to 10 percent coal moisture.

The semi-direct firing systems offers in this case the right compromise solution in view of investment costs and simplicity of operation on one hand and low energy consupmtion on the other hand.

Conclusion

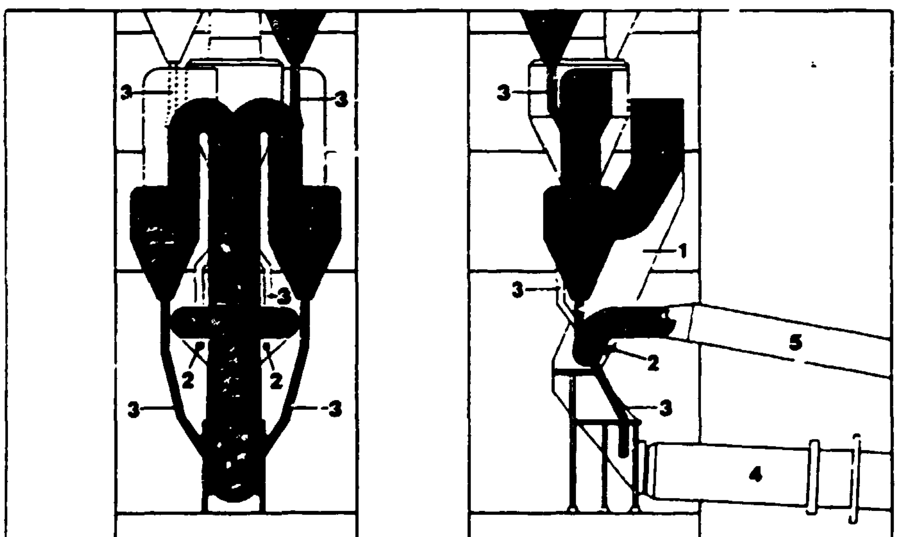
Due to the drastic scarcity and high cost of the high-quality fuels heavy fuel oil and natural gas, the correct choice of the optimal - i.e. low-cost - kiln process for a definite application has gained in importance.

A general superiority of a special process does not exist. Instead, the investment and production costs must be examined for every individual case, and in particular the question must be examined, as to which kiln process will best meet the special demands with respect to the raw material and fuel conditions.

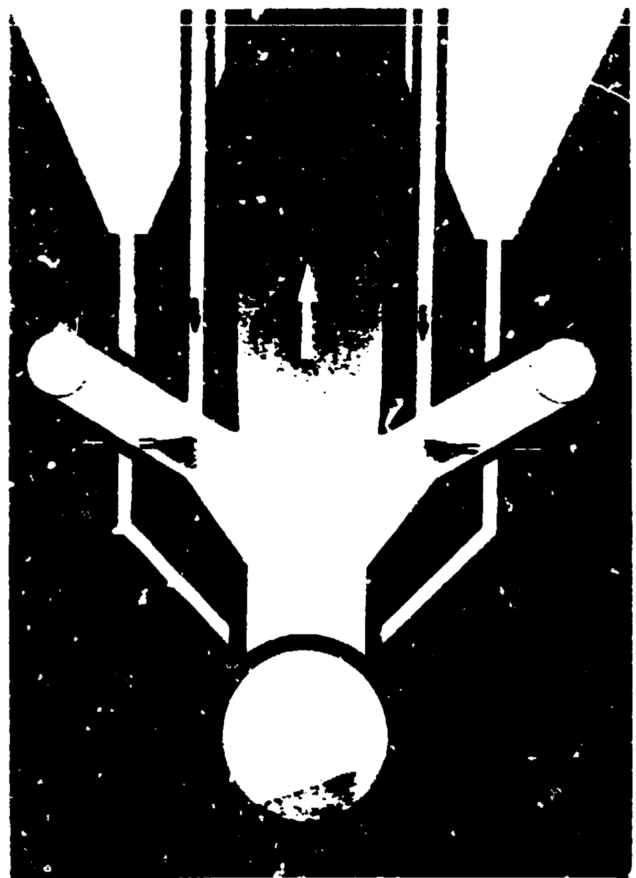
The various designs of clinker coolers should be included in the comparison of processes and the respectively right kind of firing must also be selected once again for every application.

			OUTPUT (MTPD)			TOTAL
			< 2000	2000 - 3000	> 3000	
QUANTITY			19	31	28	78
COOLER	CPAG/FULLER		9	12	17	38
COOLER	POLYS	RECUP.	9	4 (+1SR)	-	14
COOLER	POLYS	PLANET.	1	14	11	26
PREPOL	AT		14	25	16	55
PREPOL	AS		5	6	12	23
5-STAGE PREHEATER			3	-	5	8

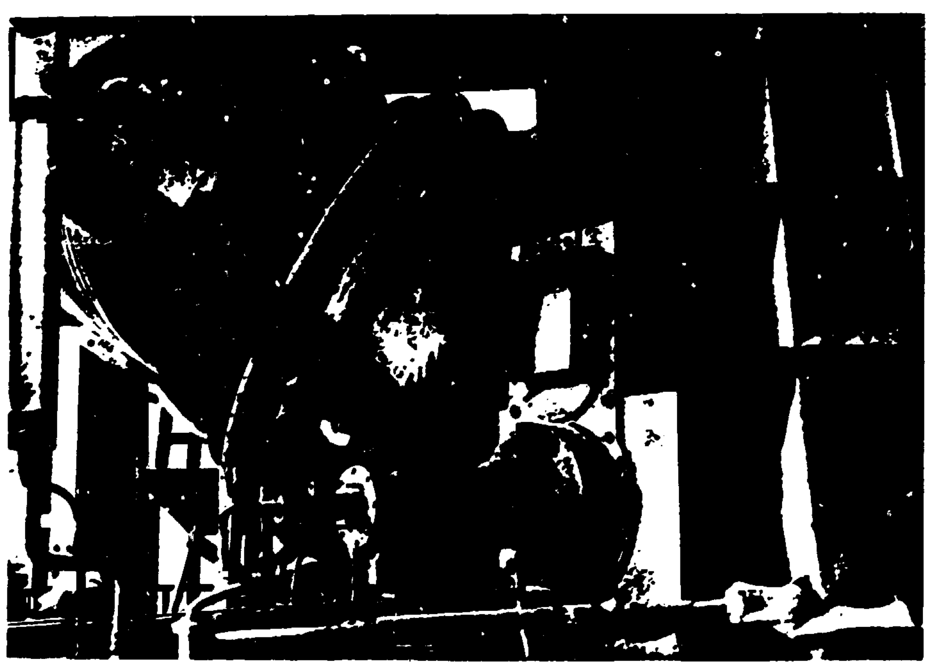
KRUPP POLYSIUS — PREPOL AS/AT - KILN PLANTS — 15 302



POLYSIUS — PREPOL AS — 14181

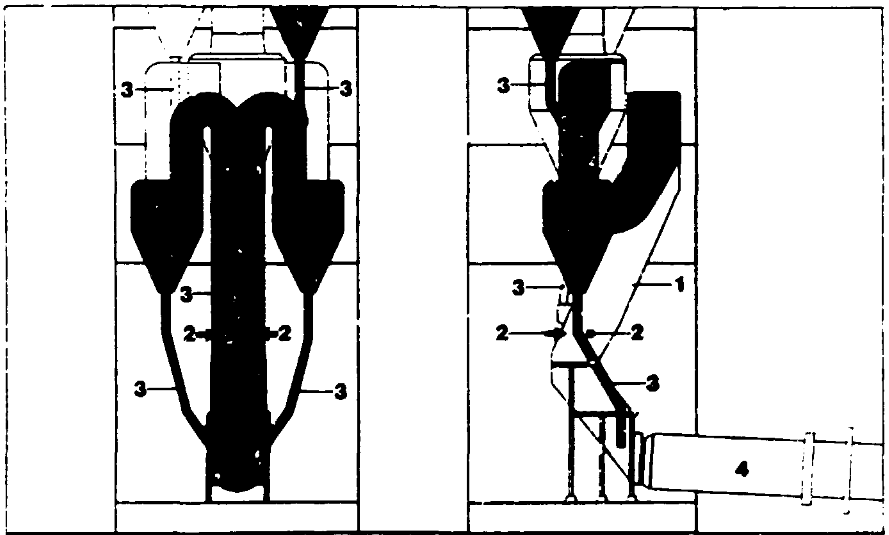


POLYSIUS | Precalciner PREPOL-AS (Section) | 13353

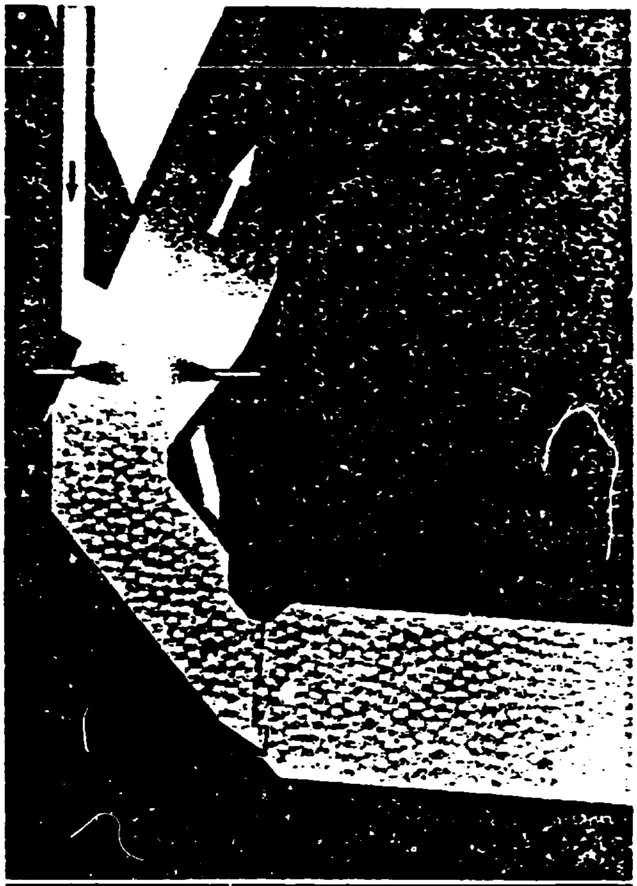


14774

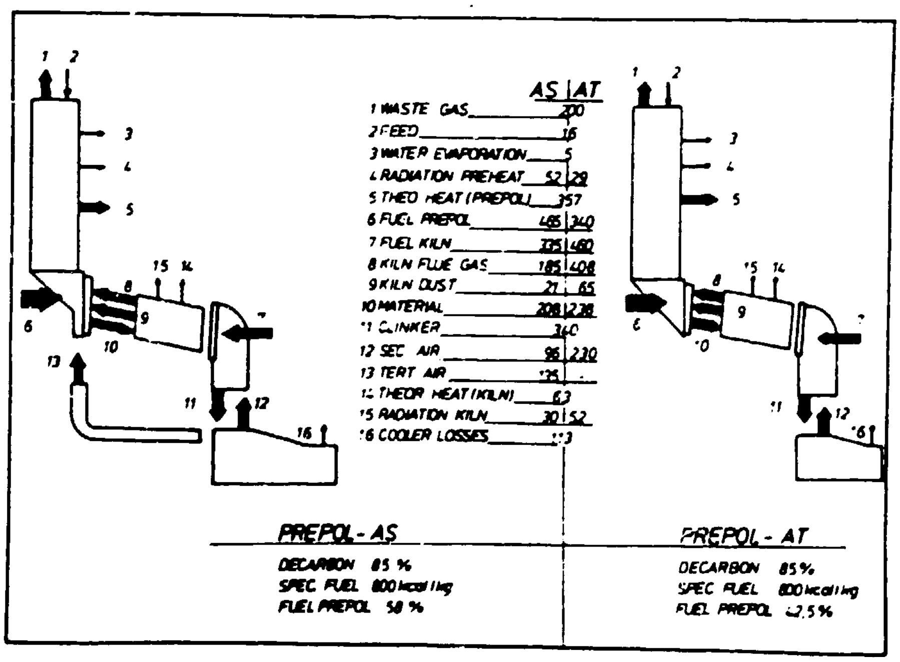
15143



POLYSIUS	PREPOL AT	14180



POLYSIUS | **Precalciner PREPOL-AT (Section)** | 13355



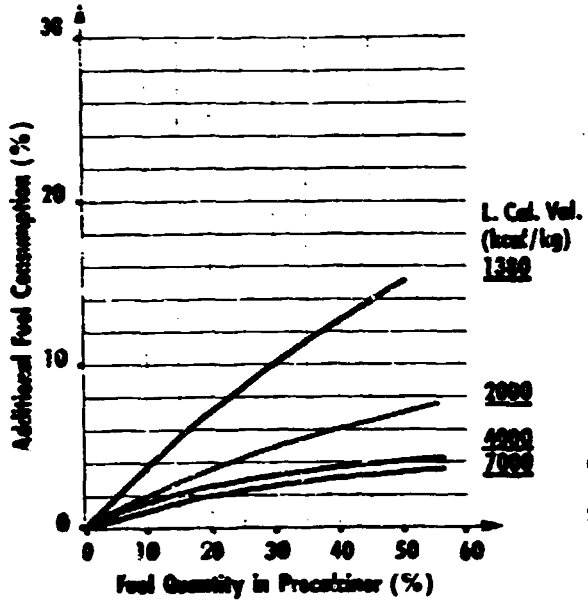
15142

CAPAC		PLANETARY	DRUM	RECUPOL	RECIPROCAT	
1200 MTPD	COST ($/MTPD)	2520,-	2701,-	2995,-	2775	
	PERCENT	139	143	166	154	
2000 MTPD	$/MTPD	1915,-	1933,-	2117,-	1940	
	PERCENT	106	107	117	107	
3000 MTPD					AT	AS
	$/MTPD	1958,-	-	1985,-	1835,-	1805,-
	PERCENT	108	-	110	102	100

KILN / COOLER PRICE PER CAPACITY
(ex works, civil not included)
15141

		PLANETARY	DRUM	RECUPOL	RECIPROCAT.
POWER KILN+COOLER (.04$/kwh)		4,1 kwh/t	6,1 kwh/t	9,3 kwh/t	10,6 kwh/t
	COST ($/Y)	,17	,25	,39	,44
	PERCENT	100	149	227	259
COAL (62.5 $/t) 7000 kcal/kg	TONS / YEAR	70860	72185	70860	70860
	COST ($/t CLINK)	7,13	7,29	7,13	7,13
	PERCENT	100	102	100	100
MAINTEN. (MAT.+LAB)	COST ($/t CLINK)	,15	,27	,10	,23
	PERCENT	100	186	71	154
LABOUR 3 SHIFTS	COST ($/t CLINK)	BASE	+1 MAN / SHIFT → 0,7	0,7	0,7
TOTAL	($/t CLINK)	7,44	7,88	7,68	7,86
	PERCENT	100	106	103	106

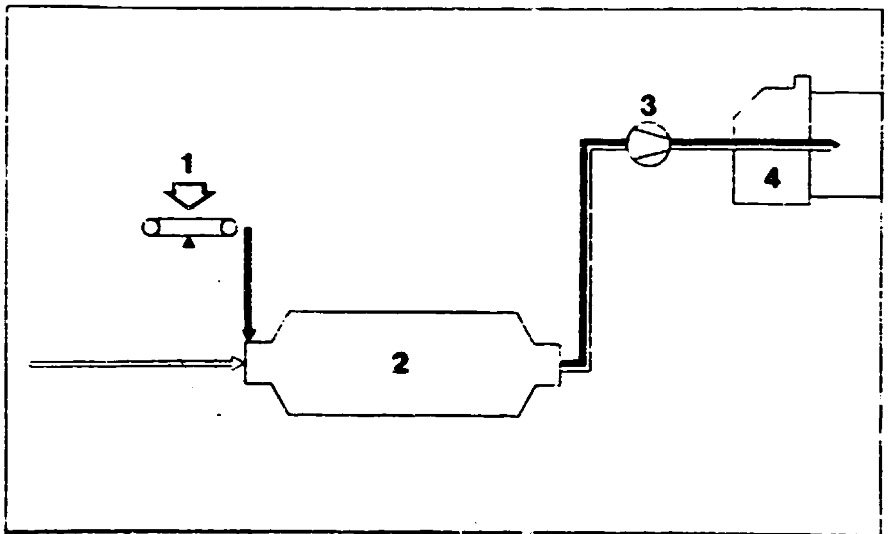
OPERATING COST COMPARISON (2000 MTPD)
15140



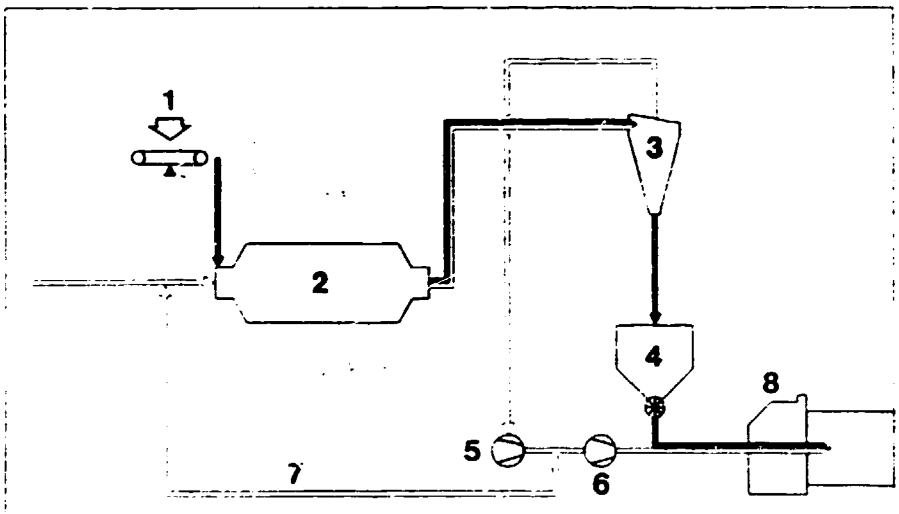
POLYSIUS | Fuel Consumption as a Function of Precalc. Fuel and Calorific Value | 13719

		Raw Mix with LSF 97			
Mix N°		1		2	
Limestone	%	95,9		95,9	
Clay	%	4,1		4,1	
Coal Type		A		B	
LCV	kcal/kg	7300		5300	
Ash	%	5,5		26,9	
S	%	0,94		3,9	
Cl	%	0,75		0,75	
Characteristics Rawmix/Clinker		RM	KL	RM	KL
LSF		97,0	95,8	97,0	[illegible]
SM		2,43	2,40	2,43	2,32
AM		2,20	[illegible]	2,20	2,41
Liquid Phase (1400 °C)	%	27,13	27,57	27,13	30,06
SO_3 (ignited)	%	0,56	0,80	00,56	1,87
Cl (ignited)	%	0,029	0,108	0,029	6,132

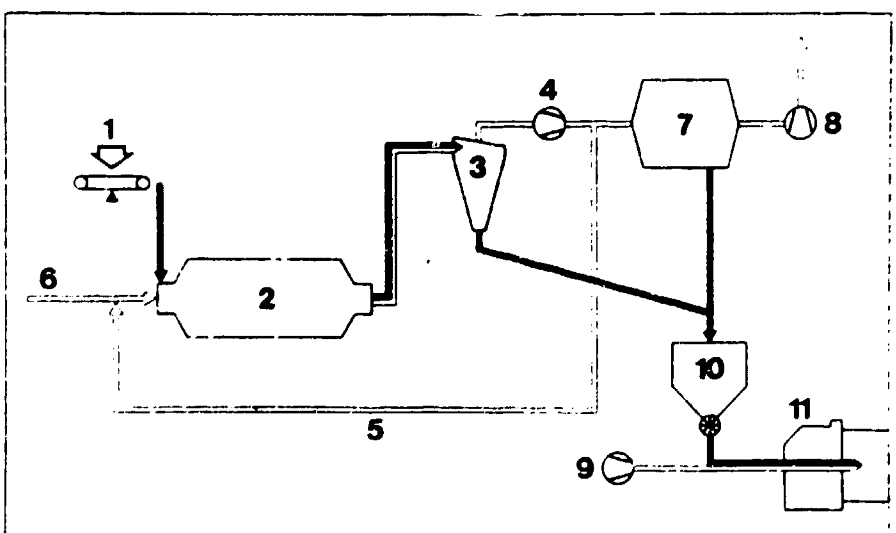
Characteristics of Rawmix / Clinker with Coal Ash | 13709



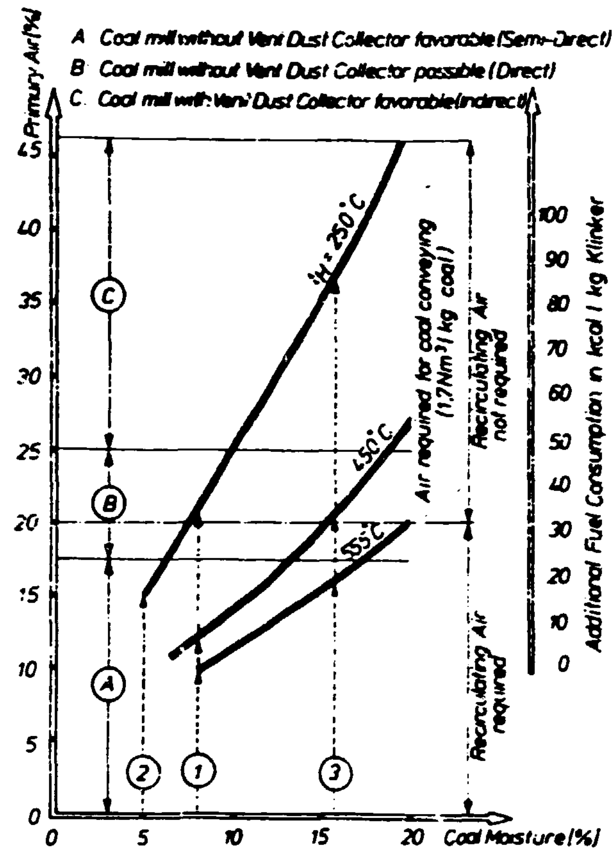
POLYSIUS | Direct Firing System | 13711



POLYSIUS | Semi-Direct Firing System | 13712



POLYSIUS | Indirect Firing System | 13713



Selection of Direct, Semi-Direct or Indirect Firing Systems

15139