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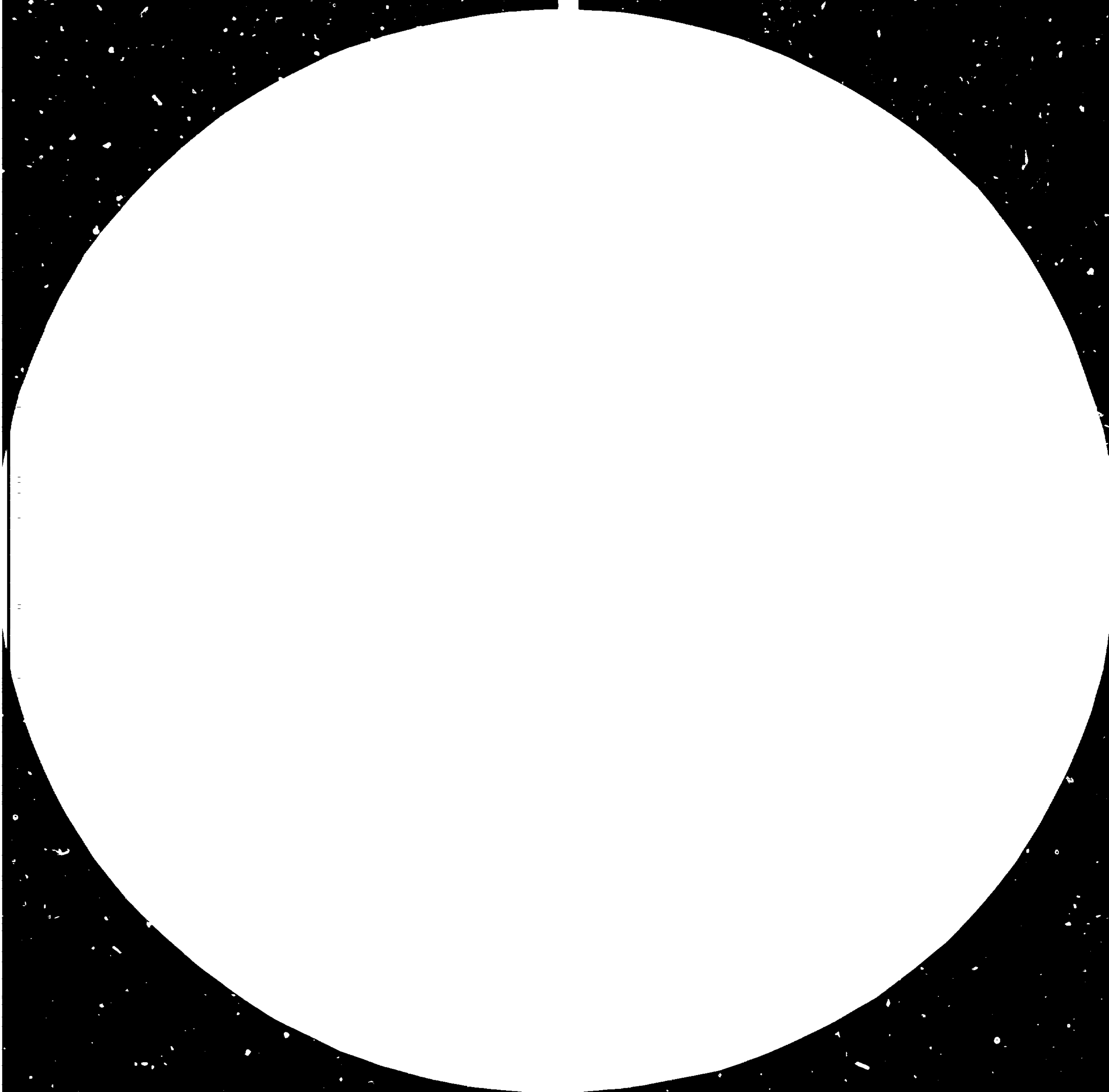

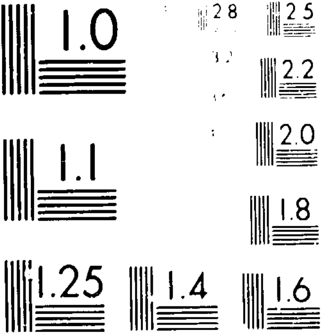
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CONSERVATION OF ENERGY IN CEMENT MANUFACTURE
FUEL AND POWER CONSUMPTION *

by

T. Enkegaard **

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When examining the prospects of energy conservation in cement manufacture there are three main targets on which to focus the interest:

1. Fuel usage
2. Electric power usage
3. Clinker usage in final cement product.

This paper will only deal with the possibilities of fuel and power savings in the manufacturing processes; the question of blended cements such as for instance slag cement or fly ash cement will be covered by other speakers.

Before going deeper into the details of possible direct and indirect energy savings it would be useful to have a general look at the ressources situation of the cement and concrete industries.

The main raw materials used in cement and concrete manufacture are limestone, clay minerals, concrete aggregates, water and energy. All of these, except energy, are abundant.

Limestone makes up 4.5% of the crust of the Earth, which means one million years of supply with the present consumption. Clay minerals and sandstone account for 69% of the crust of the Earth, and concrete aggregate and water are equally abundant, although local restrictions may occur.

Thus, the only really critical ressource in cement manufacture is energy. The cement industry consumes about 1.6% of the world's yearly fuel supply, or the equivalent of about 75 million tons of oil. It consumes about 75 billion kWh, or a little over 2% of the world's total electricity consumption.

From an energy point of view, concrete is a very attractive building material. [Fig. 2]. The only building material which consumes less energy per ton or cubic metre than reinforced concrete is wood, disregarding the potential fuel value of the wood. If we compare the relative cost per kilogram and per kilogram and strength unit we find that wood becomes considerably less attractive than concrete, which on a strength basis cost approximately half of its nearest competitor, steel. Increasing energy prices will further improve the competitive edge of concrete as the energy required for steel making far exceeds the energy required for making concrete, also when compensating for the different strength properties of the two materials.

Although the prospects for cement and concrete thus look quite good, it is nevertheless of great importance for the industry as a whole and for the individual producer to obtain the best possible economy in the manufacturing process, particularly as regards the consumption of energy.

Let us therefore have a closer look at the various possibilities of using less energy.

Fuel Usage

The main part of the fuel used in cement manufacture is spent in the burning process. Smaller amounts are used in the form of Diesel fuel used as a propellant for mobile stock in quarry and transport operations. It falls outside the scope of this paper, however, to discuss the various possibilities of obtaining savings in this relatively minor part of the total fuel consumption in a cement plant.

By tradition, the cement industry is not regarded as belonging to the group of industry called chemical industry, but rather to a sideline called "ceramics" or, in Germany "Stone and earth". The explanation is probably that most of the processes in cement manufacture are physical and not chemical, and that the industry has developed slowly from an old trade and only in recent time has adopted technologically correct methods.

The only process in cement manufacture where chemical reactions take place is the burning process. All other processes are physical, although they are subject to a certain chemical control.

In modern chemical industry it is a generally accepted practice to carry out all unit operations or partial processes separately in equipment which is specially designed for each particular unit operation.

In the cement burning process this principle was not followed for many years, as it was attempted to carry out all the partial processes in one single machine, the rotary kiln. Really, the rotary tube is only well suited for the last unit operation which is the sintering and clinker mineral synthesis, whereas it is poorly suited for the partial processes which take place below 900°C and which require good conditions for the transfer of large quantites of heat.

A decisive improvement was the introduction of the 4-stage cyclone preheater, in which raw meal is preheated under ideal f.3
heat transmission conditions by kiln gas in a so-called stepwise counter current process.

The theoretical heat consumption in the clinker burning process is about 400 kcal/kg clinker and the dominant heat consuming reaction by far is the dissociation of $CaCO_3$ taking place at 900°C and requiring 475 kcal/kg clinker. When the final result works out at 400 kcal/kg clinker the explanation is that the reaction between CaO and clay minerals produces heat. The fuel efficiency of the burning process is thus over 50% in modern kilns, which is good for an industrial process. When kiln gases and cooler surplus air are used for drying, an efficiency of about 75% can be achieved.

In a standard 4-stage SP kiln only 30-35% of the carbonates are dissociated at the kiln inlet which means that the remaining dissociation must take place in the kiln tube. The heat transfer in the kiln tube at about 900°C from gas to powder charge is poor with the consequence that the kiln tube gets unnecessarily large. Also, the CO_2-emission in the kiln charge produces an undesirable fluidization of the charge which may cause uneven material transport in the kiln.

It is therefore, from a heat transmission point of view, a considerable improvement to provide a suspension reactor or precalciner between preheater and kiln tube, in which fuel is added to raw meal suspended in air. In this way the raw meal f. 4 is almost completely calcined when it enters the kiln tube, the dimensions of the kiln tube may be reduced considerably, and the material flow inside the tube becomes very even, resulting in better brick life and cooler performance.

It is indisputable that the precalciner kiln is a great step forward from a heat transmission point of view, but is it also an improvement from a heat consumption point of view?

The best fuel economy in a heat exchange process will, all other conditions being equal, always be obtained in a true counter-flow process, which means that cold material is added at one end of the process and all the fuel at the other end. The precalciner kiln grossly violates this rule by adding about 60% of the fuel half-way up the line, but as the major energy-consuming reaction takes place where the 60% of the fuel are added, at about 900°C, the penalty for violating the counter flow principle is rather modest. The gas temperature at the exit of cyclone No. 4, counting from the top, is somewhat higher on a precalciner kiln than on a 4-stage SP kiln, 870°C versus 820°C, and consequently, the exit gas temperature after cyclone 1 is also somewhat higher, 370°C versus 345°C.

As a consequence of this the fuel consumption of a precalciner kiln should be slightly higher than that of an SP-kiln, but due to the smaller kiln tube of the precalciner kiln, the surface loss from the kiln shell is reduced from about 55 kcal/kg clinker to 35 kcal/kg clinker, which is sufficient to make the two systems almost equal as regards fuel consumption.

The special twin-string FLS precalciner system with separate preheaters for kiln and calciner has the advantage compared to the standard one-string system of a somewhat lower gas temperature, which amounts to a modest 7 kcal/kg clinker lower fuel consumption. By adding a 5th cyclone to the calciner string on both systems, the two systems work out almost equal, with a saving of 24 kcal/kg clinker for the one-string system.

The extra cyclone will account for an additional pressure loss of 80 mm WG, but the fan power consumption will only increase very little as the lower gas temperature results in a smaller gas volume. As a consequence of this, there is good reason to expect that future precalciner kilns - and probably also SP-kilns - will be 5-stage kilns, provided of course that not all gas from a 4-stage unit is needed for drying.

Regarding the power consumption of preheater kilns there has for a long time been a distinct difference in the philosophy of Japanese and European equipment suppliers. The Japanese have used rather small cyclones resulting in under-pressures of 900-1000 mm WG after the cyclones, whereas the European plant makers have preferred larger cyclones with under-pressures of only 450-600 mm WG. The corresponding power consumptions for the I.D. fan are 16-18 kWh and 8-11 kWh/ton of clinker, respectively, and the Japanese plant builders now seem to be moving rapidly towards the larger cyclone dimensions.

Although a pretty important fuel saving can be obtained by adding a fifth cyclone, the biggest fuel saving opportunity is nevertheless found in the clinker cooler. The present grate cooler which is the preferred cooler for precalciner kilns, typically operates with heat losses of 135 kcal/kg clinker, most of it in the hot cooler excess air. f.7

The amount of air needed in the burning process is sufficient, – provided ~~that~~ ideal counter current heat exchange to cool the clinker down to 100-150°C ~~exists~~, assuming a heat loss from cooler surface and with clinker of 35 kcal/kg clinker. A reduction of the present cooler losses by 100 kcal/kg clinker would mean a total fuel saving of 120 kcal, as the smaller amount of smoke gas would also result in a lower gas temperature.

The present grate cooler, which is a cross flow cooler, will probably only have little room for improvement. By using dedusted excess air as cooling air under the first part of the cooler grate a fuel saving of about 20 kcal/kg clinker is obtainable, but there will be a penalty in the form of higher fan power consumption to handle the larger air volume and the larger undergrate pressure required. It is therefore somewhat doubtful if it will be a paying proposition to use re-cycling of cooler excess air which incidentally is an old technique abandoned in most places because of increased wear and doubtful economy.

A drastic improvement in cooler economy would call for a radically new cooler type which does not seem to be near its commercial stage from any supplier. The theoretically best solution at the moment might be the rotary drum cooler which, however, will be a machine of enormous dimensions, larger than the kiln tube on a precalciner kiln. Further, it has the disadvantage that the cooler drive uses about 3 kWh/t clinker more than the drive of other coolers. f.8

The planetary cooler, which is a true counter current cooler, f.9 operating without any excess air has a potential for obtaining lower cooler losses than a grate cooler. In order to obtain a sufficiently low clinker temperature with low surface losses the cooler must be well insulated and it will become very large and heavy which poses structural problems that have not been solved so far. The present day planetary coolers do show better heat recovery than grate coolers when making theoretical f.1 heat balances, but in practice, probably because the surface losses are under-estimated, there is no significant difference in the fuel consumption of a 4-stage SP-kiln with grate cooler and with planetary cooler. The power consumption of the planetary cooler kiln is about 6-8 kWh/t clinker lower, and the installation and maintenance costs also significantly lower. As 6-8 kWh/t clinker on a cost basis corresponds to 30-40 kcal/kg clinker, the planetary cooler kiln really shows the best overall energy economy.

Unfortunately, the planetary cooler is not suitable for precalciner kilns as there is no way to take out the hot air for the precalciner.

Use of Low Grade Fuels

Compared to almost all other process industries, the cement industry is in the rather unique position of being able to use a large variety of combustible materials as fuels, also materials with high ash content and low calorific value. The use of such materials will, of course, not lower the heat consumption of the burning process in terms of kcal per kg of clinker, but it will save money and it will save high-grade fuels for other applications.

The fact that the chemical composition of the ash of such materials as oil shale, coal shale, and low grade coal is quite similar to clay permits the use of a quantity of these materials, corresponding to the amount of clay needed in the raw mix.

A precalciner kiln is particularly suited for using such types of fuel, as they burn easily and completely in the calciner. The ash will be intimately mixed with the limestone and a good and homogeneous clinker will be obtained. In a precalciner kiln with tertiary air pipe about 60% of the kiln fuel is burned in the precalciner, and all this fuel can be coal or oil shale, provided that its heat value is high enough. In a normal SP-kiln only about 30% of the fuel can be burned in the riser pipe, even when using enlarged riser pipes.

In the burning zone of a kiln it is also possible to use a certain amount of ash-rich fuel, but only corresponding to an ash absorption of about 10%. Oil shale and coal shale should be ground to normal raw meal fineness.

Other types of cheap fuels, such as wood waste, rice hulls, used automobile tyres, used lubricating oil and spent chlorine-free organic solvents are also suitable as fuels in cement kilns. Wood waste can be turned into powder in a simple, air swept hammer mill and can be used as the only fuel in precalciners. In the burning zone it can be used mixed with high-grade fuel in a 50/50 mixture.

In Brazil the government has recently introduced rationing of fuel oil so that each cement producer is only allocated a certain amount per year. The industry has responded by starting to use coal, and several SP-kilns are now adding up to 30% of unground lump-sized coal to the riser pipe. Excellent results are reported; the oil consumption has dropped by 30%, and the smoke temperature after the preheater remained at the same level. From an operational point of view the kiln performance improved with substantially less cleaning work in the riser pipe.

An interesting way of directly reducing the fuel consumption of the burning process is to use calcium-containing slags, such as blast furnace slag as a raw material. As an extreme example should be mentioned the use of a belitic waste material with about 55% CaO. A raw mix consisting of 60% of this material and 40% of limestone will have a heat of reaction of only 240 kcal/kg clinker and it can be burned in a 4-stage preheater kiln with a fuel consumption of only 500 kcal/kg clinker. Normal blast furnace slags contain less CaO than 55% but if slags can be obtained at a reasonable price, the potential fuel saving may well make their use as a raw material attractive.

Electric Power Usage

The electric power used in cement manufacturing is mainly spent in grinding and gas handling operations.

The power used for the actual grinding process of raw materials that is the power taken up by the main mill drive, depends mainly on the hardness of the raw materials and the type of mill used, ball mill or vertical roller mill.

Typically, the ball mill motor will use about 14-15 kWh/t of raw mix, whereas the roller mill drive uses typically 7-8 kWh/t with new wearing parts and 25% more with worn parts.

The mill motor consumes only part of the total power used in raw grinding, the remainder being used for gas- and material transport and for the separator.

In a vertical mill, the airflow through the mill is an integrated part of the material transport and separation processes, and the power consumption of fan and separator is typically 7-8 kWh/ton, no matter whether the raw materials are wet or dry. f.11

In a ball mill, however, the fan power consumption increases very much with increasing moisture content of the raw materials because of the increasing volume of hot gas needed for the drying process. At moisture contents below 3-4% the total power consumption of a ball mill and a vertical roller mill works out practically the same; with higher moisture contents the roller mill will use less power. This should be balanced against the greater reliability and lower maintenance costs of the ball mill. The roller mill is best suited for relatively soft non-abrasive raw materials with high moisture content.

All roller mills on the market today are of similar principle and they differ only little in power consumption per ton when grinding the same raw materials.

The ball mills show a more varied picture, with a variety of quite different types being available.

The best grinding economy is obtained by two-compartment mills, using an elevator for transport of material from mill to f.12
separator. The mills can be either of the Tirax-Unidan type
with discharge through the mill trunnion, or of the DUODAN- f.13
type with discharge through the mill shell between first and second compartment. The two-compartment Tirax-Unidan mill is only suited for small capacities and dry raw materials as the amount of air which can be passed through the mill is limited by the partition between chamber 1 and 2.

The drying capacity of the two-compartment mill can be much f.14
improved by using the DUODAN-type with peripheral discharge - at the expense of a more complicated mechanical design. The good grinding economy of the two-compartment mill is maintained.

A one-compartment ball mill with classifying lining and separator
is a mechanically simple solution. Its drying capacity is f.15
between the classical two-compartment and the DUODAN mill, but the power consumption of the mill motor is 6-8% higher corresponding to about 1 kWh/ton.

Perhaps, the simplest of all raw mill installations is the fully air swept mill, by FLS referred to as a TIRAX-mill. The material is lifted up to the separator by means of the air stream through the mill. f.16

Fully air swept mills normally have one drying and one grinding compartment. Compared to a one-compartment ball mill with elevator, the air swept mill has a somewhat shorter retention time for the material, and the mill motor will consume about 1 kWh/t more. For dry raw materials the mill with elevator is therefore to be preferred as elevator transport uses less power than air transport, but at moisture contents over 4% the gas needed for drying will usually also be sufficient for lifting the material up to the separator.

With hard raw materials with 7-8% moisture content which can just be dried with 100% utilization of kiln gases, the power consumption of a ball mill installation versus a roller mill installation works out as follows:

	Ball mill	Roller mill	
		new	worn
Mill motor, kWh/t	14	7.5	9
Fan, separator, elevator, kWh/t	5	7.5	9
Total kWh/t	19	15	18

f.17

The biggest potential at the moment for power saving in raw grinding seems to be in developing a roller mill with mechanical recirculation of material.

Many cement producers are very keen to obtain a low power consumption in raw meal grinding. It is therefore surprising to see how little attention is paid to the power consumption of the subsequent raw meal transport.

If we look at the power used by three commonly used transport systems for kiln feed, it works out as follows:-

Rubber belt elevator:	0.6 kWh/t clinker
Air lift:	2.8 kWh/t clinker
Fuller-Kineyon pump:	4.8 kWh/t clinker.

f.18

In addition, the air lift introduces 10% of false air in the top preheater cyclone, resulting in a 10% larger kiln fan and an 8% larger precipitator. The temperature of the raw meal from the top cyclone is reduced by 30°C.

The corresponding figures for the Fuller-pump are 4% of false air, 4% larger kiln fan, 3% larger precipitator and a temperature loss of 10°C.

These figures together with the greater reliability of elevators make a pretty strong point for using mechanical rather than pneumatic transport for raw meal and cement whenever possible.

Also for raw meal homogenization the use of large quantities of compressed air must be considered unnecessary and wasteful. Continuous flow-through systems consisting of one large silo serving the dual purpose of blending and storage silo have been developed by various manufacturers; as an example is shown the F.L. Smidth Controlled Flow or CF-silo. f.19

The principle is that raw meal is extracted simultaneously from what corresponds to a large number of different outlet openings, evenly spaced over the silo bottom, but at different extraction rates. In this way the entire content in the silo will be kept in motion, but raw meal in different parts of the silo will have different sinking velocity or retention time in f.19r
the silo, whereby a good homogenization is obtained.

A silo with 3-4 days of kiln consumption will give a blending factor of about 10, and the power consumption will only be 0.5 kWh/t as low pressure air is used only to fluidize the raw meal around the outlet openings. A corresponding strongly aerated system, either batch-type or continuous overflow type, will use about 3 kWh/t of raw meal.

Cement grinding has until now been the domain of the ball mill. The most widely used type to-day is a two-compartment mill, often with a classifying lining in the second compartment, working in closed circuit with an air separator.

The grinding efficiency of all machines for fine grinding is very poor as only a few per cent of the energy input is found in the product in the form of increased surface energy. The rest is lost as heat.

At the moment, however, there is nothing better available on the market for fine grinding than the ball mill, and it is therefore of interest to see what is being done in order to improve the grinding efficiency of the ball mill.

It has long been known that a better grinding economy could be obtained by using smaller grinding media in the fine grinding f.2
compartment than the balls or cylpebs with an average piece weight of 20-40 grams. For grinding clinker grit of minus 2 mm to type I cement of about 3000 cm^2/g the optimum piece weight is about 5 grams, and for grinding type I cement to type III cement it is as low as 1 gram a piece.

About 10 years ago F.L. Smidth developed a special milling system for producing type III cement in open circuit grinding. The system consists of a normal two-compartment open circuit f.2
mill, grinding a coarse cement of about 2500-2800 cm^2/g. This cement is then ground to about 4000 cm^2/g in a separate one-compartment mill with a charge of very small grinding media, about 1 gram a piece.

In a Danish cement plant very thorough comparisons of a Minipebs mill and a normal closed circuit mill were made. The Minipebs mill used about 3 kWh/ton less power than the closed circuit mill, and gave a 3-7% higher cement strength, depending on the testing age.

The mechanically difficult part in the Minipebs mill is the outlet which must be able to keep the very small grinding media inside the mill. There is therefore no outlet grate, but an overflow ring followed by a separating device which separates the few minipebs passing the overflow ring from the cement and returns them to the grinding compartment.

The Minipebs mill has not been a commercial success as most cement producers seem to prefer the closed circuit mill because of its greater flexibility in grinding several types of cement on the same mill.

Therefore F.L. Smidth has developed a new type of mill which is equally suited for straight and closed circuit grinding. This mill, called the COMBIDAN mill is a two-compartment mill with small grinding media, about 5 grams a piece in the second compartment. f.22

As such small grinding media are unable to grind clinker particles larger than about 2 mm, a special diaphragm consisting of a coarse, robust grate which only serves to keep the balls in the first compartment is provided, followed by a 2 mm perforated screening plate which ensures that no oversize particles enter the second compartment. Coarse particles screened off are returned to the first compartment by lifters between the coarse grate and the screen. f.23

The mill outlet is similar to the Minipebs mill outlet, with an overflow ring and a separation chamber that separates off stray grinding media and returns them to the second compartment. f.24

This new type of mill has during 30 months of operation in a Danish cement plant shown extremely good grinding economy:

When grinding to the same Blaine value the following results were obtained:

1. In open circuit grinding of type I cement to 3000 cm^2/g the grinding economy was improved by 9%.
2. In closed circuit grinding of type I to 3000 cm^2/g the grinding economy was improved by 11%. f. 25
3. In closed circuit grinding of type III to 4000 cm^2/g the grinding economy was improved by 12%.

These improvements in economy are in themselves remarkable, but yet another advantage is to be gained: A cement of a given Blaine value has better strength properties when ground in a COMBIDAN-mill because it has a steeper size distribution curve with less coarse and less ultrafine particles.

When grinding to the same strength, which in practice is practically the same as grinding to the same residue on 25 micron, industrial scale tests produced the following results.

1. In open circuit grinding of type I cement to the same strength, grinding economy was improved by 16% or 5.1 kWh/t.
2. In closed circuit grinding of type I cement to equal strength, grinding economy was improved by 11% or 3.2 kWh/t.
3. In closed circuit grinding of type III cement, the grinding economy was improved by 21% or 9.4 kWh/t, compared to a similar mill using ordinary grinding media.

The improvements in grinding economy obtained by the COMBIDAN-mill are very significant and there is reason to believe that this type of mill will find wide acceptance in the industry.

The closed-circuit ball mills used for cement grinding are all equipped with elevators, as air swept ball mills are unsuited for fine grinding and use too much fan power for the material transport.

The vertical roller mill is a fully air swept mill and will thus use disproportionately much fan power for grinding of a dry material as clinker. The main mill drive, however, will use less power than a ball mill, and the total power consumption of a roller mill will thus probably work out even with a ball mill for type I grinding.

The wear on rollers and grinding table will be pretty severe, and this factor in combination with the superior reliability of the ball mill has so far made the roller mill less attractive for cement grinding. A few vertical mill installations have been sold for cement grinding, but have not yet been put into operation.

If the material transport inside the roller mill could be achieved mechanically instead of by an air stream, the grinding economy could be improved considerably, and in that case the vertical mill could become attractive for cement grinding.

Summing up, the best prospects for saving energy in the cement industry or at least money on the energy bill will end up with the following advice:

1. Switch from oil to coal firing.
2. Use cheap low grade fuels to the greatest possible extent.
3. Use lime-rich slags in the raw mix if available at a reasonable price.
4. Save electric power by avoiding false air and unnecessary pressure losses in gas handling operations and by using mechanical rather than pneumatic transport whenever possible. Remember that compressed air is very expensive.
5. Last, although not covered by this paper, it should be mentioned that cements containing additions of blast furnace slag, fly ash, puzzolanas or even inert materials as for instance limestone, represent a very real potential for substantial energy savings in the cement industry. This, however, is a controversial subject that many cement producers - and of course the equipment suppliers - are not too happy about.

Main Targets for Energy Conservation in Cement Industry

1. Fuel usage

2. Electric power usage

3. Clinker usage in final cement product

FIG. 1

Material	Energy		Cost index		
	kg CE per ton	kg CE per cu.m	per kg	per kg per E-module unit	per kg per strength unit
Steel	1000	7900	15.8	2.6	2
Aluminium	4200	11400	40.8	19.4	6.1
Portland Cement	170	215			
Portland Cement concrete	25	60	1	1	1
Brickwork	150	245	2.2	9.6	8.1
Glass	700	1750	22	12	11
Wood	0.8	0.4	9.2	32.3	9.2

FIG. 2

Cyclone preheater

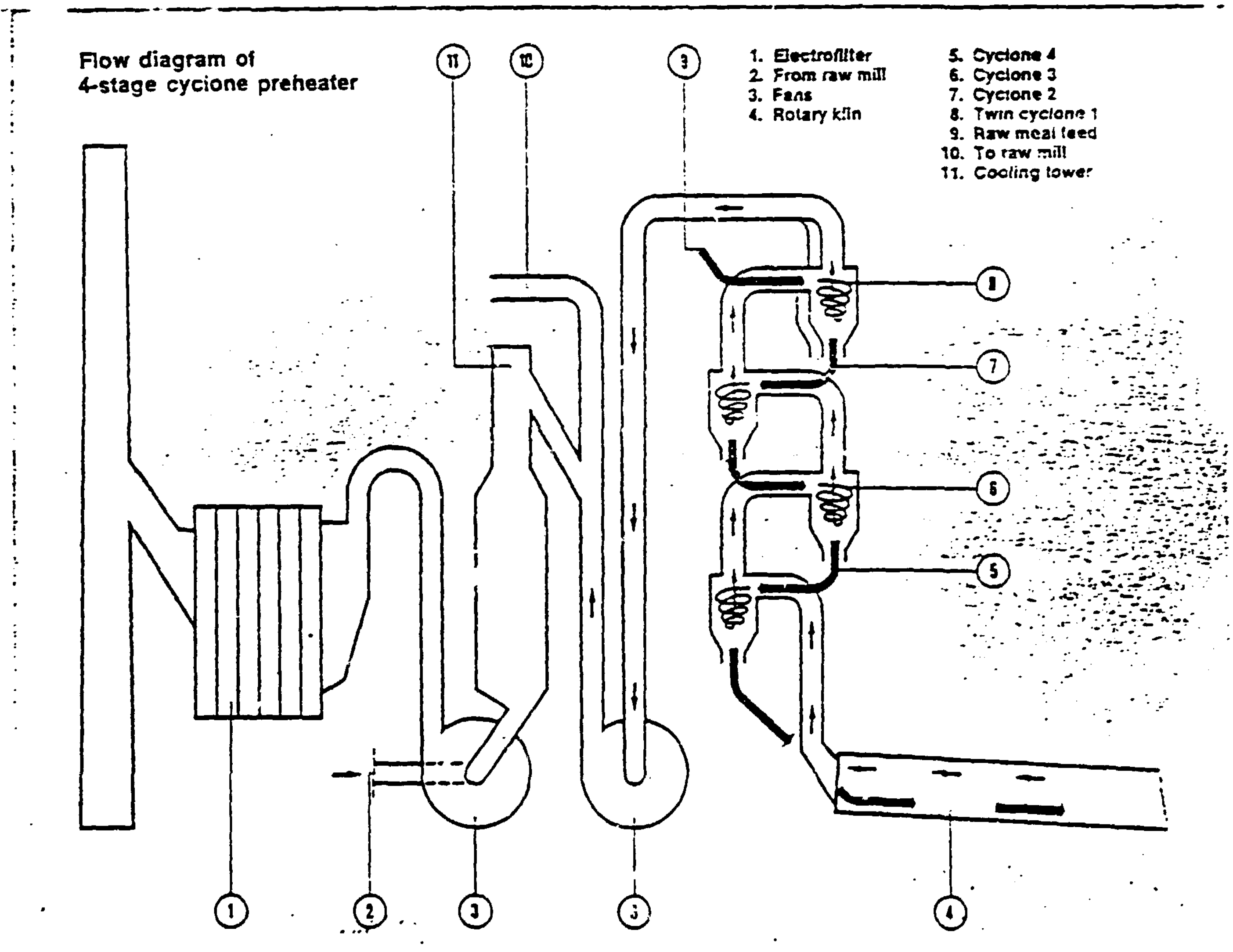


FIG. 3

FLS

Variabel Bypass 0-100% of Kilngases.
Adjustable Throat for bigger Variations

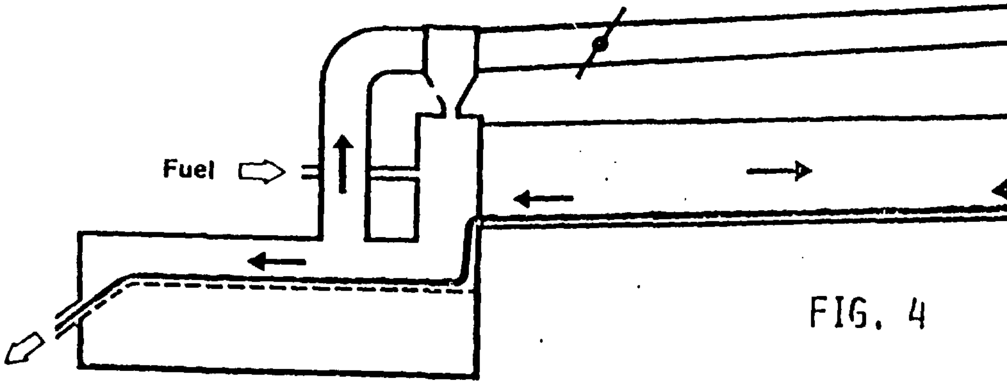
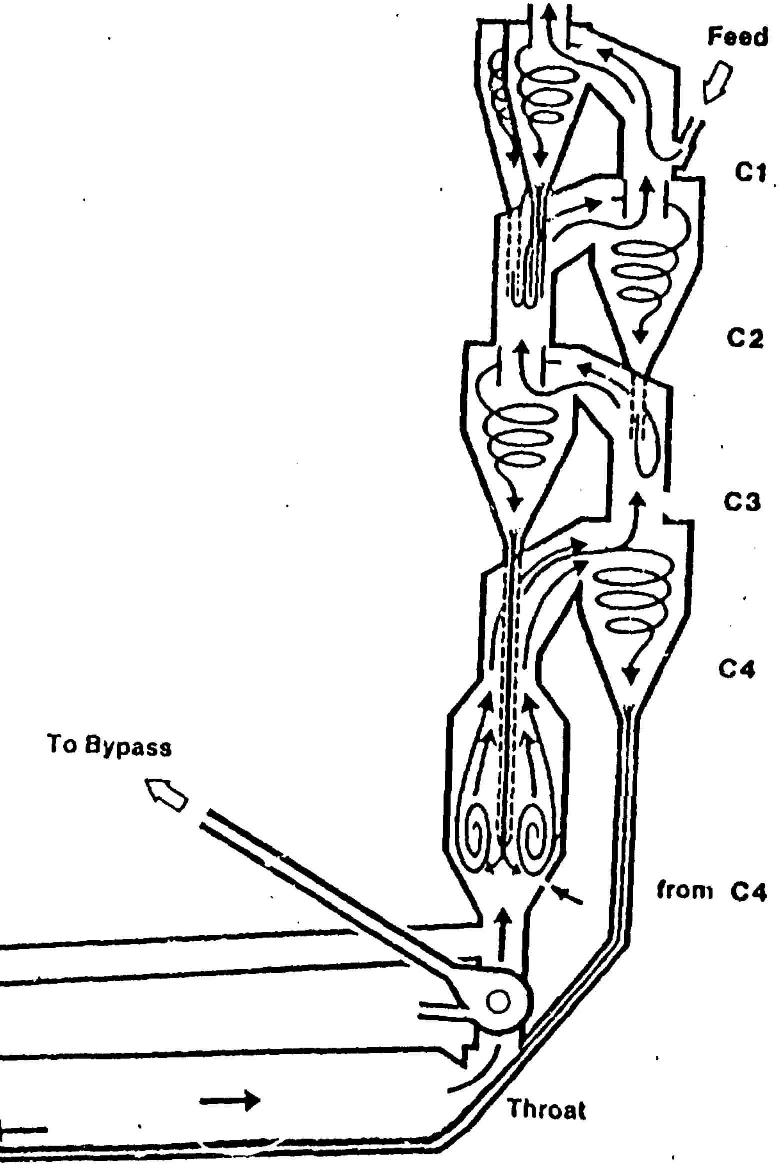


FIG. 4


Feed
C1
C2
C3
C4
To Bypass
from C4
Throat

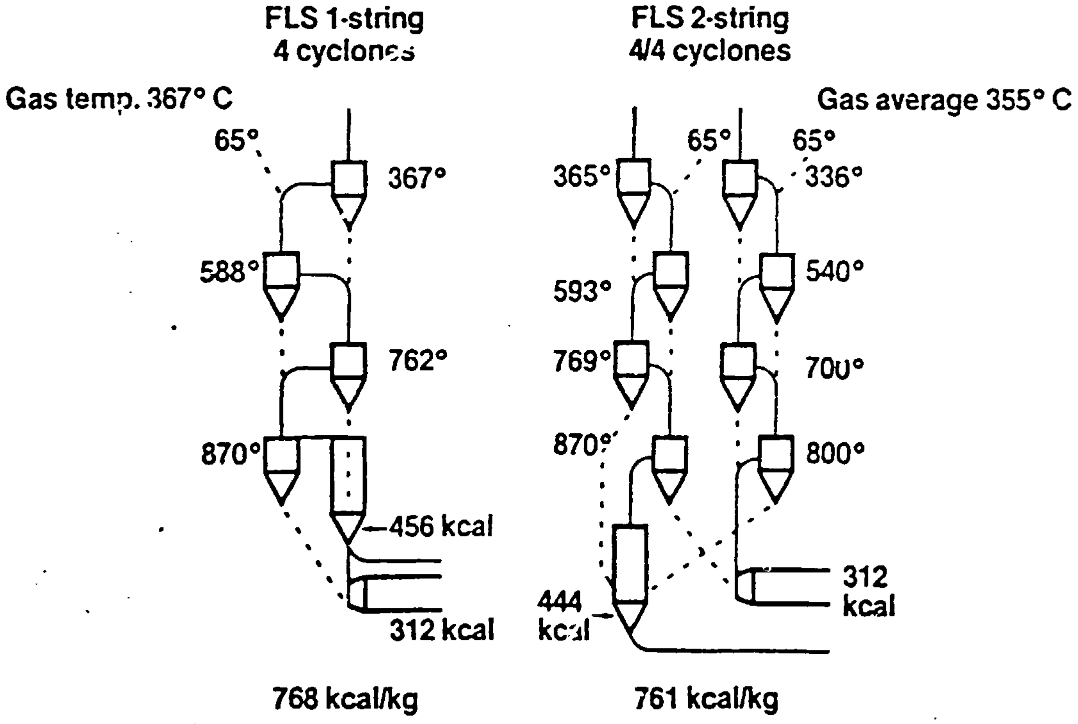

FLS 1-string
4 cyclones
Gas temp. 367° C
65°
367°
588°
762°
870°
456 kcal
312 kcal
768 kcal/kg
FLS 2-string
4/4 cyclones
Gas average 355° C
365°
65°
65°
336°
593°
540°
769°
700°
870°
800°
444
kcal
312
kcal
761 kcal/kg

FIG. 5

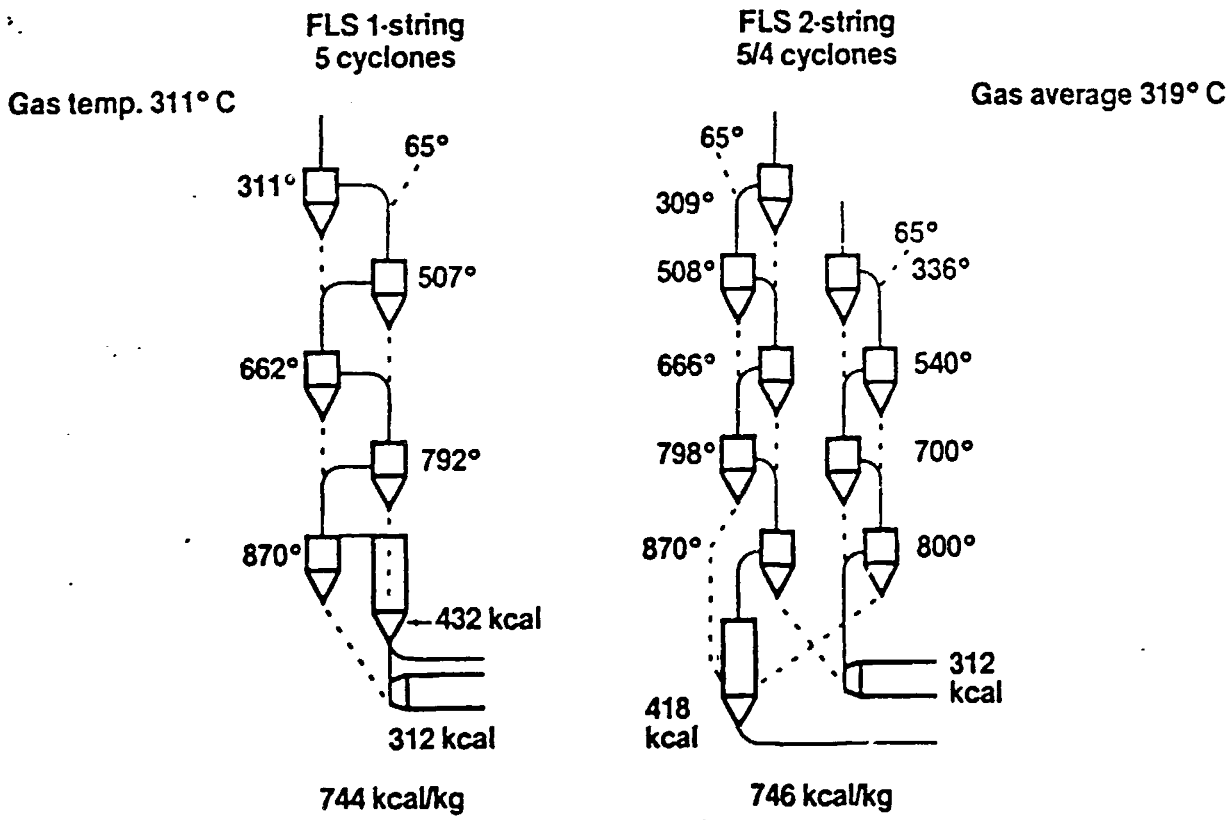

FLS 1-string
5 cyclones
Gas temp. 311° C
65°
311°
507°
662°
792°
870°
432 kcal
312 kcal
744 kcal/kg
FLS 2-string
5/4 cyclones
Gas average 319° C
65°
309°
508°
666°
798°
870°
65°
336°
540°
700°
800°
418
kcal
312
kcal
746 kcal/kg

FIG. 6

Heat Balance
Grate Cooler

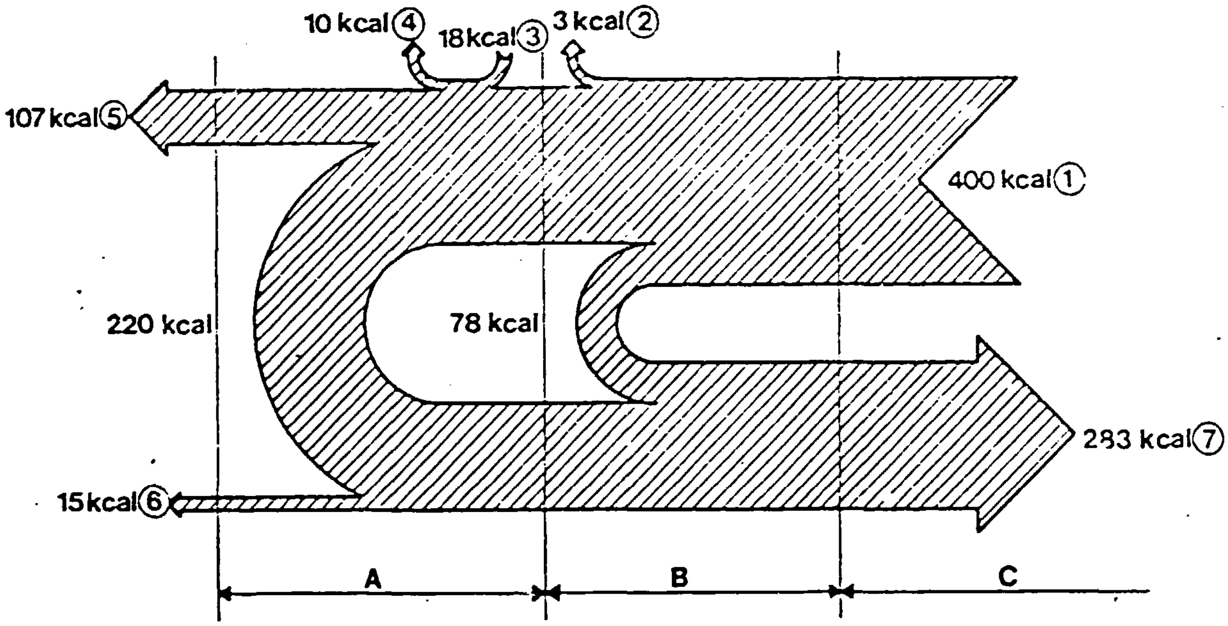


FIG. 7

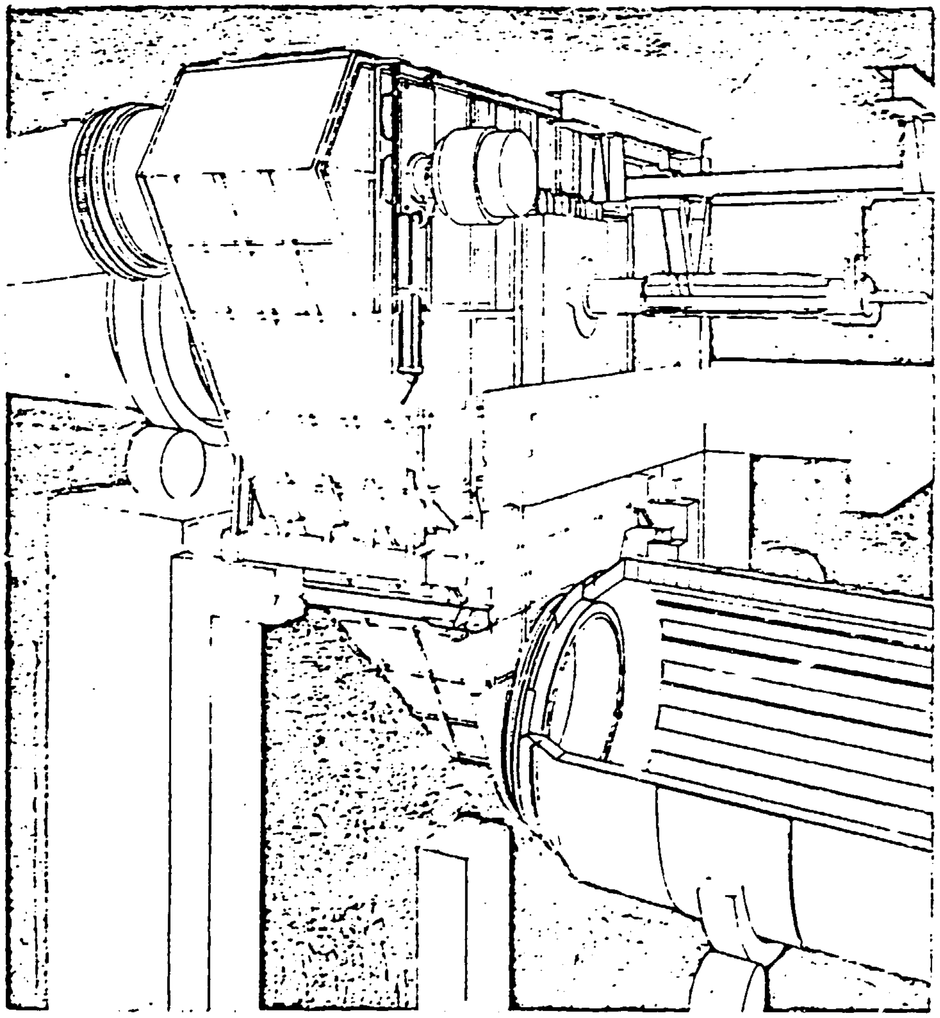


FIG. 8

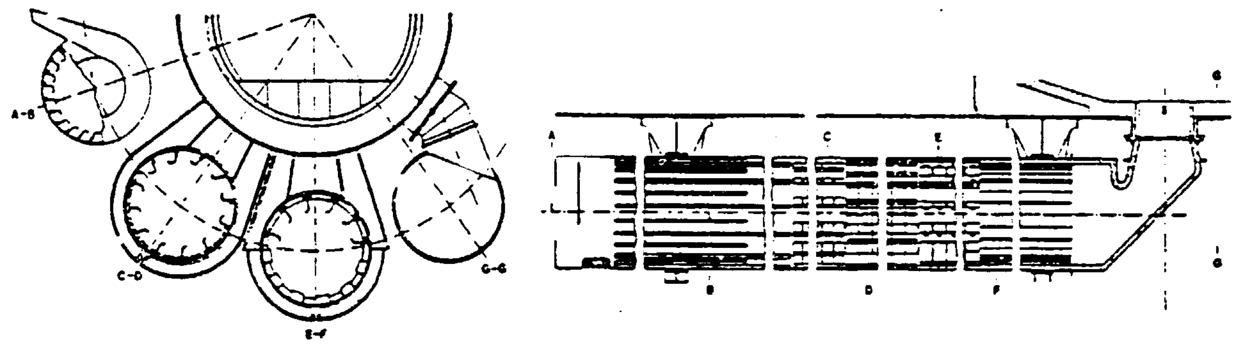
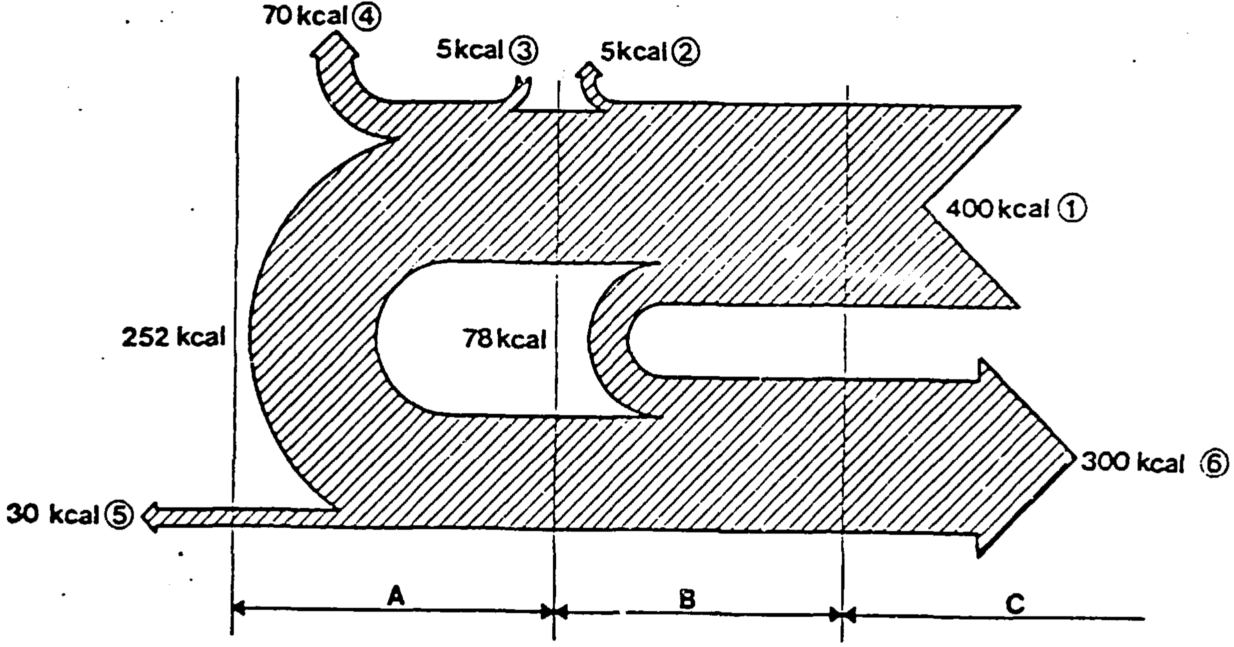
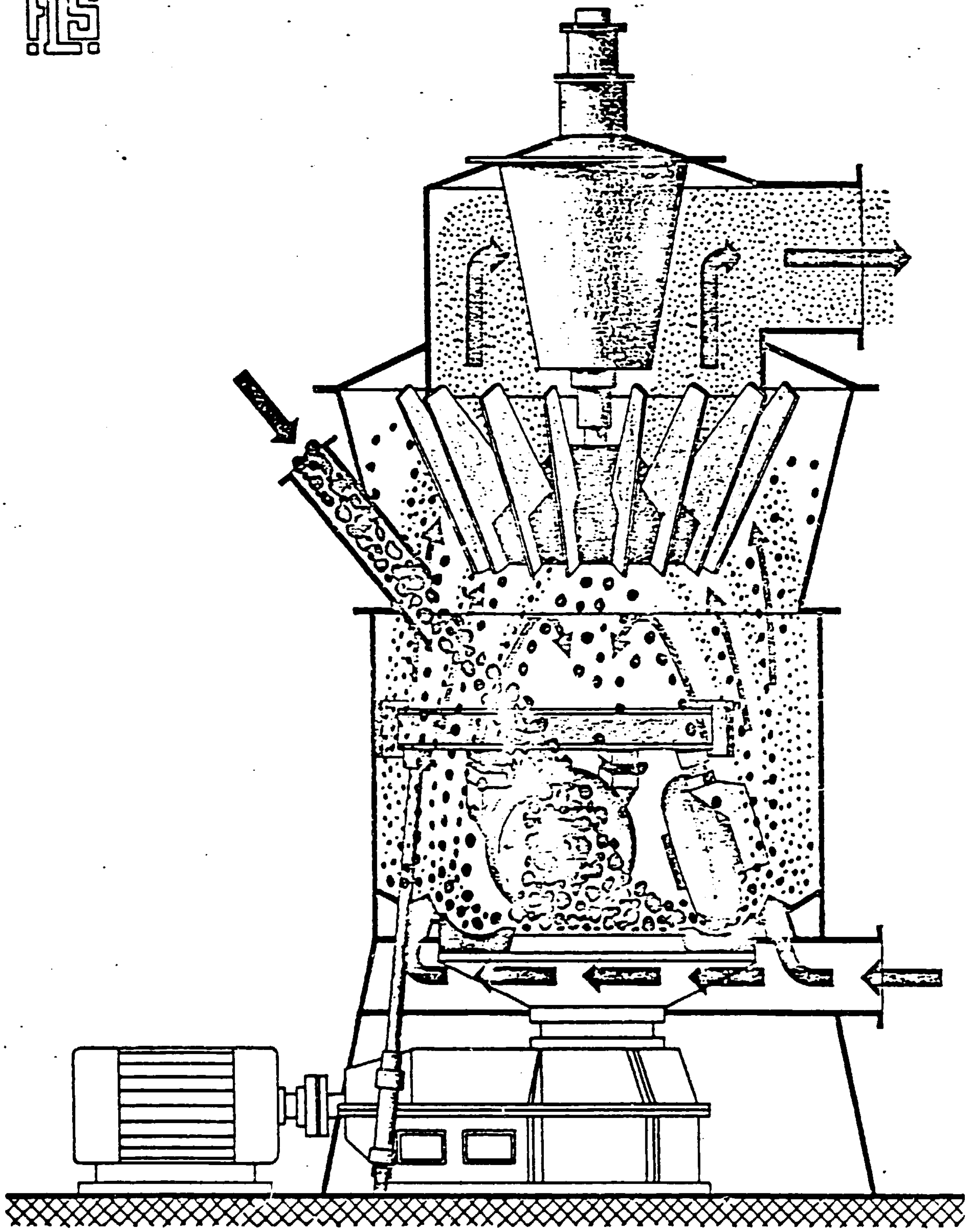


FIG. 9



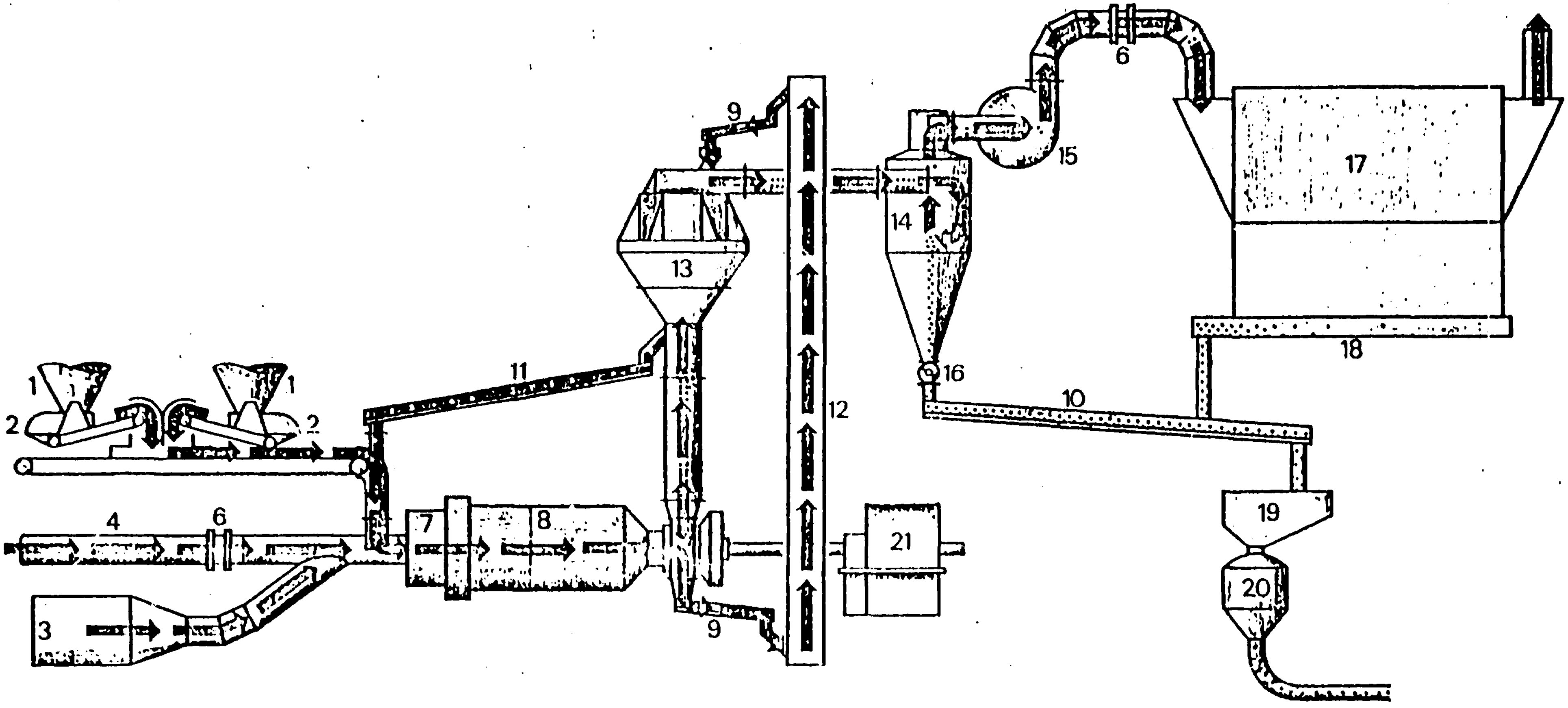
Heat Balance
Planetary Cooler

FIG. 10



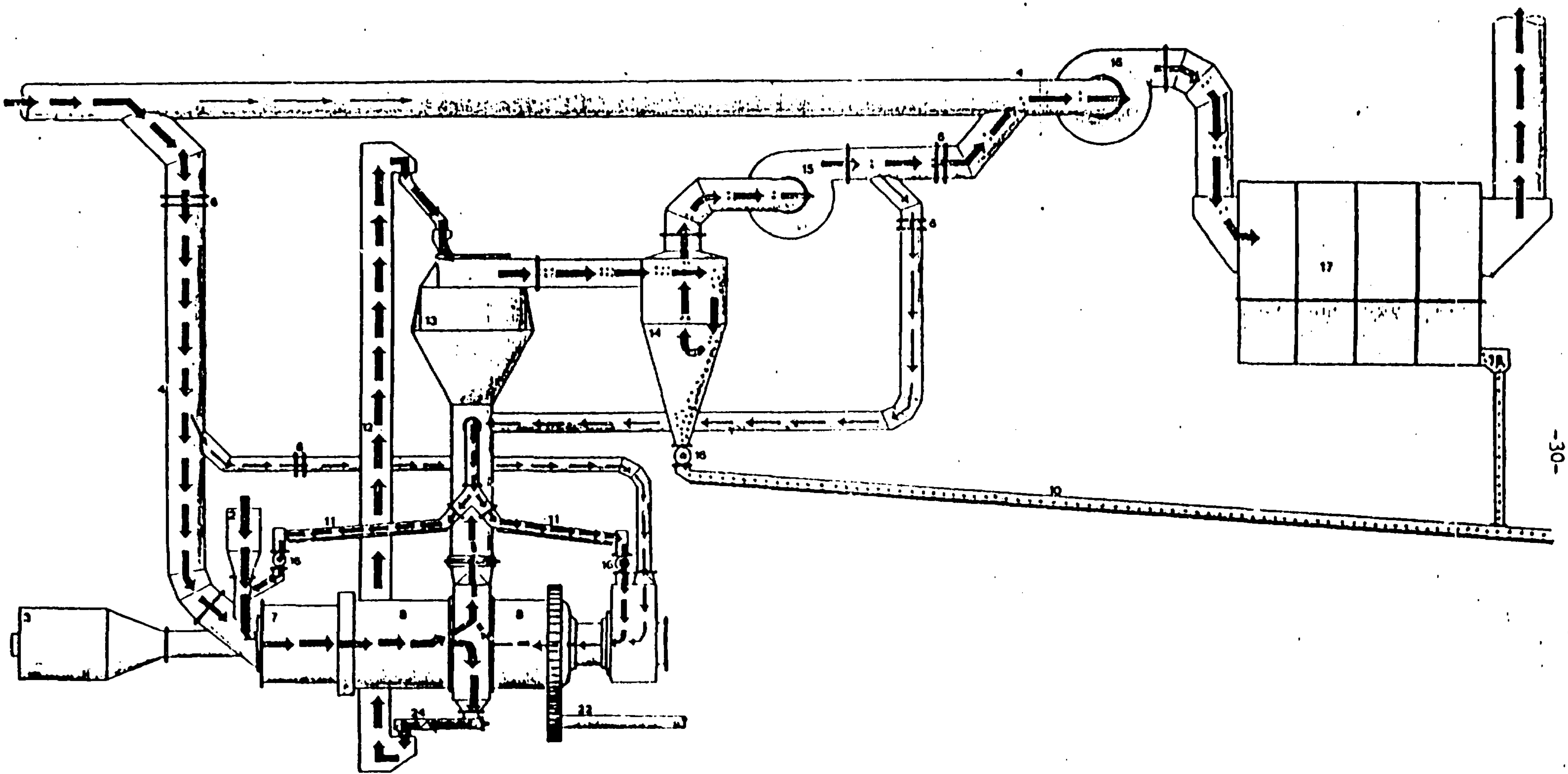
PFEIFFER, MPS-MILL

FIG. 11



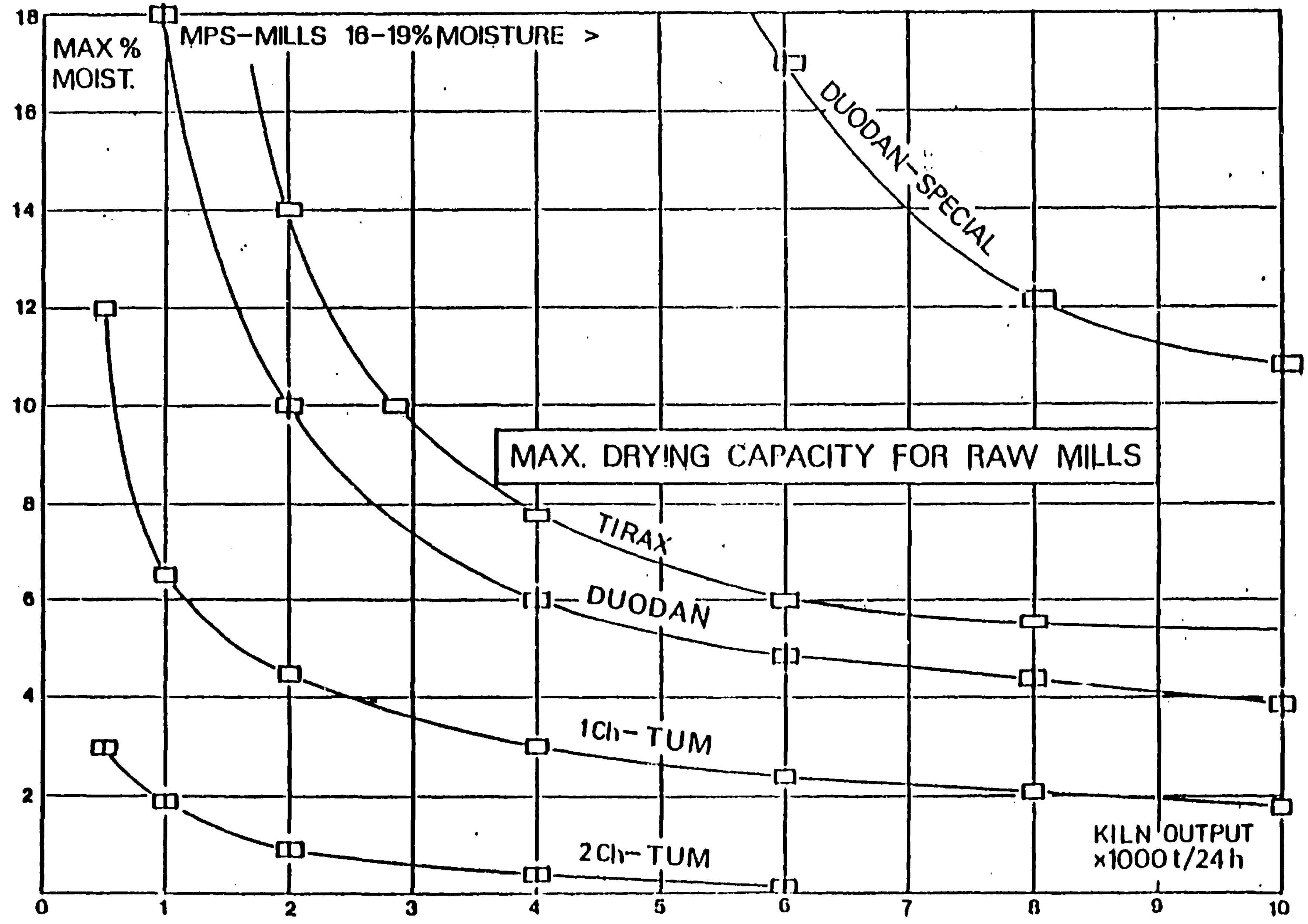
TIRAX - UNIDAN MILL WITH SEPARATOR, TYPE RTE

FIG. 12



FLS DUODAN MILL WITH SEPARATOR, TYPE RTE

FIG. 13



MAX. DRYING CAPACITY FOR RAW MILLS

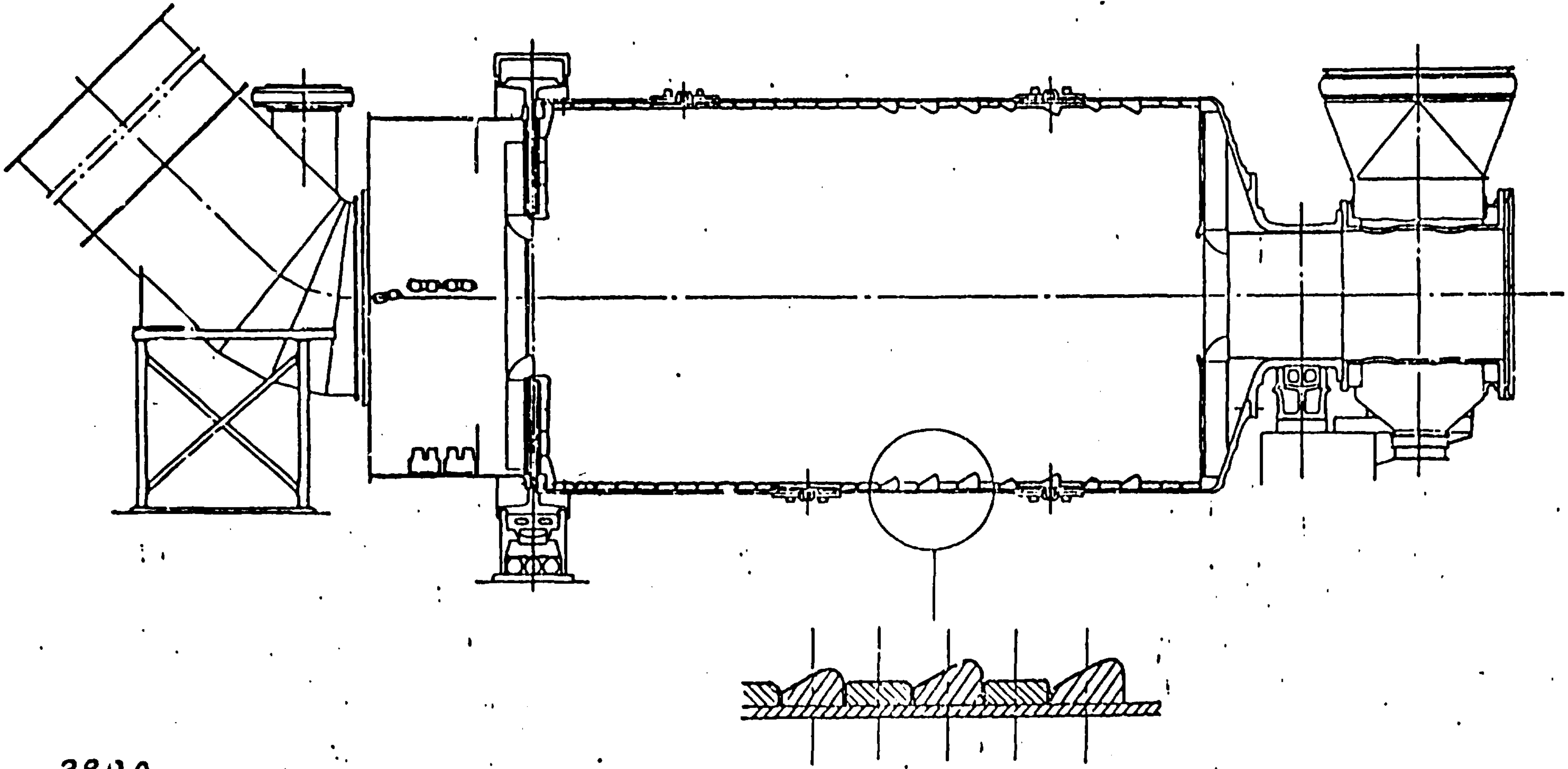
CEMENT MANUFACTURE SEMINAR

FIG. 14

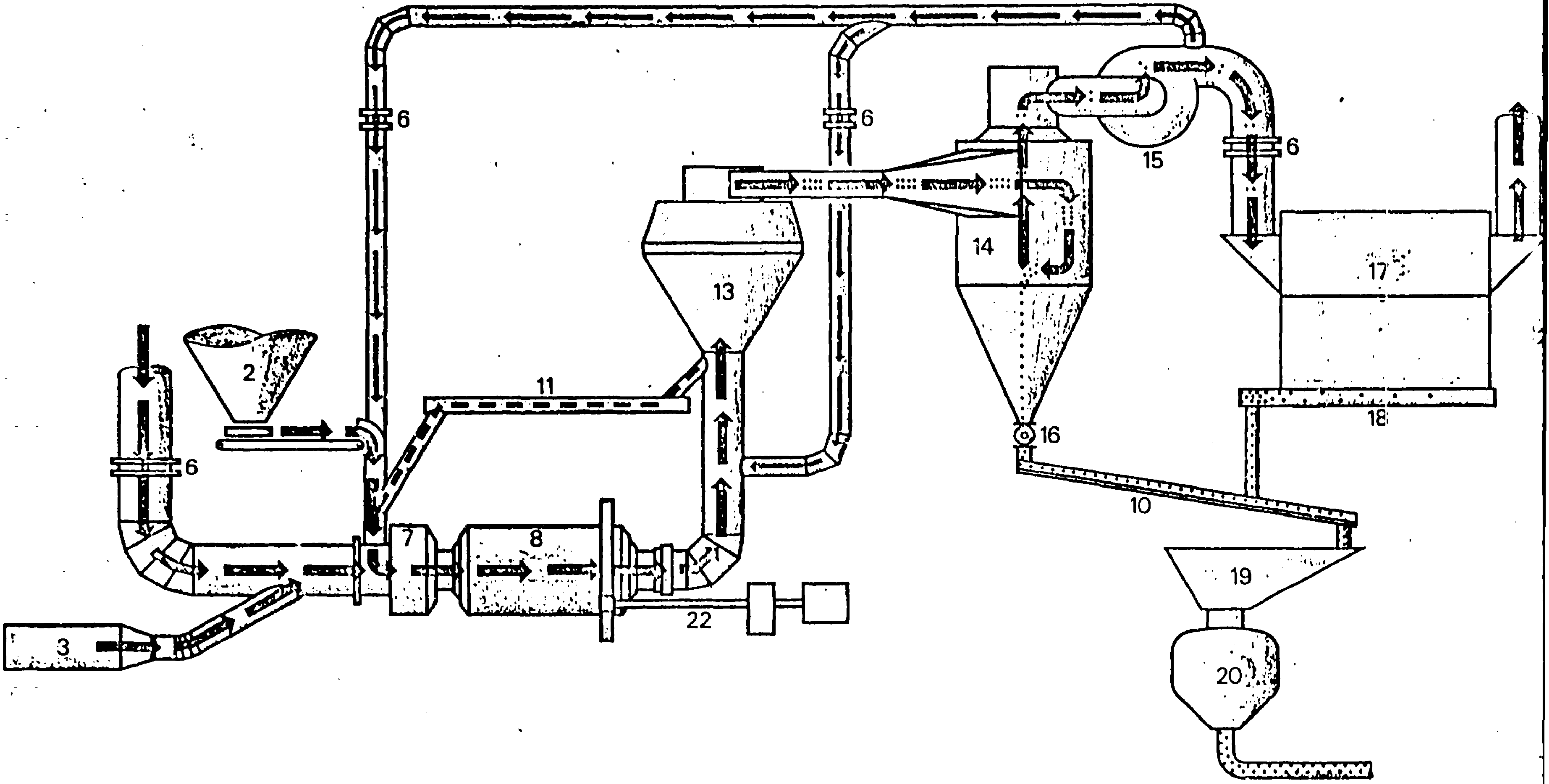
1 comp. Tirax Unidan Mill.

Classifying lining in outlet end of compartment.

FIG. 15



2890



TIRAX-MILL WITH SEPARATOR, TYPE RT

FIG. 16

Comparison of Power Consumption

Ball Mill versus Roller Mill

7-8% moisture, all kiln gas through mill

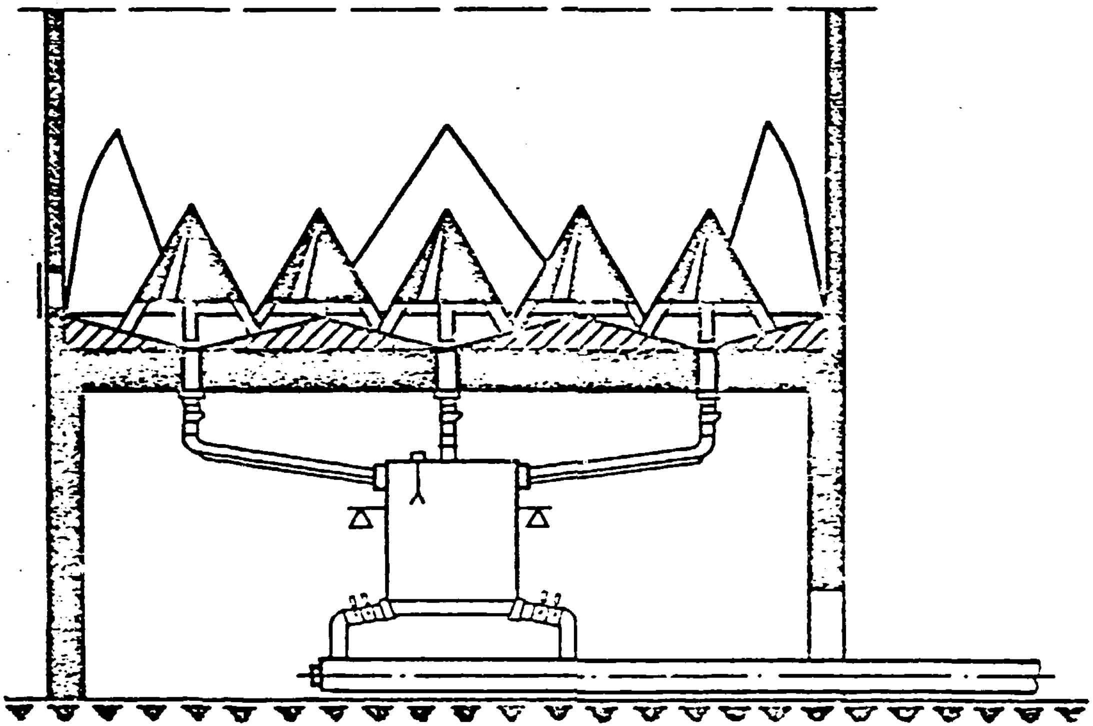
	Ball mill	Roller mill	
		new	worn
Mill motor, kWh/t	14	7.5	9
Fan, separator, elevator, kWh/t	5	7.5	9
Total kWh/t	19	15	18

FIG. 17

Transport Systems for Kiln Feed

	Rubber belt elevator	Air lift	F·K pump
Power, kWh per ton clinker	0.6	2.8	4.8
% false air to preheater	NIL	10	4
Material temperature stage 1	360° C	330° C	350° C
Power consumption smoke gas fan	100%	110%	104%
Precipitator size	100%	108%	103%

FIG. 18



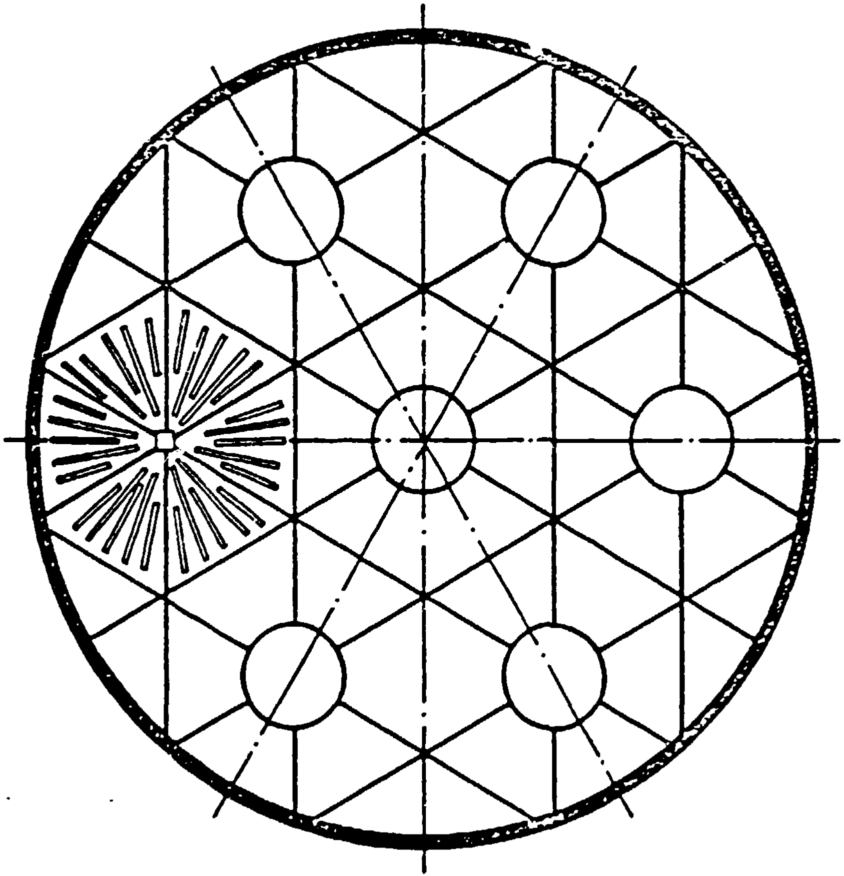


FIG. 19

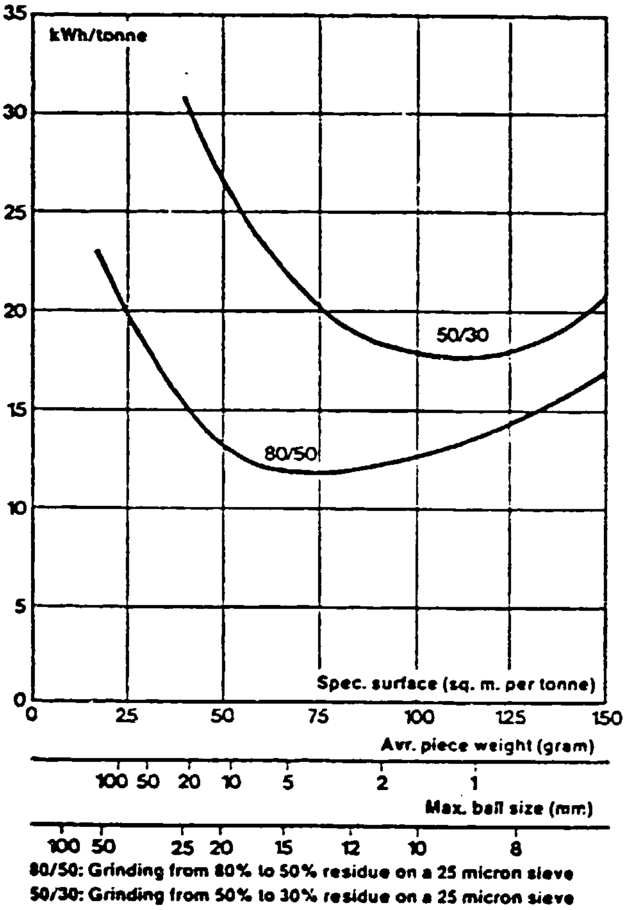
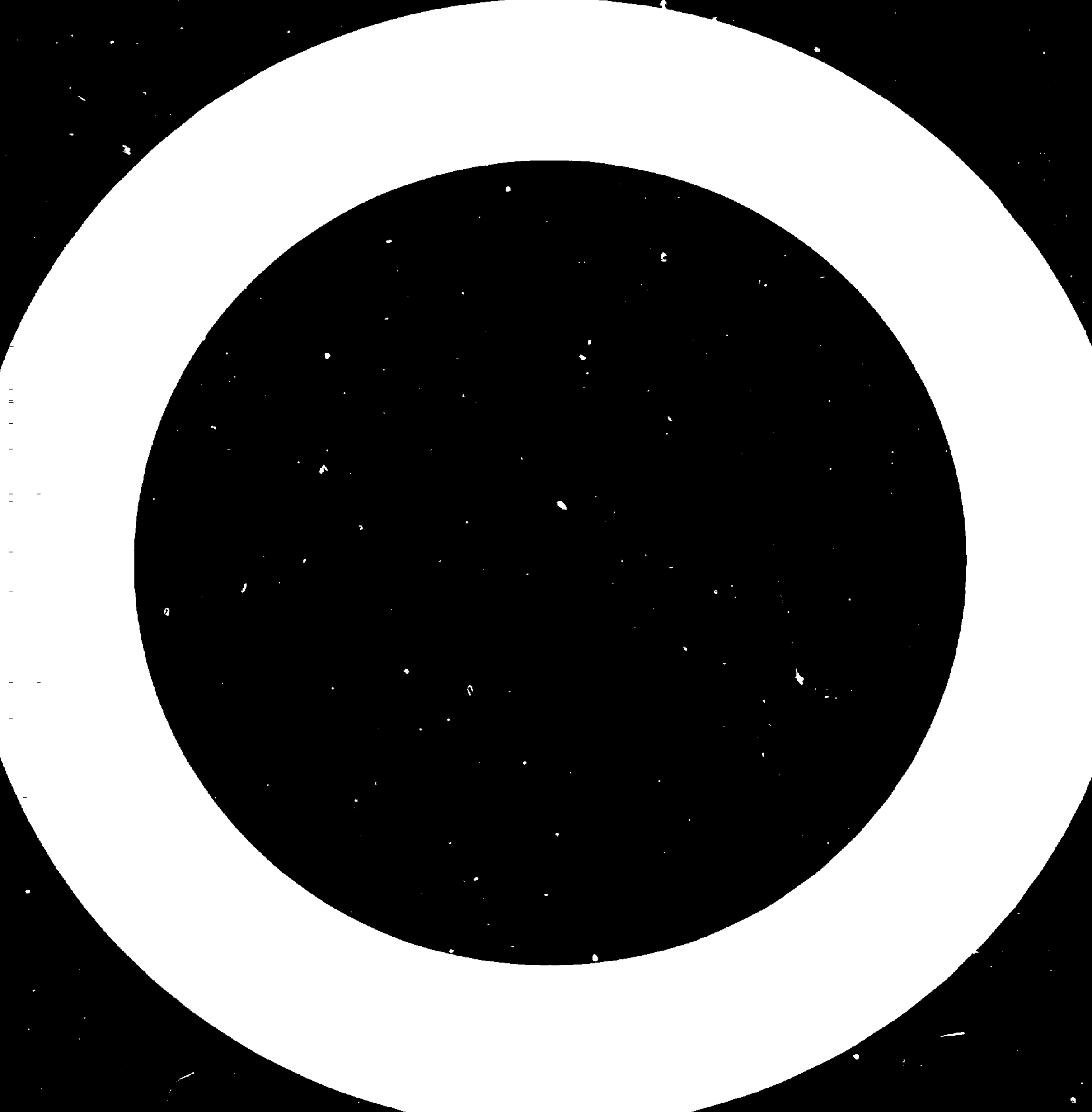
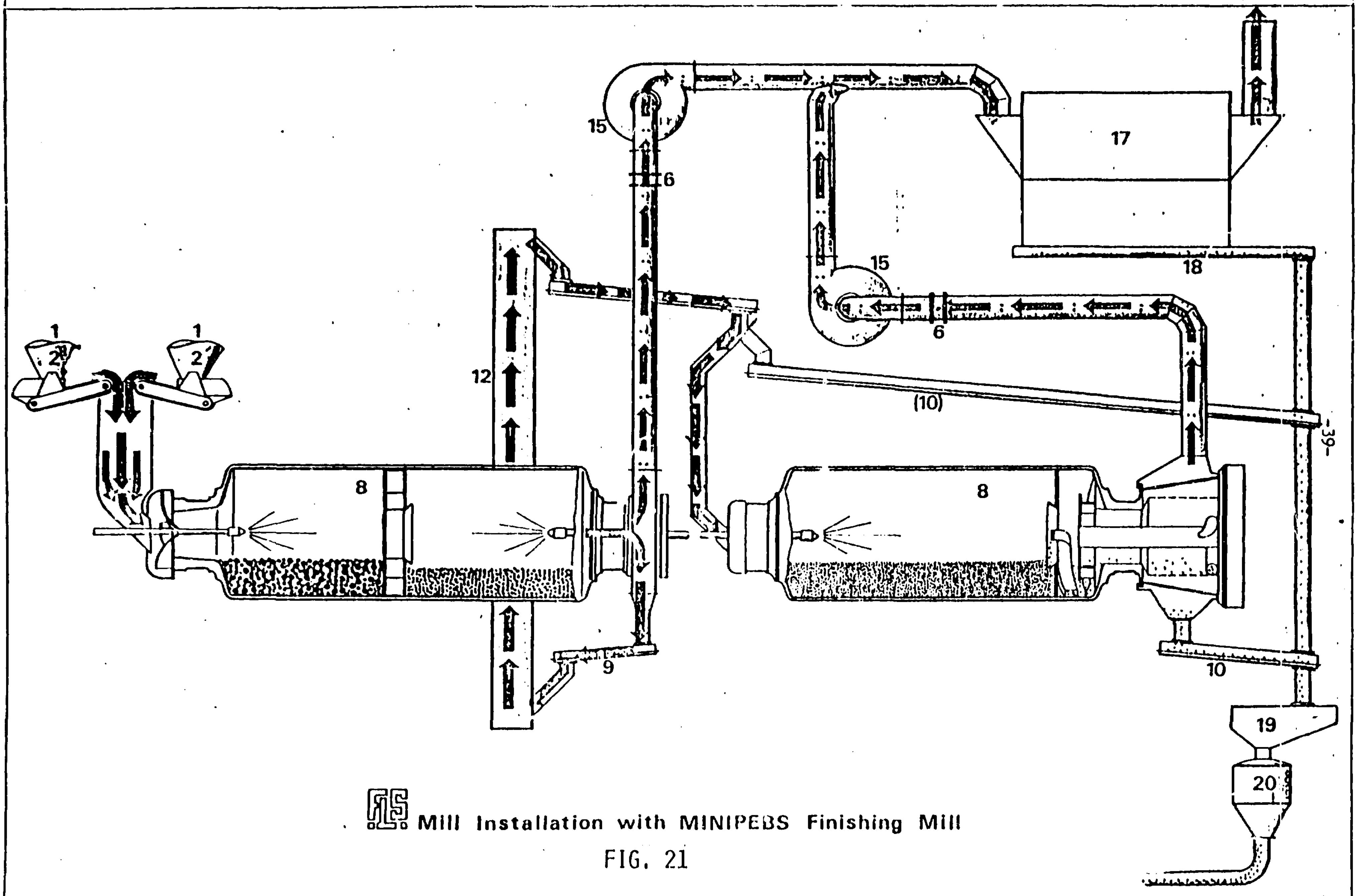


Fig. 20. Specific energy versus specific surface.





Mill Installation with MINIPEBS Finishing Mill

FIG. 21

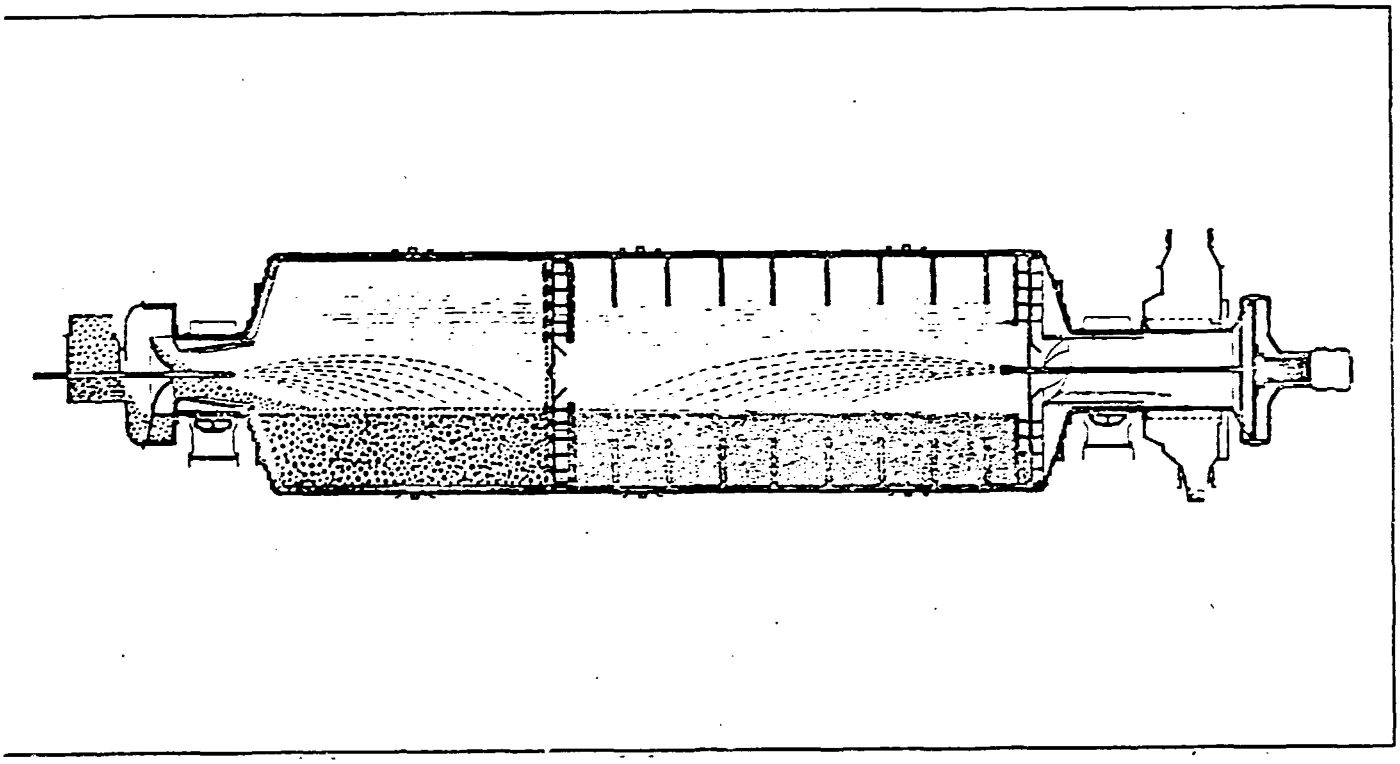


FIG. 22

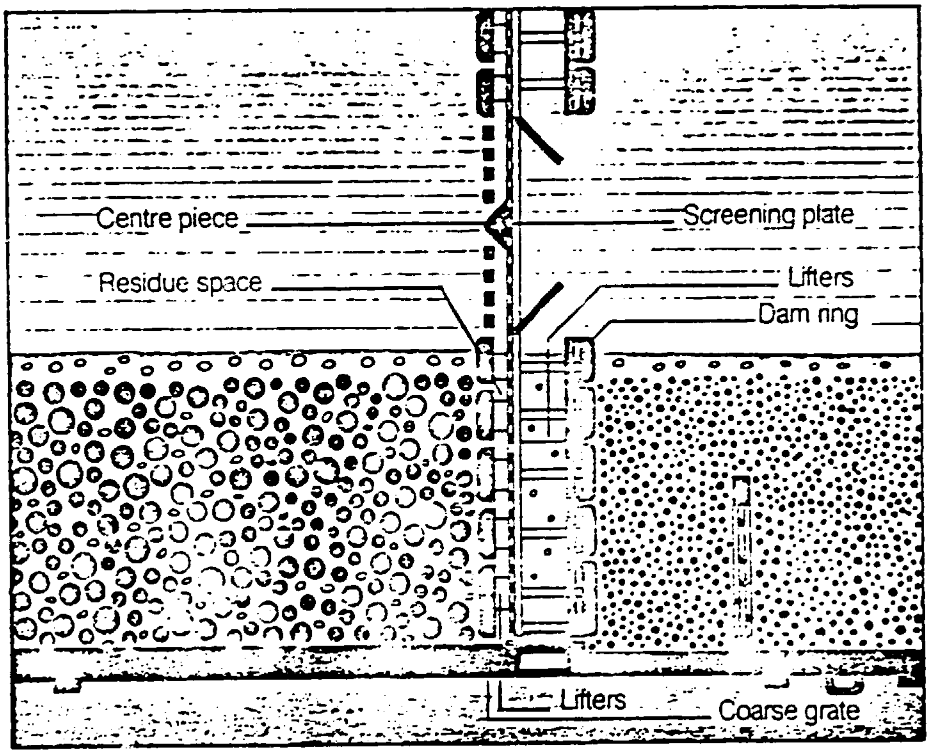

Centre piece
Screening plate
Residue space
Lifters
Dam ring
Lifters
Coarse grate

FIG. 23

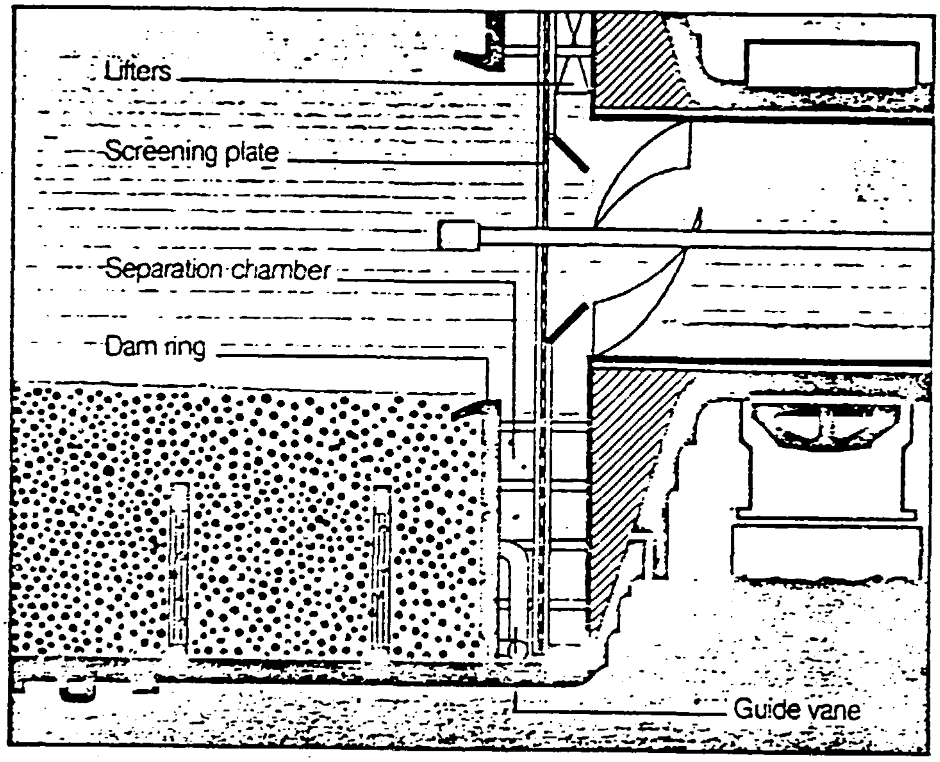

Lifters
Screening plate
Separation chamber
Dam ring
Guide vane

FIG. 24

Circuit	Fineness	Conventional mill kWh/t	COMBIDAN mill kWh/t	Saving	
				kWh/t	%
Open	3000 cm²/g	31.7	28.8	2.9	9
Closed	4000 cm²/g	44.8	39.4	5.4	12
Open	45% res. 25 micron	31.7	26.6	5.1	16
Closed	27% res. 25 micron	44.8	35.4	9.4	21

Fig. 25a. Saving in electric energy by grinding in COMBIDAN mill compared with conventional grinding.

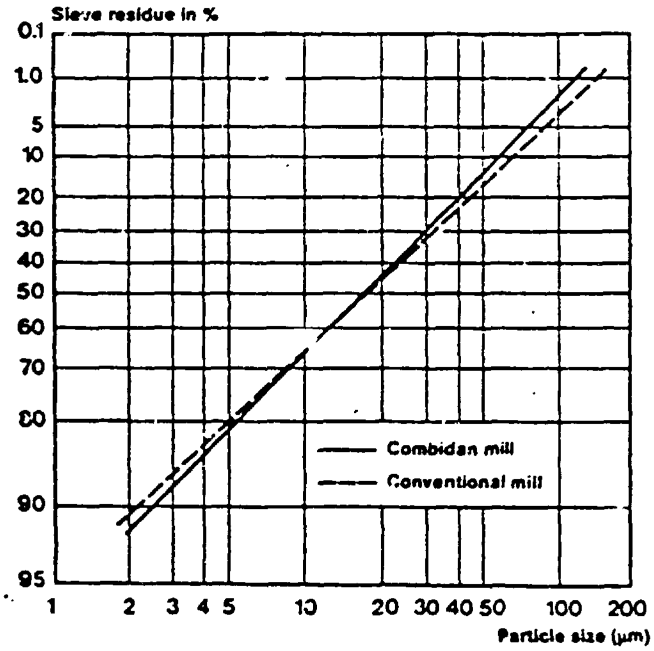


Fig. 25b. Particle size analyses of cement samples.