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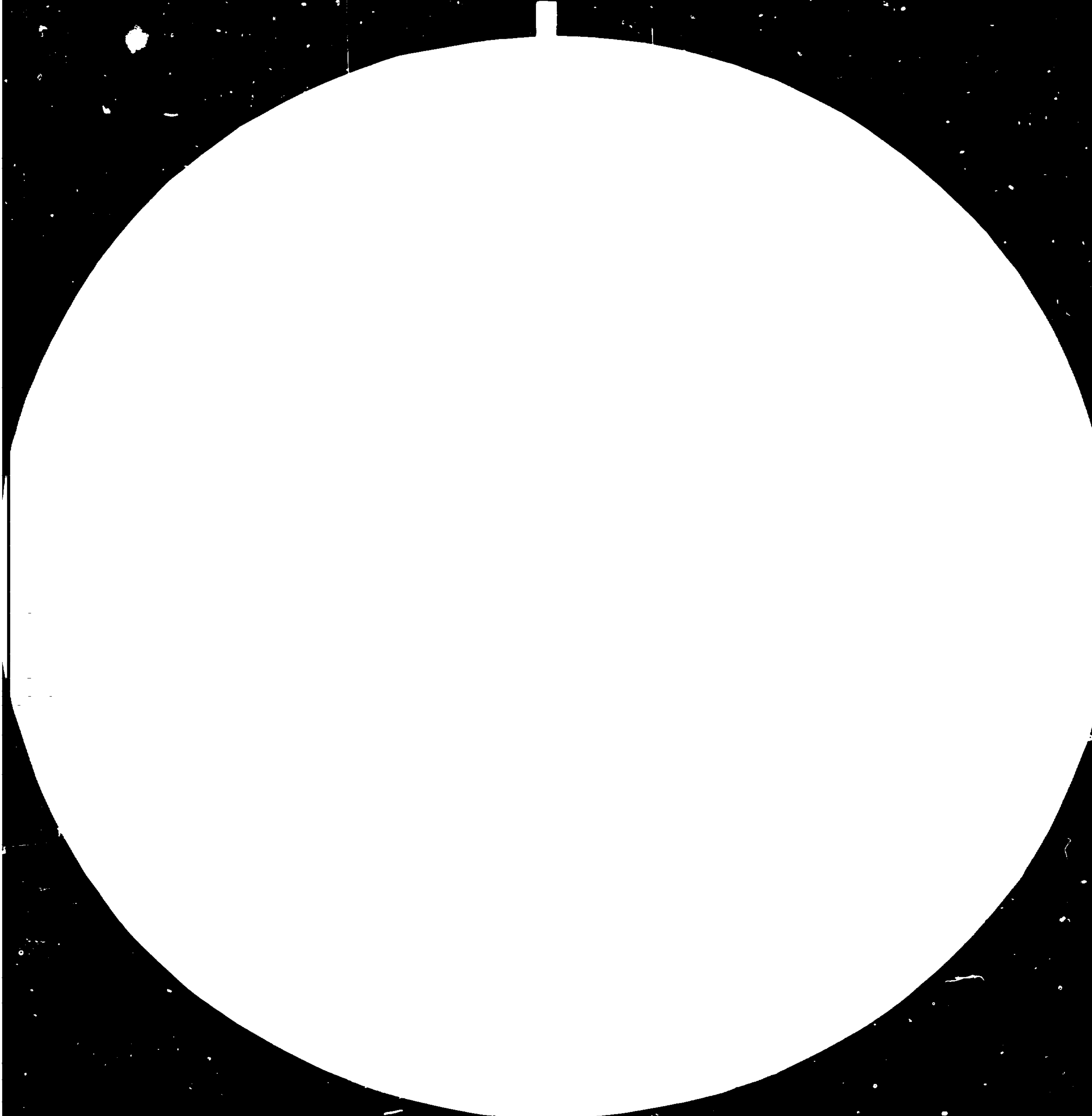

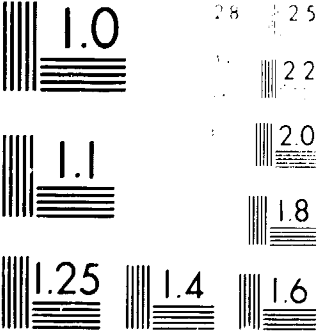
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TRENDS AND DEVELOPMENTS
IN DRY RAW MATERIAL AND CLINKER GRINDING *

by

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I. INTRODUCTION

Together with the increase in the size of cement plants, the size of the raw and finish mills has also increased. The maximum throughput for raw material grinding installations are at the present approximately 400 tons/h, and for clinker grinding installations, at present, approximately 275 tons/h of standard cement.

The main reason for selecting large mill installations is primarily the low investment cost per ton of grinding capacity. In general, no essential savings are made in operating costs, nor has the assumption been proven that large mills have a lower specific power requirement or reduced wear. Further, there has been no change in the quality of the finished product.

II. GRINDING OF DRY RAW MATERIALS

Approximately 20-30 percent of the total electrical power needed for the production of cement is required for grinding the raw material. In the dry process, the material also has to be dried, which requires a further high energy consumption, in this case, thermal energy. Comparison of the required electrical energy for grinding with the thermal energy for drying the raw material shows that the cost for drying is about the same as the cost for grinding. This is considering an average moisture content and average cost for electrical power and fuel. Therefore, it is evidently essential to utilize the available wase heat from the kiln to lower the cost of the drying process.

The use of low-temperature gases in the drying-grinding installations is especially important with mills of large diameter. If we assume a constant length-to-diameter ratio, then the throughput of the mill will increase with the 3.5 power of the diameter. On the other hand, the available area of the mill for the flow of air required for drying increases only with the square of the diameter. As a result, new methods have been found in regard to the drying possibilities in large mills.

In the following I will explain the different drying and grinding systems, especially with regard to the drying possibilities for large mills. When selecting the most appropriate grinding and drying process, many factors besides the moisture of the raw material should be considered. Consideration should be given, for instance, to feed size, grindability, wear properties, etc. All of these influential factors can be different with different raw materials. Therefore, no universally optimum grinding process is available, and the optimum system should be selected for each particular case.

A. Airswept Mill

The use of an airswept ball mill offers one possibility to use large quantities of air for drying. Fig. 1 shows a cross section of such a mill. The first section of the mill has a drying chamber which is used for materials with a high moisture content.
The raw material enters, together with the air, through the trunnion and is predried in the drying chamber which is equipped with lifters which intensively distribute the material over the entire mill cross section. This drying chamber avoids the problems that may be encountered if the moisture content of the material fed into the grinding chamber is so high that a cushioning effect on the grinding media and liner plates results in reduced grinding performance.
The dried material is transported to the grinding chamber through a lifting diaphragm. The lining and the ball charge in the grinding chamber is established to satisfy the requirements for both coarse

and fine grinding. A compromise has to be established between the requirements for coarse, and fine grinding. The feed size to this type of mill should, therefore, not surpass 30 mm, subject to the grindability of the raw material.

Since the complete material transport is pneumatic, large amounts of air are required, which makes the use of large quantities of low- temperature gases possible (such as kiln waste gas and exhaust air from coolers). A specific power requirement of 4-5 kWh/ton of final product is needed for the pneumatic conveying of the ground material. This includes the requirement for handling the waste gas, which is 2-3 kWh/ton, depending on the moisture.

The acceptable feed moisture content is approximately 15 percent. A moisture of approximately 8 percent can be dried with the use of kiln waste gas only. Under this condition, the kiln and mill must be operated together. For moisture contents in excess of 8 percent, supplemental air heating must be supplied.

Fig. 2 shows a possible arrangement of a grinding installation with an airswept ball mill. The material is fed into the mill from the feed bin with proportioning equipment. The dried and ground material is transported by the air stream to the grit separator where it is separated into product and oversized material. The oversized material is directed back to the feed end of the mill and the finished product is conveyed by the air stream to the electrostatic precipitator. At this point, the finished product is separated from the air stream. A portion of the clean air after the mill fan is recirculated back to the mill for transport purposes. The kiln exhaust gases are drawn through the mill. If the raw material has a low moisture content, the kiln exhaust gases are cooled down in the gas conditioning tower to a point which is still sufficient for the drying process. When the mill is not in operation, all of the kiln exhaust gases are conducted directly to the electrostatic precipitator after being conditioned in the gas conditioning tower. In this mode of operation the fan of the mill takes the place of the kiln ID fan.

In certain instances, such as when a bag filter is used instead of an electrostatic precipitator, the use of cylones after the grit separator are required to lower the dust loading of the exhaust gas to the bag filter.

An airswept ball mill in Portugal (Fig. 3) which is 5.8 m diam x 14,75 m long is installed with cylones for precollectors. This installation has a capacity of 320 tons/h. The complete kiln exhaust gas from a kiln with a preheater with a production of 4000 tons/day and an auxiliary air heater is employed to dry a feed material with a 12-percent moisture content. A total of 710.000 m³/h of circulating air is required for drying and conveying. Besides the very good capability for drying, the airswept ball mill grinding installation has the definite advantage of being a very simple arrangement. This, of course, assures a very simple operating method, and the maintenance becomes easy and foolproof. This results in a very high operating time availability.

The control system of this grinding installation is also very easy. The amount of feed material is controlled by means of the differential pressure across the mill. As in all cases, the remote control of the raw material proportioning as well as for the complete mill installation can be accomplished by a computer.

As previously mentioned, special considerations have been made for large mills in order to be able to draw the large volumes of gas through the mill which are required for drying. The first limiting factor in regard to the gas throughput is the size of the trunnion opening. For airswept mills, trunnion bearings of up to 3.4 m diam have been used. The circulating oil system in the bearings is used to withdraw heat from the system. The high-pressure lubrication which served to start-up also is used for contraction of the mill during the cooling down period. The temperature of the bearing bushing is monitored to control the bearing performance. It is necessary to insulate the trunnion against the inlet so that hot gas temperatures of up to 800°C from an air heater can be used.

A new development is the bearing arrangement of the mill on sliding shoes. Fig. 4 shows a cross-section through an air-swept mill which is equipped at one end with a slide-shoe bearing arrangement. The mill is equipped with a riding ring which, depending on the application of the mill, can be screwed in or welded in (Fig. 5). The riding rings are supported on two or three bearing shoes, depending on the size of the mill. The hydrostatically lubricated bearing shoes consist essentially of a bearing pedestal which is connected with the bearing housing, and the upper part of the bearing with oil pockets let into the gliding surcace (Fig. 6). Oil is pumped at high pressure into the oil pockets, which carries the riding ring, e.i. the mill. The upper part is connected with the bearing pedestal by as spherical support, allowing for a tumbling motion, so that an ideal adjustment of the bearing shoe to the riding ring is ensured. The hydrostatic oil pressure is determined by the respective load and is generated by a pump unit. It is situated between 40 and 60 bar. The oil is fed in such a quantity that a lubrication gap depth of 0.15 mm is created which is about 10 times deeper than in the case of a hydrodynamic bearing shoe, which is used for small mills and dryers with low loads. (Fig.7)

The oil supply system is equipped with all necessary monitoring facilities and with a system for power failure.
The bearing housing is completely closed and provided with a sealing against the penetration of dust and the escape of oil
With this bearing conception, the size of the mill inlet cross-section can be determined at will.
It also allows for extremely high bearing loads, and the mill heads are obviated, which in earlier days were occasionally the cause of damage.

The second limiting factor for the gasflow through the mill is the diaphragm between the drying and the grinding chamber. This diaphragm has to nave a large percentage of open area to permit the throughput of large air volumes. The design has to take this into account holding the necessary stability and has also to take into account the requirements for expansion of the walls under thermal stress. To fit these requirements the design is made accordingly (Fig. 8). The unit is constructed in segments, each segment built like a box with an open center to get the necessary stability and on the other hand allow the necessary movement due to the thermal expansion and the deformation of the shell.

B. Single Chamber Mill with Circulation System Incorporating a Bucket Elevator

In order to avoid the high energy consumption for pneumatic vertical conveying in the air swept mill, a grinding system with a circulation method incorporating a bucket elevator is used. Fig. 9 shows a cross section through this mill. Contrary to the airswept mill, the material is discharged mechanically at the end of the grinding chamber. If the application dictates, a two-compartment mill can be used in the same grinding system.

Fig. 10 shows a flow diagram of a grinding plant using an end discharge mill with a circulation system incorporating a bucket elevator. The proportioned raw material is fed to the mill where it is dried and ground and then conveyed to the air separator by means of a bucket elevator. The oversized material is conveyed back to the mill for further grinding. For drying purposes, hot air is drawn through the mill and exhausted via a grit separator and filter. The oversize from the grit separator is fed back to the grinding mill.

The feed rate to the system depends upon the amount of recirculating material. Either the capacity of the bucket elevator or the amount of recirculating load will dictate the feed rate of new material.

The amount of air drawn through the mill is kept low since the material is discharged from the mill by mechanical means. This is advantageous for the grinding proces, which will not be disturbed by the low air velocity, but is disadvantagous for the drying of the raw material. Up to 8 percent moisture can be dried provided high-temperature gases from an air heater are used. If only the exhaust gases from the kiln are used, then the amount of drying is generally limited to a material with a moisture of 4 percent.

Since the ball charge size gradation represents a compromise between fine and coarse grinding, the feed size should not exceed approximately 15 mm, subject to the grindability of the raw material.

The use of an end discharge mill in closed circuit will result, in general, in a reduction of approximately 10 percent in the power demand when compared to an air-swept mill system.

An example of a single-chamber mill with mechanical circulation system is a unit installed in the United States which grinds a medium hard material at a capacity of 290 t/h.

The moisture content of the feed is less than 1 %, while the material is coming from a predrying unit, in this case a drum dryer. The mill diameter is 4.6 m 0 and the length 8.5 m.

It is possible to combine two single-chamber units in a single mill to obtain a high capacity. Each grinding chamber is fed independentl, The ground material exits through separate discharge points in the center and is transported to two separate air separators. In this case we are talking about two totally independent grinding systems, which is two mills in one mill cylinder. A plant in South America with this type mill of 4.4 m diam x 15,9 m long grinds 290 tons/h.

C. Double Rotator

The advantages to the two above-mentioned systems, i.e.,high air throughput for an airswept mill, which al[illegible] drying of a high initial moisture content, and the low spe[illegible] power consumption for the mill with mechanical discharge, hav[illegible] been combined in the development of the Double Rotator. Fig.11 shows a cross section of a Double Rotator. The raw material is fed together with the hot gas through the trunnion into the drying section of the mill.
After the material is dried it is conveyed through the division head into the coarse grinding section of the mill. This section is equipped for coarse grinding with balls up to 100 mm. The high air velocity in this section required by the high volume of air needed for the drying process does not have a negative influence on the coarse grinding. After the material is ground it exits through the periphery of the mill shell. The oversize from the separator is fed back through the other end of the mill into the fine grinding section. This compartment is equipped with 25 to 50 mm balls and a segregating type lining. These, of course, optimize the fine grinding. Only as much air as necessary for the grinding process is drawn through this chamber.

A large amount of air for drying may, therefore, be drawn through this mill by separating the coarse from the fine grinding portion without affecting the grinding process. Consequently, a moisture of approximately 15 percent may be dried in a Double Rotator installation. However, this requires hot gases from an air heater. Feed moistures of up to 7 percent may be dried with the sole utilization of kiln exhaust gases.

A further advantage of the separation between coarse and fine grinding sections is the optimum sizing of the ball charge. This results in optimum efficiency and, therefore, a low specific power requirement. The utilization of large grinding medium in the coarse grinding chamber permits the feed of material up to 50 mm.

Fig. 12 shows a possible flow diagram of a Double Rotator installation. The proportioned feed is fed into the drying chamber. After the material is dried and coarse grinding has been completed, the material is discharged through the periphery of the shell and conveyed to the air separator. The oversize is fed to the fine grinding chamber. A small portion of the oversize is also directed to the coarse grinding chamber in order to increase the flow-ability of the material to be ground. The material which exits from the fine grinding chamber is also fed to the air separator. The hot gases needed for drying are withdrawn from the central discharge. The coarse particles in the air stream are separated with a grit separator, with the final product being collected in a dust collector installation.

Fig. 13 and 14 show a Double Rotator installation.

The largest Double Rotator today is under erection now in Hongkong. The diameter of the mill is 5.2 m Ø, the length 18 m, with drying chamber 5.0 m length and grinding chamber 6.0 plus 5.5 m length. The ball load is 295 t and the power required at the mill shaft is 4.800 kW. The mill is driven by a double pinion drive, two times 2.500 kW motor. The output of the mill is 310 t/h. The feed moisture is up to 10 %.

This driving power is almost the limit for the double-pinion drive. For larger driving powers, other drives must be chosen. An alternative solution is the ring motor which is also used for Double Rotators. The ring motor is a synchronous motor which draws its power from a frequency converter with a three-phase current of approximately 5 Hz. In order to obtain the slow speed required by the mill, a large number of poles are required, which calls for motors of large diameters.
The ring type construction around the shell of the mill makes for a good solution. If there is a possibility of making the motor rotor smaller in diameter, it can be attached to the outside of the mill head.

This offers the advantage that the motor is placed as close as possible to the mill bearing for support purposes, as well as to provide free access to the mill. The speed of the mill can be regulated in certain limits, so that the mill can operate with the speed, which gives the best grinding efficiency. Up to now 25 ring motors are installed in total, 11 are Polysius mills.

It is also possible to use central drives, also for Double Rotators. This involves the problem that the coarse material and the aeration air must be introduced through the drive end trunnion into the grinding compartment 2. A special feeding device has been developed for this purpose. Fig. 15 shows a Double Rotator with central drive. In the background of Fig. 16 the coarse material and air supply system is shown, and Fig. 17 shows a central drive that was developed by Polysius together with Flender. This design is based on decades of experience in the field of drive engineering for mills. It is a spur gear unit with triple power branching. All pinions are case-hardened and ground. The result is a high efficiency, absolute reliability in operation, and little maintenance requirement.

The gear unit builds small, which is very handy for transport and erection.

D. Possibilities of Using Separate Dryers and Crushers

If one of the aforementioned mill installations is suitable for the grinding process, but the moisture content is too high or the feed size is too large, a separate unit is required before the mill which would allow predrying and precrushing the material. A very simple arrangement is the use of a shaft dryer before the unit. Fig. 19 shows a flow diagram of a shaft dryer in combination with a Double Rotator. The proportioned raw material is fed into the shaft dryer. The material is intensively dried during its fall through the countercurrent hot gas. The dried material exits the bottom of the dryer and goes directly into the mill inlet. The material which has been carried out of the dryer by the air stream is separated in cyclones. In Spain a Double Rotator 4.6 m diam x 15.25 m long with a capacity of 240 t/h is equipped with a shaft dryer. This dryer dries the feed in the rainy season from 9 % to the normal moisture of 4 %, which is handled by the Double Rotator, designed for low air quantities, i.e. the kWh/t for the handling of the drying gas is at a very low point over the most time of the year. If required, a crusher can be installed between the dryer and the mill. Depending on the material, moistures up to 22 percent can be dried in this system.

If a material has to be predried and is very difficult to dry, then a rotary dryer can be used. This type of unit can handle moistures of mor than 25 percent. There are fundamentally two types of rotary dryers. One is the rotary dryer with a large length-to-diameter ratio and a low speed; and the second is the dispersion-type dryer which has a short length and a high speed. The rotary dryer can be used for very high evaporation capacities and for very difficult materials. For instance, a rotary dryer of 5.9 m diam x 45 m long is installed in a cement plant in Belgium. This unit handles 290 tons/h of chalk and dries form a 16-percent moisture content to less than 1 percent. This corresponds to an evaporation capacity of 40.000 kg/h. The chalk desintegrates during the drying process and therefore can be fed directly into the mill without any further crushing.

The dispersion-type dryer is especially appropriate for materials with a high surface moisture, since the material is repeatedly lifted and fed into the hot gas stream. Fig. 20 shows a cross section through a dispersion type dryer. The drying chamber is equipped with lifters which disperse the material into the hot gas stream. The material is discharged through the periphery of the mill. We are dealing here with a drying chamber of a mill which has become independent. The speed of the dryer corresponds to the speed of a ball mill. The specific evaporation capacity of the dispersion-type dryer in relation to the volume of the dryer is about twice as high as the evaporation capacity of a slow-speed rotary dryer.

A dispersion-type dryer in a French cement plant of 4.6 m diam x 9.0 m long evaporates a water volume of 20.000 kg/h. It dries 150 t/h of raw material from 18 percent down to 8 percent. The typ of dryer is also used to dry filter-cake to raw meal, when the raw material preparation is wet, but the kiln system shall be a preheater/precalciner typ.

In the event the raw material requires precrushing in addition to predrying, the impact crusher-dryer can be used. With this type of crusher a material with a moisture of about 25 percent and a feed size of up to 150 mm can be predried and precrushed to an extent making it suitable for further processing in the ball mill. A plant in Yugoslavia (Fig. 21) handles these conditions. The material is crushed to 30 mm and predried to 7-percent moisture. It is then fed into an airswept ball mill where the grinding and drying of the residual moisture takes place. This puts to the best advantage all of the exhaust gases from the kiln installation. The capacity is 240 t/h.

If the crushed material exhibits a sufficiently high amount of finished material, it may be fed directly to the separator in the mill circuit. If the crushed material still possesses a residual moisture, then additional drying has to take place in the separator. However, since the volume of hot gas which can be used in the separator is limited, and the inlet temperature of the hot gas in the separator must be low due to the type of unit, the evaporation capacity of the separator will be low. In addition, since the mill has to be scavenged with air, in this case the total air volume for the dust collection becomes larger than for drying only in the mill. Due to the higher waste gas volume and to the more intricate system in general, such a solution should only be chosen in a few exceptional cases. The separator must be fed with a chute due to the coarse feed size, and this will increase the total construction height of the mill building. In addition, the coarse feed material increases the wear in the separator. Fluctuating feed moistures may have a negative influence on the separator. In addition, another disadvantage is that the moisture in the material may form buildup in the separating chamber. A basic disadvantage of installing a crusher prior to the mill is that the crusher product becomes coarser due to the wear on both the hammers and screen bars. Consequently, the throughput of the mill is reduced accordingly. This requires the grinding job to become greater; however, conversely, the ball charge is no longer optimized because of the coarser feed size. For this reason such a system is not suitable for raw materials which cause high wear in high-speed crusher systems.

Autogenous mills are also suitable for the drying and crushing-grinding of raw material. For some materials, semiautogenous grinding is required. In all cases a secondary ball mill must also be installed which increases the capital investment. The autogenous mill system should only be considered in a few exceptional cases, for instance, with material which is hard, moist and coarse. The use of autogenous mills in the cement industry is very infrequent.

E. Roller Mill

The roller mill is another alternative in raw grinding and offers the ability to accept large volumes of air. Fig. 22 shows the cross section of the roller mill.
The raw material is fed to the roller mill through an airlock-valve. The material then drops into the center of the grinding table and is fed to the rollers by the rotation of this table. Once the material has passed underneath the rollers and has been pulverized, it is thrown over the rim of the table into an air stream. The material is conveyed by air to the grit separator located directly above the grinding area. The oversize material drops back directly into the middle of the grinding table, and the fines are carried by the air stream to the dust collecting equipment.

In the Polysius roller mill, two pairs of rollers with two rolls to each pair bear on the grinding tabel which is driven through a specially designed bevelded gear unit. Instead of one wide roller, two narrow rolls are used in each pair, each roll adapting, independently of the other, to the speed of the grinding table. This reduces the slippage between the rollers and table which reduces the wear-rate accordingly.

The support of the roller pairs within the housing allows the rollers to adjust to variations in the material bed. This way the total width of the rollers is constantly in contact with the material bed, which enables the most effective use of the grinding surface. This adaptability to the material bed results in very quiet operation.

The roller pairs are pressed down onto the material bed hydraulically by means of tension rods. The hydraulic pressure can be adjusted to suit the operating conditions in each individual case. Thus the grinding becomes economical over a large range of throughput.

In comparison to roller mills of different construction, the Poylsius roller mill can be operated with low velocities at the nozzle ring. A bucket elevator is used for a portion of the oversize circulation. This closed circuit bucket elevator has the additional advantage that it may be used to empty the mill in case of an overload which, for instance, could result after a power failure The control of the grinding system is based on the pressure drop across the mill which is similar to the controls for the airswept ball mill.

The power consumption for grinding alone is relatively low, but the power consumption for pneumatic conveying is high. This results in a total power requirement 10-20 percent lower than a ball mill, depending upon the grindability and moisture content of the raw material.

The roller mill is generally used as a combined grinding and drying mill. An effective drying action takes place during the grinding and pneumatic conveying. A relatively high volume of air is required to convey the circulating material and to discharge the finished product. This lends itself to the use of low temperature exhaust gases. A raw material moisture of up to 8 percent can be dried using the kiln exhaust gases only. If hot air from an air heater is also supplied then feed material moistures up to 20 percent can be handled. Large feed sizes up to 100 mm are allowed.
Fig. 23 shows one possible roller mill system arrangement. The proportioned raw material is fed into the mill. The finished product is carried out with the exhaust air and separated in the dust collecting equipment. The bucket elevator is shown for use in handling a portion of the circulating material. In certain instances, i.e. in particular where a bag filter is used, a cyclone can be installed between the mill and the dust collecting equipment.

Fig. 24 shows a roller mill installation in Switzerland with a capaciity of 245 t/h. Mill and mill-fan have a drive of 1250 kW each. So the overall specific power consumption for the complete mill system comes to 12,5 kWh/t. The grindability of the raw material is on the lower site, the feed size is up to 80 mm and the feed moisture up to 5,5 %. Fig. 25 shows a view into the roller mill with its two pairs of rollers, the grit outlet of the separator and a part of the special device for the dismounting of the roller pairs, which can be taken out of the housing via the large access doors, i.e. for the replacement of the wear parts.
The largest Poylsius roller mill, now in operation in Sweden, serving a precalciner kiln with a capacity of 5.000 t/d, has an output of 400 t/h with a specific power consumption of 12,5 kWh/t. Silica sand is fed to the mill preground in a wet ball mill to a high finess. Due to the very short retention time of a few minutes in the roller mill, course silica isn't ground and enriches in the courser part of the raw meal and this may lead to a worse burnability of the raw meal.

The roller mill is particularly suitable where soft or medium hard materials with large feed size and high moisture content have to be ground, utilizing low temperature gases. They are not suitable for abrasive materials, i.e. silica rich materials, which cause high wear on the rolelrs and grinding table. This, of course, in high maintenance costs and increased downtime of the plant and perhaps in a bad burnability, if the silica component is not ground fine enough.

III. CLINKER GRINDING

The present day preference in cement mills is for greater unit capacities. This is especially true when expanding an already existing plant which has sufficient flexibility for grinding a variety of different types cement in different cement mills.

This allows the large units to grind one type of cement in mass production. But the trend to large cmeent mills is also true when only one cement mill is available which must grind all types of cement. This makes it especially important that the mill can be adjusted to make different types of cement, that the quality of the cement always satisfies the requirements, and that the grinding system has a high availability.
Fig. 26 shows the schematic of a cement grinding installation operating in the close circuit, which is easily to set to different cement qualities. The proportioned clinker and gypsum are fed to the mill where it is ground and removed from the mill mechanically. The material is conveyed to the separator through the use of air slides and bucket elevator. The separator classifies the material into finished product and oversize. The oversize is weighed and returned to the mill. The amount of recirculating material controls the feed rate so that the mill always has a consistent total feed rate.

Air is drawn through the mill to assist the flow of material and to carry away the heat generated during the grinding process. This air is exhausted to dust collection equipment. A mechanical separator can be installed in the exhaust gas duct to separate the coarse material from the air stream so that the material which is collected in the dust collector can be added to the finished product.

The fineness of the finished material, and therefore the quality of the cement, can be modified easily by controlling the separator installed in the circuit. In addition, the separator produces a finished product fineness which is as consistent as possible. It is also possible, within certain limits, to vary the particle size which is responsible for the strength between 2 and 30 μ, while also preventing oversize material. Small variations may occur in the proportion of the grinding balls in comparison to the ideal load, and this is compensated for by the separator. This means the total grinding installation will operate with a reasonable specific power requirement.

The air separator as used in many cement plants is shown in Fig. 27. To date, units up to 8,5 m diam are in operation. The separator operates as follows.

The fan creates a circulating air stream while the distribution disk spreads the incoming feed material into the separating chamber where it is speared into fine and coarse material under the influence of centrifugal force.
The coarse material falls directly into the coarse collection tunnel and is carried away. The fine material is conveyed by the circulating air stream, flows through the countervanes and is separated in the outer chamber by the cyclone effect and is carried away in the outer cone. The clean circulating air stream passes through the lower guide vanes and reenters the inner chamber.

The feeding of the material to the separator is done preferably by means of air slides, since this allows for a very uniform distribution of the material into the separation chamber. This is very important in order to obtain an optimized separation.

The fineness of the finished product can be modified by the position and the number of countervanes. With separators which have a double drive, as is customary for cement mill systems, the fineness can be modified during operation by changing the speed of the distribution plate. There are separators in operation with 8,5 m diam for high quality cement with 4.000 cm^2/g acc. to Blaine and a capacity of 125 t/h, acc. to 160 t/h normal portland cement. The fineness can be modified from 2600 to approximately 6000 Blaine. The following are a few special points concerning the Polysius Turbo-Separator.

1) A two-point suspension for the rotating parts results in quiet operation and easy erection.
2) The fan and the separating plate as well as the countervane system are operated with a special drive.
3) The distribution of the material to be separated by means of a bell-shaped distribution plate results in an optimized distribution of the material in the separating chamber, and this results in a very high classification efficiency and in a high load capacity.

4) The housing is of segmental construction which results in simple erection.
5) The wearing parts are easy to replaced, which simplifies maintenance.

An alternative solution is the closed-circuit cyclone air separator (Fig. 28). The separating chamber proper is similar to that of the turbo separator described before, the most remarkable difference being that the separating air stream is generated by an outside fan of its own. The fines are carried along in the air current out of the separator and precipitated in high-efficiency cyclones. Unlike the turbo-separator, this precipitation is almost perfect and no fines are returned into the separating process. Excellent particle-size distribution of the cement with respectively high strengths are thereby achieved. Since the separating air is easily variable using a whirl regulator, the separator has a good flexibility, related to the finished product quality handled. Fig. 29 shows a cyclone air separator during workshop assembly. The first separators of this design are now in operation with outputs up to 125 tph normal cement.

The separator has a separating chamber diameter of 5.2 m and 6 cylones.

Let me say a few words about a separator which is at present in the stage of development with Polysius, the channel-wheel separator. Fig. 30 shows a cross-section of it.

The separating air passes into the separator casing coming from the fan. For separation, the air flows through the channel-wheel from outside to inside and leaves it in an axial direction, passing into the air box. The product to be separated is fed from abvoe through a centric pipe into the middle of the channel-wheel. The separating air drags the fines along which are then precipitated in cyclones. The coarse material falls out in the separator casing and is discharged.

The actual separating procedure is explained if one takes a look at the schematic diagram of the channel-wheel and product flow in Fig.31.

The feed material flows from the top through a centric pipe into the middle of the channel-wheel. With the aid of a distributor the material is distributed over the individual channels and leaves these again over the throw-off edge. An air opening has been arranged on the circumference of the wheel behind every product channel, through which the air flows radially into the wheel. Separation is then effected inside the chamber before the air openings. The air flowing radially into the opening bends the flight paths of the product particles being sucked in the process. The flight curves of the coarser particles are bent to a less considerable extent. Theyleave the separating zone in the direction of the casing wall.

Fig. 32 shows such a separator in a cement grinding system for an output of 30 tph. It has been on trial at this plant for over a year with good success.

The most essential advantage of this separator is its high precision of separation, along with its compact construction.

The cement mill itself is in all cases a two-compartment unit. The coarse grinding takes place in the first chamber. The ball size in the first chamber varies from 50 to 100 mm, top size. The length of the first compartment is determined by the feed material and the required fineness.

The ground material is conveyed through the division head into the fine grinding chamber. If necessary, the flow through the diaphragm can be regulated by changing the position of the lifters. This allows to set the material filling in the first compartment to the optimum. The fine compartment is equipped with a classifying lining, and the diameter of the balls are generally 50 to 20 mm, top size. The finished material is discharged through the discharge diaphragm.

The length-to-diameter ratio remains approximately constant for various mill diameters. The speed of the mill is generally between 72 and 76 percent of critical. The ball charge level lies between 29 and 35 percent. In this range the mill operates with the best efficiency and the wear of the lining and balls is lowest. If the length of the grinding chambers, the ball size, the type of shell lining, the circulation system, and the air separator are balanced to an optimum point, the operation of large mills has not shown any difference when compared to smaller mills in regards to quality of the product. Obviously, mills must be compared under similar conditions, for instance, similar length-to-diameter ratios, same clinker, etc.

Since most of the energy input is transferred into heat, and in most of the cases hot clinker is fed, large amounts of heat must be removed from the mill. If the heat removal is not sufficient, the product will become too hot, which may affect the quality of the cement and under certain circumstances the grinding efficiency due to agglomeration and coating effects in the mill. A certain amount of heat is carried away by radiation of the total installation. In smaller mills the remaining heat is generally removed by the air stream which is drawn through the mill. In the case of large mills, the volume of air cannot be increased in proportion to the output, since as mentioned before, the cross section does not increase in relation to the output. In addition, the radiation surfaces increase less than the output.
Therefore, other ways have to be found to dispose of the heat. Depending upon the temperature of the clinker feed, water can be sprayed into both the first and second compartments. The water can be sprayed either with the air flow or against the air flow. The amount of water is determined and distributed in such a way as to not modify the gypsum, which would cause a negative influence on the quality of the cement. The amount of water to be sprayed into the mill should be held as low as possible. If necessary, the heat can be carried away at another point in the grining system. The separator is suitable for such a purpose.

1. Separator equipped for air cooling

Fig. 33 shows a turbo separator equipped for cooling the cement by the admission of cold fresh air. The cooling air is drawn in above the separator fan and mingles with the stream of separating air in which the fines (finished product) are carried along from the separating chamber. These fine particles are intensively cooled in the air stream. Below the guide vanes through which the separating air stream re-enters the separating chamber the cooling air is extracted from the separator.

This air flow pattern ensures that the efficiency of the separator is not impaired, since the air flow in the separating chamber itself is unaffected.

The cooling air extracted from the separator carries along a certain amount of finished product with it, which has to be precipitated in a separate filter. Only mechanical filters are used for the purpose. Electrostatic precipitation is impracticable because the air to be dedusted is dry and cannot be suitably conditioned.

Economic reasons, i.e., the capital cost of the filter operating with the separator, will impose limits on the quantity of cooling air that can thus be utilized. Conceivably the cooling air could alternatively be used in a closed circuit comprising an air cooler. The air flow pattern has the result, that mainly the finished product is cooled, as the cooling air is introduced into the fines precipitation chamber. Of course, the coarse particles are also cooled, since the temperature level within the separator as a whole is lowered by the mixing of the cooling air with the separating air.

The results achieved with one installation will be reported here. The plant in question grinds standard cement at a rate of 130 t/hour. The mill is a two-compartment mill of 4.4 m diameter and a drive of 3.500 kW. Air at a rate of 80.000 m³/hour can be passed through it for heat removal. If necessary, water can be injected into both grinding compartments from the intermediate diaphragm.

The two turbo separators each have a diameter of 6.0 m. The results obtained with a cooling air flow rate of 67.500 m³/hour and indicated in Fig. 34. In this case the finished product temperature was lowered by 24°C and that of the coarse particles by 19°C. The throughput at the time was 110 t/hour, with a product fineness of 3.100 cm²/g (Blaine). The quantity of finished product collected in the mill filter was 20 t/hour. The overall temperature of the product of the grinding plant was 93°C. The specific power consumption for extracting the cooling air was calculated as 0.5 kWh per tonne of cement

Cooling the cement with air in the separator is often an interesting possibility and indeed may in certain cases - where a suitable supply of water is not available - be the only way to cool the cement. The only drawback is that a separate dust collecting system has to be installed. In the production of standard cement a lowering of the cement temperature by 25°C can be attained by means of air cooling in the separator. Also the Cyclone Type Separator can be equipped with air cooling.

2. Separator equipped for water cooling

Indirect cooling of the cement is effected in this system. As illustrated in Fig. 35, the outer wall of the separator casing is cooled by water flowing through water jackets fitted to the externally accessible surfaces of the separator. The cooling water, guided by baffles, is passed through these jackets and intensively cools the outer face of the casing, along the inner face of which the fines (finished product) flow in thin layers, so that very good heat exchange between the fine particles and the wall of the separator is achieved.

In principle only the finished product is cooled. The coarse particles undergo merely a slight lowering of temperature, since the cold outer wall also cools the separating air stream. Depending on how much heat has to be removed, only the tapered part of the casing (the hopper bottom) is cooled or, in addition, cooling is applied also to the cylindrical upper part of the casing.

The water used for cooling the cement in the separator may be fresh from the water supply system or it may be recirculated through a water cooler.
It is important that the casing of the separator should be well protected from wear at the water jackets, so as to rule out any risk of water getting into the separator. Thick wear-resistant plate can be used in these parts, or the casing can be provided with a wear lining, provided that it does not impair heat transfer.

The results obtained with a grinding plant in which the separator casing has cooling water jackets in its cylindrical as well as its conically tapered part will be presented. The plant, is designed to grind 155 t of cement per hour to a fineness of 2.700 cm²/g (Blaine). The mill is a two-compartment mill of 4.4 m diameter, driven by two 2.200 kW motors. Air at a rate of 80.000 m³/hour can be passed through it to remove heat. In view of cement quality considerations, no arrangements for water injection are provided. In order nevertheless to ensure adequate heat removal from the grinding system, a tailings cooler has been installed, in which the coarse particles returned to the mill are so cooled that the permissible temperature level in the mill is not exceeded.

For cooling the cement the two 6 m diameter air separators are equipped with a water cooling system. A total of 136 m² of cooling surface area is available on the cylindrical and tapered parts and is subdivided into segments. The water, which is circulated in a closed circuit, is supplied separately to each cooling segment and flows out under atmospherie pressure.

The results obtained with this plant are indicated in Fig. 36. The throughput was 157 tonnes of standard cement per hour, ground to a fineness of 2.700 cm²/g (Blaine). The quantity collected in the mill filter was 24 t/hour. The mill was swept with air at a rate of 66.000 m³/hour. The exhaust air had a temperature of 102°C. At the time of the test the clinker temperature was 140°C. The temperature of the finished product was lowered by 28°C, whereas the tailings were cooled by 5°C. They were fed to a separate tailings cooler in which their temperature was brought down to 54°C.

Heat at a rate of 0.9 million kcal/hour is removed with the cooling water, which is utilized almost entirely for cooling the cement.

Cement cooling in the air separator with water-cooled casing is very effective. It can moreover be accomplished very simply and can in appropriate instances be applied to existing installations by changing parts of the separator casing. A drawback is the relatively high water consumption if the cooling water is not recirculated; this solution of course involves extra expenditure on the recooler.

In a plant grinding standard cement it is, with water cooling of the air separator casing, possible to cool the cement by 40°C.

Water cooling is only possible with Turbo-separators, while Cyclone type separators have a too low surface area and are normally wear protected, which lowers the heat transfer considerably.

If there is no need, to cool the grits to keep the temperature level in the mill low, but to have a cold cement, there is the possibility to install a cement cooler behind the mill circuit, which is shown in Fig. 37. The first one, developed by Poylsius, is under erection in the United States, to cool 90 t/h cement from 95°C to 65°C.

The product to be cooled is fed into the lower part of the vessel, passes onto the rotating distributing plate of the rotor, and is distributed due to the centrifugal force in a thin layer on the inside cylinder wall. The screw flights transport the material upwards on the bin wall while it is continuously piled afresh, and it is then discharged at the upper edge of the vessel. During transport the material is intensively cooled on the wall of the vessel which is nozzled with water from outside. Distribution of the cooling water is by an annular gap in the upper water box. In the lower basin the warm water is collected. The cooling water can be circulated in an open or closed circuit with recooling.

The largest cement mill, build by Polysius in Belgium, operating in the close circuit, produces up to 275 t/h ordinary portland cement. The mill is 5.2 m in diameter and 16.4 m in length and is driven by a 6.350 kW ring motor.

An interesting design shows a cement mill in Mexico (Fig. 38). This mill, 4.4 m dia by 15.25 m length with a capacity of 115 t/h with 3.200 cm^2/g acc. to Blaine, is mounted in two slide shoe bearings. The two slide rings are welded to the ends of the mill cylinder and have a diameter of 4.56 m. Each ring is supported by three slide shoes 500 by 640 mm.
The mill is driven by a Polysius central drive (Fig. 39) of 4.500 kW. The system is equipped with a Polysius cyclon typ separator 5.2 m dia.

However, if a grinding plant is required to produce only ordinary portland cement in only one grade, the compound mill is often the appropriate choice of grinding plant, as it involves less capital expenditure and is of very simple construction.
In the compound mill - or open circuit mill - the clinker is ground, with added gypsum, in a single pass to give the finish product of the desired fineness. There is no circulating material.

The above-mentioned condition - manufacture of just one type of cement - was fulfilled in the case of a cement works in Switzerland, where it was decided to install a compound mill for the grinding of ordinary (normal-hardening) cement at a rate of 150 t/hour.

The result of this installation shall be given hereafter as an example for a compound mill system.

A longitudinal section through the mill is shown in Fig. 40. It is a two-compartment mill, 4.8 m in diameter and 16.25 m long. The first grinding compartment has a length of 4.75 m and is fitted with lifter plates. Its nominal grinding media charge consists of 103 t of balls ranging from 60 to 90 mm diameter. Having passed through the first compartment, the material is transferred through the intermediate diphragm - provided with lifter scoops and 5 mm wide slots - into the second grinding compartment. The latter is

10.75 m in length and is equipped with classifying liner plates. It has a grinding media charge consisting of 234 t of balls and Cylpebs, comprising about 35 % balls of 30 to 50 mm and 65 % Cylpebs of 12 to 19 mm size. To increase the retention time of the clinker in the first part of the second compartment, two dam rings are provided. The ground product is discharged from the mill through the end diaphragm with lifter scoops and 7 mm slots.

The mill is mounted in two trunnion bearings, 2.6 m in diameter and 1.3 m wide, and is driven by a three-phase synchronous ring motor. The motor can develop 5.500 kW at its maximum speed of 15.3 r.p.m., which corresponds to 77.5 % of the critical speed of the mill. At its rated speed of 14.5 r.p.m. (73.5 % of critical) the motor can develop 5.300 kW.

To remove heat from the interior and to assist the flow of material, the mill can be swept with air at a rate of 87.000 m^3/hour. Water is injected into the mill for additional heat dissipation and for conditioning the exhaust air for dedusting in the electrostatic precipitator. The water injection system can supply water at a rate of 3.400 litres/hour to the first compartment and of 3.400 litres/hour to the second compartment. The overall water injection rate therefore corresponds to 4.5 % of the throughput of the mill. To prevent the water droplets in the second compartment from being carried along with the air flows as soon as they emerge from the nozzle and giving rise to caking of cement on the end discharge diaphragm, the water jet is surrounded by an annular protective stream of air blown in along with it. This air also prevents deposits forming on the nozzle itself when the water supply is turned off and some leakage water continues to drip from the nozzle.

The following values were measured: For a feed rate of 150 t/hour the cement had an average fineness of 3.250 cm^2/g (Blaine). The residue retained on the 0.032 mm standard sieve was 30 %. Over an 8-hour period, with sampling at hourly intervals, the fineness was found to vary within approximately ± 100 cm^2/g. These variations are attributable to varying grindability of the clinker feed to the mill.

Further investigations showed that in some other periods the variations in product fineness were less.

The feed rate to the mill is kept constant. An electric ear monitors the loading of the first chamber and reduces the feed when this chamber becomes too full.

The specific power consumption measured at the meter of the mill drive motor was 34.0 kWh/t. In the Zeisel test a value of 34.5 kWh/t was determined for the clinker (bulk density 1.33/dm³, lime standard according to Kühl 97.1, silica modulus 2.63).

The exhaust air rate during the test was 73.000 m³/hour at 95°C, while water was injected at a rate of 2.600 litres/hour. For a clinker temperature of 70°C a cement temperature of 106°C was obtained. Fig. 41 indicates the heat balance of the plant for these conditions. The dew-point of the exhaust air was 40°C.

The heat intake items are: drive power, material heat, air supplied. The expenditure items are: material heat, air discharged, water injected, radiation and convection.

We see that despite the relatively high air flow rate, only a heat quantity of 1.1 million kcal/hour is carrid away in the air. The heat dissipated by radiation and convection is almost negligible. A substantial quantity of heat is, however, consumed in evaporating the injected water, 1.625 million kcal/hour.

From the heat balance it is evident that in compound mills of this size the only way to get rid of heat at a sufficiently high rate is by injecting water.

The average value for the throughput of this mill (Fig. 42) in 1976 was 156 t/hour, giving a product with a fineness of 3.000 cm²/g (Blaine) and requiring a specific power input of 32.0 kWh/t.

The question as to which grinding system should be used for clinker comes up for discussion over and over again. It is not possible to answer it in general terms: the advantages and disadvantages will have to be examined for each individual case. The principal criteria of assessment will be briefly reviewed.

In a compound mill the fineness of the product can be modified by varying the rate of feed and/or the composition of the ball charge. If grinding to a product fineness in excess of about 3.200 cm^2/g (Blaine) is required, however, various problems are encountered. For one thing, with increasing fineness there may occur agglomeration of the cement particles, i.e., an apparent coarsening of the product. Besides, the grinding balls and liner plates are liable to become coated, resulting in a marked increase in specific power consumption and, in some cases, preventing the desired fineness from being attained at all. These problems can be curbed by the use of grinding aids.

Air separator mills, i.e., grinding plants in which the mills operate in closed circuit with classifier equipment, can produce cements with a fineness of up to 6.000 cm^2/g (Blaine), while the fineness can be varied within wide limits by suitably altering the separator settings. Agglomeration and coating of grinding media are substantially prevented because the mill itself does not have to grind the product to such fineness all at once, while the recirculation of material and its therefore more rapid passage through the mill also have a favourable effect in this respect.

For fineness of around 3.200 cm^2/g the specific power consumption (for the grinding plant as a whole) is approximately the same for the two types of mill. For higher fineness values, however, the specific power demand of the compound mill exceeds that of the air separator mill.

The quality of cement is very often characterized merely by stating its fineness, more particularly its specific surface area in cm^2/g determined by the Blaine test. What really matter to the user, however, are its strength properties.

A cement will harden more rapidly according as the surface area of its hydraulically active constituents is larger. More particularly, a high proportion of particles in the 0 - 3 microns range means high early strength, while a high proportion of 3 - 25 microns means a final strength. This in turn means that, for equal specific surface area, a cement with a step particle size distribution and therefore a high proportion of particles below 25 microns, will attain the highest strengths. The cement ground in air separator grinding plants generally have a steeper particle size distribution than those ground in compound mills, i.e. cements with equal specific surface area attain higher strengths when ground in air separator mills. Alternatively, to attain a certain required strength, a cement often have to be ground to a higher specific surface area in a compound mill than in an air separator mill.

Besides particle size distribution, chemical changes in the material due to high temperatures in the mill or to water injected into it are likely to affect the setting behaviour and strength development of the cement.

High temperatures in the mill should be prevented by water injection. But if this adversely affects the quality of the cement, the mill temperature can alternatively be kept down by cooling the material fed to the mill. In an air separator grinding plant this can suitably be done by cooling the material in the circuit.

Since the grinding media suface area in a compound mill with its finer ball charge is larger than in an air separator mill, there is generally somewhat more wear. With present-day very hard materials used for grinding media, with wear rates of 50 g/t for the ball charge as a whole, this does not significantly affect plant operating results, however.

In terms of overall capital cost the compound mill is found distinctly to have the advantage over the air separator mill. Not only is the whole cost of the recirculating and separator equipment saved,but maintenance is easier and cheaper.

To sum up, it can be stated that the compound mill offers an alternative to the air separator mill for clinker grinding, even in cases where very high throughput rates are required. It can be used successfully when the desired product is portland cement of normal fineness.

The increasing production costs for cement clinker lead to an increasing use of additives for the cement production, i.e. more and more clinker is substituted by other materials like fly-ash, slags, and so on.
This led to new solutions in designing grinding plants for cement. As an example a grinding plant for slag cement in Germany shall be described.

The cement grinding plant is built in a port area of the River Rhine and comprises the following main parts:

(1) Clinker receiving station: deliveries in whole train-loads.
(2) Receiving hopper for blastfurnace slag and for gypsum. Both these materials are delivered by barge and unloaded by a crane.
(3) Conveying systems connecting the clinker receiving station with the clinker silo and the slag/gypsum receiving hopper with the [illegible] re and gypsum store.
(4) [illegible] silo with a capacity of 9.000 t.
(5) [illegible] e, of 12.000 t capacity, a roofed circular building of [illegible] m diameter. The slag is deposited in it by a stacker belt in three sectors of 120 degrees each, using the chevron system of stockpiling. While the third sector is being build up in this way, the reclaiming scraper begins to remove slag from the end face of the first sector. The store has been designed to achieve optimum homogenization of the slag, besides short storage times, so as to minimize the risk of setting and objectionable lump formation.

(6) Gypsum anhydrite store, of 3.500 t capacity, likewise a roofed circular building, 28 m in diameter.

(7) Cement grinding plant equipped with a tube mill of 4.2 m diameter and 14.5 m length.

(8) Three cement silos, each of 2.500 t capacity and each equipped with a loading bay for bulk carrier road vehicles.

(9) Loading berth for the dispatch of bulk cement by tanker barge.

The principal features of the grinding plant are shown schematically in Fig. 13. It is designed for the closed-circuit grinding of slag cement (portland blastfurnace cement) at a rate of 50 - 75 t/hour, the slag being dried in a pneumatic conveyor dryer installed ahead of the mill.

Four steel preliminary bins for the mill feed components were installed, namely, one bin of 300 t capacity for cement clinker and three 200 t bins for blastfurnace slag, gypsum and other materials respectively. Weigh belt feeders are used for proportioning these components. The rate of tailings return flow to the mill is determined with a continuous measuring device. The mill drive comprises a girth gear, two pinions, two gearboxex and two 2.000 kW slipring motors. The finished product from the mill is cooled in a cement cooler. The exhaust air from the dryer and from the mill is passed through fabric filters with compressed air cleaning of the filter media. The filter for the pneumatic conveyor dryer has been designed for 50.000 m^3/h at 120°C, and the filter for the mill has been designed for 48.000 m^3/hour at 120°C.

Other items of equipment for the grinding plant include two hot gas producers fired with natural gas or light fuel oil. One of these units, with a thermal output of 5×10^6 kcal/h, is assigned to the pneumatic conveyor dryer, while the other, with 3×10^6 kcal/h, is assigned to the tube mill.

Equipment for the storage and dispensing of a liquid grinding aid is also provided.

In planning the grinding plant a design concept was sought which would obviate the handling and intermediate storage of dried slag prior to grinding. However, in order not to have to put up with possible quality impairment due to feeding wet slag to the tube mill, the use of auxiliary heat fed to the mill as a normal procedure for drying the slag in it was not acceptable. Instead, the slag would have to be dried immediately before entering the mill. At the same time, however, it had to remain possible to investigate to what extent the heat generated in the grinding process could, without detriment to product quality, be utilized for drying the mill feed material. For this latter mode of operation, the second hot gas generator was provided as an auxiliary heat source.

In view of these considerations, the proportion of blastfurnace slag in the cement to be ground, and the amounts of water introduced into the mill with this slag, are certainly of major significance. To meet these requirements the only effective method was to install a pneumatic conveyor dryer directly before the mill inlet. With this arrangement it is possible to control the moisture content of the weigh-fed slag by controlling the heat input, so that the slag can be supplied dry or with any desired moisture content - and without intermediate handling or storage - to the grinding mill.

Fig. 44 shows the pneumatic conveyor dryer, or flash dryer with the rotary air-lock gate at the entrance to the riser duct, the inlet chute for feeding the material into the duct, the duct itself with input connection for hot gas supplied by the firing unit, and the cyclone at the top of the duct. The dried slag is separated from the exhaust air in this cyclone and is delviered direct to the mill inlet, where it joins the other mill feed components. The moisture in the slag fed to the dryer is continuously monitored and automatically taken into account in controlling the proportions of the mill feed components. Coarse particles of slag, which are not carried up in the air stream, fall out of the riser duct and are discharged through a flap valve direct to the mill inlet.

The riser duct of the dryer is 0.8 m in diameter, and the cylone inlet is 22 m above the entry point of the material into the duct. The cyclone has a diameter of 3.25 m.

The cost of the pneumatic conveyor dryer, including the associated filter and hot gas producer, was about 25 % compared to the cost of a separate drying installation with its requisite equipment for the handling and possible intermediate storage of the slag.

The mill system is equipped with a Polysius cyclone type separator.

The diameter of the separating chamber is 4.5 m. The four peripheral cyclones are each 2.0 m in diameter. The circulating fan, installed outside the separating chamber, has a capacity of 150.000 m^3/hour at 100°C. The fan is equipped with an inlet vane control system for altering the circulating air rate and is powered by a 200 kW 950 r.p.m. squirrel-cage motor. The distributing disc and counter-vane system have a special gear unit with 200 kW DC motor.

For dedusting the air separator, an adjustable amount of air is extracted from the circulating flow and fed to the mill filter. In the design of the plant this amount was estimated at 4 per cent of the air circulation rate, but in actual practice it is considerably less.

With a moisture content of 8 - 10 per cent in the feed, and the specified residual moisture of less than 1 per cent after drying, the specific heat requirement of the dryer has been in the region of 1.000 kcal/kg of H_2O. The measured exhaust gas discharge rate from the dryer was about 50.000 m^3/hour at 120°C. The differential pressure of the dryer, including the cyclone, is about 22 mbar. The throughput was 42 t of dry slag per hour.

From the experience with the operation of the pneumatic conveyor dryer it emerges that correct feed-in of the moist slag into the riser duct is extremely important, otherwise caking and build-up of deposits are liable to occur in this part of the system, causing operational disorders. The hot gas flow and velocity below the material entry point, as well as the distribution of the material in the riser duct, must be properly interadjusted.

In the cyclone and in the downpipe leading from the cyclone to the mill inlet a considerable amount of wear occurred in the initial stage of operation. This problem was solved by installing wear-resistant plates and cast basalt linings.

Extensive investigations were conducted with a view to optimizing the grinding plant. In these investigations particular importance was attached to obtaining a finish-ground product that would attain the correct cement strengths and concrete strengths, with good workability properties.

Grinding HOZ 35 L with 57 percent blastfurnace slag to a fineness of 3.800 cm^2/g acc. to Blaine the mill system reaches an output of 71.5 t/h. The separator efficiency for a circulating load of 2.5 was 77 percent, the residue on the 32 micron sieve was 8.2 percent, which gave a very high product quality. The specific power consumption was 48.9 kWh/t for the complete plant, included 3.5 kWh/t for the separator.

About 40 % of the electric energy consumed in the production of standard cement is claimed by clinker grinding. If the thermal energy input for burning the clinker is also included, and adopting the present-day average energy cost of 0.068 DM/kWh and 23 DM/10^6kcal the percentage breakdown of the overall-cost of energy for the production of normal portland cement leads to the fact, that 72.5 percent must be spent for the clinker burning, i.e. for the fuel. The rest of 27.5 percent is electrical power with the main energy consumer: clinker grinding, which is therefore of particular interest as a target for energy-saving efforts.

The limits of what is attainable in this respect are predetermined by the physical laws of size reduction. The intensive efforts of the users and suppliers of grinding plants have had the result that modern finish grinding with ball mills has almost exhausted the posibilities for further reduction of energy consumption in this grinding technique.

Significant savings in the cost of energy are therefore to be expected only from other grinding methods. Besides the quest for fundamentally new methods and the development thereof, there has in recent years been futher development of the roller mill for the finish grinding of cement. It has thus become an interesting alternative method for the purpose.

A new energy-saving cement grinding method will have to compete with the ball mill operating in closed or in open circuit, these methods being the criteria against which any new one must be assessed. The basic requirements applicable to a new grinding method can be defined as follows:
- attaining a product range of equivalent quality:
- low electric energy consumption:
- low overall operating cost, including capital expenditure, wear, servicing and maintenance.

Cardinal criteria for judging the quality of the cement produced are the workability properties and the quality of the concrete made from it.

Three roller mills for grinding test purposes in connection with the further development of the roller mill were available in the Polysius testing laboratory:
- a laboratory mill of about 2 - 3 kW drive power rating:
- an experimental mill of 8 kW drive power rating:
- a pilot-plant size roller mill of 28 kW drive with a grinding bowl diameter of 0.8 m.

Depending on clinker grindability, the last-mentioned mill attained throughputs of more than 2 t/hour in grinding standard cement. The mill has an integral air separator incorporated in the casing.

In the first stage, five years ago, Polysius began grinding clinker in the experimental grinding plant which initially was unmodified, i.e. had been adjustet and optimized for raw meal grinding. The cement produced in this grinding process did indeed meet the 28-day strength requirement for portland cement grade PZ 35, but its 2-day strength below average. The very steep particle size distribution curve moreover suggested that the concrete made with this cement was likely to have poor workability.

So the first aim was to produce PZ 35 with good "normal"properties. Starting from the raw mill configuration of the grinding plant the optimum configuration for grinding cement from clinker was found by systematic modification of the operating parameters speed, grinding force, grinding bed depth, feed particle size, air/material ratio, air separation method and separating conditions as well as by the testing of modifications to the design features of the mill.

The tests showed that product quality is affected, in the main, by the design of the grinding elements and by the air separation conditions. A decisive improvement was achieved by changing the shape of the grinding elements, bringing about a longer period of residence on the grinding bowl and a more stable build-up of the bed of material. As a result of altering the separation conditions a sufficiently broad particle size distribution of the finished product was obtained. This stage of development was completed with the production of a substantial sample quantity of cement for comparative investigation on the basis of concrete technology.

When it had been established that "ordinary" standard-grade cement of satisfactory quality could thus be produced, the development of the plant was directed to the production of the superior grades PZ 45 and PZ 55 and of slag cement. Furthermore, the roller mill had to be optimized with regard to throughput and power consumption. At the same time, wear tests were carried out. Now that these investigations have likewise almost been completed, we are able to produce portland cement of the strength classes 35, 45 and 55 as well as portland blastfurnance cement ("Hochofen"cement) which in respect of quality are at least as good as the cements of these classes commercially available at the present time.

A roller mill grinding plant for cement works as follows:
The clinker is fed to the mill through an air lock. The material pulverized on the grinding bowl is carried along in the air stream to the integral separator, from where the oversize particles are directly returned to the grinding bowl, while the fines are swept out with the air stream and precipitated in cyclones. The greater part of the circulating air is returned to the mill, while a small proportion is discharged to the dust collecting equipment. In this part of the system the heat generated in the grinding process and the heat contained in the clinker fed to the mill are removed. Since the power consumption of the roller mill itself substantially less than that of the ball mill, less grinding heat is produced. Hence the familiar problems of grinding heat removal are simpler to solve, the more so as large quantities of air are needed for transporting the material in the mill and can be utilized for heat removal. This ample air supply is also advantageous in drying moist blastfurnace slag during grinding, as the entry temperature can be kept low, so that then no problems with gypsum dehydration are encountered.

The air velocity in the nozzle ring of the mill is set to so low a value that the larger clinker particles can fall and subsequently be returned to the mill by a small bucket elevator. The low velocity involves less jet-action wear in this part of the casing, while there is also less pressure loss, so that the circulating air fan can operate with lower power consumption.

The experimental grinding plant used in the tests is of essentially the same layout as the system described here.

A typical test in this experimental plant shows the following data:

Using the full power of the mill drive motor is was possible to attain a throughput of 1.6 t/hour for a product fineness of 2.850cm^2/g (Blaine). The specific power consumption for the mill alone is 17.8 kWh/t, which is only about 60 % of the corresponding figure for a comparable ball mill. The specific air rate is 3.1 m^3/kg, corresponding to 320 g/m^3 dust load downstream of the air separator.

Thus, for a grinding plant designed for an output of 80 t of portland cement per hour a roller mill with a grinding bowl diameter of 4.1 m is required. The total power consumption of the grinding plant is 26.5 kWh/t, corresponding to a 20 % saving in comparison with the ball mill. Apart from the mill itself, the largest energy consuming unit in the roller mill grinding plant is the circulating air fan, which has to be designed for a capacity of 240.000 m^3/hour in the case envisaged here, while the exhaust air rate is 45.000 m^3/hour, which is sufficient to discharge excess heat from the system without having recourse to water injection. A ball mill for this throughput would have a diameter of 3.8 m in a closed-circuit system.

In order to assess the economy of the roller mill finisch grinding process, it is necessary to determine the overall operating costs and compare these with the corresponding figures applicable to present-day ball mill grinding processes: power costs, capital expenditure, cost of wear, servicing and maintenance costs.

Taking into considerderation, that the different items will vary from case to case, there is a favour for the roller mill system in the range of 5 to 10 percent.

This encouraged a German cement plant to install a roller mill for clinker grinding with the financial aid of the government. This mill is successfully in operation since several months. Detailed information will be available in the next month.

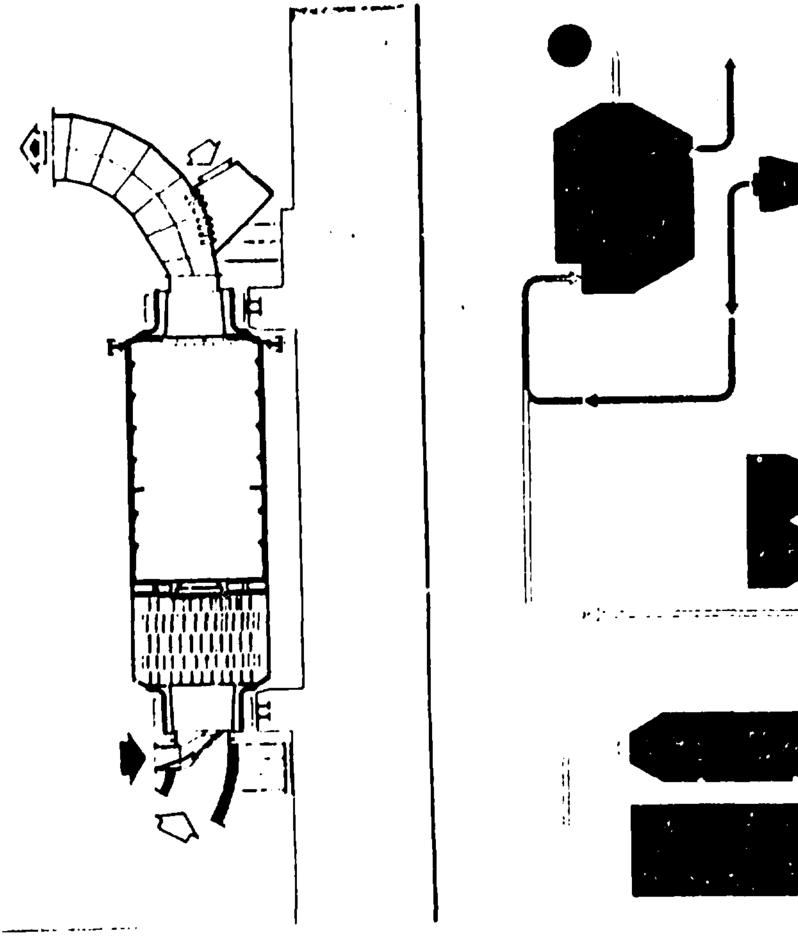
Along with the further development of the roller mill the development of other new grinding techniques must not be neglected. With such techniques it may well prove possible to increase the effectiveness index based on the values relating to single-particle comminution - at present ranging up to 9 % for ball mills and up to 15 % for roller mills - to something like 30 % or more.

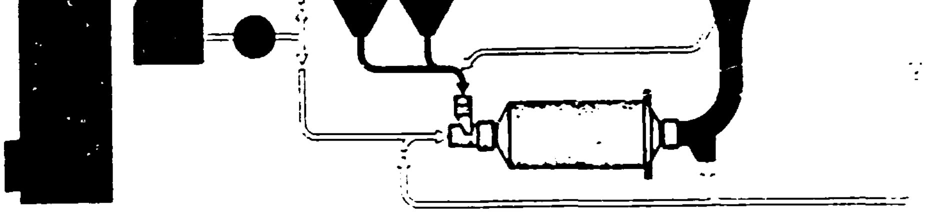
This leads away from grinding based on impact, squeezing or abrasion to grinding purely based on pressure or better compression, which gives the highest grinding efficiency.

For other solutions like vibratory mills, planetary mills, jet-mills or similar systems we see no real chance in the cement industry with increasing mill capacity and increasing energy prices.

1: air swept mill
2: air swept mill - flow sheet
3: air swept mill - plant
4: air swept mill with bearing slide shoe
5: air swept mill
6: slide shoe
7: slide shoe in function
8: **diaphragm**
9: one chamber mill
10: one chamber mill - flow sheet
11: double rotator
12: double rotator - flow sheet
13: double rotator
14: double rotator - plant
15: double rotator - central drive
16: double rotator - central drive
17: double rotator - grit inlet
18: central drive unit
19: shaft dryer
20: dispersion type dryer
21: impact dryer
22: roller mill
23: roller mill - flow sheet
24: roller mill
25: roller mill - internal view
26: clinker grinding system - flow sheet
27: turbo separator
28: cyclon type separator
29: cyclon type separator
30: channel - wheel separator
31: channel - wheel - system
32: channel - wheel
33: separator - air cooling
34: separator - air cooling
35: separator - water cooling
36: separator - water cooling

37: cement cooler
38: clinker grinding mill with slide shoe bearing
39: central drive unit
40: compound mill
41: compound mill - heat balance
42: compound mill
43: slag cement grinding plant
44: slag cement grinding plant - dryer - flow sheet
45: slag cement grinding plant
46: roller mill for clinker grinding - flow sheet





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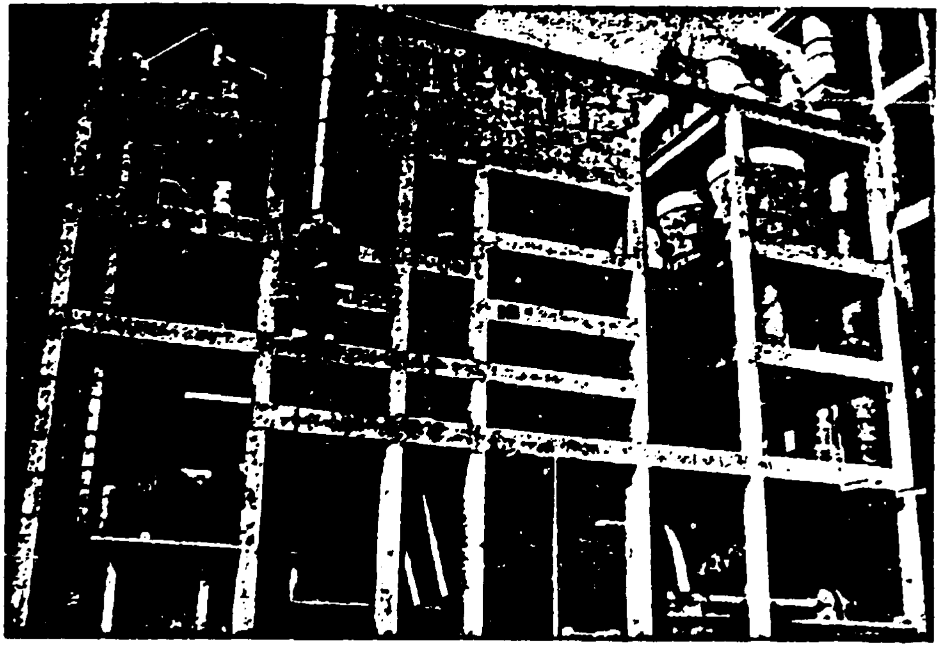

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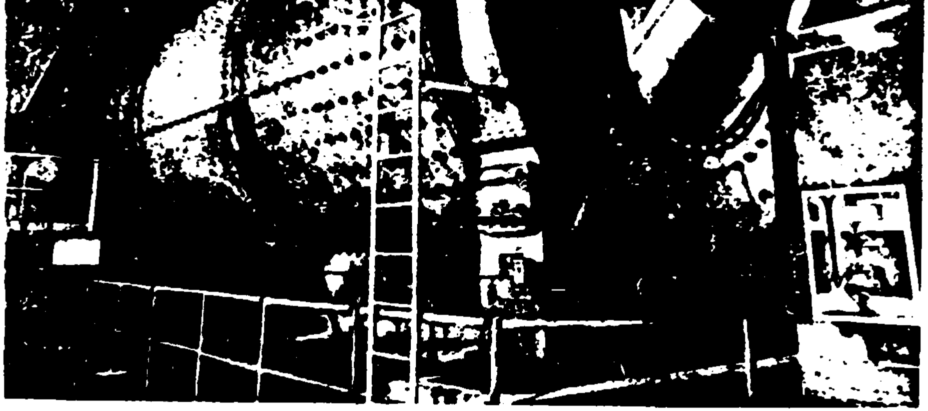

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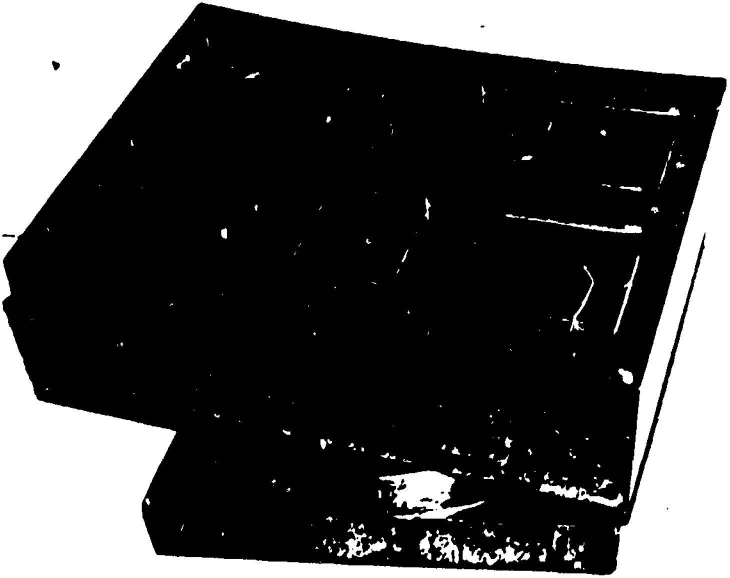

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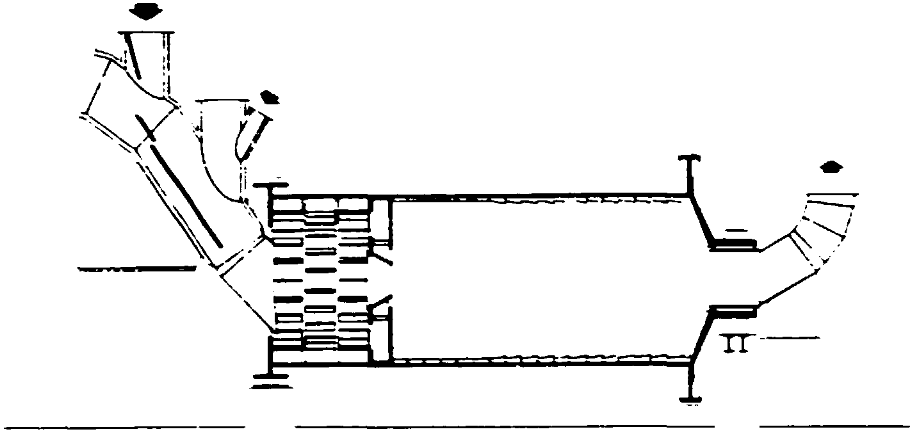

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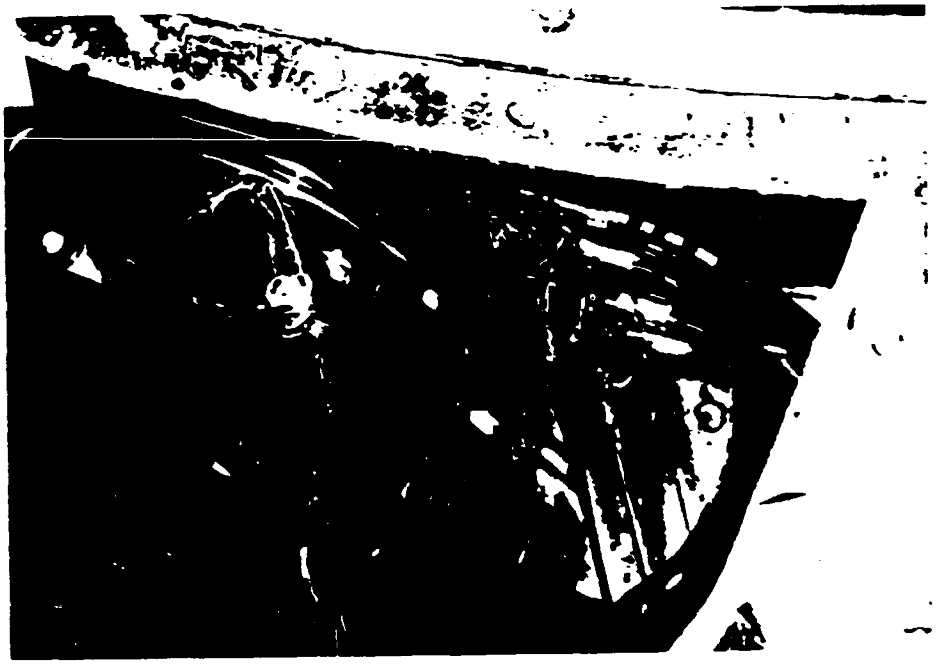

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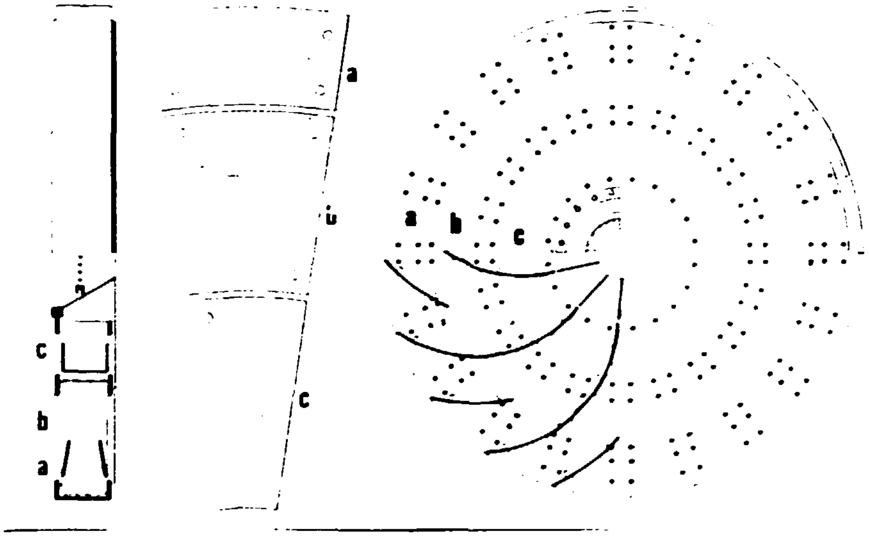

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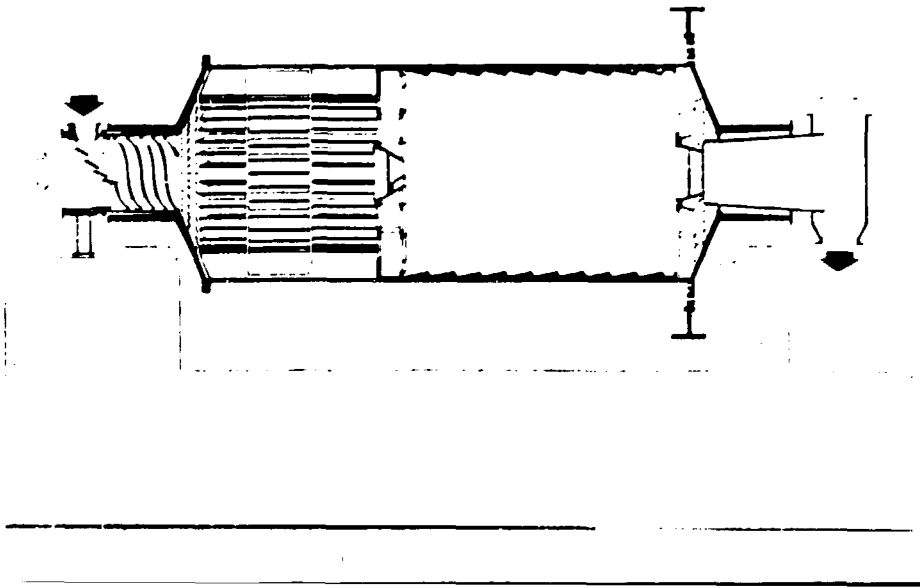

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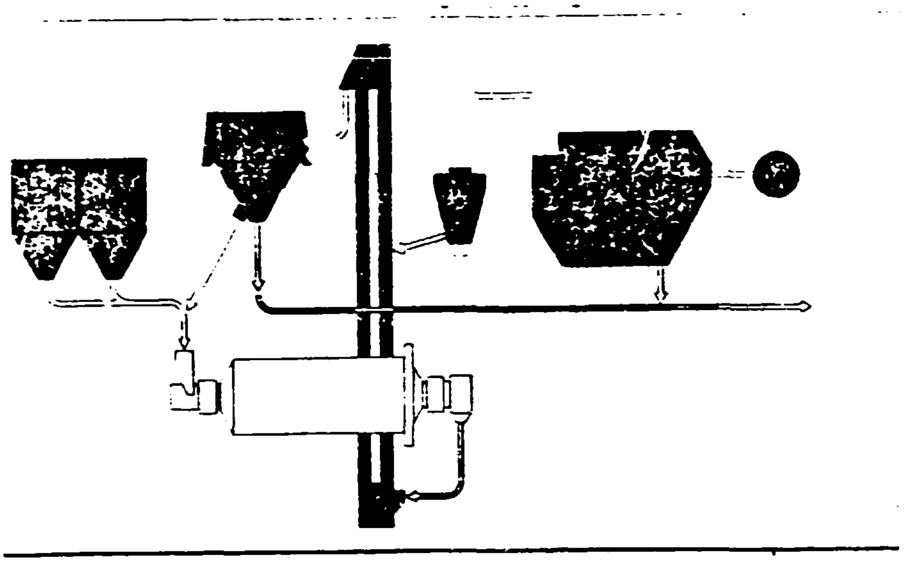

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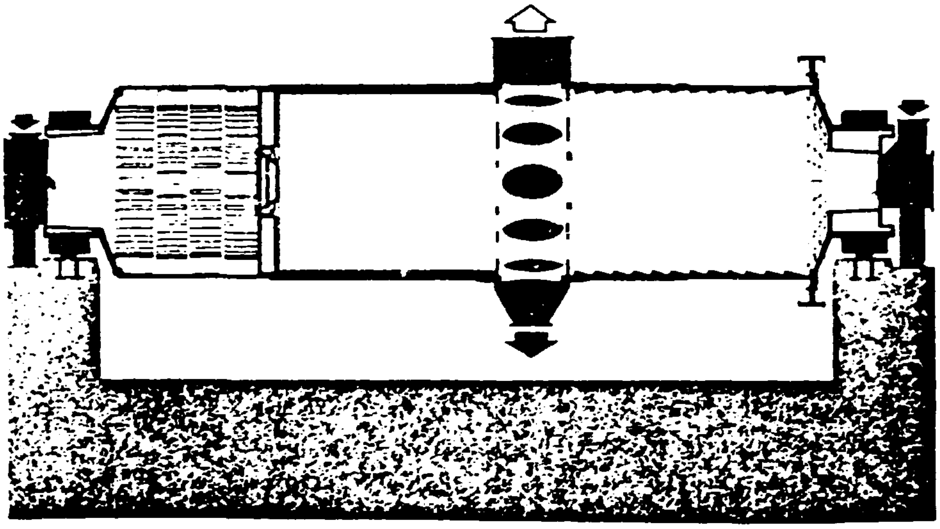

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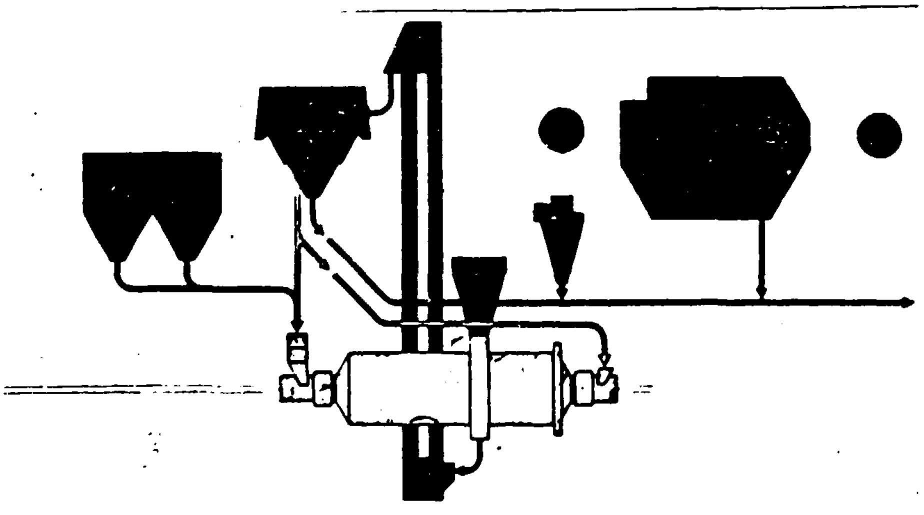

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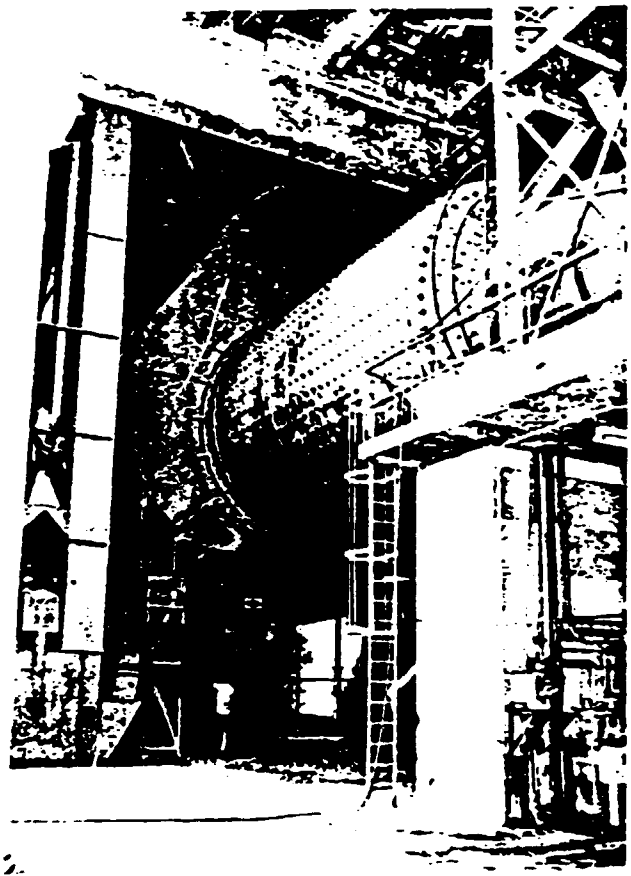

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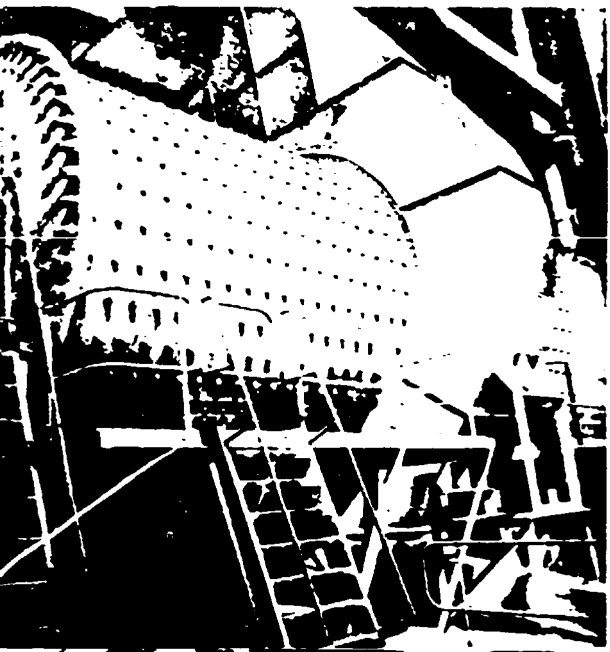

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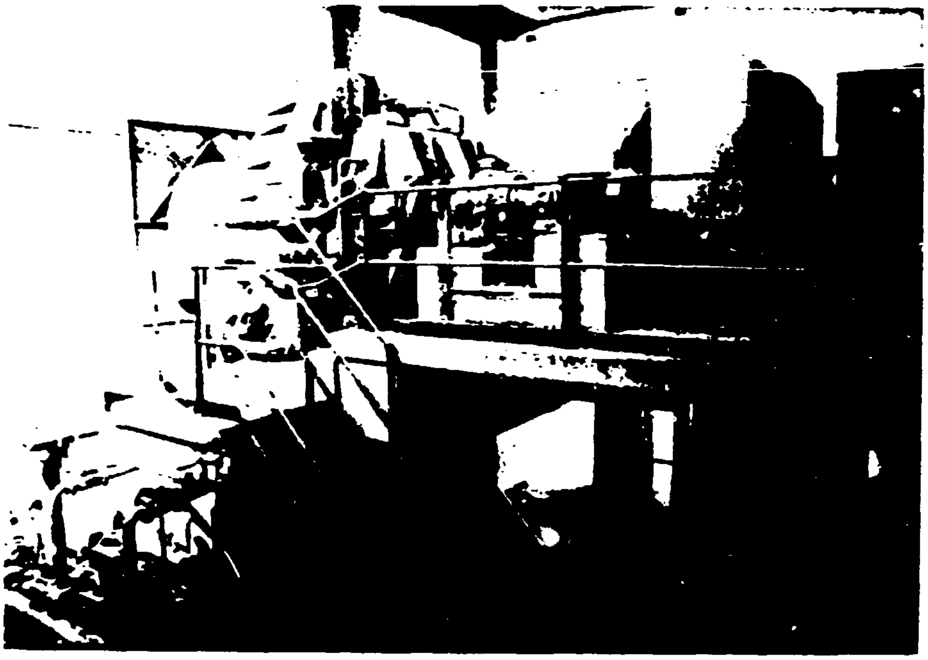

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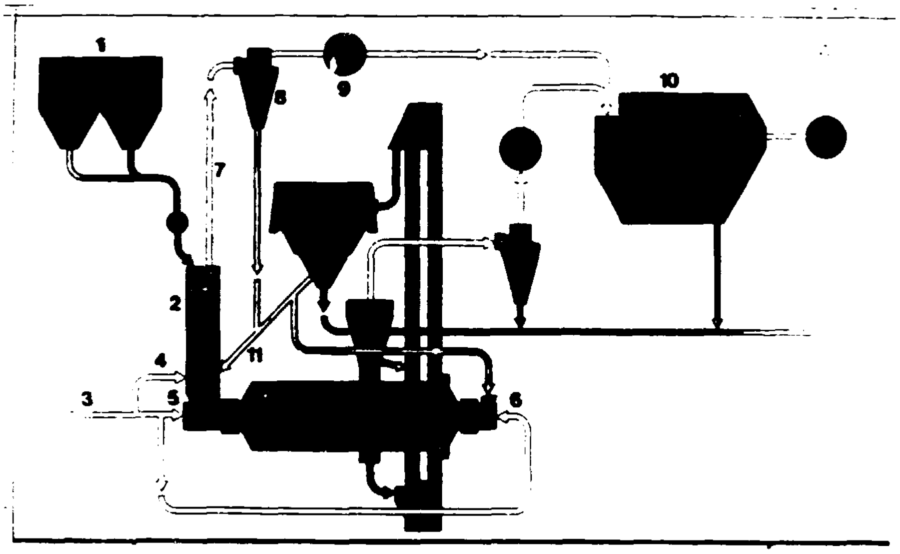

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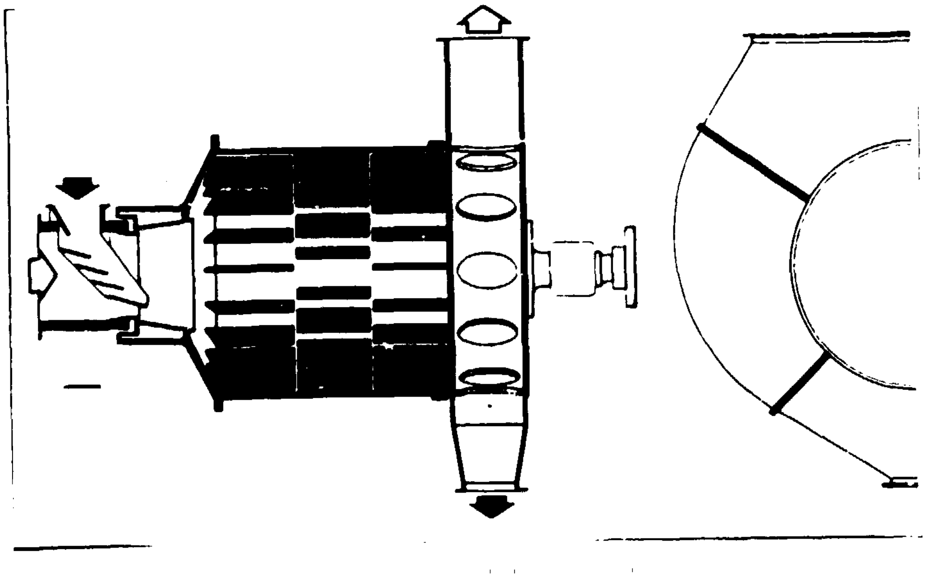

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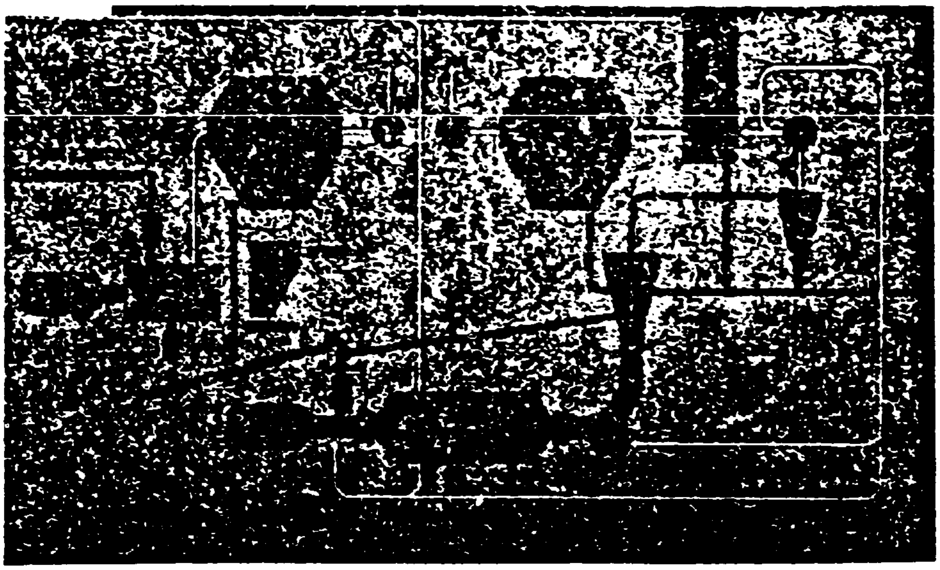

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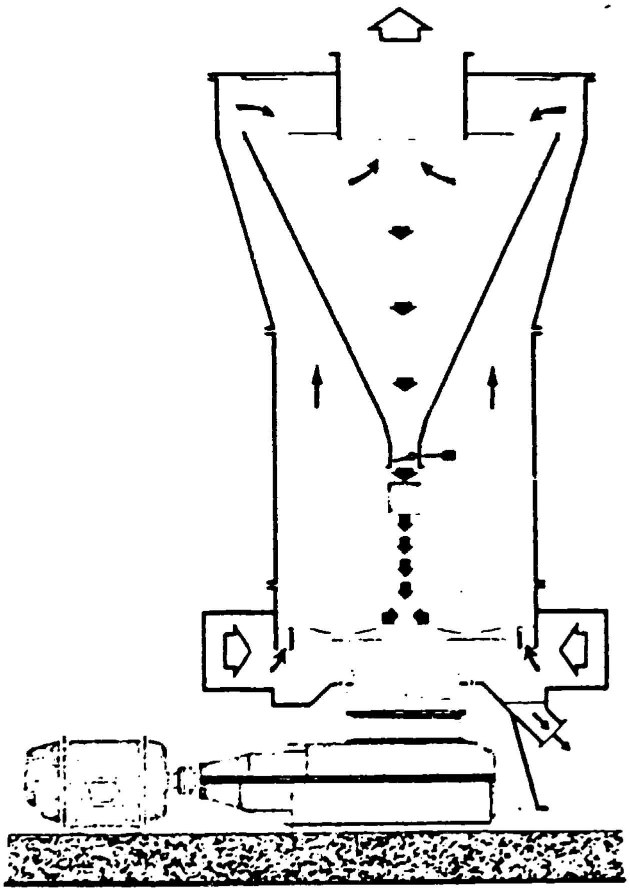

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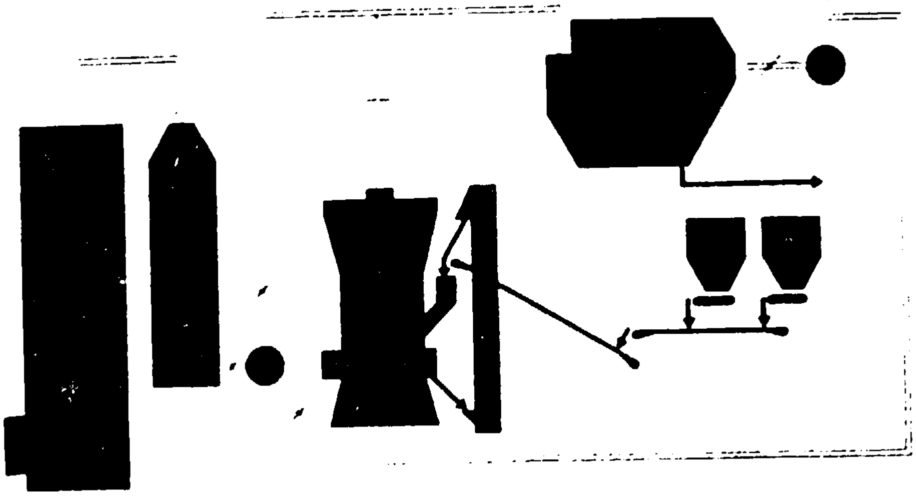

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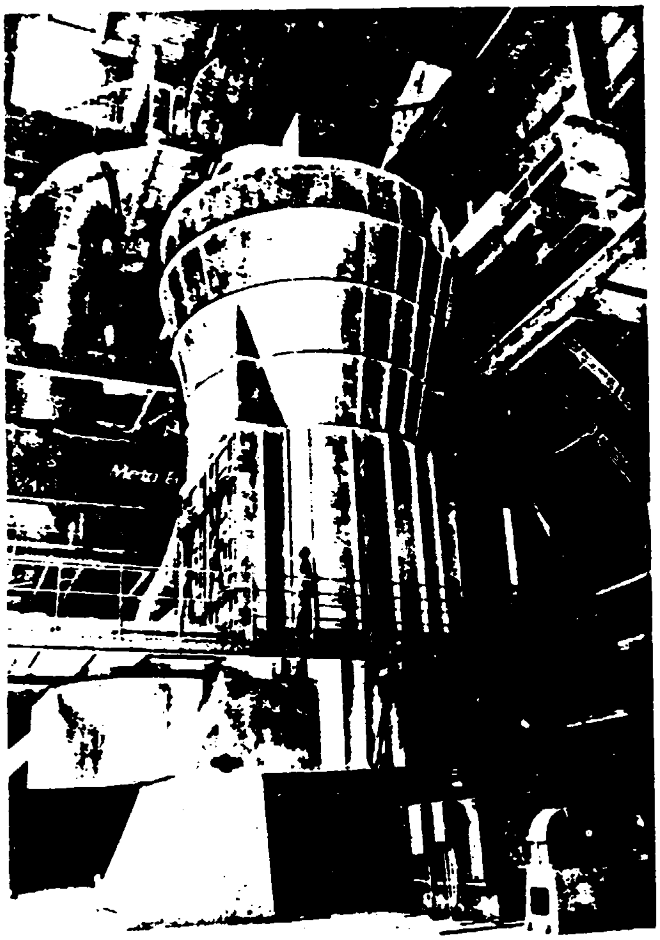

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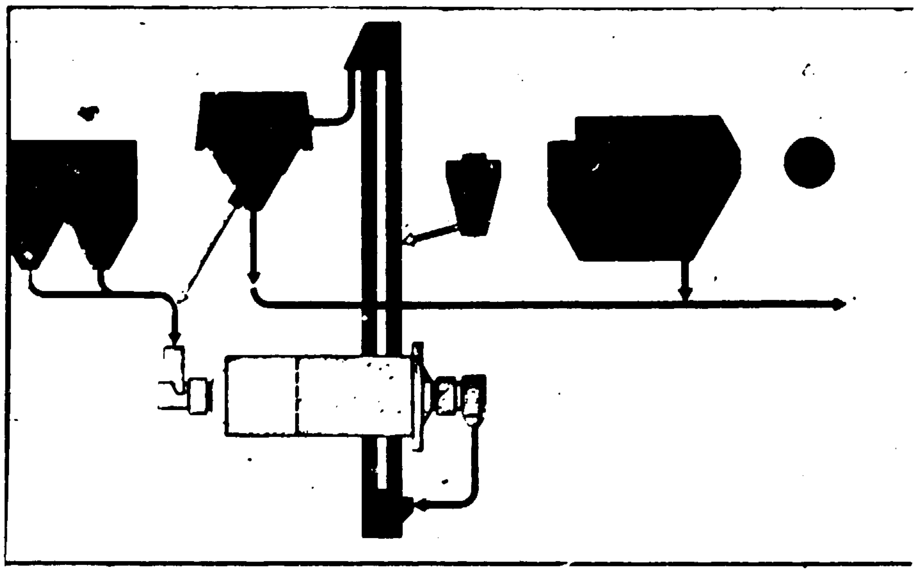

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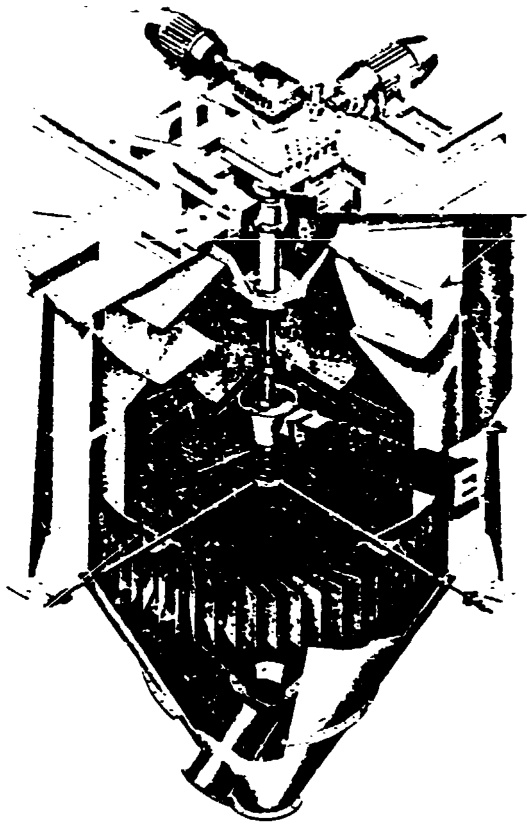

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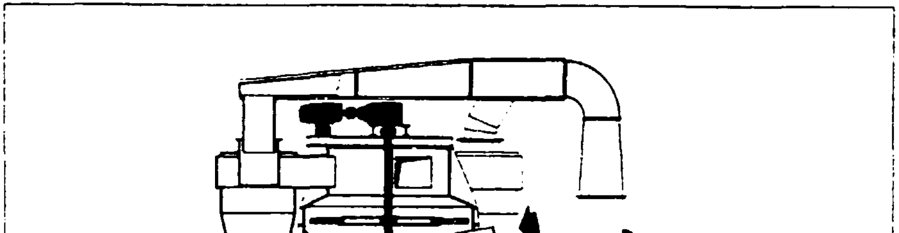

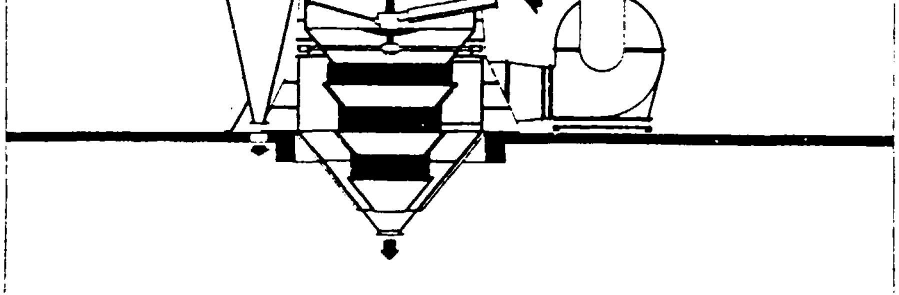

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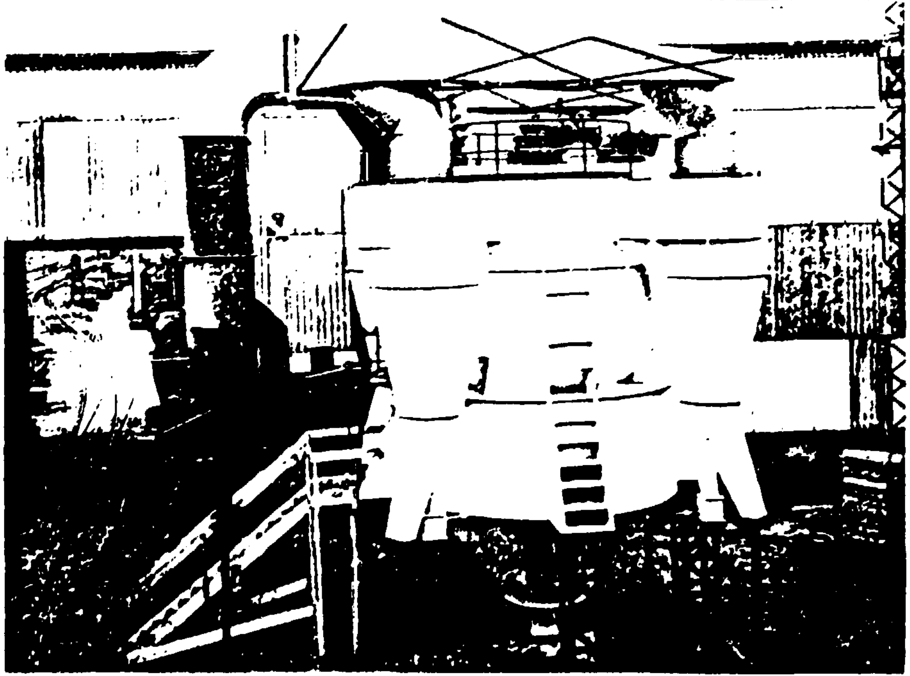

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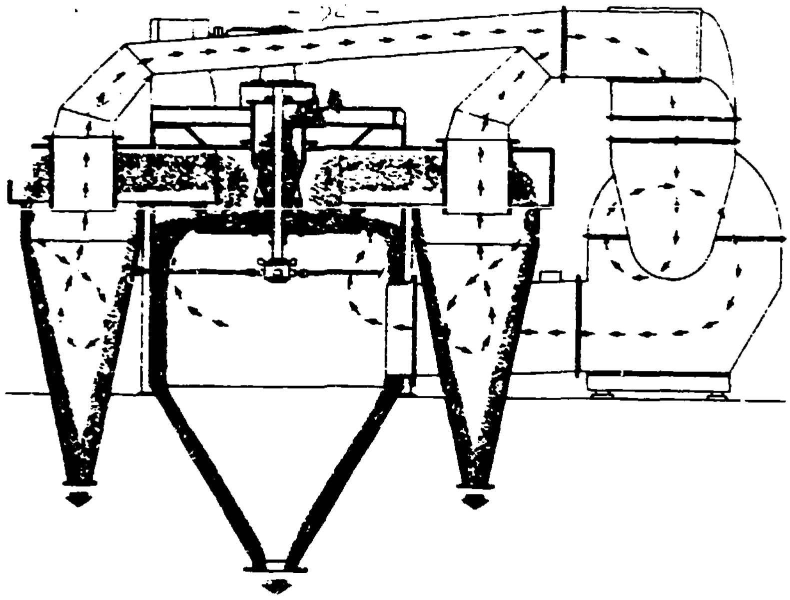

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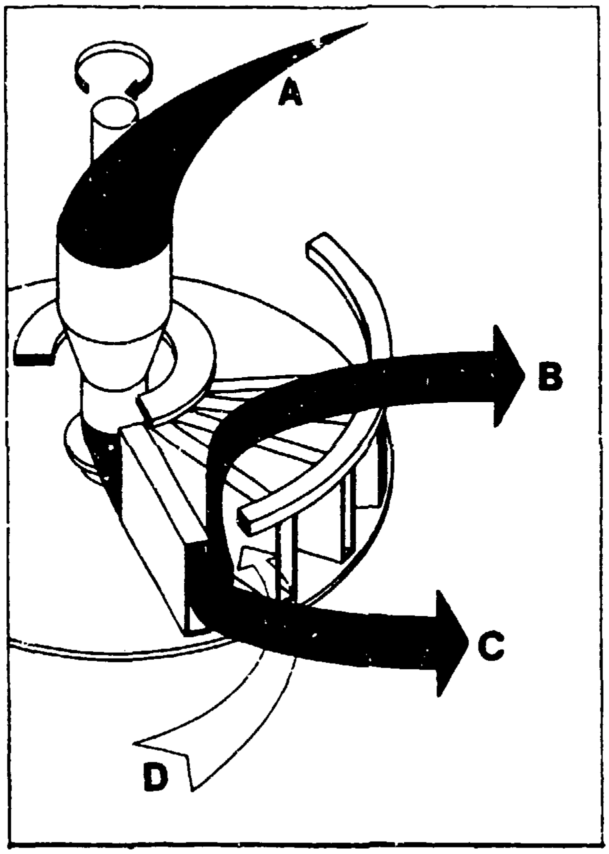

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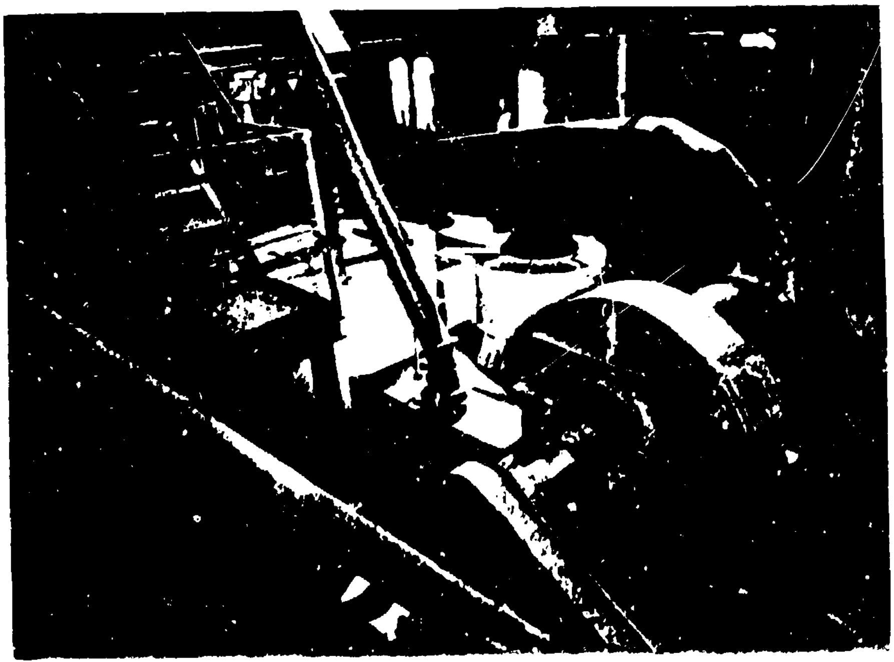

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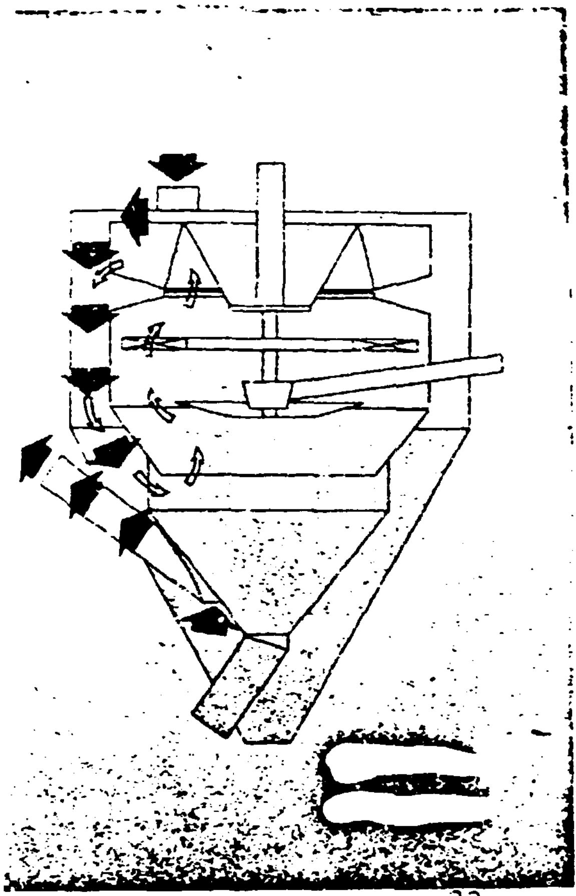

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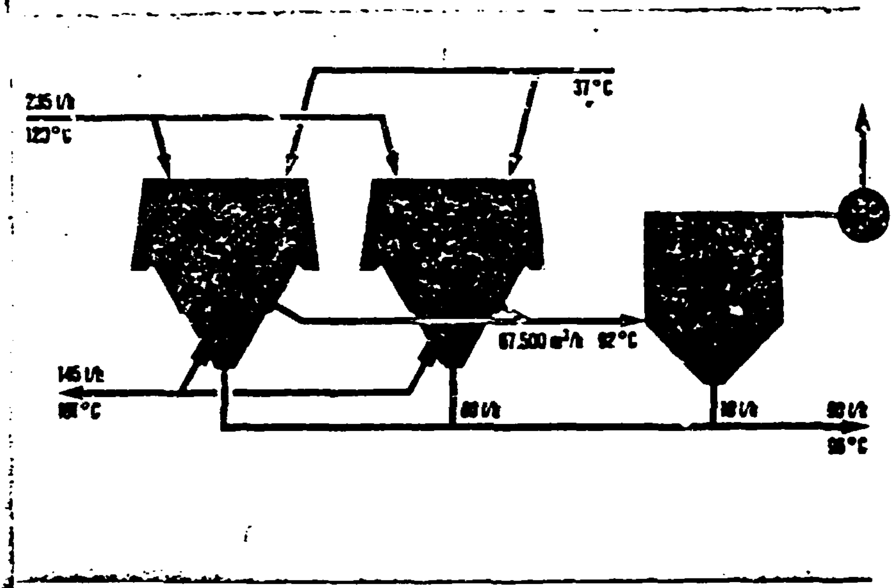

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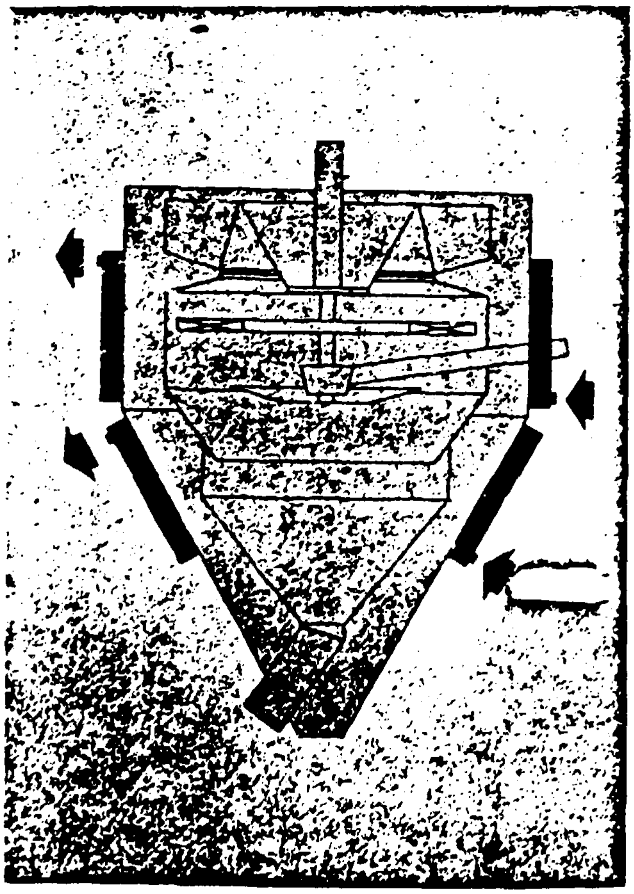

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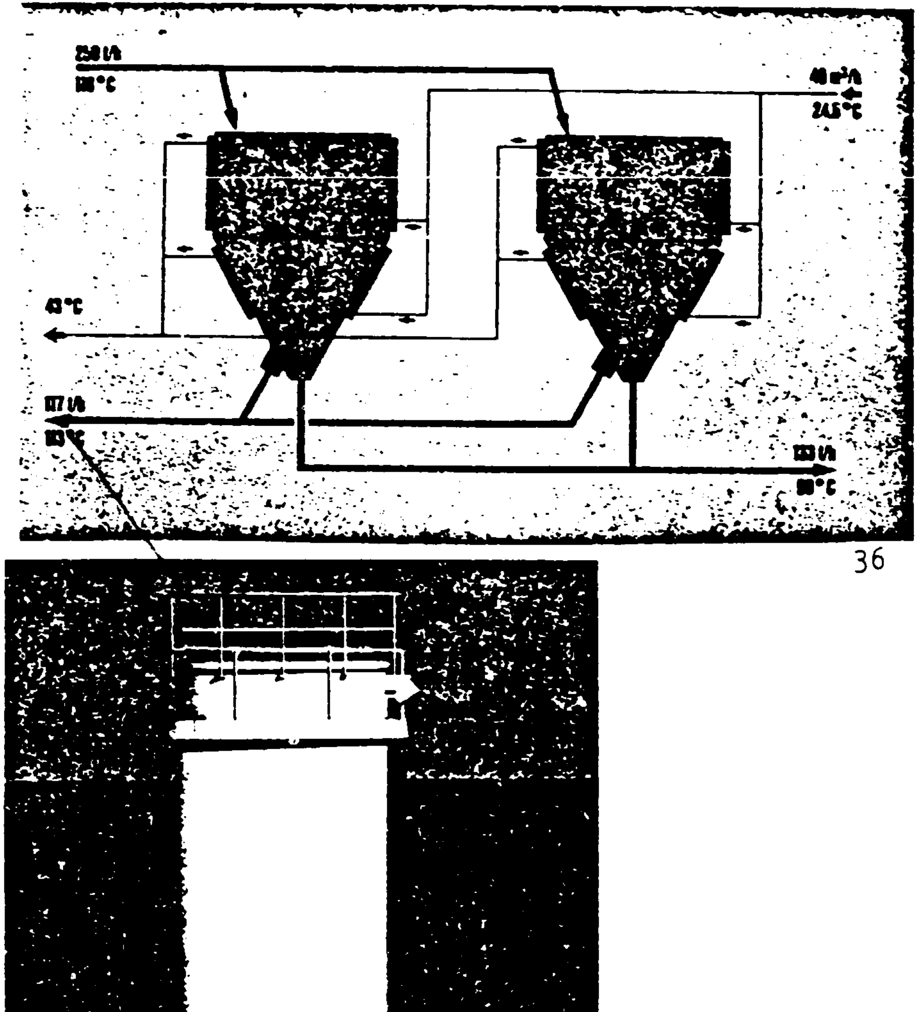

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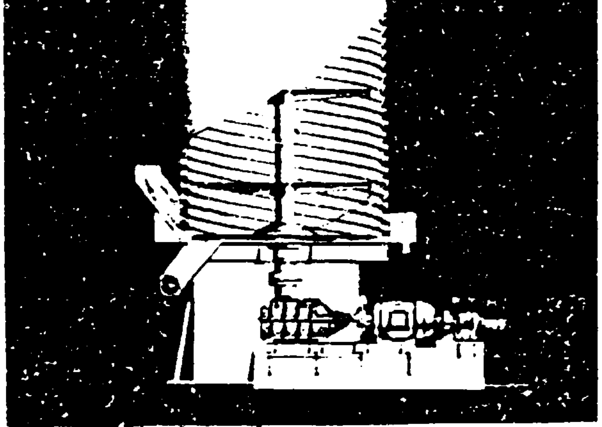

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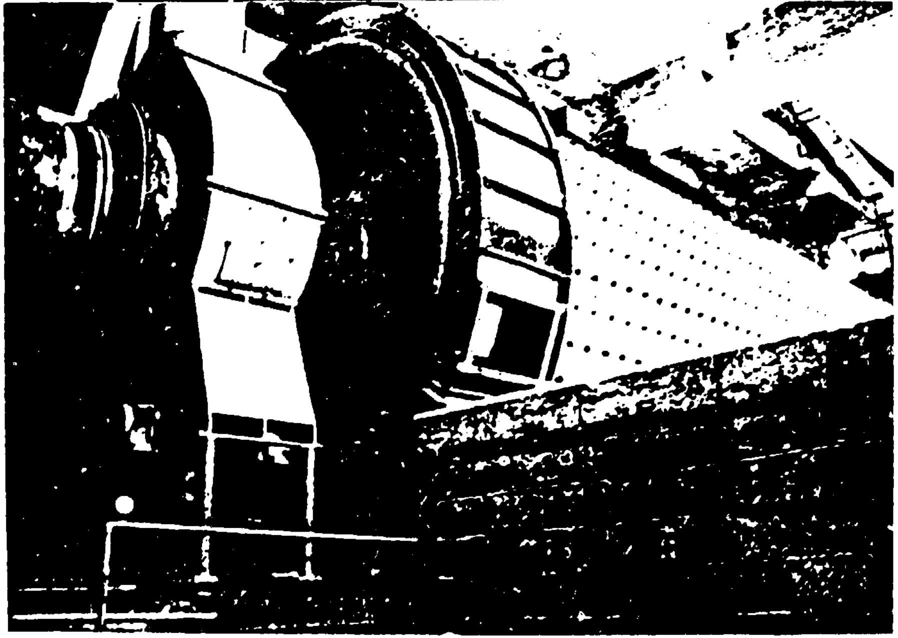

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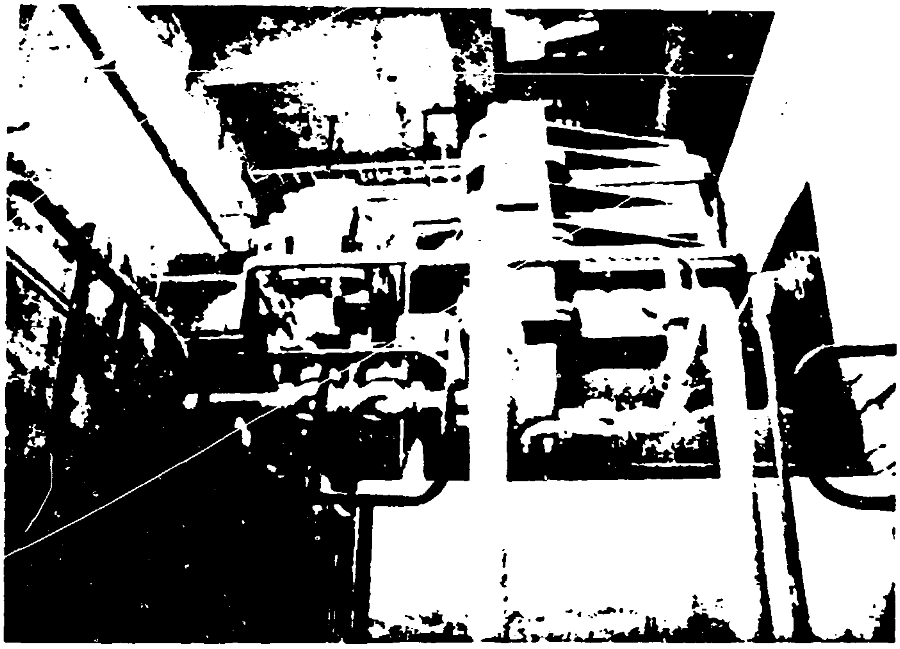

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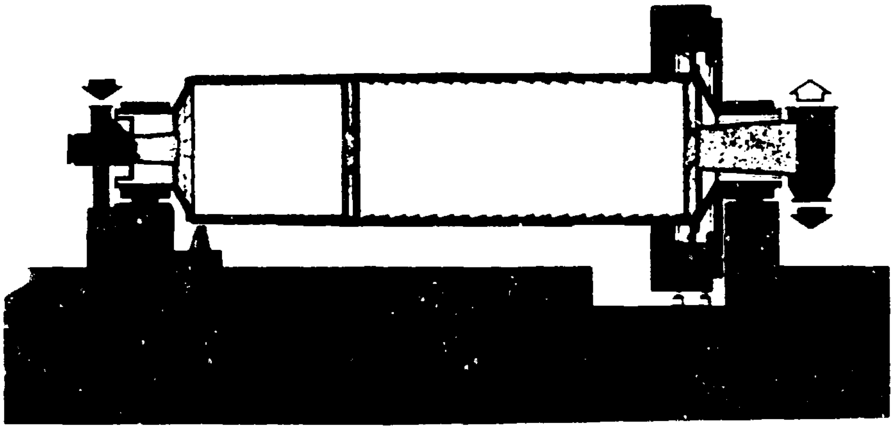

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Heat intake	
Drive power	4.050.000 kcal/kg
Material heat	1.890.000 kcal/kg
Air supplied	335.000 kcal/kg
	6.275.000 kcal/kg
Heat expenditure	
Material heat	2.860.000 kcal/kg
Air discharged	1.470.000 kcal/kg
Water injected	1 626.000 kcal/kg
Radiation and convection	320.000 kcal/kg
	6 275.000 kcal/kg

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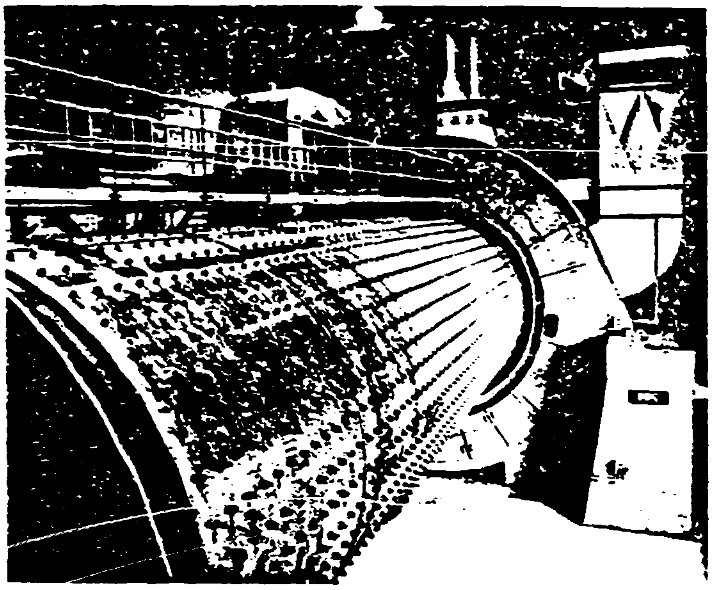

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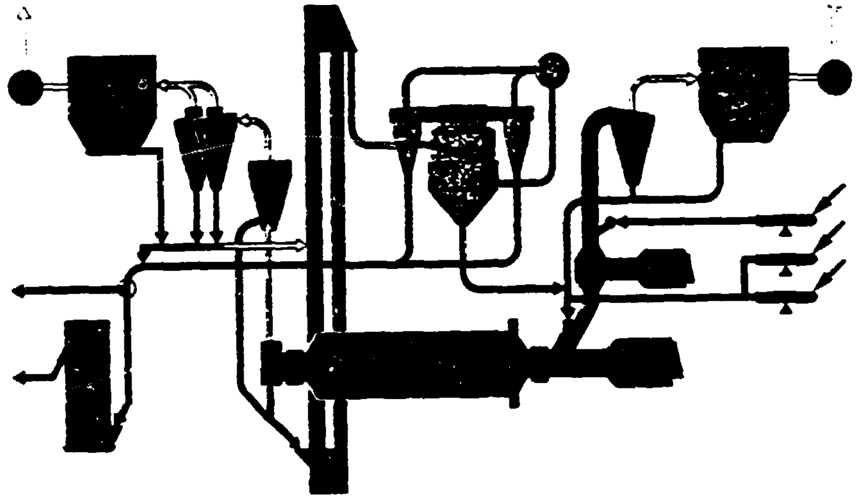

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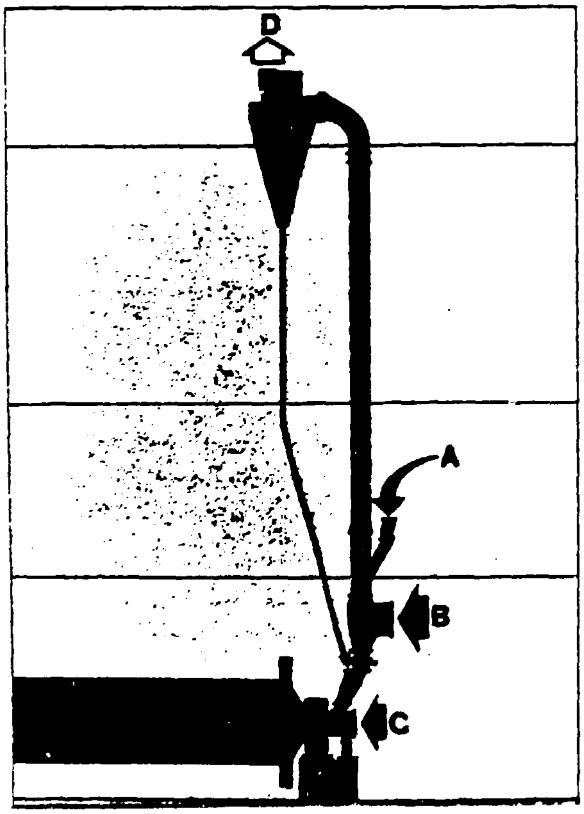

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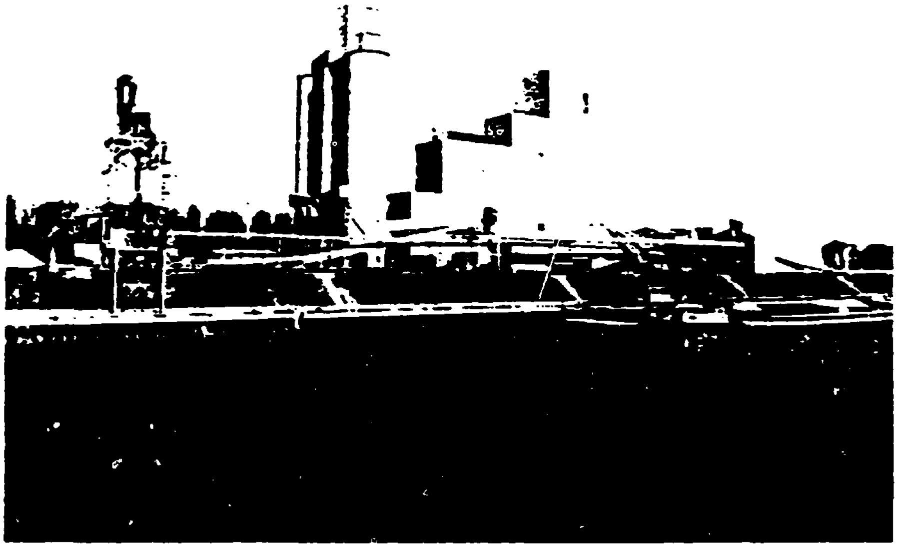

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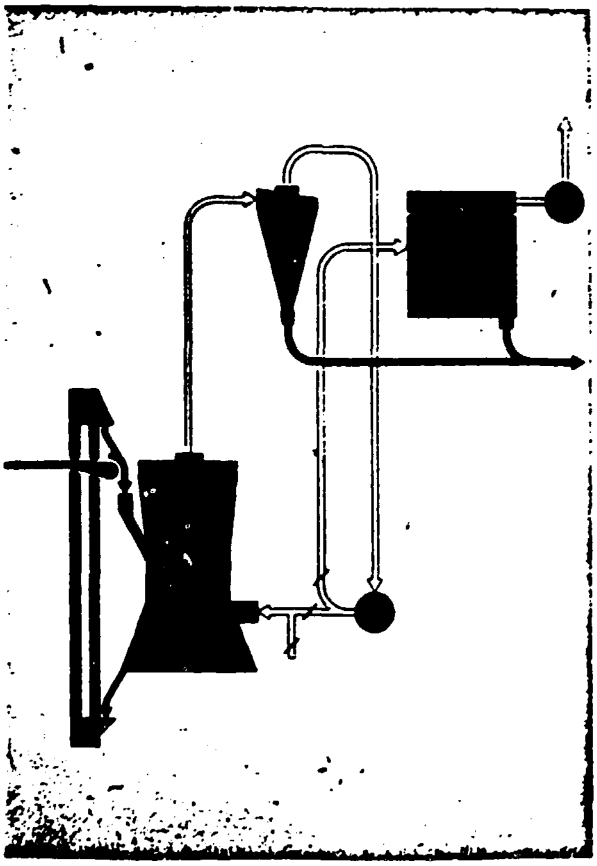

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