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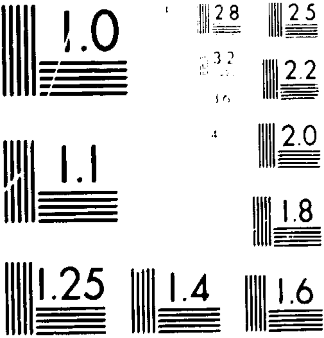
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ECONOMICAL ASPECTS OF LOESCHE-VERTICAL-KILN FOR COMPACT CEMENT PLANTS OF SMALL CAPACITY *

by

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Introduction:

The demand for cement increases in industrialized countries at a rate of about 4% p.a. according to investigations of CEMBUREAU. This may not be the case in Central Europe, where the cement consumption seem to have reached a relatively static level but may generally apply for industrial areas on the other continents. Over 55% of the present world cement consumption is produced in 5 West European countries, Germany, Italy, France, UK, Spain and in U.S.A., Canada and Japan. In these countries, mainly in Japan, plant or unit capacities have reached considerable dimensions. It appears that the largest units are operating in countries of very high population density and good infrastructural conditions (railway, roads, water transportation). In the U.S.A., however, the unit capacities rank last of the industrialized countries, obviously due to a very large geographic area which is only in a few parts densely populated. This situation seem to lead to medium size capacities to serve a local market. The development of the fuel supply for cement kilns in industrialized countries, even in those where certain oil or gas resources are available, tends definitely to the use of coal. At present about 30% of the world cement production is based on coal and about 70% use oil or gas, while other types of fuel with the exception of certain waste materials and oil shale, have not yet found entry into the cement industry. In 1985 the use of coal is expected to reach about 85% against only 15% of oil and gas if the price difference between oil or gas and coal remains at the present level.

Certain countries, not owning own fuel reserves, like for instance Switzerland, will change to coal almost completely within the next year. In others the authorities grant favourable credits or tax advantages for the installation of coal grinding plants for the conversion of cement kilns.

The long-run effect of higher fuel and energy cost, as well as transportation costs, will be reflected in the cement industry's investment pattern. The cement industry is required to revaluate the type of fuel, size of cement plants and its location as well due to market and costsavings potential.

For the major expansion of cement industry in non industrialized countries it is, however, necessary to bring the investment level for Small Scale Cement Plants as low as possible as private investors will have to be interested in this enterprises. This has been noted by Mr. Cognet and Duvigneau of Industrial Projects Department of World Bank in Washington, not only for eccnomical, but also for technical reasons too. In these countries, mainly very huge in surface area and very low population density, large cement plants cannot be considered because:

There is no sufficient market demand for large plants; there are not sufficient raw material reserves for large capacity;

there are inadequate infrastructural facilities for transportation of heavy equipment, and cement transportation is too far away beyond the reach of distribution areas by large cement plants.

Smaller cement plants should be located in remote districts, catering the demand of this area, using their own raw material resources, like limestone, clay and - if possible - the solid fuels too.

In the past, small cement plants have been represented both by Rotary Kiln and Vertical (shaft) Kiln Plants. New processes technologies have been developed in improved homogenization and nodulizing technique, especially for Vertical Kiln Plants resulting in up-to-date technology and product quality which does not differ from those of a rotary kiln. These new technology cannot be compared anymore with the technology of 20 years ago or back in 1912, when first mechanical vertical kiln was invented. Cement producing units of this type have always proven to be an economical success, assuming that certain basic requirements have been met.

<u>These are as follows:</u>

1. Conditions for Economical Feasibility

1.1. Plant Situation

Areas remote from larger industrial centres which are difficult to supply with cement for reasons of expensive transport are the places where a compact plant is the solution to serving a developing local market, provided suitable raw materials are available. So, if transport costs for the unit of a mass product like cement are higher than the production cost difference between a larger and a smaller plant, it will be worthwhile to check on the feasibility for a compact plant. There may be political or strategic consideration, but those will be the exception. Tariff protection should be avoided as it will result in a higher cement price.

1.2. Plant Capacity

Experience has shown that the smallest reasonable production unit for cement is a plant producing 60,000 t/year. A plant of lower capacity can not be economical as the specific installation and operating costs cannot justify the investment.

Plants with 90.000 t, or even 120.000 t yearly production are very likely to be economically sound, if the general conditions mentioned under 1.1. are met. Plants up to 200.000 t/y are still considered to be Compact Plants, but not above this capacity.

1.3. Comparison to Other Processes

Compact Cement Plants are generally equipped with vertical kilns. The small ground space such a kiln requires allows the layout to be compact as all other mechanical sections of the plant, expecially the grinding mills, can be located near the kiln for close mutual supervision. Transport of materials can be kept to a minimum length, and the static components of the plant, i.e. raw material storage and the silos for raw meal and cement can be arranged like satellites around the mechanical centre of the plant. Consequently, the buildings and foundations are equally "compact". They are considerably smaller and cheaper than those of a otary iln ement lant of equal capacity.

Once capacity of a Cement Plant exceeds the above mentioned 200.000 t/y, which means the installation of more than three vertical kilns initially, the total investment cost of a Vertical Kiln Plant is likely to equal that of a rotary one. These costs, including all the mechanical and electrical equipment from the quarry to the packing plant as well as buildings, foundations, roads within battery limits, auxiliary housing, offices, laboratory, workshop, ground, civil works, quarry survey and opening, normal legal expenses and unforeseen, but for a plant operating under normal circumstances, are not the only reasons to decide in favour of a

Vertical Kiln Compact Plant. Of even more importance are the lower operating costs, mainly maintenance, fuel and electricity consumption and most of all, the high utilization rate of the vertical kiln due to few moving parts, and the lining which is safe under all operating conditions. The value of being able to stop the kiln for several hours or up to 15 days without endangering mechanical parts or the lining and without damaging cement quality, are also worth mentioning. Kiln should not be ignited again. Fire is kept in sintering zone.

2. Technological Presumptions

2.1. Raw Material

Since there is only one way to produce a raw meal suitable for the production of Portland Cement, the composition of the raw materials is independant of the burning process. All raw materials are suitable provided they permit the composition of raw meal as defined for the production of Portland Cement.

2.1.1 Raw Material Preparation

With the exception of very few places, where natural raw material composition exists in the quarry, it is necessary to mix the raw mill feed from several components. In order to achieve a chemically uniform mill feed, it is desirable to keep a sufficient stock of raw material, whereby the stock of each component should be as chemically constant as possible. Selective mining in the quarry should be avoided, if possible, as it always introduces a factor of uncertainty, aside from the additional cost.

Pre-crushing which is usually effected by a One Step Hammer Mill, need not be finer than 80 mm as the Roller Mill, which is exclusively applied for raw meal grinding in vertical kiln plants operating to the Interground Fuel Process, requires no finer feed. It may, nevertheless, be desirable to crush somewhat finer to improve the efficiency of a pre-blending bed.

2.1.2 Pre-blending

In a small scale cement plant, pre-blending might be essential as it is in a larger one in case raw materials are heterogenous. The notion that a pre-blending or pre-homogenization bed installation is "too expensive" is basically false. If the cost for this important plant section appear to be too high, then a small scale cement plant is wrong for the particular application, and cement must be brought in from other sources. No section of a plant can be omitted for cost reasons, that applies in particular for the pre-blending. A successful operation is possible only if a chemically constant raw material is available at all times to produce raw meal.

2.1.3 Nodulizability

Vertical kilns are fed by nodules or pellets of uniformly sized balls of about 15 mm dia. They consist of the finely ground mix of coal and raw meal, and require about 14-18% water. These nodules are shaped on Disc Type Nodulizer, and great care is taken to feed the fine Black-meal at constant bulk weight in relation to the volume of water spray into Nodulizer. The nodules produced have to be plastic, porous and should be strong enough to stand mechanical handling like the drop to the revolving chute of kiln and the pressure of the material layer in the preheating zone of the kiln.

The nodulizability can be checked in the laboratory and a test will allow exact prediction of the behaviour of the nodules in the kiln. Experience has shown that plastic materials result in better nodulization and nodules formed of such material do not tend to collapse when exposed to sudden heat. There are also many mechanical adjustments known to the expert to produce suitable nodules of any raw meal, in special shaped disc, even if the components contain little plastic particles. So far, no raw material has been found that could not be nodulized properly to withstand the mechanical stress of being dropped onto the pre-heating zone of the kiln.

2.2. Fuel

2.2.1 Suitability for the Interground Fuel Process

All solid fuels of carbonaceous nature are suitable for the Vertical Kiln Process, while gas or liquid fuels cannot be used. Preferred are coals not containing too much volatiles as some of those are lost during the process. This should be avoided, if possible, for the sake of maximum fuel economy. Coals containing no more than 20% volatiles are suitable. Consequently, anthracite, petrol coke, or low volatile bituminous coals are preferred, as well as char coal, metallurgical coke or charred lignite, or charred brown coal, as practiced since 1960 in Australian Vertical Kiln Plant. The ash content is of minor importance, as the ash is finely distributed and becomes part of the raw meal. It has to be chemically calculated with the other raw material components.
The advantage of the Interground Fuel Process for Vertical Kilns in comparison with Rotary Kilns, cannot be overstated when we take into consideration

that the energy the process consumes, may be derived from a low value fuel like coke breeze, anthracite duff, char coal, or a high ash content coal.

2.2.2 Reactivity

When deciding to use a certain fuel, it is nevertheless necessary to control its reactivity. It must be borne in mind that the Interground Fuel Process does not follow the reaction of the carbon exclusively with oxygen to CO_2, but the so called "Hauenschild Equation" $Ca\ CO_3 + C = Ca\ O + 2\ CO$ which reacts with oxygen to CO_2 (Partly "gas fired" kiln). Naturally, it is preferrable to use coal of high reactivity, but again, no fuel has yet been found of such low reactivity and might not be used.

3. Plant Layout

3.1. Plant Sites

The decision where to install a Cement Plant is governed by the topographical situation, the prevailling wind and, of course, the location in relation to the quarry at the main road or railway. A specific advantage of a Vertical Kiln Plant is that it can be located on a slope or a hill side, provided that these are not too steep. A Compact Plant can gain by such an inclined ground as transport ways can be shortened.

3.2. Ecological Aspects

In countries where industrialization is still in an early stage, dust precipitation for the kiln stack is not always necessary, provided that the plant does not operate near dwellings or industries. It is also possible to install an electrostatic precipitator, the only dust-collecting unit for cement kiln, at a later date, as the space required for it, will always be protected in the layout.

The dust emission is not excessive, but still too high for an densely inhabited country. It is better to arrange the plant in such a way that prevailing wind carries the fine flue gas away from the plant without settling on other plant sections. Flue gases look worse due to evaporated water.

There is no noise emission above the limits set for industrial plants in highly industrialized countries. Vertical Kilns have no external heat radiation nor do they cause any vibration.

3.3. Material Transport

The short distances over which material has to be transported in a Compact Plant, are one of the main advantages of the arrangement as mentioned under 1.2. While this is generally correct, no two Compact Cement Plants can be expected to be based on the same layout. As mentioned under 3.1., topographical conditions and the situation between quarry and loading station as well as the different nature of raw material must all be taken into account in determining an optimum layout for the individual plant. Certain section of the equipment may be standardized, but there cannot be anything like a Standard Compact Cement Plant.

3.4. Plant Control

While the chemical control is more or less independent of the cement producing process, the plant control, both automatic and manual as well as the technical supervision is very simple in a vertical kiln plant. Except for the burner, there is no permanent attendance or manual labour necessary in the mechanically operated sections of the plant. This is not true for material handling, if it is done by loaders, trucks, etc. While all sections of the plant are fully instrumented, only material flows are automatically controlled in a simple way. Control boards are located in each plant section and generally not in a Central Control Room. In order to keep the operation simple and inexpensive, automatic sampling and analyzing is normally not provided.

4. Costs

4.1. Installation Costs

The installation costs or volume of investment cannot unfortunately, be based on a formula. The nature of the raw materials, the geographical situation, the conditions for transport, erection and commissioning, climate and altitude of plant, and last bot not least the costs and availability of credit, are of such a considerable influence that a breakdown of the costs can only serve as a general guideline. This will become more obvious as the mechanical and electrical equipment represent hardly more than half the total costs, while the other half depends on the aforementioned local conditions.

4.2. Specific Comparison

For the same matter it becomes apparent that the often heard opinion Vertical Kiln Plants are cheaper than Rotary Kiln Plants, applies only to comparatively small capacity units. This is because only the kiln itself differs from a Rotary Kiln Plant, its clinker cooler and coal grinding section in case solid fuel is applied for kiln firing, while all other equipment from the quarry through the pre-blending, the raw material grinding, the homogenization to the clinker grinding and the packing plant are identical for both Vertical and Rotary Kiln Plants. Naturally, the compact layout results in savings in foundations and length of transport apparatus, but once, due to the plant capacity, more than three vertical kilns are needed, the cost advantages might disappear.

4.3. Operating Costs

Even more than the investment costs, the operating costs of a Vertical Kiln Plant offer substantial advantages over a Rotary Kiln Plant of equal capacity. The extraordinarily high utilization rate of this static kiln is the basis of its suitability for places remote from services available only in industrialized areas.

Maintenance on a Vertical Kiln is next to Nil. The lining in the shaft need not be changed for more than 15 years. The lining in the sintering zone, which is only 1/6 of the total kiln height, lasts about two years. The only revolving part of the kiln is the grate. It turns with five revolutions per hour, a speed so low that it is not visible on the shaft. Wear is no factor under these operating conditions, even grate is acting as clinker crusher too.

4.3.1 Electrical Energy

Power consumption for the total plant stays below 85 kWh per ton cement. This is due to the following factors:

About 40% of total required electrical energy for the production of 1 ton of bagged cement is related on clinker (cement) grinding in conventional horizontal ball mills. Compact Vertical Kiln Plants, producing a more porous clinker, can use Vertical Roller Mills in conjunction with very precise air separators to meet all requirements for the production of Standard Cement qualities. By means of the application of this type f.e. Loesche Mill, 25-30% electric energy could be saved. As this air-swept mill incorporating its pulse-jet-filter is free of product dust within 2 minutes after stopping the feed to the mill, cement raw material too will be ground in same mill, saving another 20% of electrical energy compared with Horizontal mill. As a Vertical Mill can be fed with much coarser feed (max. 80 mm), mainly only one precrushing unit is applied, saving electrical energy costs, wear costs and consequently maintenance costs too.

As Vertical Roller Mills could grind even moist and sticky raw materials up to 20% moisture content, no pre-dryer will be necessary. The Vertical Mill acts as dryer, separator and mill body represents one unit and, in case locating the filter on top of the silos, the ground product is transported without additional electrical energy into Kiln Feed Storage or Cement Storage Silos.

The Loesche Vertical Kiln is a stationary kiln. The only moving part is the grate which revolves about 4 times in one hour. The kiln drive requires 1,25 kWh/t clinker compared with roughly 17-20 kW/t clinker for a rotary kiln unit which includes, however, the energy consumption of the kiln fan (Vertical Kilns operate with natural draft of exit gases), cooler drive and ventilator (Vertical Kiln incorporates the cooler while combusting (kiln) air is acting as cooling air), clinker crusher (vertical kiln discharge grate is acting as crusher) and last not least the required primary air fan for kiln firing device (vertical kiln feed has its fuel interground), kiln air (cooling air for clinker) is acting as combusting air and air blowers require 10 kWh/t clinker.

In case a rotary kiln is fired with solid fuel, an additional Coal Grinding (and Drying) Plant is required. The Loesche Vertical Kiln technology does not require a separate fuel pulverizing or drying plant as solid fuel and raw materials are ground and dried together in one Vertical Loesche Mill. In this case, further 5 kWh/t cement could be saved. Total Specific Energy which could be saved in favour of a stationary kiln ranges up to 30 kWh/t cement which cannot be neglected in feasibility studies.

4.3.2 Heat Energy

The theoretical requirement of heat energy (expressed in kcal) for burning one kg of clinker of same quality orginating from same raw materials remains constant for both kiln types (Horizontal - Vertical) applying dry or semi dry processes. Its value ranges between 50 - 55% of practical heat requirement for clinker burning only (f.e. between 800 - 1200 kcal/kg clinker). The remaining 45 - 50% are so called Heat Losses which differ from kiln technology application. Generally we note the following main Heat Losses:

1) Evaporation of Water in Kiln Feed

For kiln technology applying nodules like Vertical Kilns and Lepol Kilns, about 120 kcal/kg clinker are required for this purpose (~ 15%). Consequently exit gas temperature drops below 100°C and its waste gases may not be used for drying processes (f.e. for raw material, solid fuel), in case of its necessity. Rotary Kilns (Long Dry Kiln, SP Kiln) do not operate with granulated feed. The exit gas temperature is consequently much higher (> 300° C) and heat losses too in case, latent heat of gases cannot be used for drying purposes for instance. In any case, literature indicates a loss value of at least 190 kcal/kg clinker (~ 22%).

2) Radiation and Convection Heat Losses

Literature indicates for Long Dry Kilns and SP Kilns a value of 150-200 kcal/kg clinker (19-25%) while a Vertical Kiln of same daily clinker production rates to 60 kcal/kg clinker (7,5%) due to the fact that a Stationary Kiln is perfectly insulated and layer of insulation (about 0,8 m thick) has not to be moved round like at Rotary Kiln.

3) Clinker Sensible Heat - Clinker Losses, Cooler Losses-

The discharged Vertical Kiln clinker has normally a temperature less than 100° C and its losses are given to 15 kcal/kg clinker (1,8%). This type of kiln is an excellent Heat Exchanger as mentioned before. Heat Losses for SP or Long Dry Kiln depend upon type of integrated clinker cooler and cooler-system. In some cases hot clinker cooler air is used again as primary or secondary air for kiln burner (recoverable heat). Exact values may not be indicated but it range between 65-150 kcal/kg clinker (8-19%).

4) Exit Gas Losses

As indicated before, exit gases leave a Vertical Kiln with a temperature below 100° C due to good Heat Exchange between not exit gases leaving sintering zone and passing through the layer of dry semi wet and at least wet nodules, before leaving the Kiln Hood. The value of these losses are 18 kcal/kg clinker, based on leak air free exit gases volume and 22 kcal/kg clinker (<3%) based on effective exit gas voulme. Exit gas temperatures from Long Dry Rotary or SP Kilns operate with exit gas temp. above 300° C and the immens Hat Losses should be recoverd by using these heat for drying purposes in Crushers, Dryers or Raw Material Grinding Units if possible and necessary. Specific losses are given between 175 kcal/kg cl. (22 %) for SP Kilns and 380 kcal/kg cl. (48%) for Long Dry Kilns.

4.3.3 Conclusion of Energy Consumption

Summerizing 4.3.1 and 4.3.2 the decision whether a Rotary or Vertical Kilns should be recommended is in favour of Stationary Vertical Kilns, as its electrical energy and heat consumption are much lower when comparing both Kiln Systems of same daily clinker production of same raw materials. Operating- and consequently the Production Cost - are much more economic in respect of energy consumption, one of the main factors in a feasibility study considering Production Costs.

4.4. Maintenance Costs

As already mentioned, spare part consumption of a Vertical Kiln Plant are negligible. Spare part requirement for crushing and grinding sections are normal in relation to the abrasiveness of the raw materials, including solid fuel. Based on tests and experiences, specific costs can be estimated very closely, but they are still dependent on individual conditions.

5. Miscellaneous

5.1. Delivery and Installation Time

All mechanical and electrical equipment can normally be on board ship within 12 months after order and technical clearance. During this time, buildings and foundations, civil engineering jobs, quarry opening and road or rail connection should be established. This provided, the erection time should not exceed six months. The plant will be taken into operation by sections. An overall period of three months should be allowed for this.

Naturally, shipping installments, erection and trial period are to a certain extent overlapping, so that the total period between order and full production should not exceed 21 months.

6. Summary

Industrial growth in many less developing countries with inadequate infrastructure but with natural resources of cement raw material and solid fuel in sufficient quality and quantity leads to the interest in identification whether Small Scale Cement Plants would be justified. As in recent past most of research and marketing efforts of cement manufacturing equipment have been based upon Large Scale Production Units, a reviving interest of former Small Scale Cement Plant Technology comes into picture again. The Loesche Company in Germany has never stopped the supply of turn-key Vertical Kiln Plants even in industrial countries, since 1955 more than 10 Small Scale Cement Plants have been put into operation in 4 continents, based on Interground Fuel Process and improved Vertical Kiln Technology, in such a way that clinker quality does not differ from clinker quality of modern Rotary Cement Plants any more. These short report is to be understood as a concise summary of the many individual factors that decide the economical and infrastructural success of a Compact Cement Plant, based on Loesche Vertical Kiln.

They lead to the following conclusions:

- If market requirements are restricted to Small scale consumption, the installation of a Compact Cement Plant is indicated.

- The advantages of a Vertical Kiln Cement Plant are:
  - low investment costs
  - substantial savings in space
  - low operating costs
  - low maintenance costs
  - high degree of reliability (over 95%) due to long durability of refractory bricks

-high flexibility
-simple construction
-compact foundations
-no heavy castings
-low alcali cement can be produced

- The use of low cost, unspecified coal makes a Vertical Kiln Plant an up-to-date proposition in today's energy conscious world.

Düsseldorf, July 1980

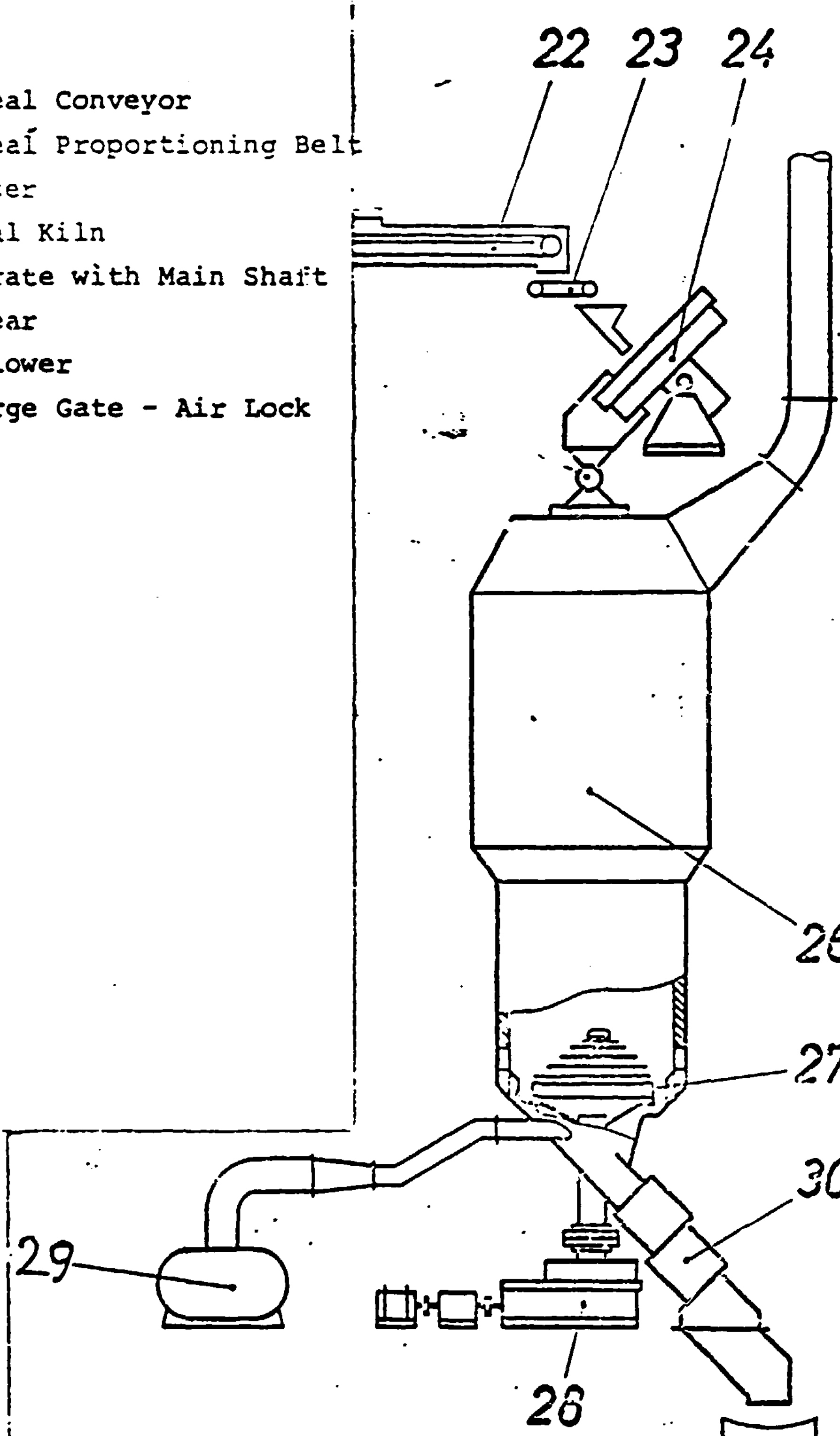
Horst Klatt

Process Engineer
of LOESCHE GMBH

Enclosures (Drawings)

Vertical Kiln
Vertical Mill
Compact Cement Plant

22 - Blackmeal Conveyor
23 - Blackmeal Proportioning Belt
24 - Nodulizer
26 - Vertical Kiln
27 - Step Grate with Main Shaft
28 - Main Gear
29 - Kiln Blower
30 - Discharge Gate - Air Lock



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COMPACT CEMENT PLANTS

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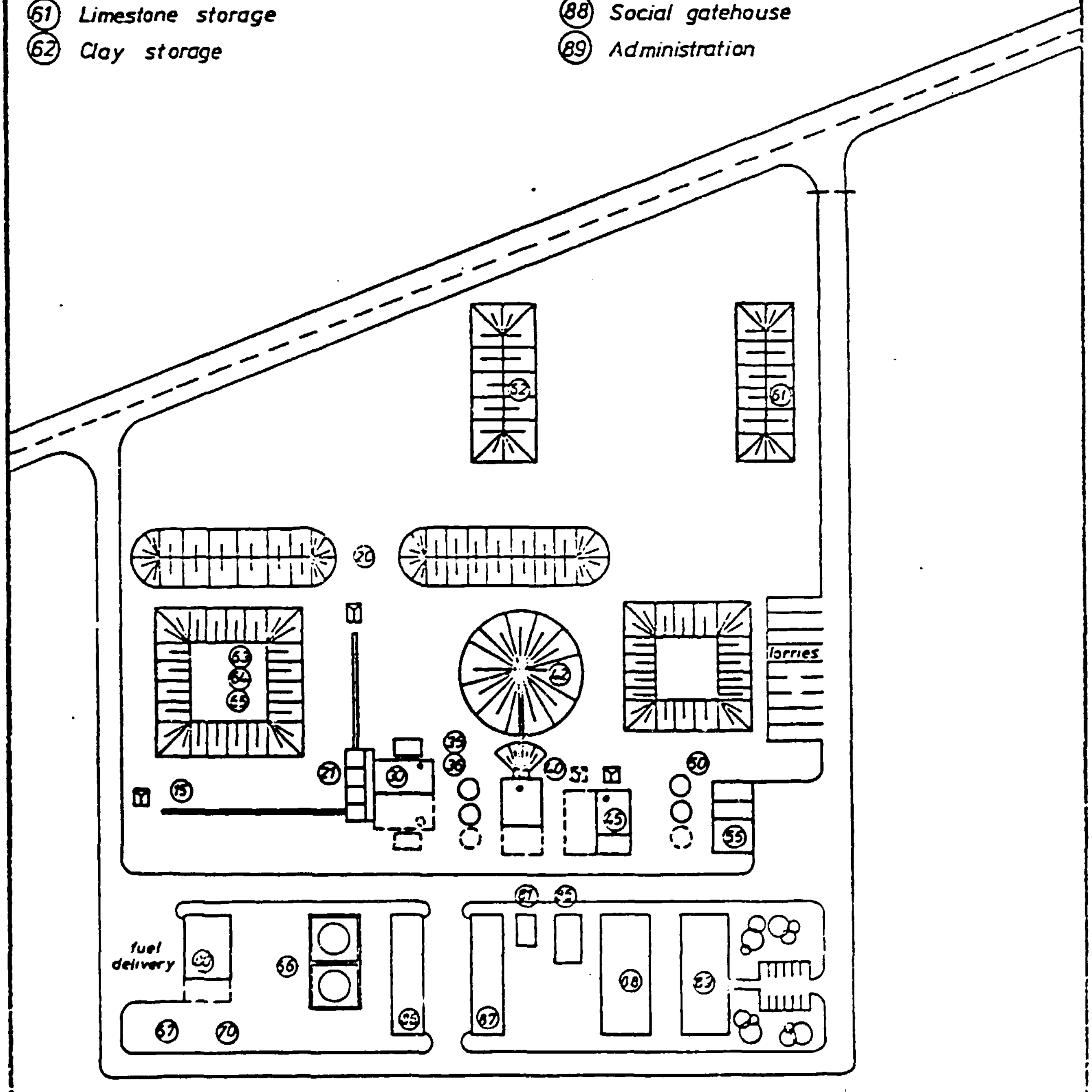
- (15) Coal and feeding
- (20) Raw material preblending
- (21) Raw material intermediate storage
- (30) Dry grinding plant
- (35) Raw meal blending silos I and II
- (36) Raw meal storage silos I and II
- (40) Vertical kiln
- (42) Clinker storage clinker and gypsum feeding
- (45) Cement grinding plant
- (50) Cement sotorage silos I and II
- (55) Packing plant
- (61) Limestone storage
- (62) Clay storage
- (63) Additive storage
- (64) Coal storage
- (65) Gypsum storage
- (66) Fuel storage and distribution
- (67) Water storage and distribution
- (70) Water supply drills and pump station
- (80) Power plant
- (81) Substation and electricity distribution
- (85) Laboratory
- (86) Workshop
- (87) Magazine material storehouse
- (88) Social gatehouse
- (89) Administration



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