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UNITED NATIONS INDUSTRIAL
DEVELOPMENT ORGANIZATION

MANUFACTURING GUIDE

LIME INDUSTRY[1]

by

Felix Sobek*

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* Consulting Engineer in Düsseldorf, Federal Republic of Germany, and in Austria.

1/ The following report gives the names of some of the firms which are known to manufacture and/or trade in this commodity, but the list should not be regarded as exhaustive. Inclusion in the list does not imply any recommendation by UNIDO. The views and opinions expressed in this paper are those of the consultant and do not necessarily reflect the views of the secretariat of UNIDO. This document has been reproduced without formal editing.

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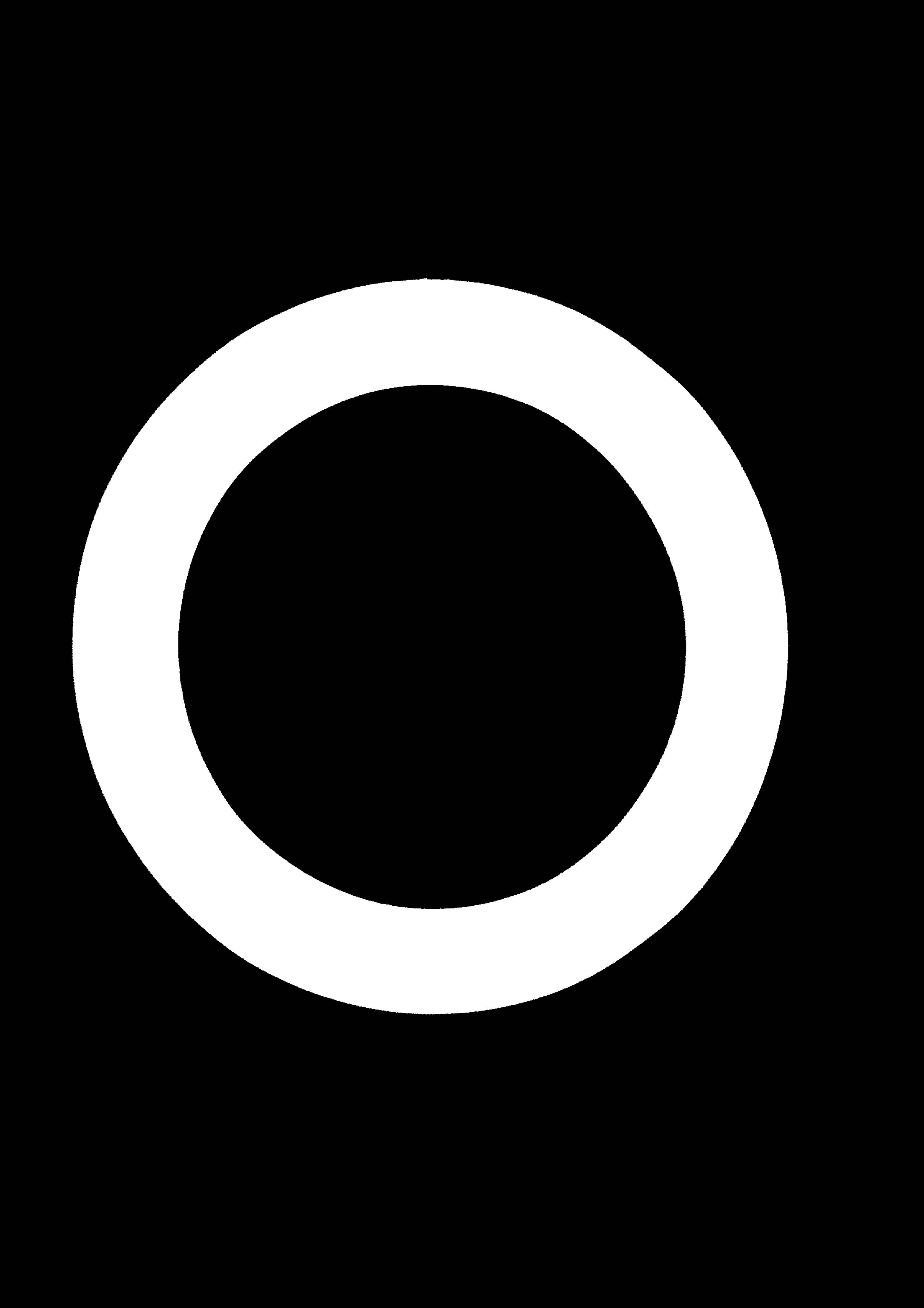

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1. Introduction

There is hardly anyone in the world who does not know the expression "lime". With the help of lime one can build houses and whitewash walls and it is also well known that it can be spread on soil as a fertilizer thereby improving the growth of plants because of the chemical or physical reactions.

There are certainly several other application possibilities for lime but these may well be either too complicated or not necessarily of interest to the non-professional to be discussed here.

How is it produced? You calcine it.

This simple process is nothing more than :

Limestone + heat = lime + carbon dioxide

The following guide should give all interested persons, private as well as governmental organisations and institutions, a general impression of the most modern technology for the production of quicklime and its by-products, as well as indications of the possibilities which exist to satisfy the growing demand for this product, particularly in the developing countries.

Had a patent bureau existed thousands of years ago, the people who lived in Mesopothamia (over 4000 years ago) could have claimed the rights to the invention of the manufacture of quicklime.

In this century quicklime and its by-products belong to the most important materials of traditional and modern production methods in the industrialized countries. This has forced the manufacture of lime in these countries to develop from its traditional stage - as was still practised in the past century - to the most modern techniques with a suprising speed.

It is no wonder then that this development has not run parallel with the non-industrialized countries because of their lack of greater production and quality requirements.

The need to catch up on industrialisation because of the population explosion in most developing countries, the fact that this development is being concentrated within a very short period of time, and the amount of fully detailed offers of very modern industrial equipment has led, in many cases, to hurried investment decisions.

The task of someone involved in the establishment and expansion of industry in developing countries should be, therefore, to adapt the recommendations to the individual need of the receiver to prevent incorrect investments being made.

A further aim of this publication is, therefore, to give information as to how an adaptation of the recommendations suggested can help overcome one of the development stages of this industry e.g. an adaptation to the present requirements, to the import possibilities and to the availability of raw material and fuel. This could preferably be accomplished by making use of the repeated possibility of introducing compromises to modernising older production methods and/or by simplifing modern technology.

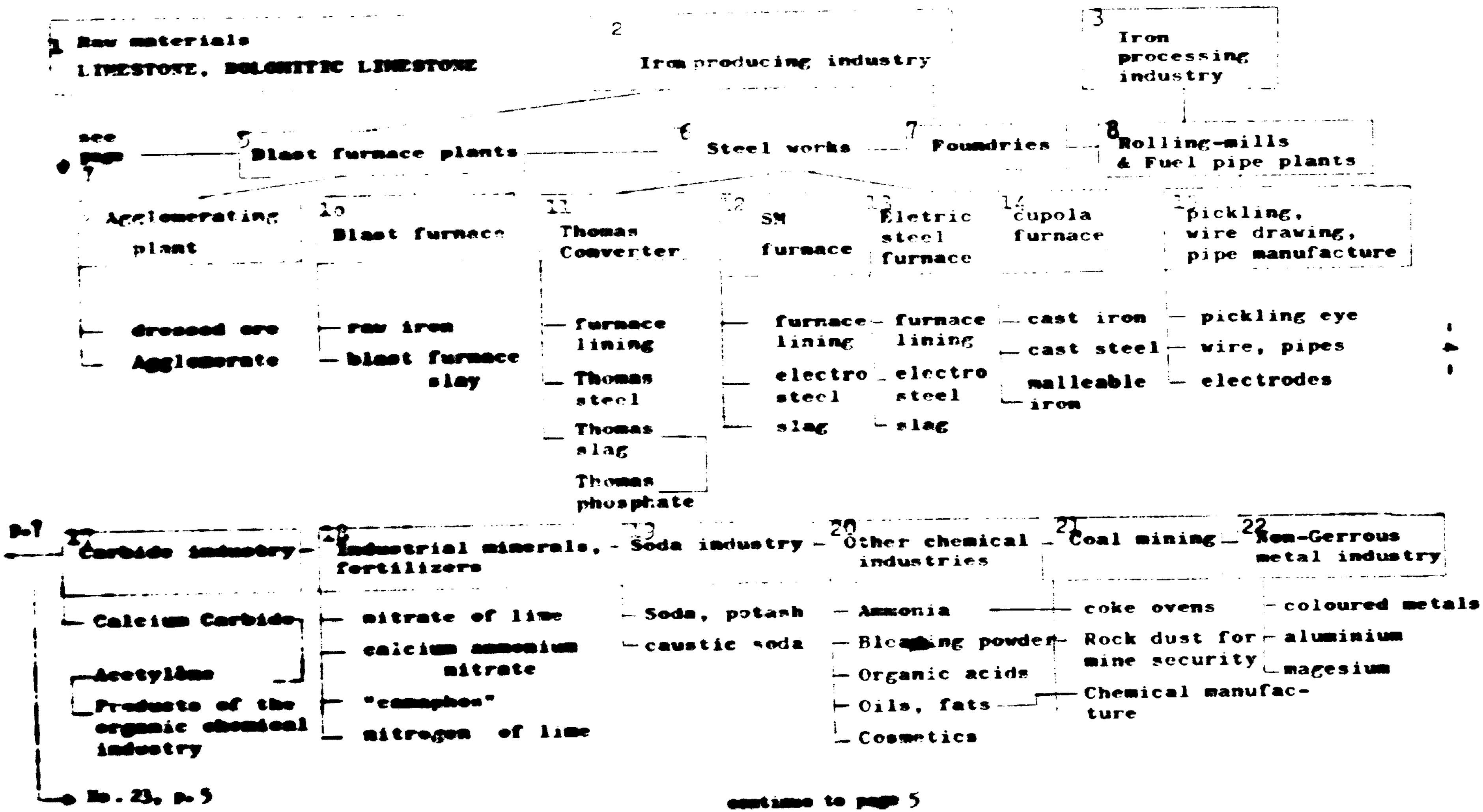
Market/...

2. Market.

Only when one realises how versatile the utilisation of calcium is as an indispensable element in our society will this guideline be of specific importance.

It is for this reason that the following schematic summary of the utilisation of lime and dolomite is given.

APPLICATION OF LIME AND DOLOMITE



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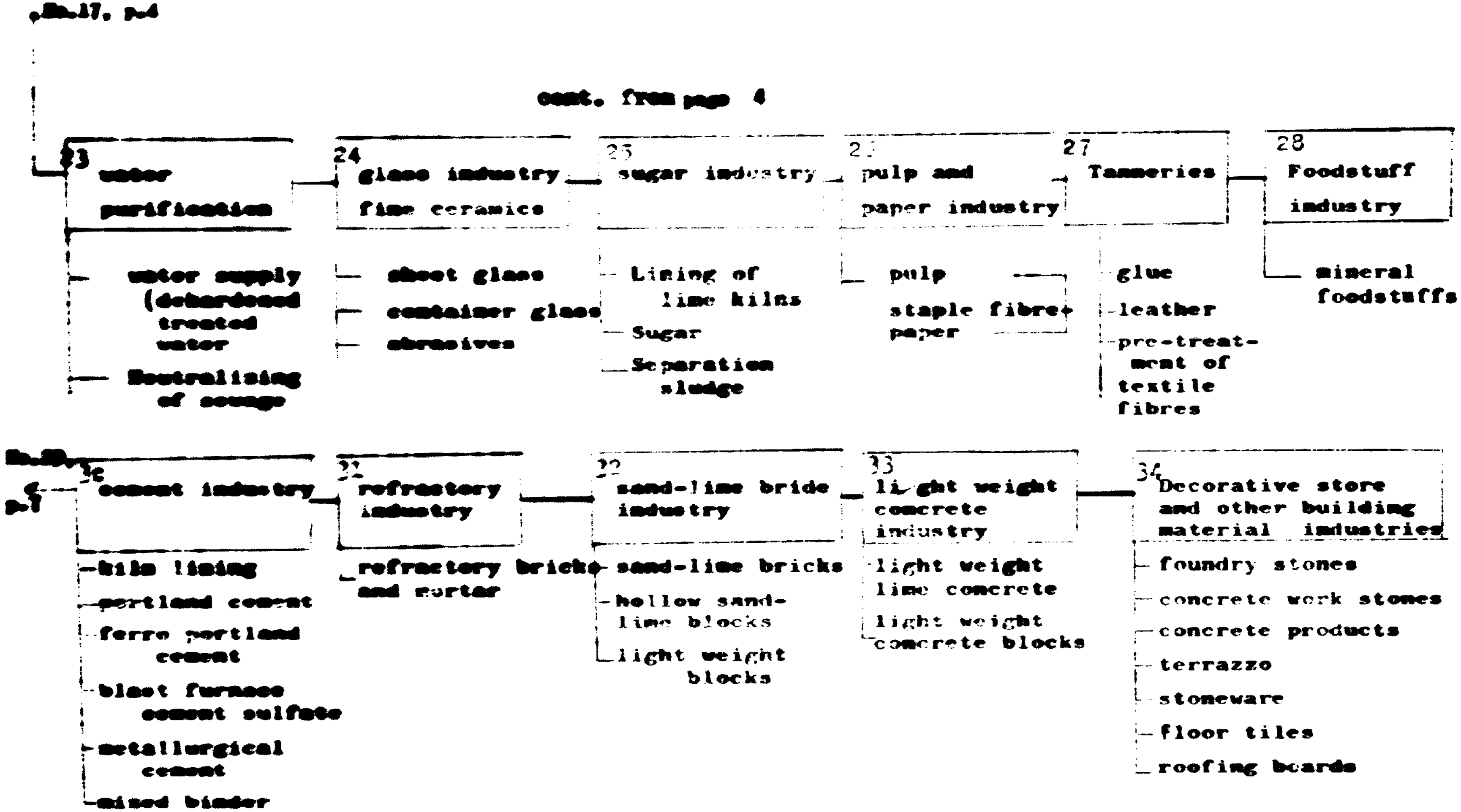

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4 Iron and steel industry

Limestone, dolomite limestone
(Blast furnace chips, foundry limestone)
Limestone, crushed
Quick lime, in lumps (steel works lime)
and crushed (agglomerating plant lime)
Sintered dolomite, in lumps and crushed
sintered dolomitic limestone

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16 Chemical industry and other industries

Limestone, dolomitic limestone, in lumps
and crushed, calcite, in lumps and
crushed, semi-acid dolomitic, calcined
lime and dolomite, in lumps and crushed
calcium hydrate
sintered dolomite, in lumps and crushed
sintered dolomitic limestone

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29 Construction materials industry

Limestone, dolomitic limestone, calcite,
in lumps, grains and crushed
semi-acid dolomitic air hardening and
hydraulically hardening lime
sintered dolomitic limestone

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35 Construction industry

Limestone, dolomitic limestone,
as rubble, ballast, chips, sand and flour
calcite and terrasso chips
tar macadam, asphalt macadam
semi-acid dolomite
air hardening and hydraulically hardening
lime

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41 Agriculture

Lime marl, magnesia marl
manuring limestone and dolomitic limestone
in lumps
manuring lime and dolomitic lime
slaked lime and dolomitic lime mixed lime
feed lime, poultry grit

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The/...

The construction industry is of primary importance because of its binding agent requirements. As a result, this industry is the primary consumer of lime. However, in such developing countries where lime has as yet not been produced and where in its place for instance cement has been used as a binding agent, it is becoming increasingly obvious that there is a tendency to work towards an independence of cement or clinker import.

In countries where cement is already being produced and where there is therefore no doubt about the availability of limestone deposits there is a clear tendency to establish lime industries, the purpose being to obtain a cheaper binding agent than cement.

Since the establishment of steelworks, chemical industries and refractory industries; since the discovery of soil de-acidification through lime; because of the advantage of addition of lime to animal feedstuffs; and in particular since the start of construction material industries with lime as raw material, the industrialization of the lime industry has developed, taking these new consumers into consideration.

It is consequently of the greatest importance to market policy to realize that the development of an industrialised lime manufacture is not, as in the industrialised countries, growing organically with the growth of the potential of the consumer industries. It is rather emerging sporadically as a newly founded industry.

The trend towards large kiln units with the purpose of obtaining a more favourable depreciation of the invested capital and thereby remaining competitive through correspondingly low sales prices should only be applied to developing countries after careful investigation, in spite of the validity of this consideration for industrialized countries.

The pre-requisite for the rational operation of high capacity lime kilns is a corresponding consumer market which should be divided preferably among a number of different consumer industries. With regard to continuity, steel works and the chemical industry are normally more stable consumers than the construction industry which is liable to reduce its activity during the winter period in the polar and temperate zones.

In sub-tropical and tropical zones significant variations in the consumption of the construction industry can be registered due to the influence of rainy seasons and the like.

When conducting market surveys, and especially when a significant part of the production of the new or expanding manufacture is meant for export, it is recommended that market surveys also be conducted in the importing countries, in cooperation with the authorities of that country.

While it is relatively easy to obtain the consumption figures of the lime consuming industry, it is generally more difficult to get exact information about the requirements of the construction industry.

At all times over or under estimates should be avoided and it is recommended that use be made of the help provided by governmental offices and institutions.

This/...

This provides, at least as far as public construction plans are concerned, a possibility of assessing relatively accurate consumption figures based on the amount of anticipated construction works calculated as cubic metres of wall.

When the private construction sector is predominant, estimates of the volume of walls to be constructed within a certain unit of time can be calculated by the application of multiplication factors adjusted with due regard to future tendencies.

The method of calculation of the consumption of lime can be seen in a few actual figures in the following table. The mortar required for a given wall structure is calculated by means of factors showing the ratio between consumption of mortar and wall area or wall volume.

The amount of lime used for masonry mortar or plaster work mortar is finally calculated on the basis of the thickness of the plaster coat for internal and external walls and for ceilings, the mortar requirement for the plastering, and the usual proportions of sand and lime.

It is, of course, impossible to deal with all types of building stones. The following table shows the mortar consumption of masonry of full bricks.

Wall thickness cm	Brick dimensions cm			Format symbol	Building material requirement per 1 m2		Building material requirement per 1 m3	
	L	W	H		pieces	litres	pieces	litres
5,2	24	11,5	5,2	DF	33	12	—	—
7,1	24	11,5	7,1	NF	33	14	—	—
11,5	24	11,5	5,2	DF	66	26	—	—
	24	11,5	7,1	NF	50	24	—	—
12,0	25	12,0	6,5	RF	52	25	—	—
24,0	24	11,5	5,2	DF	132	64	550	270
	24	11,5	7,1	NF	99	60	412	250
36,5	24	11,5	5,2	DF	190	105	541	285
	24	11,5	7,1	NF	149	96	407	261

<u>Exterior plastering</u>

Particularly in tropical countries with heavy rainfall attempts are being made to protect the masonry by means of exterior plastering of greater thickness, an average being 20mm. It can be assumed that

the/...

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7,1	24	11,5	7,1	NF	33	14	—	—
11,5	24	11,5	5,2	DF	66	26	—	—
	24	11,5	7,1	NF	50	24	—	—
12,0	25	12,0	6,5	RF	52	25	—	—
24,0	24	11,5	5,2	DF	132	64	550	270
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Particularly in tropical countries with heavy rainfall attempts are being made to protect the masonry by means of exterior plastering of greater thickness, an average being 20mm. It can be assumed that

the/...

The same thickness is averaged for the plastering of exterior ceilings. It is unrealistic to have too thick a layer as, due to their excessive weight, such layers may become detached from their foundations because of vibrations.

Interior plastering

The thickness of the plaster is generally related to the smoothness of the plaster backing but can, in most cases, be assumed to have an average of 15mm.

The plastering of interior ceilings should not exceed 15mm, not even in cases where fire-retarding or fire-resistant ceilings are required. The plastering thickness is assumed to be the layer of mortar from the surface of the plastering to the backing.

In the following table some reference figures for mixing proportions between lime and sand in masonry and plastering mortar are quoted :

Masonry mortar

(Mixing proportions in volumetric units)				
Lime putty 1,3 *	Hydrated lime 0,6 *	Hydraulic lime 0,8 *	Highly hydraulic hydrated lime — Roman lime 1,0 *	Sand ** (fine natural sand 1,3 *
1				3,5
	1			3
		1		3
1,5				8
	2			8
			1	3

Litre/...

* Litre weight (kg/l) which should not be exceeded by calculation of the mixing proportions.

** The figures stated for the sand component are only meant as a guide. Variations of up to 20% are possible depending on the type of sand used.

Plastering mortar

Type of mortar	Lime putty	Hydrated lime	Hydraulic lime	Highly hydraulic hydrated lime — Roman lime	Sand
litre weight of components 1) (kg/dm3)	1,3 2)	0,5	0,8	1,0	1,3 3)
Lime mortar	1	or 1			3,5 3
Hydraulic lime mortar			1		3
Roman mortar				1	3
Standard mortar for further cement addition	1,5	or 2			9

1) Litre weights in kg/dm^3 which are used as the basis for the calculation of weight units from volumentric units when the actual litre weights are unknoom.

2) At a moisture content of approximately 50% based on the wet weight.

3) A moisture content of 2-5% by weight.

Ram/...

3. <u>Raw materials.</u>

It is probably necessary to mention in which periods of the Earth's history exploitable deposits of limestone and dolomite were found since this gives some information about the raw material used in the lime industry.

The various formations of limestone, dolomite, chalk, tufaceous limestone and travertine were created during a period of approximately [illegible]0 million years beginning in the period of Precambrium and extending through the Paleozoicum and Mesozoicum periods into the present time.

Limestone is a fine to coarse crystalline rock, the main constituent of which is mineral calcite.

When a new lime industry is to be established it is recommendable to search for such limestone deposits which not only have chemical compositions which show the highest possible percentage of

Calcium carbonate, $CaCO_3$, but also have a physical structure which satisfies the static and dynamic requirements of the calcining process.

If calcium carbonate is found in the combination calcium-magnesium carbonate, $CaCO_3$ $MgCO_3$, the material is called

Dolomite. Dolomitic limestone consists of calcium-magnesium carbonate compositions with varying quantities of $CaCO_3$ and $MgCO_3$.

[illegible]/...

The calcination of such materials often presents many difficulties since the temperature at which the $MgCO_3$ component starts to release CO_2 is below 800°C, and the process is terminated at a lower temperature than that of the more stable $CaCO_3$.

Chalk, which has been deposited from a slurry of calcium shells of small creatures, is often found in a very pure form. However, because of its extremely soft physical structure problems often arise during the calcination, particularly in lime shaft kilns of larger dimensions where the resulting abrasion causes difficulties in the transport of the gases because of the formation of dust.

Marble, a coarse-grained, very hard material, is in every respect a good raw material for the manufacture of lime as is

Shell limestone which consists largely of shells. Because of its density, this raw material treats well and has an even lower abrasion percentage than marble during the crushing and calcining process.

To the limestones of low density and high porosity belong :

Travertine or tufaceous limestone which, in particular, presents transport problems in connection with continuous firing processes such as in oil or gas fired shaft kilns. However, on the other hand, because of its porosity it requires less time for calcination than do more compact types of limestone.

The/...

An important factor is the consideration of the various geological structures of raw materials suitable for the manufacture of lime should be taken into account when the careful selection of the firing technology and the size of the kiln shaft is made.

[illegible]

In the event of no geological maps or similar information being available in connection with larger industrialization projects, it is advisable to determine the size and quality of deposits by means of systematic drillings.

Investigations can be carried out without any greater expense if already existing quarries are going to be improved or operated in a more rational way. A well-planned establishment of checking trenches may, in such cases, give valuable investigation results. Such checking trenches are extended horizontally into unexploited rock to a width the size of a man's body. Occasionally it is sufficient to remove the grass and the humus layer to determine the extension of the surface of the deposit. Samples obtained in this manner can, in the same way as samples from drillings, be subjected to chemical analysis and the results compared with the analyses of the present quarry exploitation.

[illegible]

A complete chemical analysis comprising the following components, particularly in connection with the opening of new quarries, should be carried out :

Calcium/...

Calcium oxide	CaO
Magnesium oxide	MgO
Silica	SiO_2
Aluminium oxide	Al_2O_3
Ferric oxide	Fe_2O_3
Sulphur trioxide	SO_3
Phosphorous pentoxide	P_2O_5
Sodium oxide	Na_2O
Potassium oxide	K_2O
Carbon dioxide (loss of ignition)	CO_2
Water	H_2O

Quality of the raw material

The required quality of the finished product will determine whether the quality of the raw material is high enough for the manufacture of quicklime.

The highest quality raw material and a high degree of calcination is required by the iron and steel industry, to a certain extent by the chemical industry and, last but not least, by the construction material industry.

Contamination of the limestone is one of lesser importance when the calcined product is to be utilized in the construction industry. However, in the latter industry reasons of profit impose an upper limit of 10 impurities in the raw limestone because of the correspondingly low content of $CaCO_3$ and $MgCO_3$ (below 90% and sometimes even lower than 80%).

Even though specific fuel requirement depends on the percentage of the calcinable fraction, the total fuel consumption will also

include/...

is the additional fuel required to heat the inert material which must be dragged through the entire firing process as ballast.

If the amount of impurities increases steadily the result will be that the profitability of the mining, dressing and transport of the material will prove questionable.

When the limestone in a quarry area is of varying quality selective mining can be unavoidable yet necessary.

The already mentioned fact that the specific fuel requirement depends on the percentage of calcinable raw material will, if differences in quality are disregarded, lead to over-firing or under-firing of the product. This means that the input of fuel can only remain constant in cases where the percentage of $CaCO_3$ and $MgCO_3$ in the raw material fed to the kiln is constant.

<u>Problems and economic aspects of transportation</u>

An overall plan for the establishment of a lime manufacturing unit will usually depend on the quality and exploitability of a deposit.

In fortunate cases the main consumer and the deposit are situated within an economic distance of each other. The transportation of consumable production supplies is then of secondary importance since the fuel, which by weight constitutes the largest portion of these, does not amount to more than 10-15% of the finished calcined product.

In most cases, however, a compromise is required. This results in the limitation of quality for the benefit of easier transportation of the finished product. In cases such as these rationalisation

[illegible]/...

of the internal transport and a well-planned factory layout provide a certain compensation.

An important principle should be that the calcining unit always be situated close to the raw material deposit, if conditions permit, in order to take advantage of the fact that limestone normally loses at least 40% (theoretically 43.9%) of its weight during the firing process. This is due to the leakage of carbon dioxide.

In large scale mining the continuous retreat of the quarry walls where the actual mining is taking place will create the problem of a constantly growing distance between the pile of blasted material and the fuel hopper of the crushing plant. This means that in large scale production the pre-crushing plant must be able to be moved with the quarry wall.

This example, which is of particular relevance to the cement industry should, however, also be considered in connection with smaller production units. In the event of manual raw material dressing being necessary at the mining site as is normal in such industries, the problem of raw material transport from the quarry to the kiln can only be solved by a suitable means of transportation.

Transport equipment such as trucks, dumpers, etc. have large depreciation costs and therefore rank high on the list of production costs.

[illegible]

It is inadvisable to start immediate blasting of limestone at a random site as soon as the decision to mine a certain deposit has been taken.

Gm/...

On the contrary, a careful and detailed overall plan for the mining operation should be prepared by determining the anticipated level of the quarry floor, solving the problem of removal of overburden, establishing a plan for drilling and blasting and planning the loading and transport of the material.

The correct planning of these activities is a pre-requisite for the rational operation and low production costs, no matter if the mining and manufacture are to be on a large, medium or small scale.

Many good deposits have been exhausted in a short time because the quarry floor, for reasons of convenience, was established at too high a level and the removal of overburden was not properly planned.

Drilling and blasting

Limestone, being a medium hard rock, can normally be mined by means of blasting.

The three usual methods are :

chamber blasting
blasting in series
blasting in large boreholes

Of these, blasting in series and in large boreholes belong to the blastings with so-called extended charges because of the way in which they are carried out, while chamber blastings are performed with so-called demolition charges.

Even though the application of one or other type of blasting is

based/...

based on the structural characteristic of the massif, the chamber blasting is also often used in such cases where this method, because of a loose structure, creates an outwards directed explosion of the wall combined with a high percentage of shattering of the rock.

The reason for this is that the preparation of boreholes is complicated and expensive, particularly in smaller works which depend mainly on manual operations or only have insufficient equipment at their disposal.

In this connection the fact that chamber blasting consumes a larger amount of explosives with a lower degree of efficiency than do the other blasting methods should be taken into consideration.

However, when the structure of the massif so allows, the multiple chamber blastings can nevertheless prove quite economical since the yield of material lies between 25 and 35 tons per man per hour.

The consumption of explosives is estimated at 0,30 to 0,35 kg per solid cubic metre in such blastings. In this case, however, a higher number of large boulders are to be expected as a result and further explosives will have to be used for the re-blasting of these.

Blasting in series is generally preferred in spite of the higher wage intensity and the lower yield of only 5-10 tons per man per hour.

The reason for this is the lower consumption of explosives which depends on the structure of the massif, on the depth of boreholes

and/...

and on the distance of the boreholes from each other as well as from the quarry wall.

A quarry which is laid out in terraces provides easy access and offers good and safe positions from where the miner in charge of the blasting can conduct and supervise the work.

Particularly in developing countries frequent electric power failures should be taken into account as these render electrical equipment somewhat unreliable and compressors driven by explosion engines are not always part of the equipment of the mining companies.

Hammer drills, driven by gasoline engines, are often used but these are difficult to move around and to operate due to their large volume. In spite of these shortcomings, blasting should be carried out as blastings in series in a quarry of well laid-out terraces whenever possible.

Blastings in large boreholes are performed in a manner similar to those of blastings in series but making use of drilling equipment which can be sharpened and is moveable.

The diameter of the borehole can reach 300 mm and the length is usually 25-45 metres or more.

An operation with large borehole blastings will require a minimum output of 1000 tons per day in order to be profitable and presupposes loading and transport facilities of a correspondingly large scale.

Explosives/...

Explosives

Dynamite has been and still is often used as an explosive, as is occasionally gun powder, in many parts of southern Europe and in developing countries. Since the 1960's a mixture of ammonium nitrate and carbon known under the name of ANX has been used in increasing amounts.

The so-called slurries which are a mixture of TNT, ammonium nitrate, sodium nitrate, water and a binder are used particularly in the United States.

The advantage of slurries is that they can be loosely filled into the boreholes. However, now, as before, the use of dynamite ignited by detonators and fuses or by electro-detonators and a dynamo is a widely used method.

Dressing and stock piling

Many possibilities exist between the dressing of the raw material with mallets and the hand picking of the right sizes of stones, and mechanised and automatic crushing and screening equipment. Apart from the size of production, other factors such as the depreciation period of the invested capital, various social considerations and the available source of energy play an important role.

These considerations are closely connected to the required stock of dressed raw material prepared for calcination.

The degree to which the calcining unit of a partly or fully mechanised plant is necessarily independent of the crushing and screening equipment, determines the size of the raw material silos.

This/...

This, translated into terms of a predominantly manual plant, means that the extraction of the rock, the amount of labour employed in the crushing operation, the hauling of crushed material to the vicinity of the kiln and the piling of the raw material prepared for calcination, should be related to the desired independence of the calcining unit of the preceding operations.

In both cases certain importance must be attached to the influence of weather conditions on the prepartory activities as well as leave days (especially several in a row) although these do not effect the calcining operation.

A mechanical crushing and dressing plant consists fundamentally of a crusher which is situated below street level and is fed by means of a chute. The material crushed to the maximum required grain size is transported by means of a conveyor belt to a multiple deck screen, or several deck screens, which is normally situated on top of a battery of silos in such a way that individual grain fractions fall into separate silos.

The various fractions can now be extracted from the silos by chutes and, depending on their size, be supplied to the individual consumer as stones for calcination, ballast for road construction, chips for road surfaces, etc.

4. <u>Process technology</u>

It would prove far too detailed to list and describe all the existing technologies within the limits of this guide. Simultaneous development in various countries and in particular the geographic distances between such places of development has resulted in older technologies being further developed, in many cases rather well, without their becoming

known/...

known outside the boundaries of these areas.

The present Manufacturing Guide to the Lime Industry will not be limited to one process but will give a universal evaluation of the application of modern calcination technologies in developing countries.

The following technologies are listed alphabetically according to the names of their inventors or kiln manufacturers :

Azbe system

Azbe Corporation, St. Louis, Missouri , USA

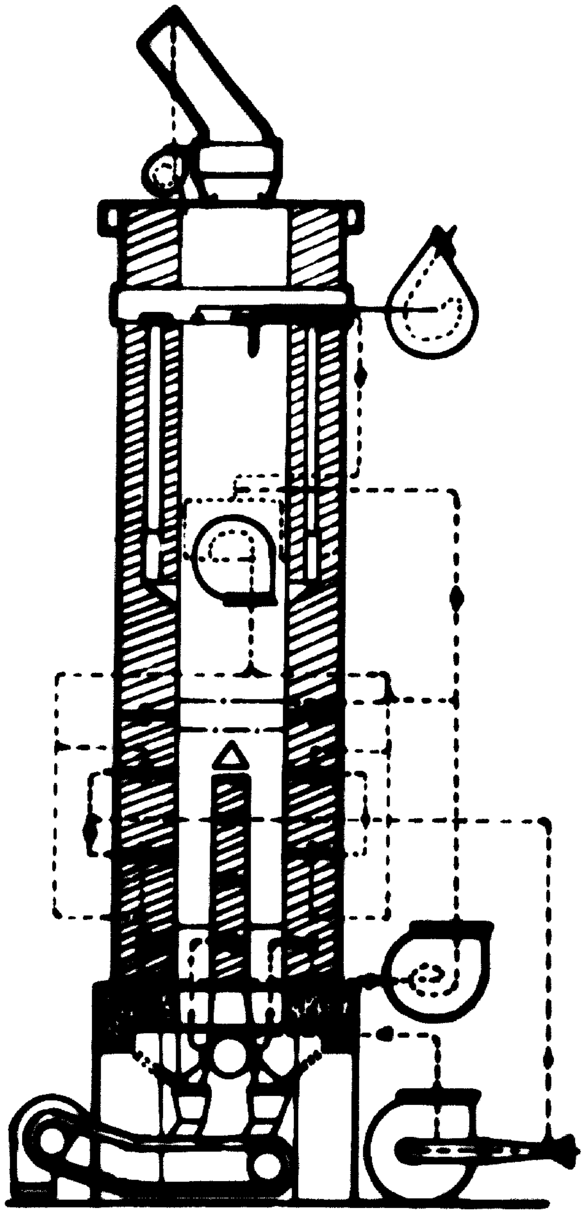
The most important feature of this kiln is that the lower part of the shaft is divided by a vertical wall of refractories. Installed in this wall is a fuel oil gasification chamber into which a hot mixture of exhaust gas and air is injected.

The mixture is produced by extracting the hot exhaust gas from the shaft at the base of the pre-heating zone and by adding to it the required amount of cold primary air. 65% of the air rises through the cooling zone while the remaining 35% reaches the kiln together with the exhaust gas by means of a circulation fan. A large proportion of the atomised oil evaporates in the gasification chamber but because of oxygen deficiency is only a fraction of the oil burned within the chamber.

The oil gas emerges from the chamber through the ports and enters the column of material where it is burned in the calcining zone of the kiln.

Type of fuel : heavy fuel oil.

Beckenbach/...



Azbe system

Beckenbach system

Dipl. Ing. Karl Beckenbach, 4005 Büderich, Fed. Rep. of Germany

The most important feature of this kiln is an internal shaft in the centre of the round shaft which gives the effective volume of the kiln an annular cross section.

The combustion chambers are radially situated in the external shell and open into refractory bridges which connect the internal with the external shaft. Two levels of combustion chambers are situated on top of each other.

The spaces below the connecting bridges are free from material which facilitates the smooth entry of the combustion gases into the material. It is also noteworthy that the two combustion levels create three individual calcining zones of which the two upper ones operate in counter-flow while the lower one operates in parallel-flow.

The parallel-flow in the lower part of the shaft is created by means of injectors. The air which enters the kiln through these injectors is pre-heated in recuperators. A mixture of cooling air and combustion gases is drawn from the shaft above the top burners and is returned to the shaft below the combustion chambers.

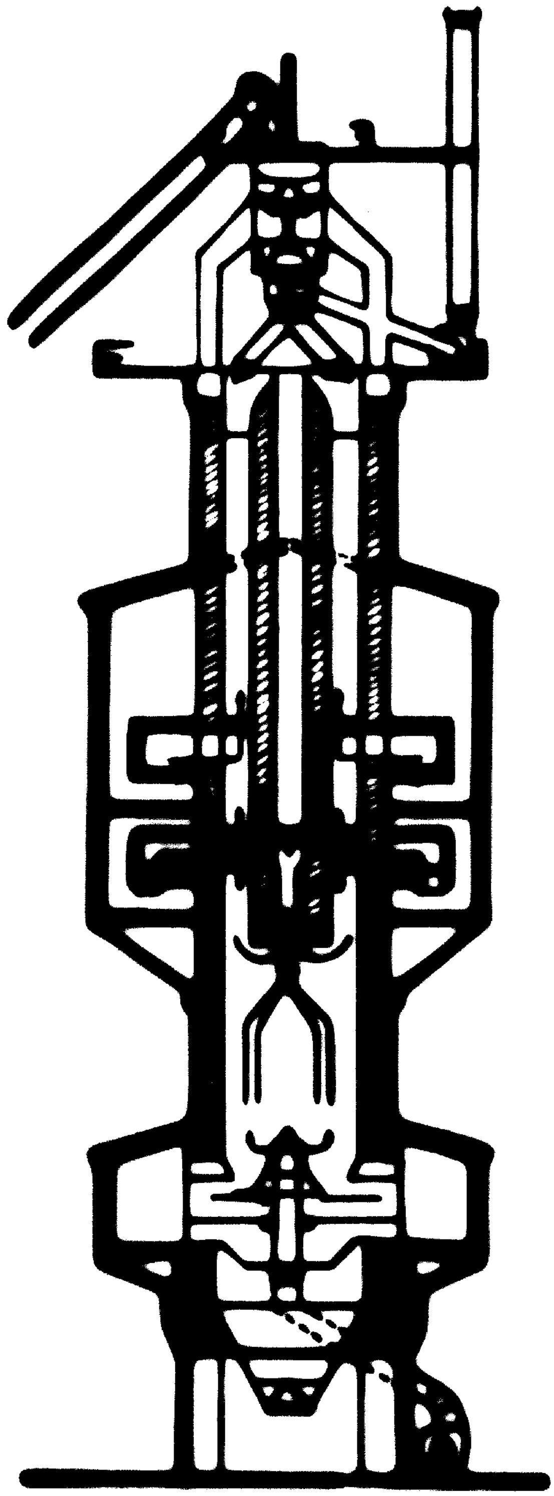
Type of fuel : heavy fuel oil and gas.

Fiedler system

Fiedler KG., 6368 Bad Vilbel, Frankfurt, Fed. Rep. of Germany

The most important feature of the kiln in this system is the

rectangular/...



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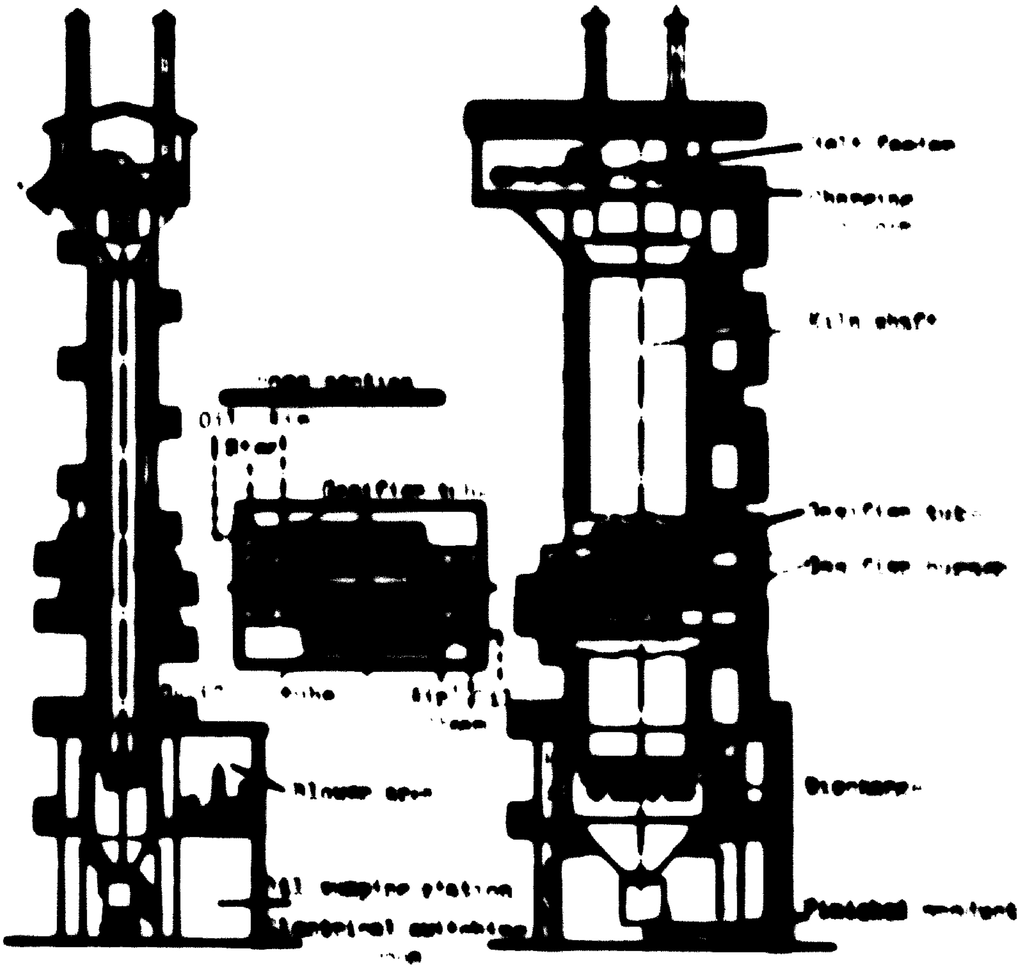

Oil
Kiln shaft

rectangular cross section of the shaft which has been designed with a ratio between length and width of 1,6 : 1, with a view to attaining complete contact between material and gases.

The technology of the kiln is based on combustion of the fuel in stages in counter-flow; several oil gasifiers are placed above each other alternatively on both sides of the kiln. The oil gas is supplied to the kiln mixed with an air volume equal to 0,5 of the oil gas volume.

Cooling and combustion air is blown into the shaft at its base. In this way the combustion of the oil gas takes place in direct contact with the material.

Type of fuel : heavy fuel oil and gas

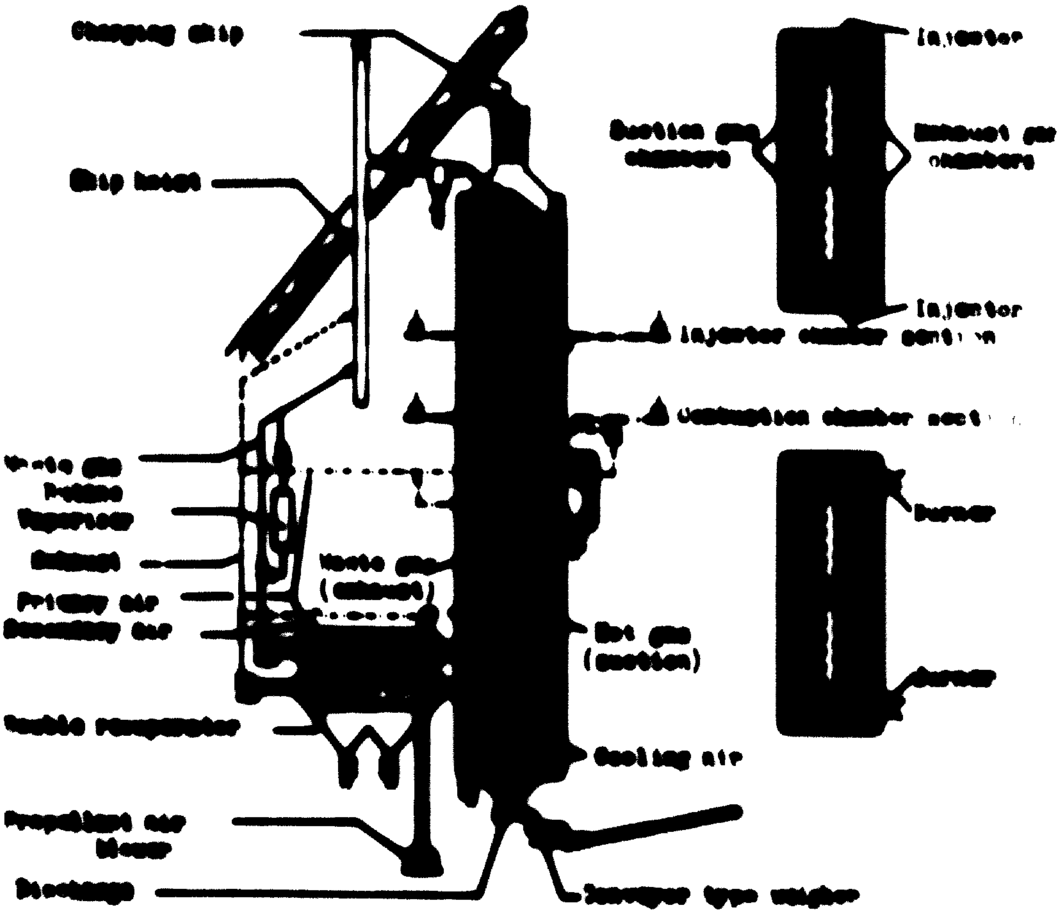
[illegible] transverse-flow kiln system

Produced by : Powerfect Ges.m.b.H., 6673 Kirkel/Saar, Fed. Rep. of Germany

The most important feature of this kiln is that the reaction gases do not reach the material in counter-flow or parallel-flow but pass through the material in transverse-flow from left to right in the upper part and from right to left in the lower part of the shaft.

For this purpose the rectangular kiln shaft is divided horizontally into exhaust and suction gas chambers with partition walls constructed like a grate. This allows gases through the material situated between the grate. By separating the gas chambers at approximately the middle of the shaft it is possible to divide the gas flow into

two/...


Injector
Injector

two and thus let it pass through the material from both sides.

Type of fuel : heavy fuel oil and gas.

The parallel-flow regenerative kiln

[illegible]

Produced by : Maerz Ofenbau, Zurich, Switzerland.

The most important feature is that this multiple shaft kiln consists of at least two shafts.

Two shafts, interconnected by a channel, are filled with stone. These shafts are fired alternatively in parallel-flow from the furnace mouth at the top of the shafts at intervals of several minutes. The exhaust gases pass through the connecting channel and through the second unfired shaft in counter-flow, pre-heating the material, and return to the furnace mouth. The charging is carried out alternately during the reversal operations.

The discharging of the lime from both shafts is continuous.

The cooling air is blown into both shafts simultaneously from the bottom.

Type of fuel : heavy fuel oil and gas.

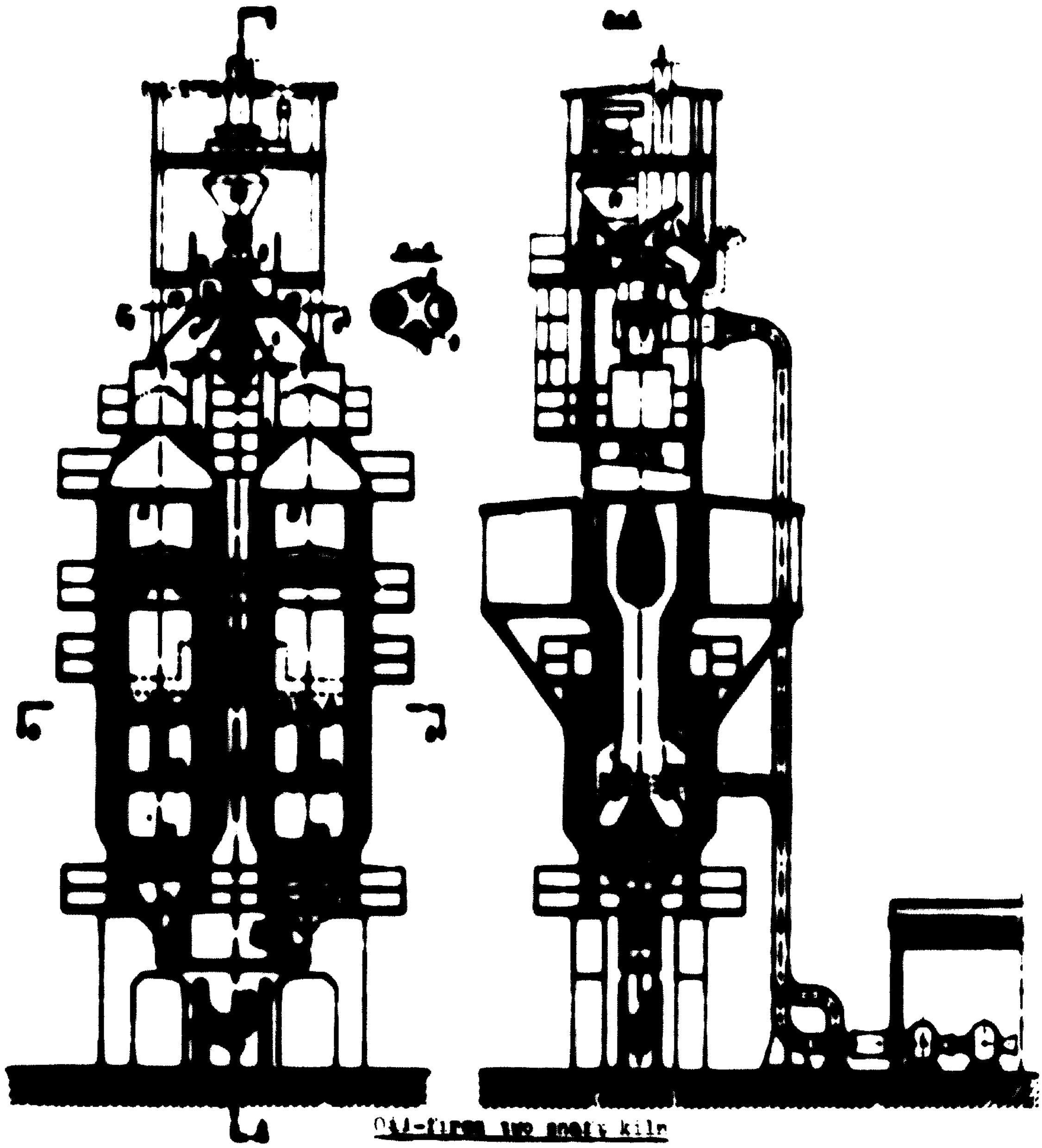
[illegible]

Produced by : [illegible] AG., Fed. Rep. of Germany.

Industrie Ofenbau, Ges.m.b.H., Düsseldorf, Fed. Rep. of Germany.

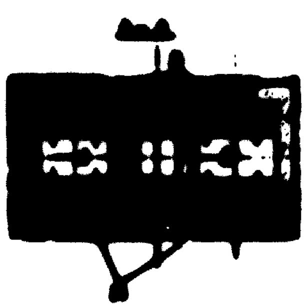
[illegible] AG., Siegen, Fed. Rep. of Germany

The/...

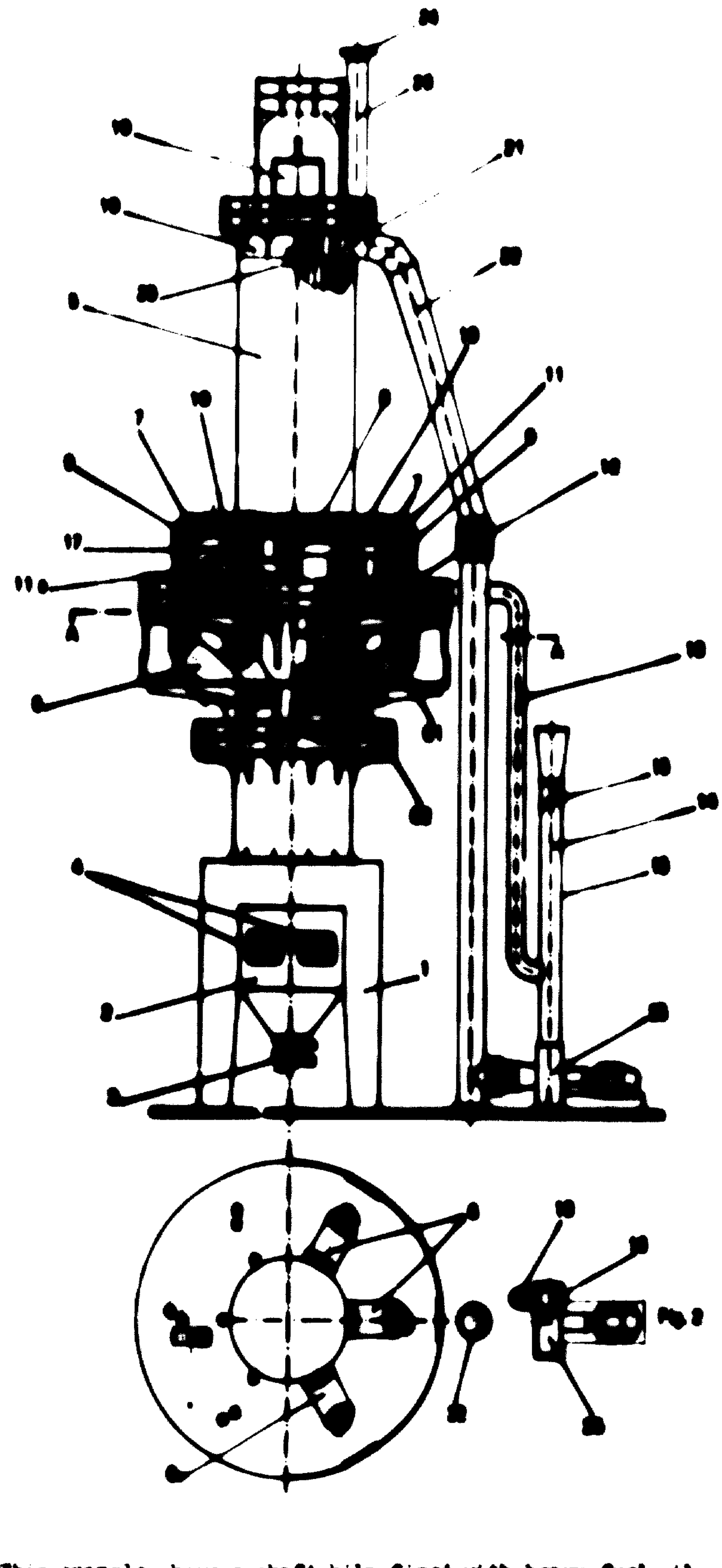


Oil-fired two shaft kiln

A, B Kiln shafts
1. Fixed lower section of throat
2. Lifting and rotating reversing bell
3. Cover plate for 1
4. Inlet port for air and materials and exit port for waste gases
5. Intake line for air of combustion
6. Stack
7. Hydraulic cylinder for 2
8. Connecting piece to stack
9. Feed hopper
10. Drop bottoms of 11
11. Weighing bunker
12. 13. Dischargers for 14 and 15
14. 15. Limestone containers
16. Limestone discharge bunker
17. Joint faces
18. Ignition arch
19. 20. Admission pipes for cooling air
21. 22. Double push trucks for limestone discharge



3. Supply pipe for cooling air
4. Connecting ducts between A and B



Interofen
Entbmt.

[illegible]

1. Kiln base
2. Collecting hopper
3. Hopper discharge
4. Inlet louvres for cooling air and secondary air of combustion
5. Kiln shaft
6. Reactors for gasification of oil
7. Feed pipe for primary
8. Ring main for primary
9. Feed pipes for cleansing gas
10. Ring conduit for carrier gas
11. Semi-circular conduit for carrier gas
12. Carrier gas blower
13. Rising pipe for carrier gas
14. Space for accumulation of waste gas
15. Butterfly valve
16. Waste gas stack
17. Carrier gas feed pipe
18. Kiln throat
19. Charging valve
20. Bell
21. Waste gas suction duct
22. Down pipe for waste gas
23. Emergency stack
24. Safety valve
25. Waste gas exhauster

This example shows a shaft kiln fired with heavy fuel oil with 6 gasification reactors

The most important feature of the kiln of this system is that no matter whether the fuel is oil or gas the exhaust gases of the kiln are carburetted into combustion gases of corresponding low calorific value which can be supplied directly to the kiln.

By separate control of volume and pressure of the combustion gases as well as of the exhaust gases which influence the kiln atmosphere, a uniform flow of gases through the material is achieved.

Through the technique of producing a combustion gas of any desired calorific value, the process temperature can be controlled and the product manufactured with variable degrees of calcination.

Type of fuel : heavy fuel oil and gas.

Union Carbide system

The most important feature of this system is that the fuel is supplied to the centre of the shaft through water-cooled burner beams.

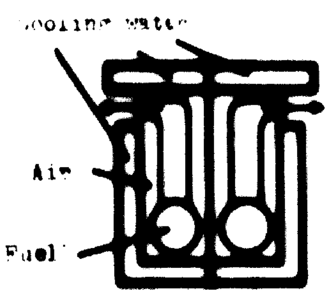
By means of this technology it is possible to construct kiln units producing up to 600 tpd. The burner beams of this technology should be particularly emphasised since it is their design which makes the establishment of shafts for such large outputs per unit possible.

It is, of course, necessary to cool the burner beams continuously as particularly the ones situated in the upper calcining zone are exposed to the full reaction temperature.

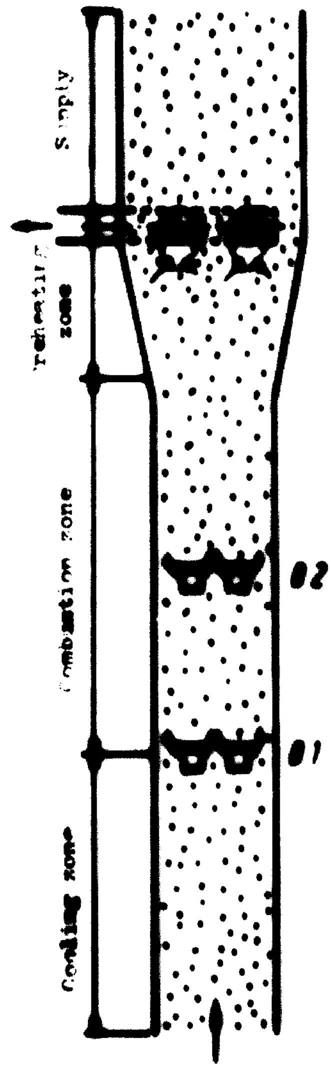
The gas exit parts are replaced by small burners when oil is used as a fuel.

Type of fuel : heavy fuel oil and gas.

p33/...



Burner beam
(diagrammatic)



Union Carbide system

__West system__

West's (Manchester) Limited, Manchester, United Kingdom.

The most important feature of this system is that the heavy fuel oil is brought to gasification in pipe-shaped chambers by being sprayed on the wall of the chamber through a circular rotating nozzle which extends into the chamber and points towards its exterior.

The pipe-shaped chambers which are pointing downward at an inclined angle are heated to the cracking temperature of the oil through radiation from the glowing material in the kiln.

Suction in the shaft results in the gases being drawn out of the gasification chambers into the material in the kiln.

Type of fuel : heavy fuel oil

All these kilns have several things in common. Some of the features are similar, nothing is entirely different and the degree of efficiency of all is high. How the efficiency of a kiln is calculated will be shown in the following notes.

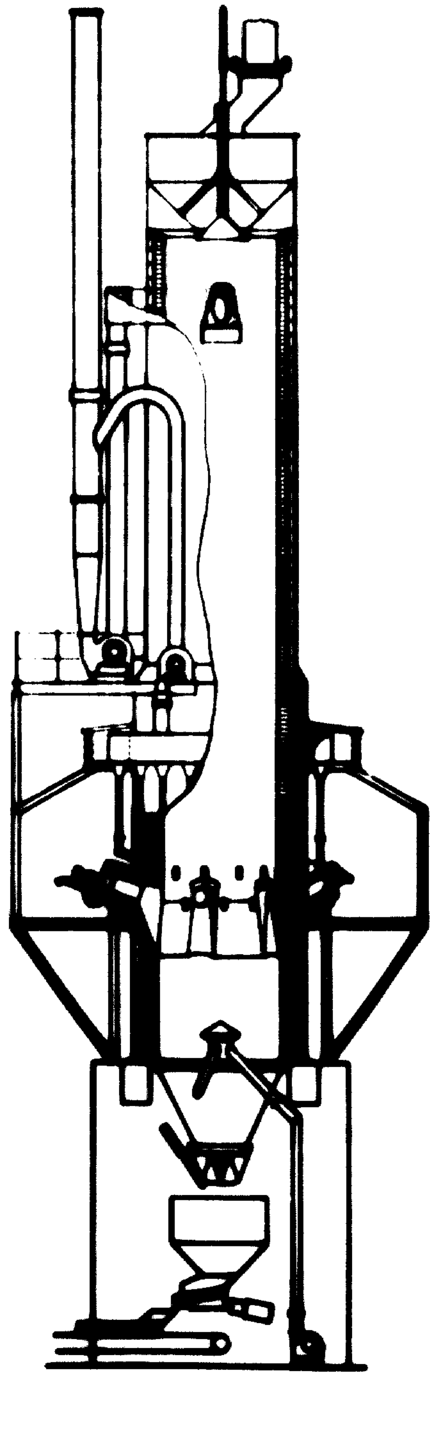
The specific fuel consumption is low and falls between 900 and 1100 kcal/Nm^3 depending on the actual efficiency.

The quality of the products corresponds in every respect to the high requirements demanded because of the sophisticated processes which are controlled by the most modern measuring and control equipment.

A result of the high degree of automation is that the labour requirement is extremely low (one or two men per shift). As is the structure of

p35/...

GENERAL ARRANGEMENT
70/75 TON/DAY KILN



Wet system

all of these calcining units similar so is the material required for their construction, and because of equalized production costs the prices of the kilns are generally comparable.

The following graph (page 37) shows a comparison of the prices of several kilns and demonstrates how the establishing cost of a kiln compares with its daily output.

This comparison establishes the fact that, with complete independence of the price structure of mutually competing products, the purchasing costs of all large scale calcining kilns become increasingly favourable with the rising specific calcining output. This circumstance is in adverse proportion to the requirements of the developing countries.

Better than all price information, which is of no validity when not confirmed by the manufacturer, is an analytical expansion of standard prices whereby the price per ton of daily output is shown as a function of the daily output.

The graph shows for instance that the cost of one of the examined kilns with an output of 20 tons per day, here called "x", amounts to :

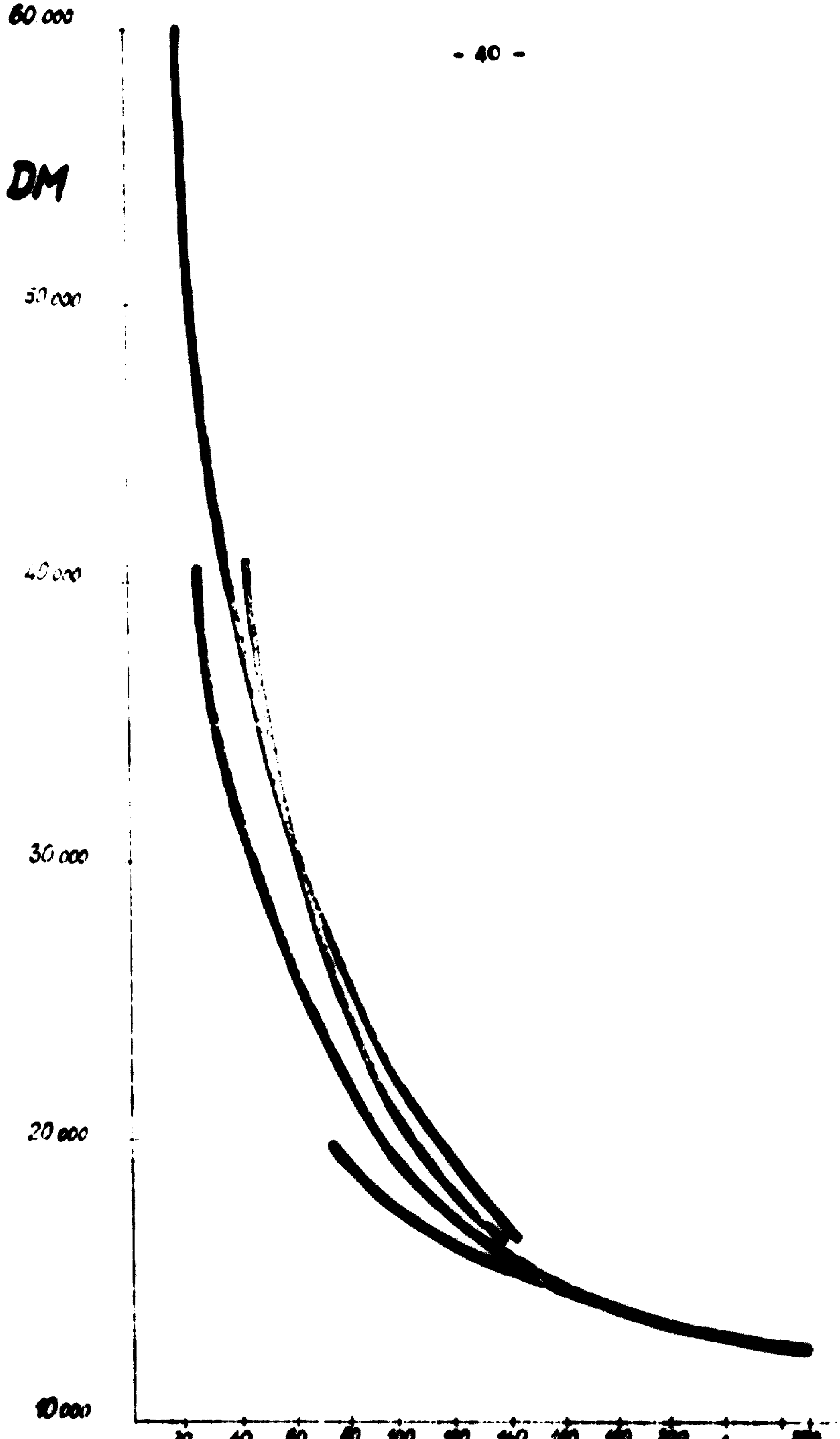
$$\frac{x}{20\ \text{tpd}} = \text{DM } 40.000 \text{ per ton of lime capacity.}$$

Similarly, the cost of a kiln producing 200 tpd as an effect of the positive influence of the daily output on the economy of the erection cost will amount to :

$$\frac{x}{200\ \text{tpd}} = \text{DM } 15.000 \text{ per ton of lime capacity.}$$

From this it is obvious that the developing countries will have to

depreciate/..


DM
60.000
50.000
40.000
30.000
20.000
10.000
20
40
60
80
100
140
200
ton/d

depreciate high investment costs when purchasing small kiln units because they only rarely require larger kiln units for already mentioned and known reasons.

It has been shown by UNIDO experts in market surveys and assessments as well as by statistical bureaux of various governments that the upper production limit of required kiln units still lies in most cases below 20 tons per day. Only in some cases, particularly in such countries which require lime as a raw material for industrial use, are kiln units with a larger daily output demanded.

The centre of gravity of the consumption lies in the geographically widespread construction industry which is occasionally reluctant to pay high freight rates for lime produced in distant industrial plants because of an already existing low market price.

In such countries where lime is produced in field kilns or by the similar cottage industry, the price of lime has been fixed at such a level that high depreciation costs cannot be covered.

As only quality requirements are gradually increasing, it is impossible to base higher prices of lime produced in highly industrialised plants on the higher quality of the product.

Finally, should the social viewpoint be considered an important factor in connection with the establishment of factories with a high level of output since such plants operate with a low degree of intensive labour.

This many-sided problem has in specific cases been successfully approached through subjective and individual treatment which will be described in the following chapters. Certain terms, which apply to all types of

kilns/...

kilns, such as specific thermal consumption, kiln efficiency and dissociation degree of the limestone, should be explained.

The specific thermal consumption is defined as the amount of calories supplied to the kiln within a certain unit of time, divided by the weight of quick lime produced in the same unit of time, i.e.

$$\frac{\text{kcal (fuel)}}{\text{kg (quick lime)}} \Big/ \frac{\text{unit of time}}{\text{unit of time}}$$

The calculation of kiln efficiency is interesting as a basis for further calculations particularly in connection with feasibility studies or for similar investment oriented purposes. It can be defined as the ratio between the theoretical heat requirement and the specific thermal consumption and is usually expressed in percentage.

The following factors are used in the calculation :

Specific thermal consumption (kcal/kg quicklime)
free CaO content in quicklime (kg CaO free)

residual CO_2 content in quicklime (kg CO_2)

factor 1.2742 = $\frac{\text{molecular weight CaO}}{\text{[illegible]}}$

factor 7.53 = $\frac{\text{heat of formation of [illegible]}}{100}$ (kcal/kg)

Efficiency (%) = $\frac{\text{[illegible]}}{\text{specific thermal consumption (kcal/kg [illegible])}} \cdot 100$

$$= \frac{753 \cdot (\text{CaO total} - 1.2742\ CO_2)}{\text{specific thermal consumption}} \cdot 100$$

The dissociation degree of the quicklime is calculated as follows :

Dissociation/...

$$\text{Dissociation degree (\%)} = \frac{CaO\ free}{CaO\ total} \cdot 100 =$$

$$= \frac{CaO\ total - 1.2742\ CO_2}{CaO\ total} \cdot 100$$

<u>Choice of fuel</u>

It may interest the responsible government bodies as well as investing banks and the lime producers themselves to study a comparison of the production costs of one ton of quick lime using various fuels.

This comparison is valid for the Federal Republic of Germany under the conditions prevailing before the time of the oil crisis 1973/74 and has been supplemented by a study shown in the following table. This study demonstrates the fact that the advantage of utilising the cheaper oil calories will disappear as the oil price increases towards, and above, the level of the coke price.

A further study shows the development of the profit under conditions of increasing coke and fuel oil prices at various sales prices of the quick lime.

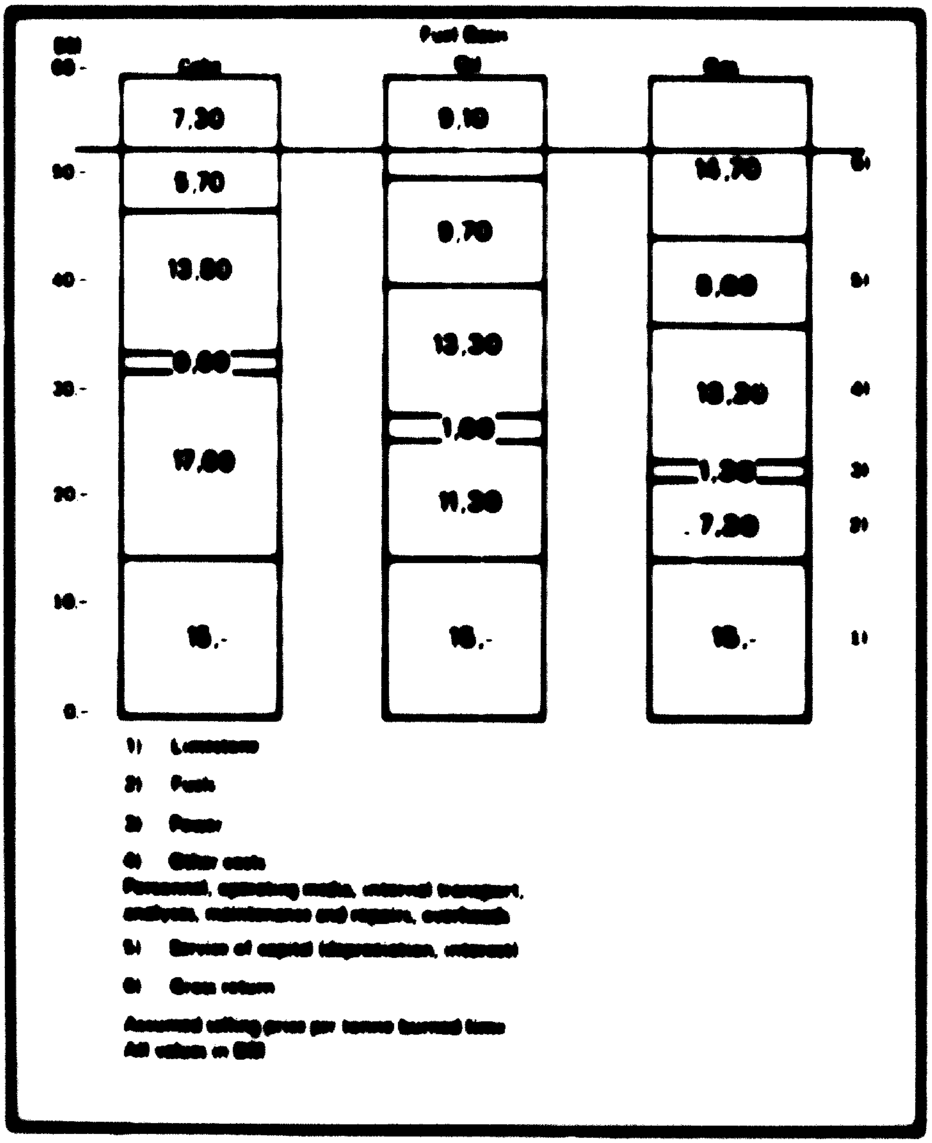
It is already clear that the international price development will show a continuing upward trend because of the decreasing oil reserves of the world, independent of the present oil crisis.

It will, therefore, be necessary in each specific case of a new investment, according to the actual time and location, to enter into considerations following the described pattern (or other similar patterns) in order to arrive at a realistic and feasible calculation.

The already stressed necessity to give individual treatment to each case was mentioned with this problem in mind and also considering

the/...

Comparison of production costs per tonne burned lime using various fuels



Development of fuel costs by rising coke and fuel oil prices

year	consumption per ton of lime	
	coke ([illegible]) 128.5 kg	oil ([illegible]) 104.0 kg

year	anticipated purchase price		Fuel costs per ton of lime		
			coke	oil	difference
1972	137.- DM/t	109.- DM/t	17.60 DM	11.30 DM	6,30 DM
1973	155.- "	109.- "	19.90 "	11.30 "	8.60 "
1974	165.- "	109.- "	21.20 "	11.30 "	9.90 "
		110.- "	21.20 "	11.40 "	9.80 "
		120.- "	21.20 "	12.50 "	8.70 "
		130.- "	21.20 "	13.50 "	7.70 "
		140.- "	21.20 "	14.60 "	6.60 "
		150.- "	21.20 "	15.60 "	5.60 "
		160.- "	21.20 "	16.60 "	4.60 "
		170.- "	21.20 "	17.70 "	3.50 "
		180.- "	21.20 "	18.70 "	2.50 "
		190.- "	21.20 "	19.70 "	1.40 "
		200.- "	21.20 "	20.80 "	0.40 "
		203.85 "	21.20 "	21.20 "	-.-

Development of profit by rising coke and fuel oil prices as well as different sales prices.

year	Anticipated purchase prices ([illegible]) Coke	([illegible]) Oil	Gross profit by sales prices of DM 60.-/t Coke	DM 65.-/t	DM 70.-/t	Gross profit by sales pr.of DM 60.-/t Oil	65.-/t	DM 70.-/t
1972	137.-DM/t	109.-DM/t	7.3o DM	12.3o DM	17.30 DM	9.10 DM	14.10 DM	19.10 DM
1973	155.- "	109.-"	5.- "	10.- "	15.- "	9.10 "	14.10 "	19.10 "
1974	165.- "	109.-"	3.70 "	8.70 "	13.70 "	9.10 "	14.10 "	19.10 "
		110.-"	3.70 "	8.70 "	13.70 "	8.95 "	13.95 "	18.95 "
		120.-"	3.70 "	8.70 "	13.70 "	7.90 "	12.90 "	17.90 "
		130.-"	3.70 "	8.70 "	13.70 "	6.90 "	11.90 "	16.90 "
		140.-"	3.70 "	8.70 "	13.70 "	5.85 "	10.85 "	15.85 "
		150.-"	3.70 "	8.70 "	13.70 "	4.80 "	9.80 "	14.80 "
		160.-"	3.70 "	8.70 "	13.70 "	3.75 "	8.75 "	13.75 "
		170.-"	3.70 "	8.70 "	13.70 "	2.70 "	7.70 "	12.70 "
		180.-"	3.70 "	8.70 "	13.70 "	1.70 "	6.70 "	11.70 "
		190.-"	3.70 "	8.70 "	13.70 "	0.65 "	5.65 "	10.65 "
					196.15-.-	"	5.- "	10.- "
		200.-"	3.70 "	8.70 "	13.70 "	- 0.40 "	4.60 "	9.60 "
		203.05 "	3.70 "	8.70 "	13.70 "	- 0.80 "	4.20 "	9.20 "
	198.80 DM/t							

the differences in availability of fuel in the individual developing countries.

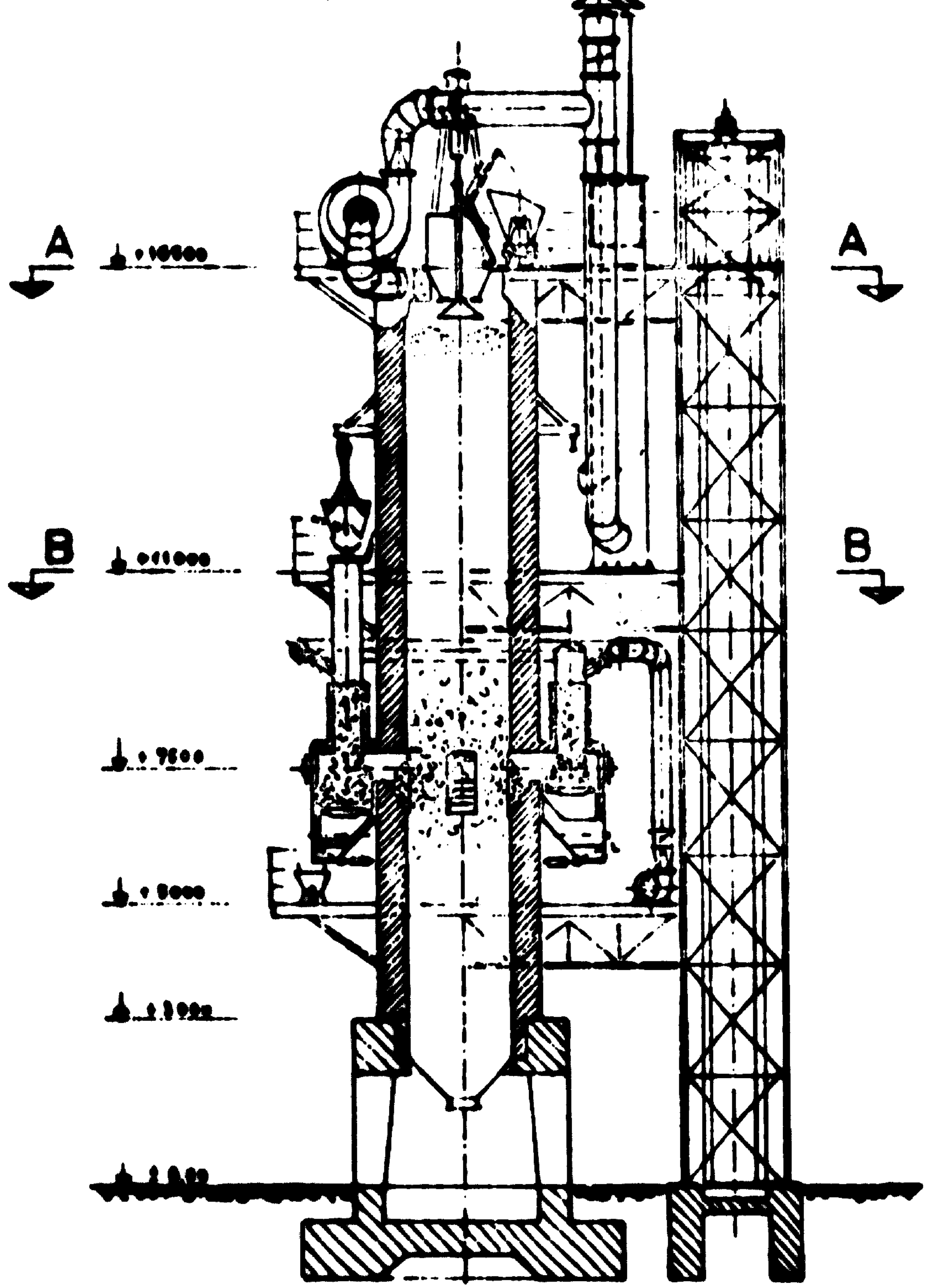
Examples of individual planning of lime plants

In a West African developing country plans were made for the manufacture of lime to be utilised as a binding agent in ordinary mortar as well as in a new type of building block.

Fuel oil as well as coal and coal products, all of which had to be imported, had to be disregarded as fuel.

The abundancy of forests in the country and the endeavour to create new territories for settlement through deforestation brought about the idea of making use of this wood, if possible in its green state, as fuel in the lime manufacture.

The following sketch shows the solution of the problem.


A
A
B
B

Another example is worth mentioning because of its completely opposite nature.

In a South East Asian developing country, favoured by an abundancy of crude oil, the predominant tendency was to conserve the forests in order to avoid erosion and to increase the utilisation of oil as a fuel.

The assignment was to design a standard kiln with industrial characteristics which could be constructed in larger numbers, independent of importation of instruments and equipment parts.

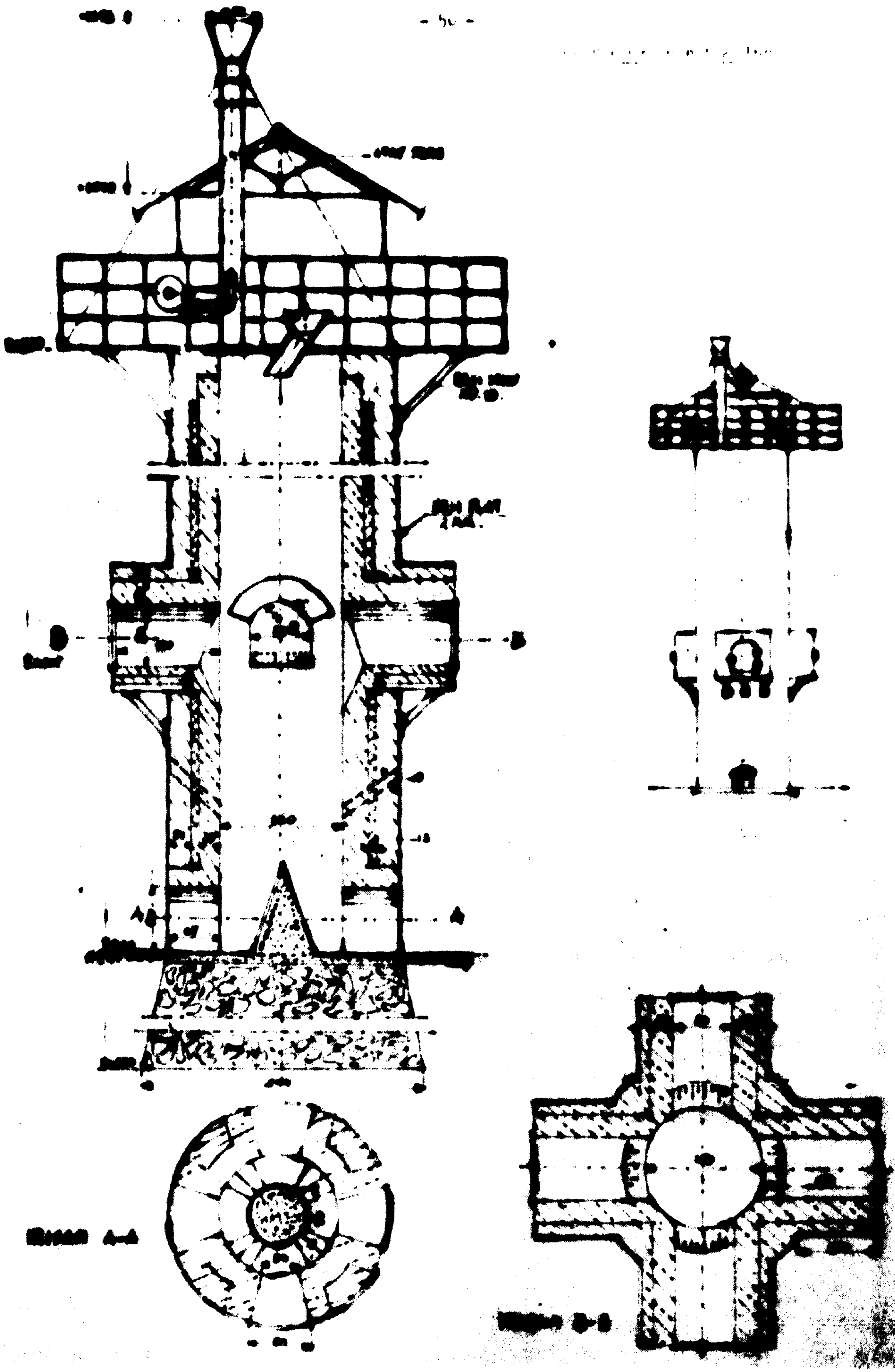
The attached sketch shows that the shaft wall was designed as a brick construction. Feeding and discharging is performed manually. The firing is performed by means of an injection system for heavy fuel oil, and the injectors are designed in such a way that they can be manufactured in local workshops.

An injection tube installed in the chimney and fed by a cold fan produced in the country itself is used instead of a complicated and sensitive hot gas exhaust fan.

The specific capacity of such a kiln amounts to 6-10 tons per m^2 per 24 hours.

The most interesting feature of this kiln is, however, the investment cost per ton of daily production compared with the same cost figure for the smallest of the conventional kilns described earlier in this manual. It amounts to approximately DM 5.000 per ton of daily production as opposed to DM 40.000 per ton of daily production.

p47/...



In the first example concerning a wood-fired lime shaft kiln, no special emphasis could be put on the import free construction of the kiln as at present no manufacture of steel parts, machinery or refractories has been established in the country. The opposite situation influenced the planning of the oil-fired standard kiln - described in the second example - where a kiln which could be manufactured exclusively in the country itself was designed.

The estimated prices are correspondingly different : approximately DM 300.000 for the wood-fired kiln and DM 50.000 for the oil-fired standard kiln.

There is, of course, more than 100% difference between the production capacities of the kilns. This condition does not, however, have any significant influence on the final price. For instance, an oil-fired kiln constructed according to the demonstrated pattern with two firing levels and a corresponding free shaft diameter as well as a corresponding effective shaft may cost more than the original figure above (DM 50.000) but less than DM 100.000.

These two examples prove clearly the individual manner in which the developing countries must be advised, particularly concerning the design of lime plants, in order to create realistic projects which serve their particular purposes.

General description of the principles of the lime calcining process in shaft kilns.

The firing is in most cases still performed according to the principle of counter current which means that the column of material sinks in the direction of the shaft foot while the fire burns in the direction of the shaft top. The shaft is divided into three zones which, according to

their/...

their functions (starting from the shaft top and moving in the direction of the flow of material), are defined as follows :

Pre-heating zone

Firing zone (reaction zone)

Cooling zone

The shaft dimensions, i.e. the effective working shaft height and light shaft diameter, result from the desired output per unit of time whereby the height and the diameter must be proportionately related to one another. This proportion is calculated on the basis of the heat transfer conditions which depend on the time the product spends in the firing zone as well as on the particle size of the lime stone feed. The firing temperatures can vary between 850°C and 1200°C depending on the physical and chemical properties of the lime stone.

Assuming that a correct choice of the dimensions of the shaft and the individual zones has been made, the exhaust gas temperature will lie in the region of 200°-300°C when liquid or gaseous fuels are applied.

The temperature of the lime discharged at the feet of the shaft should as a rule not exceed 80°C.

The lining of the shaft should correspond to the process temperatures which means that a regular commercial quality of fire clay refractories can be used if the fire is evenly distributed over the total cross section of the shaft and no uncontrollable heat concentrations occur.

The aluminium oxide content of the lining in the firing zone should not exceed 60%. In the pre-heating and cooling zones fire clay bricks with 30-40% aluminium oxide content are normally fully satisfactory.

If the system functions well the lining in the firing zone should have

a/...

a life of two to four years depending on the wear caused by the abrasiveness of the raw material. The life of the lining in the pre-heating and cooling zones is as a rule twice as long as the lining in the firing zone. These estimates refer to refractories which comply with recognised international standards.

5. Process and quality control

Control of the firing process.

According to technology a recorder-controller for a high capacity lime shaft kiln often costs as much as a small semi-mechanised shaft kiln.

The price always depends, of course, on the number of specific process variables which must be measured, recorded and controlled.

Measurements of volume

The measurement of the volume of gases is normally carried out by means of a determination of pressure difference according to the Bernoulli energy equation.

The equation for the flow can be expressed as

$$Q = c\sqrt{\Delta P}$$

where c is a factor which depends on the design of a throttle arrangement in the pipe (measuring diaphragm or a venturi nozzle), the dimension of the pipe, the density of the medium and a few other variables.

The whole measuring equipment for one flow measurement normally consists of the throttle arrangement, a measuring diaphragm accurately manufactured according to the calculations of a specialist, a ring balance and some metres of plastic tube. The ring balance performs the calculation

according/...

according to the above mentioned formula.

However, if one is willing and able to calculate the pressure difference can be read from a Krell manometer (similar to a U-tube) and the resulting cost of the instrument for a flow measurement is reduced by 60-80%.

It is, of course, also possible to record the measuring results by means of a recording ring balance.

Measurements of pressure

As in the case of volumetric measurements positive as well as negative pressures can be measured by means of indicating or recording instruments as well as by simple U-tubes.

Here again it is a question of money as to which instrument is chosen.

The necessity of measuring volume as well as pressure is related to the firing technology, i.e. the particular kiln in question. However, under other circumstances to be described below, complicated instrumentation can, as a rule, be waived.

Measurements of temperature

A measurement of the process temperature, called direct measurement, is impossible due to the difficulty of placing a thermocouple in the firing chamber. All measurements in the kiln shaft are, therefore, indirect measurements which means that the the thermo elements only protrude to a certain position in the kiln lining so that they cannot be damaged by the descending lime.

The measuring results can be shown on indicating instruments or can be registered on a recorder with one or several colours.

Each/.

Such types of equipment consist of compensation instruments for compensation of the variations in the external temperature at the reference point, as well as so-called compensation cables for the connections between the thermocouples and the instruments.

Regarding the necessity for measurement of temperature, it should be pointed out that information about the temperature in pipes for hot gases or in the lining of the firing or sinter zone can warn about super heating and consequent damage of material or equipment. A certain minimum of instrumentation should therefore always be provided.

Exhaust gas analyses

It is indispensable during the start-up period of a kiln (and later recommendable at certain intervals) to carry out analyses of the exhaust gas. The purpose of such an analysis is to determine :

a) The CO_2 content in the exhaust gas which serves as a control of the efficiency of the dissociation process;

b) The O_2 content which shows whether the dissociation process runs as stoichiometrically as possible, i.e. with neither too high nor too low a proportion of combustion air. The calculation of the air value consists of a multiplication of the measured O_2 value by the factor 3,76, the ratio between the oxygen and the nitrogen in the air;

c) The CO content which is a control of whether a correctly chosen air factor does in fact result in complete combustion;

d) If required, the H_2 and CH_4 content according to the fuel utilised, in order to determine whether the combustible gas components have been completely utilised in the firing process.

Very/...

Very expensive electrical instruments for gas analysis which operate automatically on a physical basis are available, as well as less expensive automatic instruments which operate on a chemical basis.

The importance of proper maintenance during continuous operation is equal for both types of instrumentation.

The so-called Orsat-apparatus for manual operation is a very satisfactory piece of equipment for gas analysis which is indispensable in any lime calcining process, provided it is operated and maintained by trained personnel.

Whenever a new lime kiln is put into operation, be it even in the smallest plant, it should be done with the co-operation of a specialist who could at least adjust the kiln according to the desired production capacity by means of an Orsat-apparatus.

The following rules are generally valid for and applicable to any firing technology :

Raw material

The chosen granulometry should be kept within a narrow range since any grain which is larger than the standard remains uncalcined in its centre, assuming an equal time of exposure to the temperature of the firing zone. Any grain which is too small will, on the contrary, be burnt up if not sintered.

Raw material and fuel

Before the raw material is fed into the kiln it should be weighed or its quantity determined volumetrically according to the expected capacity of the kiln, and loss of ignition considered. The same applies to the

fuel/...

fuel as, because of a knowledge of its calorific value, its quantity is determined by gravimetric or volumetric measurement and must be brought into accordance with the quantity of raw material in order to regulate the development of heat in the kiln.

With reference to the chapter about the control of the firing process it can be said that good firing results can be obtained even without complicated measuring and control instrumentation if only the above mentioned basic rules are observed, combined with a minimum of equipment and know-how.

<u>Quality control</u>

A range of investigation possibilities for determination of the quality of the quicklime exist in the continuation of the possibilities for control of the firing process described in the previous chapters.

The normal quality control consists of :

a) determination of the residual content of non-liberated CO_2 in the calcined product
b) determination of the CaO content
c) reactivity test of the calcined product.

a) <u>Determination of the CO_2 content</u>

The residual CO_2 content determination is of interest in order to evaluate the firing process as well as with a view to the practical utilisation of the product. This determination can be described as the first step in the calculations of the kiln efficiency and dissociation degree already described in a previous chapter.

According to a testing procedure established by the Union of the German

Lime/...

Lime Industry (Bundesverband der deutschen Kalkindustrie e.V.), the water of hydration as well as the residual carbon dioxide content can be determined during one procedure.

The analysis requires :

1 electrical muffle furnace with a firing range to 1100°C and equipped with a temperature reading instrument
1 analytical balance, accuracy 0,01 g
1 desiccator with a drying medium
various crucibles

Procedure : 5 or 10 g of finely powdered quick lime is accurately weighed in a previously weighed crucible and heated to 580°C in the furnace permitting two hours soaking time at this temperature. The sample is then allowed to cool to room temperature in the desiccator.

The weight loss is determined by weighing. The result is the content of water of hydration in the original sample and is expressed by the percentage of the original total weight.

Afterwards, the same sample is heated to 1050°C and soaked at this temperature for three hours.

This calcination removes the residual CO_2 from the lime sample and the amount is determined by a final weighing after cooling to room temperature in the desiccator. The CO_2 content is expressed in the percentage of dehydrated weight of the sample.

b) Determination of the CaO content

Certain users of lime, in particular the chemical industry, power stations, water supply works, etc., require a specification of the calcium oxide

content/...

content of the lime. The method of determination consists of the solution of lime in hydrochloric acid and neutralisation with sodium hydroxide, a so-called titration.

This analysis requires :

1 analytical balance (as above)

2 50 ml burettes

a number of conical flasks with 500 ml volume

1 n hydrochloric acid

1 n sodium hydroxide

phenol phtalein solution (0,1 g per 100 ml ethanol)

distilled water

Procedure : 1,00 g finely powdered quick lime, accurately weighed, is mixed with 50 ml distilled water in a conical flask. Approximately 40,00 ml 1 n hydrochloric acid is added from a burette and the flask with its contents is heated to boiling. 100 ml distilled water is added after three minutes of boiling and the whole mixture cooled down to room temperature. 3-5 drops of phenol phtalein solution are then added and the sample titrated with 1 n sodium hydrochloride until the colour changes to red.

One drop of 1 n hydrochloric acid is added as a control, whereby the red colour should disappear again.

The percentage of CaO $\pm$ 0,2% is calculated by the formula :

$$\%\ CaO = 2,8\ (a-b)$$

where

a = amount of 1 n hydrochloric acid added (0,05 ml accuracy)

b = amount of 1 n sodium hydroxide added (0,05 ml accuracy)

c) Reactivity test of the calcined product

Basically the same equipment is used for the reactivity test of the lime. This test is required as a safety guarantee by various consumers and is used furthermore to give information about the product's rate of slaking or affinity for moisture for the pur ose of good utilization of the lime hydrating plant, if such is available.

There are several graduations between soft-burnt and hard-burnt lime and the safest method of determination described in the following is based on the reaction

$$Ca(OH)_2 + 2\ HCl \rightarrow CaCl_2 + H_2O$$

Procedure : 50 g calcined lime of 2-5 mm particle size is added in one portion to 1 litre of water at 40°C and stirred. A number of drops of phenol phthalein is added at the same time. A red colour appears as the slaking (formation of $Ca(OH)_2$) takes place.

4 n hydrochloric acid is then tritrated from a 500 ml burette until the red colour disappears. Additional hydrochloric acid is added at any new sign of red colouring in such a way that the solution always remains colourless. This continues for ten minutes and the consumption of hydrochloric acid is recorded every minute. The values are entered into a diagram on time.

50 g CaO correspond to approximately 430 ml 4 n HCl, while, at the same time, extremely hard-burnt lime consumes only approximately 20 ml HCl.

The reactivity of the product should be of intermediate value as agreed with the consumer.

Extraction of samples

All analyses should be carried out on so-called representative samples taken/...

taken from the production over an extended period of time. Before the extraction and weighing of the laboratory sample the individual samples should be intimately mixed, crushed and then divided into equal parts. One part of each sample should then be mixed once more and the sample for analysis should only be taken from this representative mixture.

6. Putative costings

It seems to be difficult to extract some valid basic factors from the previous chapters on which the example of a calculation of production costs can be based.

This should, however, not keep us from showing the readers the guide as to how such a calculation can be composed so that they may be able to perform the calculation themselves, using the individual cost figures relevant to the actual conditions.

The following example is based on a manufacture of 14,000 tonnes of lime per year.

The present sales price of quick lime in Germany (1973/74) is approximately DM 70.00 per ton. A further analysis of the profitability based on this sales price and the calculated production costs would, however, lead to a false conclusion since the basic factors vary from country to country.

The example is based on a 100% utilisation of the manufacturing plant, i.e. it is assumed that the planned yearly production capacity is reached and the total production sold.

The calculation of the production costs based on German figures lead to the following result :

Cost component	price per unit DM	per ton quantity	production costs DM	total costs per year DM
A) <u>Raw material cost</u>				
Lime stone	8,00/t	1,875	15,00	210,000
B) <u>Manufacturing costs</u>				
Wages 6 men, 2400 h/year	10.00/h			144,000
Additional cost to cover leave				24,000
Fuel	109,00/t	0,104	12,00	168,000
Electricity	0,07/kWh	23	11,30	158,200
Miscellaneous costs:			1,60	22,400
consumable stores, transporation maintenance and repair analyses administration			6,30	88,200
			46,20	646,800
C) <u>Financial costs</u>				
Depreciation 10% of 1,6 mill DM (capital investment)				160,000
Interest 8% of 0,8 mill. DM (50% of the capital investment)				64,000
			16,00	224,000
D) <u>Total production costs</u>		DM	62,20	870,800

Aa/...

As a further example of a summary putative costing calculation for the production of burnt lime in a West African developing country, the following list of putative costings is given :

1)	Lime stone from Kompina, franco factory Douala, hand crushed and sorted	CFA 3000/to
2)	Wages for wood-felling and cutting (the wood can be obtained from the State, free of charge), charging and discharging as well as transportation franco factory Douala	CFA 1400/to
3)	current per kwh	CFA 20
4)	wages for a worker per day	CFA 350

Costs for burnt lime per ton

limestone	1730 kg x CFA 1.400	CFA 2422
wood	340 kg x CFA 3.000	CFA 1020
technical current	40 kg x CFA 20	CFA 800
wages (2 workers)		CFA 100
capital cost		CFA 638
production costs for burnt lime per ton		CFA 4980

Summary/...

Summary

After havin referred in general terms to the application of lime and dolomite the present guide deals in the chapter on "MARKET" with the characteristics of the part.cular users who, because of their growing demand of quick lime, require an accelerated industrialization and modernization of the production methods.

The recommendation is made not to over or under estimate the potential of the market when planning new investments or expansions aimed at increasing the production capacity.

In view of the importance of the construction industry which, particularly in developing countries, accounts for the majority of the market demand, special emphasis is placed on describing in detail the fundamental background of the requirements of this industrial branch, supported by figures.

The chapter on "RAW MATERIAL" lists various naturally occuring lime stones with reference to their performance during the calcination process.

Practical information concerning sample drillings, sample quarrying and the investigation components of the complete analysis is given in the chapter on "LIMESTONE DEPOSITS".

The chapter on "QUALITY OF THE RAW MATERIAL" deals with the various quality requirements of particular users of lime, and it is conclusively demonstrated that even lime for the less demanding construction industry imposes limits on the feasibility of exploitation of raw material with a large impurity content.

Especially when planning new lime manufacturing plants the location of the

plant in relation to the main consumers is of great importance as well as the distance from the quarry to the manufacturing plant. The fact that these conditions should not be overlooked even when planning small plants is described in the chapter, "PROBLEMS AND ECONOMIC ASPECTS OF TRANSPORTATION".

In the chapters on "MINING, DRILLING AND BLASTING" and "EXPLOSIVES" an introduction is given to the planning of a quarry and the normal methods of blasting as well as a comparison of the yields of the various blasting methods.

Finally, a mechanical dressing plant for the raw material as well as sorting is discussed under the title "DRESSING AND STOCKPILING".

A total of eight different kilns are described in the chapter on "PROCESS TECHNOLOGY". This does not mean, however, that any of these technologies can claim to be better than other technologies not mentioned.

All firing technologies which are not utilising liquid or gaseous fuels have purposely been omitted. The reason for this is that in spite of the decrease of the crude oil and natural gas resources of the world, the probability of substituting these fuels with coal or coke is particularly limited in developing countries.

Kilns of the kind already described or ones belonging to similar technologies are therefore constructed where the market requirement makes them feasible.

The choice of kiln type is becoming more and more frequently dependent on the kiln's purchase price in addition to the local availability of fuel.

As is described at the end of this chapter, further greater investment

intentions/...

intentions in developing countries are often influenced by the need for smaller kiln units.

It is shown in a diagram that the prices of industrial kilns expressed in terms of investment cost per ton of daily production capacity can be four to six times as high for small kiln units as for larger kilns.

The result of this collection of observations is that in the absence of a corresponding range of offers of small, standard shaft kiln units of simple construction but still of advantageous kiln efficiency, the kiln suppliers are often replaced by individual engineering efforts.

The independent consulting engineer is required to create a suitable production unit tailor-made to suit all requirements where, because of the reasons mentioned above, a standardised product does not fit into the structure of the established economic and industrial system.

The same chapter then explains some technical terms which are of importance for the technician as well as for the salesman and the industrial economist, namely specific thermal consumption, kiln efficiency and dissociation degree.

A comparison of production costs per tonne burned lime using various fuels is supplemented by two tables which show the development of the fuel costs as well as the gross profit at various sales prices under the influence of rising coke and fuel oil prices.

Two examples of individual design of lime plants in two developing countries with totally different infra-structures, illustrated by sketches, form the final part of this chapter.

The chapter on "PROCESS AND QUALITY CONTROL" covers an important aspect of lime manufacture in view of the considerable investment costs

necessary/...

necessary and in spite of the very frequent but false assessments of its relative appropriateness and necessity.

The chapter of this title, therefore, describes the most important procedures and instruments of the recording and control equipment used for the control of the firing process, and lists the requirements in order of merit.

This chapter also mentions the most important and universally valid pre-requisites for attaining a good quality of calcined product namely, good control of the particle size of the raw material, and co-ordination of the raw material feed rate and the fuel input in order to maintain constant temperature conditions in the kiln.

The most frequent tests of the calcined product, i.e. determination of residual CO_2 content and total CaO content, and reactivity test are described under the heading "QUALITY CONTROL".

The necessary laboratory equipment and chemicals as well as the test procedures are described.

An example of the calculation of production costs is finally shown in the chapter "PUTATIVE COSTINGS".

Producers of Rotary Kilns and Industry Equipment

CIM BROGETTI	Bergamo, via Gramsci, Italy Telephone : 035-25 34 63 Telex : 30347
CREUSOT LOIRE ENTREPRISE	75 Paris, 5 rue de Montessuy, France Telephone : 551.73.79 Telex : Baten a 20.657
PRAGOINVEST	Praha, Ceskomoravska 23, Czechoslovakia
F.L. SMIDTH u. CO A/S	DK-2500 Kopenhagen-Valby-Dänemark Telephone : Folasmidth Telex : 27040 flsco dk
VOEST, Vereinigte Osterreichische Eisen und Stahlwerke AG.	A-4010 Linz/Donau, Austria Telephone : (072 22) 54 4 11 Telex : 02-1785
ZOUBOV Engineers	B-1180 Bruxelles, avenue de Saturne, Belgium Telephone : 740 910

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