CHEMICAL LIME

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October 28, 1992

Mr. Rick Marinshaw
MRI
401 Harrison Oak Blvd.
Suite 350
Cary, N.C. 27513

Dear Mr. Marinshaw:

Per our telephone conversation of October 28, 1992, I am forwarding the information that you requested in reference to the Maerz Lime kiln. I have included a copy of a letter from Maerz which is the only substantiation of this data. We have plan to test some of our stacks in the near future, but no acceptable data.

With the letter from Maerz is some information on the kiln and some process data that I have presented at other times. For your information, I have included a copy of the brochure "The Parallel Flow Regenerative Lime Kiln".

Thank you for your patience in getting this data and I hope that it is acceptable for your needs.

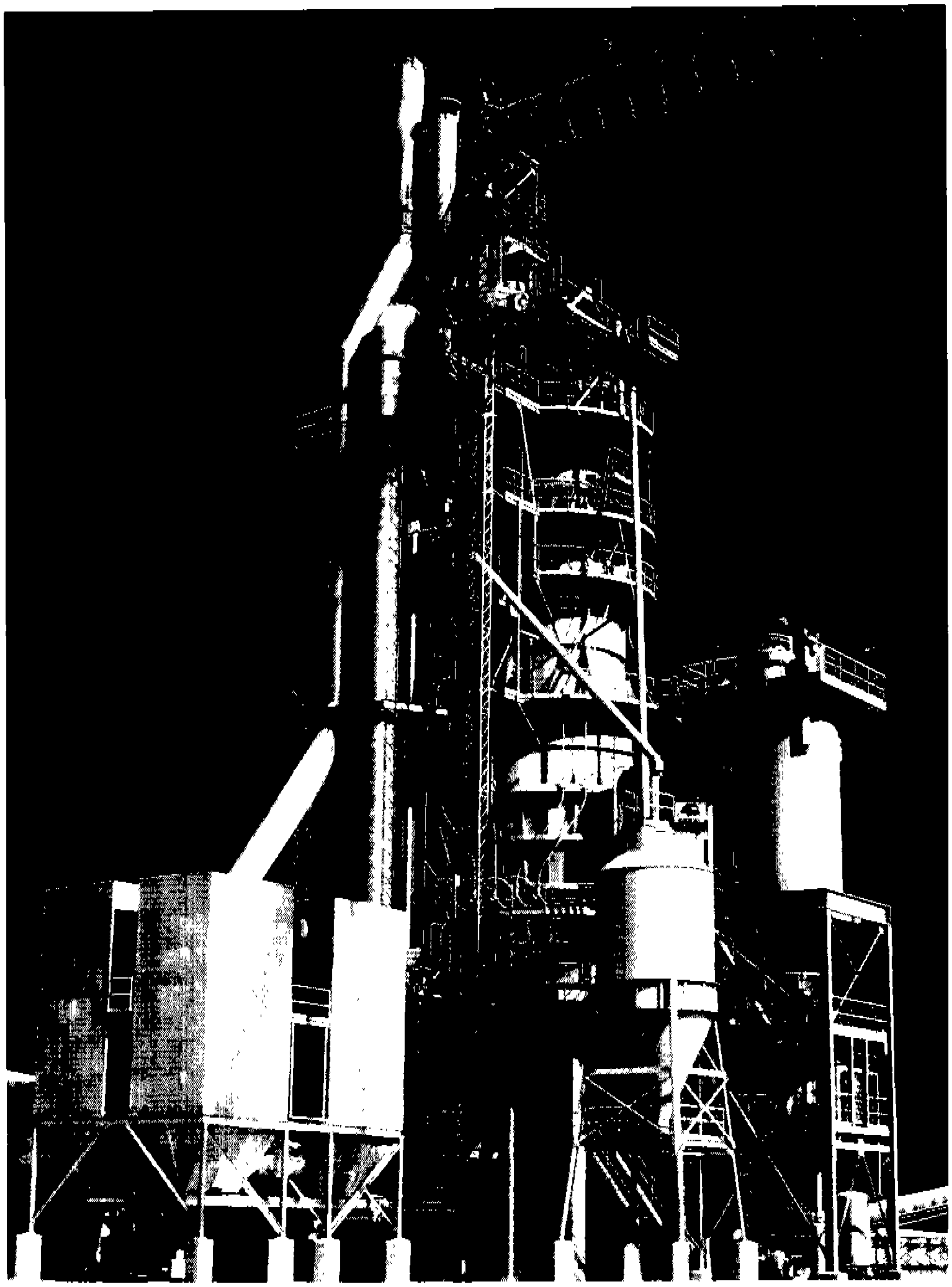
Sincerely,

Johnney G. Bowers

JGB/djoc

MAERZ

The Parallel Flow Regenerative Lime Kiln



CHEMICAL LIME
GROUP

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The Parallel Flow Regenerative Lime Kiln (PR-Kiln)

1. The Process and Thermal Characteristics in Kiln Design

The calcination of limestone is a simple chemical process; when heated the carbonate decomposes in accordance with the equation $CaCO_3 = CaO + CO_2$ + 753 kcal/kp CaO. The decomposition temperature depends upon the partial pressure of the carbon dioxide. In a gas of combustion atmosphere of normal pressure and 25% CO_2 the dissociation commences at 810°C, in pure CO_2 atmosphere this would be at 900°C.

In order to decompose the stone core it is necessary to lead the required dissociation heat from the surface area of the stone through an insulating shell of calcined lime down into the core; the stone surface area, therefore, has to be heated to above 900°C. When producing soft-burned lime the surface area of the charge must not, however, exceed 1100 to 1150°C as otherwise recarbonation of the CaO will occur, and the slaking properties will be reduced. Diagram 1 indicates the permissible heat absorption rate–according to F. Wuhrer[1]–of a spherical piece of lime, 125 mm diameter relative to the calcining time if the surface temperature is to remain constant at 1100°C.

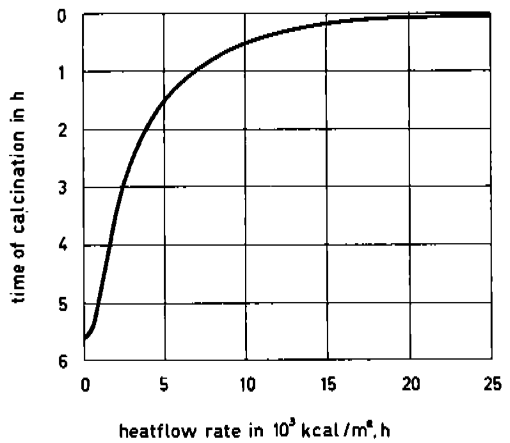


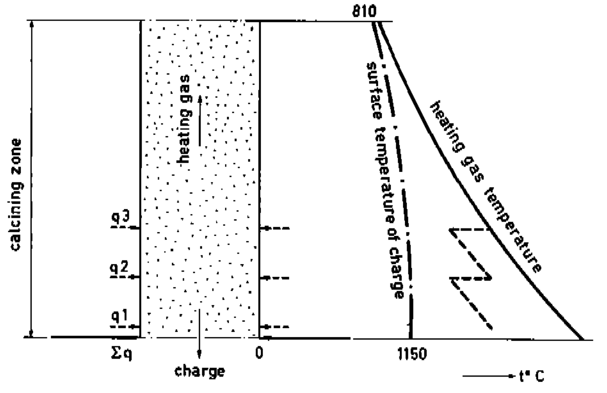
Diagram 1: Permissible heat flow rate during calcination of a spherical piece of lime of 125 mm in diameter

The ordinate indicates the time for calcination in hours and the abscissa the permissible heat flow rate in kcal/m² sphere surface area, per hour. The time for calcination is to be read from top to bottom in order to simplify a comparison with diagram 2. At the beginning of calcination a tremendous amount of heat may be transmitted into the charge, which is still in the form of carbonate, without loss in quality, whilst towards the end of the calcination there is a considerable drop in the permissible heat flow rate.

[1] "Brennprobleme in der Kalkindustrie und ihre Lösungen" Zement – Kalk – Gips 8 (1965) p. 386–394

A kiln burden, however, is not made up of an even grain size, but of a variable sized loose material. For the smaller grain the permissible heat flow rate will drop to the minimum value after a short firing time which means that during the firing to complete calcination of the larger sized stone much less heat must be applied than it would appear from diagram 1. The requirements for the kiln charge material to be provided with the optimum amount of heat during each phase of the calcination can be ideally met when using oil or gas firing with the parallel flow heating system. Diagram 2 compares in a schematic manner parallel flow heating with the usual counterflow heating, and for the purpose of better understanding of the differences it has been assumed that already fully burnt combustion gases are fed into the kiln. In the case of the counterflow heating the hot gases enter the burning zone at the bottom end and in the case of parallel flow heating at the top end. The ordinate represents the height of the burning zone, whilst the abscissa represents the temperatures.

The chain-dotted curve indicating the permissible surface temperature of the charge, commences at 810°C and at no time should the surface temperature exceed 1150°C. The unbroken curve shows, in a very simplified manner, the kiln gas temperature with single-stage heating (heat applied only at the end of the burning zone). In the case of counterflow heating the lime in the lower part of the calcining zone is, by necessity, being strongly overburned and sintered due to the great difference between the permissible temperature of the charge and the effective hot gas temperature. By means of a multistaged and also complicated heat supply (– – – – –) or by addition of cold waste gases it is possible to reduce the hot gas temperature in the critical zone; it is difficult, however, if not impossible, to evenly distribute the individual quantities of fuel q_1 to q_3 over the cross sectional area of the kiln. In any case, the heat available from the hot gases at the beginning of the burning zone, where the limestone is capable of absorbing a virtually unlimited amount of heat, will always remain rather limited. The parallel flow heating system (diagram 2b), however, complies ideally with the optimum heating conditions, as a comparison with diagram 1 shows: maximum temperature difference at the start of calcination, minimum temperature difference towards the end of the calcining procedure. Parallel flow heating of the kiln is the best precondition for the production of soft-burned lime. It is also possible to produce a harder burned lime and for this it is merely necessary to slightly increase the heat input.
The thermo-dynamic characteristic of the kiln is the



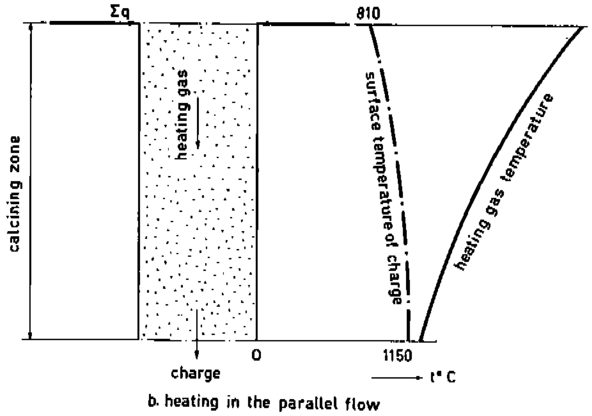


Diagram 2: Course of temperature in the burning zone

regenerative preheating of the combustion air. In kilns with the usual counterflow heating the combustion air is preheated in the cooling zone by the sensible heat of the calcined lime. The enthalpie of the lime, however, limits the preheat temperature of the air, whilst surplus sensible heat in the waste gas which cannot be recovered in the stone escapes. Many designs have incorporated recuperators to recover this waste heat, but such heat exchangers are rather prone to disruptions due to dust-laden hot gases. In the case of the parallel flow regenerative kiln the preheating of the air has been solved in an ideal manner: the stone preheating zone also acts as a regenerator and the charge as chequers. This kind of regenerator is completely insensitive to dust-laden or corroding gases and, at the same time, shows excellent heat transfer characteristics.

The regenerative preheating of the combustion air makes the thermal efficiency of the kiln practically independent of the excess combustion air factor λ which considerably simplifies the setting of the correct length of the flame. A larger surplus of air produces shorter, and a smaller surplus of air a longer flame. The regenerator, of course, requires two units which, necessarily, results in a kiln consisting of at least two shafts.

Diagram 3 shows the basic construction of the kiln and illustrates two phases of the flow. 1 and 2 are

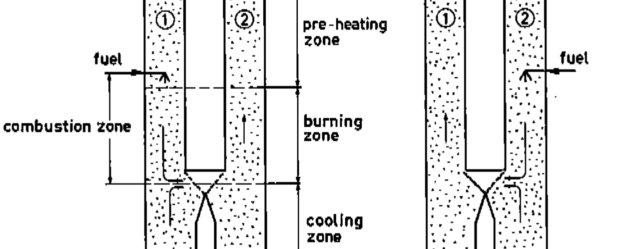


Diagram 3: Direction of flow in PR-Kiln

the two shafts containing the material for calcining which are connected to each other at the bottom end of the burning zone. The reversal devices and lime discharge arrangement have been omitted from this diagram. Both shafts are alternately being charged with limestone and lime is discharged continuously at the bottom of both shafts. Fuel is supplied to only one of the two shafts, in the phase shown on the left to shaft 1 and in the phase shown on the right to shaft 2. The fuel is introduced, evenly distributed over the cross section of the shaft, at the bottom end of the preheating zone. The air for combustion is introduced under pressure at the throat above the charge and the system is pressurised throughout. The air is preheated in the regenerator (preheating zone) before it mixes with the fuel. The flame passes through the burning zone from the top to bottom (parallel flow heating). The waste gases leave the fired shaft (primary shaft) via a bank of material and enter the secondary shaft, passing upwards in opposite direction to the charge. They calcine (even if to a small degree) the limestone in the secondary shaft and heat up its regenerator (preheating zone). The supply of fuel and air for combustion is transferred from one shaft to the next at intervals of 12 minutes (at nominal output). Cooling air is introduced under pressure continuously, at the bottom end of both shafts.

The waste heat from the calcining zone of the secondary shaft is insufficient to preheat the stone to its dissociation temperature (810°C), the calcining zone, therefore starts below the fuel inlet where the stone has reached the temperature of 810°C.

The excellent thermal conception of the kiln can be satisfactorily proven by means of the heat balance. The sum of effective heat (dissociation heat) and heat losses results in the thermal requirement of the kiln. The heat losses consist of the loss through the walls of the kiln, the sensible heat of the discharged burned lime and the sensible heat in the exhaust gas. The loss through the walls can be kept to a minimum, i.e., 40 kcal/kp burnt lime, by the use of appropriate insulation. Sufficient supplies of cooling air will bring down the temperature of the calcined lime when discharged. At a discharge temperature of 70°C the heat loss will be $1.0 \cdot 0.188 \cdot 70 = 13$ kcal. Cooling air is required at a ratio of 0.64 Nm^3/kp of calcined lime.

The mean waste gas temperature of the kiln is 90°C and should, because of condensation and corrosion, not lie markedly below this. Assuming a heat requirement for the kiln of 840 kcal/kp of calcined lime the following amount of waste gas will result:

Products of combustion

($\lambda = 1.0$): $1.168 \cdot 0.840 = 0.980$ Nm^3/kp

Air:

excess from burning ($\lambda = 1.20$)

$1.100 \cdot 0.20 \cdot 0.840$	= 0.185
cooling air	0.640
	0.825 Nm^3/kp

CO_2 expelled 0.37 Nm^3/kp

The waste gas loss is therefore:

$(0.980 \cdot 0.330 + 0.825 \cdot 0.312 + 0.370 \cdot 0.409) \cdot 90 =$
$= 66$ kcal/kp.

To the heat requirements of the kiln must be added a further 13 kcal/kp for the evaporation of 2% stone moisture and the heat loss due to this water vapour. The result of this is a thermal requirement of $753 \cdot 0.94 + 40 + 13 + 66 + 13 = 840$ kcal/kp when producing a calcined lime of 94% free CaO.

In this calculation it still remains to be proven that the waste gas loss is, in fact, only 66 kcal/kp, i.e., that a waste gas temperature of 90°C is effectively feasible. With the help of the heat balance of the preheating zone this proof is quite easily attainable. Losses due to unburned matter cannot occur in this type of kiln; the excess of air in the primary shaft is 20%, in the secondary shaft, including the cooling air, about 60%. Furthermore, by passing through two burning zones, connected in series, the fuel gases have a long burning path.

As illustrated in diagram 4 the heating gases supply the preheating zone with heat quantities q_{RG} (heat content of combustion gas for $\lambda = 1.0$) + q_L (heat content of excess air and cooling air) + q_{CO_2} (heat content of expelled CO_2). The calcination of the limestone surface commences at 810°C. The difference in temperature between heating gas and stone at the upper part of the burning zone of the secondary shaft can be at the most 30°C due to the long gas path and the high Reynolds number. The heating gases, therefore, enter the preheating zone at a temperature of 840°C. Their heat content is
$(0.980 \cdot 0.362 + 0.825 \cdot 0.332 + 0.370 \cdot 0.519) \cdot 840 =$
$= 689$ kcal/kp.

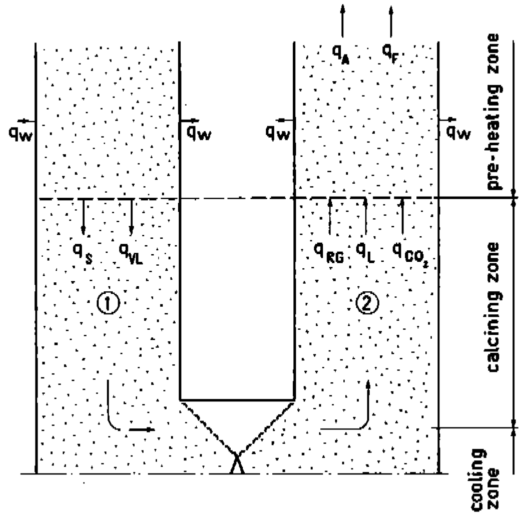


Diagram 4: Heat intake and heat loss of preheating zone

This heat has to cover the heat loss through the walls q_W of 10 kcal/kp and the heat loss q_A of 66 kcal/kp, to evaporate the stone moisture (q_F) and to preheat the limestone and air for combustion. (q_S, q_{VL} = heat content of preheated stone and preheated air for combustion, respectively). The stone is preheated to the temperature t_S°, the air for combustion to $(t_S - 30)$ °C. By balancing the heat intake and heat output the following calculation is obtained:

$689 = 1.74 \cdot c_S \cdot t_S + 1.100 \cdot 1.20 \cdot 0.840 \cdot c_L \cdot (t_S - 30) +$
$+ 66 + 10 + 13$. Exchanging c_S the specific heat of the stone with 0.260 and c_L the specific heat of the air with 0.329, t_S will equal 748°C.

From the waste gases leaving the calcination zone the limestone can therefore only be preheated to 748°C and the air to 718°C. The conditions for heat transfer might permit a preheating of the limestone to (heating gas temperature —30) °C, in this case to (840 —30) °C = 810°C, but for this the preheating zone lacks the necessary available heat, a main characteristic in contrast to other lime kilns. The conception of the kiln might therefore permit a drop in the waste gas temperature to below 90°C, but the danger of water vapour condensation sets this limit. The waste gas temperature of 90°C in the calculation for heat requirement is therefore justified.

2. Structural Details of Kiln

2.1. The shafts

The regenerative system and the parallel flow heating demand a kiln with at least two shafts. With a small sized grain and high output three shafts are used because of the resistance to gas flow created by the charge column. In periodical rotation only one shaft at a time is heated whilst the other two work as flue shafts (secondary shafts). The distribution of the waste gases over two shafts reduces the gas speed at the secondary side by half and the flow resistance to approximately one quarter. The three shafts are positioned to each other at an angle of 120°.

The kiln, independent of the number of shafts, is reversed approx. every 12 minutes at nominal output. In the case of a double-shaft kiln, the two shafts reverse their function every 12 minutes, i.e., one particular shaft is heated up every second period. In the case of a triple-shaft kiln, however, one particular shaft is heated every third period only and during the two interval periods it acts as a flue shaft.

The cross section of the shafts may either be rectangular or circular. Oil-fired kilns were formerly built exclusively with rectangular shafts, circular cross sections were preferred with gas heating. A particular characteristic of the kiln is the connection of the shafts towards the bottom end of the burning zone. At that point the kiln gases leave the heated shaft via an embankment of material and enter the flue shaft(s) via further embankments. The connecting channels between the shafts vary according to the cross section and number of shafts.

The following diagrams deal only with the flow of the combustion gases, the flow of the cooling air, which is continuously fed into the shafts is not considered.

The easiest method is to lengthwise place two shafts with rectangular cross section side by side in such a manner that the kiln gases can flow from one material embankment straight into the next (diagram 5a). The space above the embankments is arched over. Should the width b of the shaft be too wide, particularly when using a finer grain, the gas distribution in the secondary shaft would become unfavourable; in that case the two chambers are arranged as illustrated in diagram 5b. The kiln gases leaving the primary shaft through two embankments at the ends of the longer side of the cross section, are led through side channels, the soles of which are being made up by the banks, to the secondary shaft into which they enter evenly through two lateral banks.

In the case of a triple-shaft kiln with rectangular cross section, the shafts and channels are arranged as illustrated in diagram 5c. The combustion gases from primary shaft 1 flow, as in diagram 5b, at both sides into the side channels which lead to the secondary shafts 2. There they enter the flue shafts at one side, as with shaft 2 in diagram 5a, but the side of entry changes with each burning period (at nominal output approx. every 12 minutes), so that each secondary shaft, even if at different times, is supplied from both sides.

Kilns of circular cross section have circular connecting channels, as illustrated in diagram 6. The waste gases leave the primary shaft radially over the whole circumference and enter the secondary shafts in the same manner. Diagram 6a shows the two shaft kiln, diagram 6b the triple-shaft kiln. In contrast to the triple-shaft kiln with rectangular cross section, the secondary shafts are continuously supplied with combustion gases from all sides.

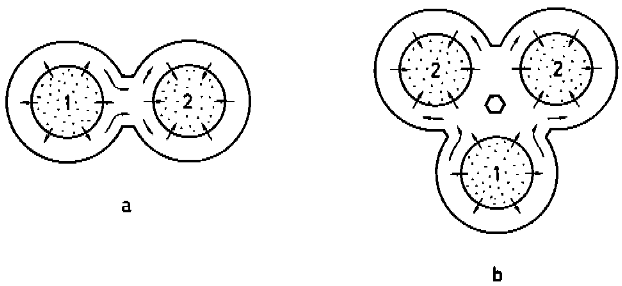


Diagram 6: Arrangement of shafts with circular shaft cross section

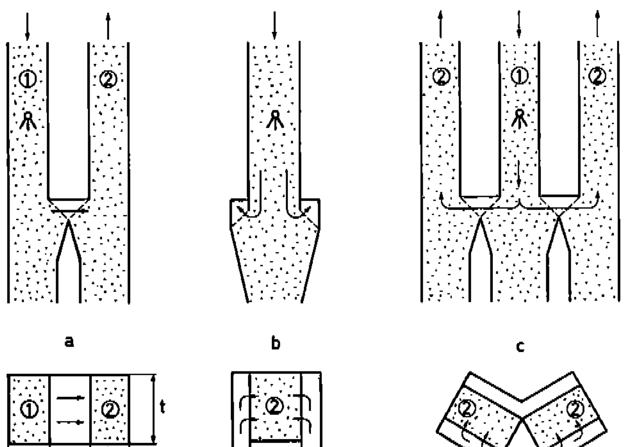


Diagram 5: Arrangement of shafts with rectangular cross section

2.2. Fuel Supply

Diagram 7 shows the supply of fuel, in the diagram on the left for gasfiring, in the one on the right for oilfiring as applied until now.

The gas is fed from a ring main through a number of steel lances and evenly distributed over the whole of the kiln cross section, to the charge of the primary shaft. The lances enter at the upper, cooler part of the preheating zone and are hanging freely into the vertically descending charge. In the secondary shaft the lances are protected from dust and, at the same time, are cooled by flushing air, preferably taken out of the pipe carrying the combustion air. The life of the bare steel pipes can be prolonged considerably by means of a special insulation[2]. The lances are not insulated over the whole of their length; the lower

[2] Patents applied for

part remains bare. The flushing air, which, due to the insulation at the upper part of the lance enters the lower not insulated part of the pipe in a relatively cold condition, still has sufficient cooling power to lower the temperature of the bare pipe end. The amount of gas is regulated by means of a valve and is distributed through nozzles evenly to all lances.

Diagram 7b illustrates the fuel oil supply and the construction of the preheating zone as realized until

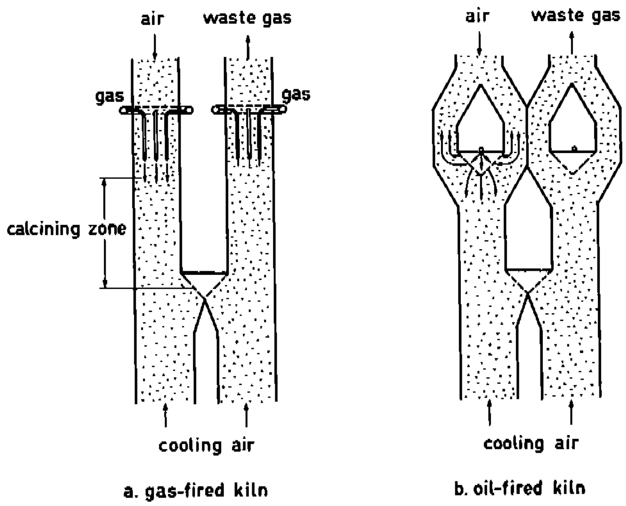


Diagram 7: Fuel supply

now. In the lower part of the preheating zone two materal embankments are formed by a bridge of firebricks onto which the heating oil is sprayed through two rotating burners mounted in opposing kiln walls. The major portion of the combustion air flows into the cavity above the embankments, mixes with the fuel and then distributes itself in the form of gas over the cross section. It is possible, however, to feed the fuel oil in a similar manner as gas, i.e. via lances. The construction of the kiln, therefore, becomes equal for gas and oil heating, the firebrick bridges in the preheating zone of the oil-fired kilns are eliminated, and the preheating zone forms a simple extension to the calcining zone without changing the kiln cross section. The amount of oil is regulated by means of metering pumps and distributed to the separate lances. Coke is unsuitable as a heating medium in the PR-kiln. It also would be inadvisable to use a lean gas such as blast furnace gas, for the heating of the kiln, as the low heat requirement of the kiln could only be met with preheated gas. The preheating of the gas, however, would require a much more complicated kiln design.

2.3. The Charging of the Kiln

A kiln with such a high thermal efficiency necessarily demands constant throughput. During each reversal a measured amount of stone is released into a shaft which will absorb the waste heat of the kiln gases after the reversal. The weight of the charges remains constant, independent of the kiln output, only the number of charges per hour and the duration of the heating period are regulated. At nominal output the kiln is reversed and charged every 12 minutes approximately, at a lower output the interval will be longer.

To maintain the level in each shaft every batch has to be charged into the appropriate shaft. To achieve this there is a stone hopper above the charging platform, in the case of a double-shaft kiln with two outlets and in the case of a triple-shaft kiln with three outlets. If the kiln is charged by means of a conveyor belt, the stone hopper is also weigh hopper. The conveyor belt can be set to two speeds to facilitate accurate weighing of each batch. If the kiln is charged by a skip hoist the batch weigh hopper is situated at ground level. The hopper above the charging platform into which the skip is emptied then only serves for the distribution of the charge to the appropriate shaft. Diagram 8 illustrates schematically the charging arrangement on a double-shaft kiln, on the left in the closed position during the fir-

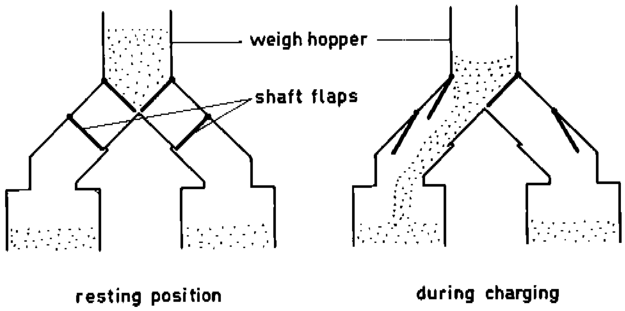


Diagram 8: Charging of the kiln

ing period and on the right during the reversing action. The stone hopper has two traps at the bottom, which can be opened alternately. The stone then slides down a chute to the appropriate shaft. The shafts are sealed by traps, which are opened during the charging process. Details of the traps, as well as an arrangement for the even distribution of the charge over the shaft cross section, have deliberately been omitted from this diagram.

2.4. The Reversing

The periodical reversing of the heating from one shaft to another requires reversing devices for fuel, combustion air and waste gas. The fuel is distributed by means of valves, combustion air and waste gas are reversed by means of double-acting hydraulic cylinder operated flaps. Diagram 9 shows the position of the flaps, at the left for the firing shaft and at the right for a waste gas shaft. In the diagram on the left the combustion air line is open and in the one on the right the connection to the flue is open. The reversal procedure is controlled by the kiln automation.

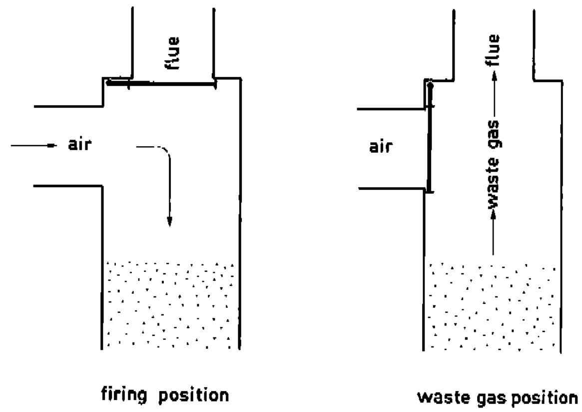


Diagram 9: Wastegas-air-reversing

Cooling air flows continuously into all shafts. Even distribution of the cooling air to primary and secondary shafts is obtained by using reversible regulating flaps.

2.5. The Discharge Device

The calcined lime is continuously discharged from all shafts, i.e. from kilns with a rectangular cross section by means of reciprocating tables, from cylindrical shafts usually by means of circular discs which move excentrically on a circular, fixed bearer plate. Discharge tables and discharge discs are hydraulically operated. The rate of discharge is automatically regulated by the kiln programmer according to the probed level of the stone in the preheating zone. Diagram 10 shows the arrangement of the discharge device of a double-shaft kiln with rectangular cross section. Under the cooling zones of both shafts lie the moving discharge tables at the embankments of which the calcined lime falls down. A small hopper is situated underneath each discharge table to collect the lime discharged during a 12-minute burning period. Due to the high pressure in the kiln these hoppers are sealed off from their environment by

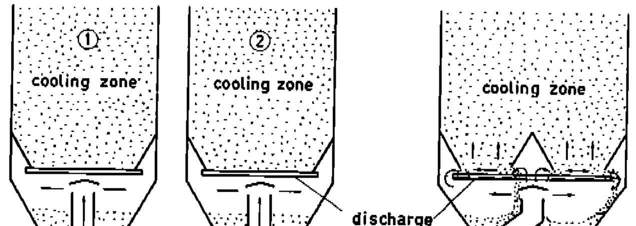


Diagram 10: Discharge device

airtight, hydraulically operated flaps. During each reversing period the flaps open, the lime drops into the pressure-free reception hopper out of which it is taken by means of a vibrator feeder. A roof like saddle is constructed above the discharge table, in the case of a circular kiln it is a cone. Cooling air is led into the hoppers from where it reaches the charges via the embankments on the discharge tables.

2.6. The Hydraulic System

All movable parts of the kiln are hydraulically operated; these are the flaps at the discharge end and at the throat, the flaps at the weigh hopper and the discharge device. The valves in the air lines, the reversing valves for fuel and flushing medium, and the stone level probes are also hydraulically operated. The oil hydraulic system has the advantage that it produces great forces with small construction elements, it is very safe and only requires a minimum of servicing. Furthermore, as standard cylinders are used, it is inexpensive. The hydraulic system consists of an oil reservoir, pumps, filters, cylinders and control valves.

2.7. The Kiln Lining

The preheating and cooling zones are lined with abrasion resisting firebrick, whilst the burning zone – in consideration of combustion with preheated air and the high cross section output – has a magnesite lining. After a period of time a thin crust of dust deposits onto this lining which contributes considerably to the protection of the brickwork. Naturally, all walls are appropriately insulated. The inner lining has a thickness of 250 mm, then follows a layer of insulating brick and, on the outer side, towards the steel shell, a further insulating mass.

In the case of rectangular shafts standard bricks can be used to a large extent; in addition only few simple special shapes are required which results in low lining costs and easy storing of spare bricks.

3. The Auxiliary Installations of the Kiln

It would exceed the limits of this description if all auxiliary installations were dealt with. Consequently, the fuel input control arrangements are not discussed, i.e. the installations before the burners or fuel lances. The handling of the stone and the removal of the calcined lime are also disregarded.

3.1. The Blowers

The whole of the kiln system is pressurised. The air for combustion and the cooling air are led into the kiln by rotary piston blowers at pressures of approx. 2500 mm WG and 1500 mm WG respectively. Rotary piston blowers supply practically constant volumes of air, independent of the resistance of the charge column. Depending upon the size of the kiln two or more groups of blowers are installed, whereby each group consists of two blowers, one for the combustion air, and one for the cooling air, these blowers being driven by one motor by using a belt drive. It is desirable to be able to regulate one each of the combustion air and cooling air blowers by a variable direct current motor, in order to adapt the amount of air to any desired kiln output and all quality requirements. From the combustion air blowers an air duct leads to the kiln throat, from the cooling air blowers a duct to the discharge device. The combustion air is admitted to the kiln above the charge, and the cooling air enters the lime charge through the lateral material embankments, on the discharge devices.

For reasons of soundproofing, the blowers are mounted in a room shielded by thick concrete walls with soundproof doors. The blowers are provided with inlet and outlet silencers. During the reversal period the kiln must be de-pressurised, even though the blowers are running continuously, therefore appropriate air escape valves are provided.

3.2. The Metering and Control Devices of the Kiln

The kiln is provided with all metering and control devices required for its fully automatic operation. The various instruments are housed in a control console in the control room. A mimic panel with control and warning lamps indicates the material flow, the position of the various flaps and valves and signals irregularities in the operation. The quantities of fuel and air, the temperatures in the channels between the shafts, the temperatures of the waste gases and the discharged lime, as well as the static pressures in the kiln system and the pressure of the fuel are metered. Controlling the exact fuel quantities required becomes more important, the higher the thermal efficiency of the kiln. The amount of fuel is set by hand according to the required kiln output; in the case of oil heating by means of metering pumps, in the case of gas heating with the aid of a control valve. Should the temperature in the connecting channels of the shafts, which is usually measured optically and for additional safety also with a thermocouple, exceed a predetermined maximum value towards the end of a burning period, the amount of fuel per period is automatically reduced or immediately shut off. The required amounts of air are set by controlling the speed of the direct current motor, or by starting or switching off one blower group.

3.3. The Kiln Programmer

The kiln programmer (diagram 11) initiates the reversing operation automatically, regulates the sequence and operation of the individual stages of the reversing and stone charging and maintains an even discharge of burned lime. Direction of the fuel, combustion air and waste gas are reversed at regular intervals depending on the kiln output. At nominal output this happens every 12 minutes, at reduced output at longer intervals. A programme selector powered by a variable speed direct current motor with reduction gear initiates the reversing process; it contains all switching procedures for a complete cycle, that is, in the case of a double-shaft kiln the switching procedures over two firing periods, or with a triple-shaft kiln those over three periods. The number of revolutions of the direct current motor, which is proportional to the revolution time of the programme selector is set by hand according to the desired kiln output and controlled by a tachometer to maintain a constant speed. The stone level in each kiln shaft is ascertained periodically (approx. every 30 seconds) by probes and the rotation of the chain wheel associated with the probe transferred onto a potentiometer. The output value of this potentiometer (actual value) is fed into a regulator which, simultaneously, receives a nominal value from a potentiometer, coupled to the programme selector.

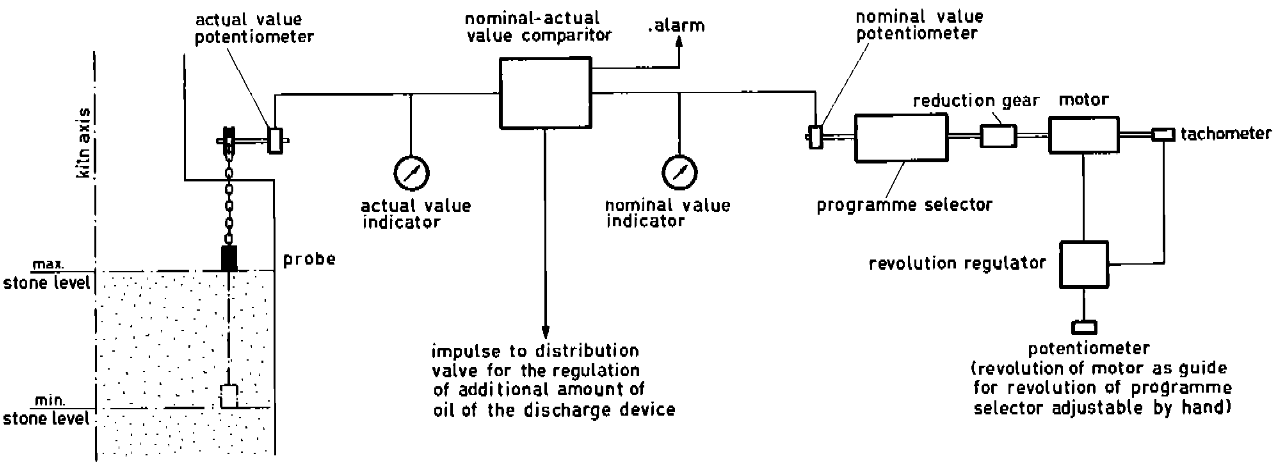


Diagram 11: Schematic arrangement of kiln regulation

Should the actual value fall behind the nominal value, the regulator increases the hydraulic oil flow to the discharge device. The discharge device then moves quicker and the stone level drops faster until the output value has reached a certain rate below the nominal value and the supply of additional oil is switched off again. The basic amount of oil is chosen such that the sinking of the stone level remains behind the nominal value and thus an adjustment of the amount of hydraulic oil becomes necessary in one direction only (increasing). On this basis the regulating device becomes easier to operate.

The nominal and actual values of the charge level in each shaft can be read instantly on instruments, the nominal value indicator being fitted with scales reading from 0 to 100%, and the actual value indicator with scales ranging from –20 to +120%. The nominal and actual values of each shaft are also fed into a relay which actuates a warning light as soon as a predetermined difference in output is greater than the potential difference in the regulator.

4. Characteristics of the Kiln

4.1. Grain Size of the Stone

A small range of grain size is an ideal precondition for any kiln, but, by necessity, a widely varying grain sizing will occur when crushing the stone. Because of the low temperature difference at the end of the burning zone and the parallel flow heating, the PR-kiln is able to calcine a wide range of grain size. The ideal range of grain size is 1:2, but a widening of this range to 1:4 is permissible in the PR-kiln. Furthermore, the range of grain size is not the only criterion, the form of the grain too plays a role. The minimum grain size for the PR-kiln is 18–20 mm and the maximum size of grain may rise to 200 mm if the corresponding range is adhered to. The concept of the kiln permits, particularly in this respect, many variations.

4.2. The Quality of the Stone

A comparison between diagrams 1 and 2 gives a clear indication that the heating by parallel flow is the ideal precondition for the manufacture of soft-burned lime with a low CO_2 residue at, simultaneously, a high output of the kiln. It would exceed the limits of this kiln description to include wet slake or titration curves of limes produced in PR-kilns. By appropriate regulation of the flame, the PR-kiln can produce medium-burned or even hard-burned lime.

4.3. The Kiln Size

Today's trend is to have plants on a large scale and thus, in general, the upper limits are the ones of interest. PR-kilns with a daily output of 500–600 tons are already in operation, but do not represent the maximum size of kiln. Such kilns, however, can only produce such an output if a large-sized grain is used. The lower capacity margin is not determined by structural, but by economic factors. The installations for the automatic operation of a kiln are not considerably cheaper for a small kiln than they are for a plant on a large scale, therefore, the investment costs per ton/year of burned lime are higher the smaller the kiln. Even so, under certain conditions, PR-kilns with a daily output of 50–75 tons may be quite economical.

4.4. The Range of Kiln Output

The output of a PR-kiln can be varied within a wide range; it is quite possible to operate the kiln at only one-third of the nominal output, without considerable influence on the fuel consumption. At reduced output, the power consumption will drop accordingly.

4.5. Excess Air

In the case of the usual counterflow heating, the excess combustion air is of considerable influence on the fuel consumption of the kiln. In the case of the regenerative kiln, on the other hand, the air factor has hardly any effect, because although the excess combustion air reduces the temperature in the regenerator, the same amount of heat is recovered. Without thermal disadvantage one can, therefore, set the air volume to produce a short or long flame and thus adapt the fire in the kiln to the quality demands. As the cooling air does not take part in the combustion and therefore dilutes the products of combustion, the CO_2 content in the waste gas is lower in a PR-kiln.

4.6. The Power Requirements of the Kiln

The power comsumption varies according to the stone size and at nominal output is between 15–25 kWh/t but drops considerably when output is reduced.

CHEMICAL LIME GROUP

P.O. Box 121874
Fort Worth TX 76121-1874
Telephone 817-732-8164
Fax 817-732-8144

For more information on Maerz Kilns, please contact Johnney Bowers, Chemical Lime Company.
Chemical Lime is the North American Licensee for Maerz Kilns.

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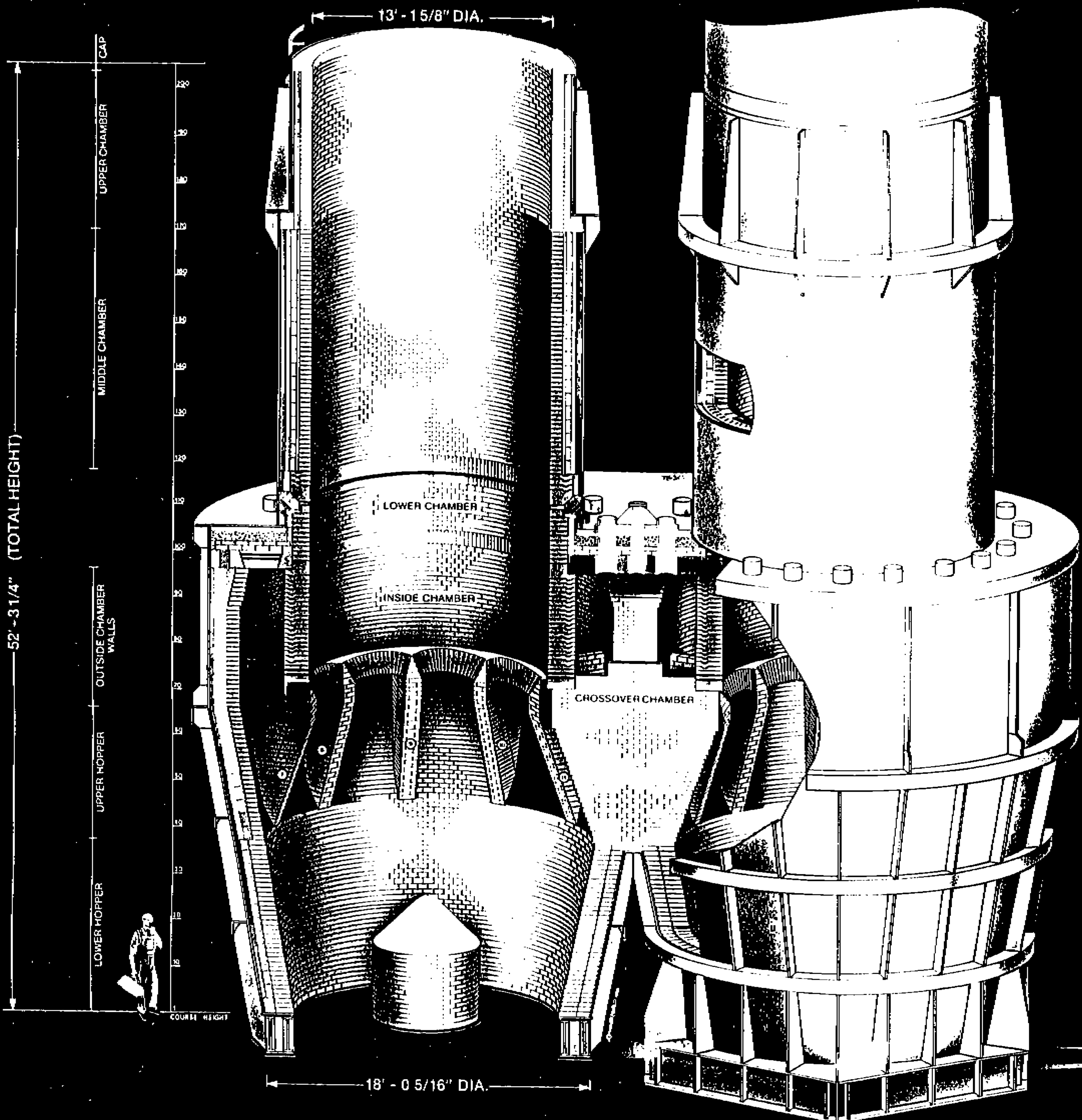
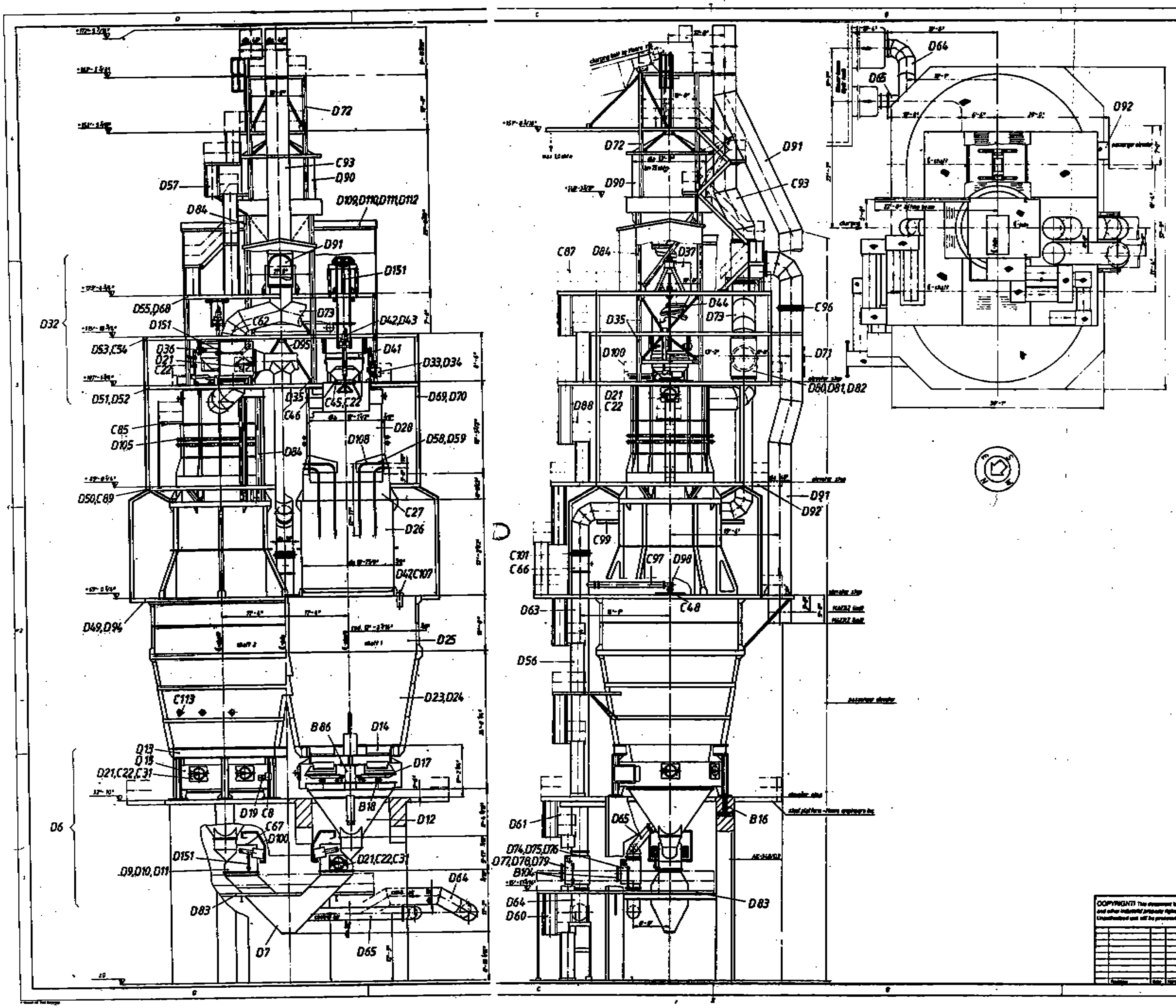


MAERZ
VERTICAL LIME KILN
600 tpd, DS TYPE

LEGEND

- GR 16 - 20
- SHAC CASTABLE
- GR - 20
- GR - 28
- BRIKCRETE
- RADEX-A
- ABRASION RESISTANT FIREBRICK



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Chemstar Lime, Inc.
Ten Mile, Idaho

Steelbinding Assembly

MAERZ

AK-340/D1

MAERZ
OFENBAU
RICHARD-WAGNER-STRASSE 28 · POSTFACH · CH-8027 ZÜRICH · TELEFON 01/202 53 96 · TELEX 815 324 · FAX 01/201 36 34

TELEFAX

Ref/réf: KS/fc Datum/date: 20.09.90 Nr./No: 1738/90

An/to/à: Chemstar, Arizona
Attn. Mr. M.J. Pirnau

Betr./subject/réf: OK-1725/A
Your fax dd September 19th, 1990

Dear Sirs,

With reference to the above fax and the telephone call on September 19th, please be informed as follows:

We have done stack emission measurements on a coal fired kiln in Germany and found the following figures:

NO_2 average 332 mg/m^3 dry (standard conditions 0° C, 760 mm Hg)
SO_2 average 145 mg/m^3 dry
CO average 500 mg/m^3 dry

The S-content in the coal was 0,5-0,8 %, the heat value of the coal approx. 8000 kcal/Kg = 14400 BTU/lb. The kiln was operating on an output of 300 tpd.

Based on the figures of the 300 tpd kiln the emission on a 500 shtpd kiln in pounds/hour would be:

NO_2 34 pounds/hour
SO_2 14 pounds/hour
CO 50 pounds/hour

The measured emission figures of a natural gas fired kiln in Austria were:

NO_2 50 mg/m^3 dry (standard conditions as above)
SO_2 less than 10 mg/m^3 dry
CO 15 mg/m^3 dry

In pounds per hour emission figures on a 500 shtpd kiln would be:

NO_2 5 pounds/hour
SO_2 less than 1 pound/hour
CO 1,5 pounds/hour

With reference to our telephone conversation concerning the use of different grain size please be advised that a kiln with 4 m diameter would produce approx. 500 shtpd using grain size 3/4 to 2 1/2 inches and 600 shtpd using grain size 2 1/2 to 7 inches.

A kiln with 3,5 diameter, as it is in operation at Domlim, Canada is producing 390 shtpd using 3/4 to 2 1/2 inches and 510 shtpd using stone 2 1/2 to 7 inches.

At Domlim in Canada the operation of the kiln in campaigns is common practice because there is only one kiln installed in the plant.

We shall elaborate a more detailed operating schedule regarding grain size and campaigns as soon as you can give us your stone grain sizes available.

Best regards,
MAERZ OFENBAU AG

F. Jahn ppa K. Scheibenreif

F. Jahn ppa K. Scheibenreif

PS. We have just received the emission figures from a coal fired kiln in Sweden (450 mtpd)

CO 390 mg/m^3 dry (standard conditions)
SO_2 10 mg/m^3 dry
NO_x 330 mg/m^3 dry
or
CO 38 pounds/h
SO_2 1 pound/h
NO_x 33 pounds/h

We shall recheck the SO_2 figures as they seem to be extremely low.

MAERZ PROCESSING

FEED: 2½" TO 5"

HARD STONE

6% ON SHATTER TEST

PRODUCT:

DISTRIBUTION:

4%	0 - ½"
5%	½ - 1"
10%	1" - 1½"
25%	1½ - 2"
56%	>2"

DUST:

1% OF FEED — Feed To The Dust Collector

MAERZ KILN DUST (Feed To The Dust Collector)

QUANTITY: 1% OF KILN FEED

QUALITY: 60% $CaCO_3$
40% CaO

GRAIN DISTRIBUTION:

GRAIN SIZE (MICRONS)	PERCENTAGE
< 40	4
40 - 60	18
60 - 100	13
100 - 125	10
125 - 160	10
160 - 200	15
> 250	30

TYPICAL STACK GAS ANALYSIS FOR 600 STPD MAERZ

	UNITS	GAS	COAL
O_2	%, Dry Vol	9.5	7
CO_2	%, Dry Vol	20	25
CO	#, /hr	2.5	60
SO_2	#, /hr	1.6	17
NO_x	#, /hr	8	41

KILN STACK CONDITIONS

DIAMETER	-	4 FEET
STACK HEIGHT	-	172 FEET
ACFM	-	62,000
TEMPERATURE	-	270°
DISCHARGE VELOCITY	-	82 FT/SEC.

PM 10 For Current Bag collector Technology will guranttee 0.02 grains/SCF maximum emissions. No current test data available.

JGB
10/28/92