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DP/ID/SER.B/62
5 May 1976
English

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EXAMINATION OF SHAFT LIME KILNS OF SIND ALKALIS LTD

IS/PAK/75/074

PAKISTAN

TERMINAL REPORT

Prepared for the Government of Pakistan by the
United Nations Industrial Development Organization,
executing agency for the
United Nations Development Programme

United Nations Industrial Development Organization

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United Nations Development Programme

EXAMINATION OF SHAFT LIME KILNS OF SIND ALKALIS LTD

IS/PAK/75/074

Project findings and recommendations

Prepared for the Government of Pakistan
by the United Nations Industrial Development Organization,
executing agency for the United Nations Development Programme

Based on the work of F. Sobek, lime industry adviser

United Nations Industrial Development Organization
Vienna, 1976

Explanatory notes

References to dollars ($) are to United States dollars.

A full stop (.) is used to indicate decimals.

A comma (,) is used to distinguish thousands and millions.

References to "tons" are to metric tons.

Besides the common abbreviations, symbols and terms, the following have been used in this publication:

DIN	Deutsche Industrie-Norm
kcal	kilocalories
Nm^3	Volume of gas at standard temperature (0°C) and pressure (760 mm Hg)

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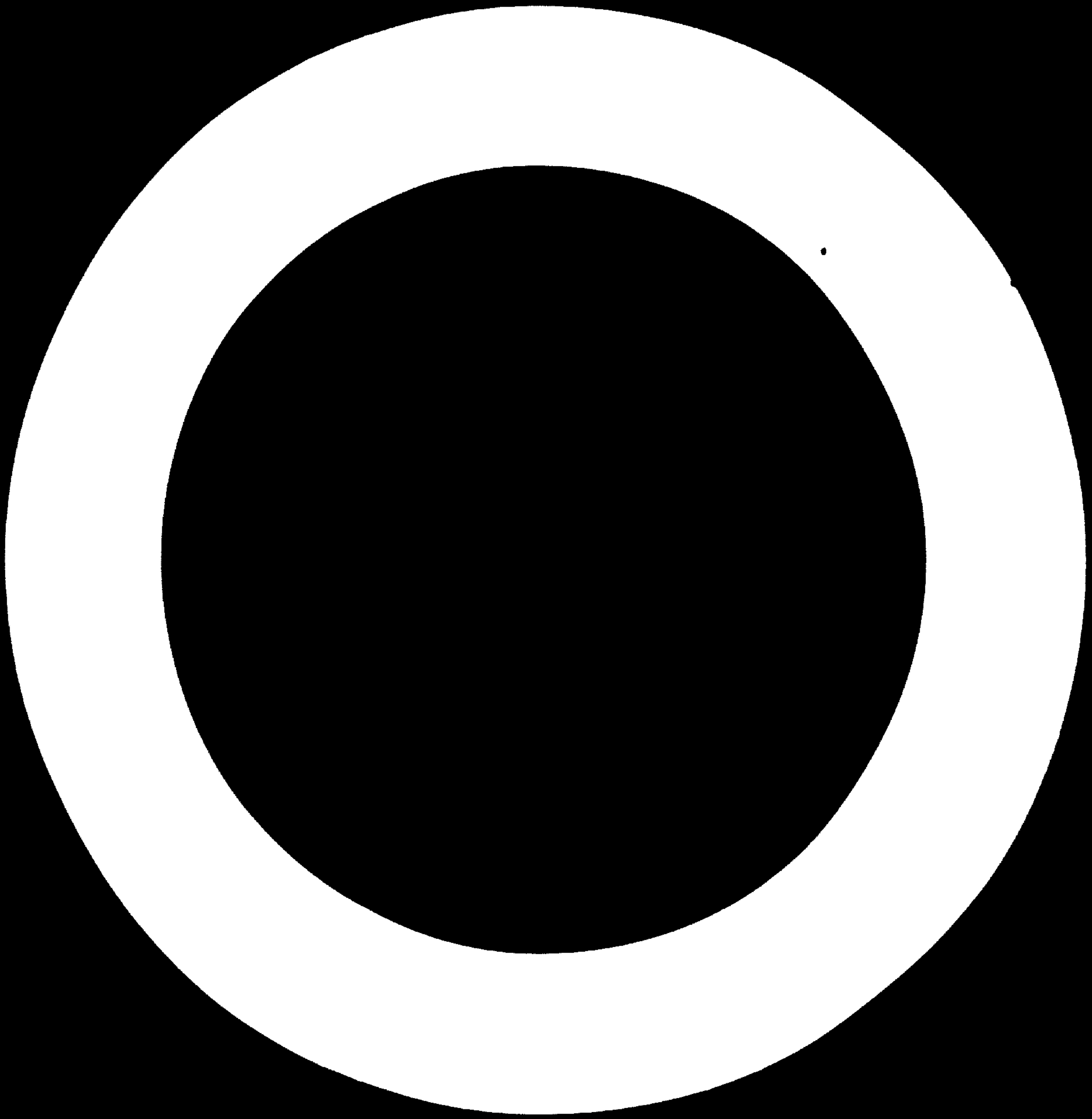
ABSTRACT

The Government of Pakistan has decided to promote employment and improve housing conditions by developing the manufacture of building materials. Many of them are in short supply, and their costs are expected to increase and to affect housing and construction adversely, if countermeasures are not taken. As a first step, Pakistan has requested the assistance of the United Nations Industrial Development Organization (UNIDO) for the lime industry. Other activities are expected to be established as a follow-up to this first project.

The mission was entitled "Evaluation of Shaft Lime Kilns of Sind Alkalis Ltd" (IS/PAK/75/074) and was financed by the United Nations Development Programme (UNDP). During his mission, the expert examined a lime kiln plant the performance of which had been inadequate from the outset. While he was able to suggest stopping the secondary air fan after opening the vibrator windows and to propose the recirculation of exhaust gases to lower the calorific value of the fuel (natural gas), he found that installation of a separate cracking installation could provide all the benefits required. A detailed plan for such an installation is annexed to the report.

The expert also visited another lime kiln operation and suggested additional process-control equipment to improve its burning process.



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INTRODUCTION

The Government of Pakistan has decided to promote employment and improve housing conditions by developing the manufacture of building materials. Many of them are already in short supply, and their costs are expected to increase. Unless countermeasures are taken, such increases could adversely affect the housing situation and the building industry. The Government has therefore requested the assistance of the United Nations Industrial Development Organization (UNIDO) in improving the country's lime industry. An adviser to the lime industry was sent to Pakistan on a two-week mission, which was financed by an appropriation of $2,765 by the United Nations Development Programme (UNDP), under the symbol IS/PAK/75/074. Other activities are expected to be established as a follow-up to this first project.

In the course of his mission, the expert examined the lime kiln plant of Sind Alkalis Ltd at Landhi-Karachi. This plant, which had been designed by a firm in the Federal Republic of Germany and built by one in Denmark, had never performed satisfactorily. As planned and built, its combustion installations did not take into account the fact that, if natural gas were to be used as its fuel, it would first have to be cracked into "poor" gas. Furthermore, the kilns of this plant were both sucked and pressed, a method that experience has often proved to be unsatisfactory.

In an attempt to compensate for these disadvantages to some degree for the time being, without capital expenditure, an experimental process was developed in all details, in consultation with the works management. Since this new method of operation does not constitute a final solution to the problem, a process was worked out for the structural modification of the existing plant and the addition of gas-cracking equipment. Detailed plans for such an installation are annexed to the present report.

At the suggestion of the Federal Chemical and Ceramic Corp. Ltd, Karachi, the expert also visited the lime plant of Ittehad Chemicals at Kala Shan Kaku, near Lahore. We found that the shaft lime kiln there, which also used natural gas as fuel, could be improved by changing the method of operation and by minor investments in measuring and regulating devices that would permit the quality of the lime to be improved and the wear on the fireproof casing to be reduced.

I. FINDINGS

The shaft lime kilns at Landhi-Karachi

Ever since its erection ten years ago, the lime kiln plant of Sind Alkalis Ltd at Landhi-Karachi has been operating unsatisfactorily. As designed and constructed, the combustion installations of the plant did not take into consideration that, if natural gas was to be the fuel, it would first have to be cracked into "poor" gas (that is, gas of low calorific value) beforehand. Moreover, the kilns of this plant had both sucked and pressed draughts, a system that experience has often proved to be unsuitable.

In an attempt to compensate, in some degree for these disadvantages for the time being, without capital expenditure, an experimental process was developed in all details and was discussed with the works management. Since this new method of operation does not constitute a final solution of the problem, a process was developed by the expert that would entail the addition of gas-cracking equipment and structural alterations of the existing plant. Plans for such an installation and an estimate of the capital expenditure involved are annexed to the present report.

The shaft lime kiln at Kala Shan Kaku

At the suggestion of the Technical General Manager of Federal Chemicals Corp. Ltd, the principal associate of Ittehad Chemicals and Ittehad Pesticides Ltd the expert visited the installation of these companies at Kala Shan Kaku. In addition to the plant that produces chloride of lime, there is an Italian (Forindus) shaft lime kiln with a rated capacity of 20 tons/day. At the time of the visit, however, actual output was only 12 tons/day. The specific fuel requirements were calculated at 1,012 kcal/kg.

Except for an indicating volumeter, there were no measuring instruments. Consequently, the kiln must be operated blind as regards all of the currents of the media, and particularly the quantities and pressures of the primary air and the recirculation gas. Under these circumstances, it is to the credit of the works management and their engineers that a relatively good quality of lime was being produced. Recommendations for upgrading this plant were made and are described elsewhere in the present report.

II. RECOMMENDATIONS

Theoretical considerations

The direct use of gaseous fuels of high calorific value is not possible with thermal processes whose object is to treat material in mild heat by flames of low impulses (that is, those that are long, soft and steady) and with the longest possible times of direct contact.

Natural gas that includes appreciable amounts of propane, butane or mixtures of them must therefore be dissociated before it is brought to the kiln burners. In the present case, a natural gas was used that had the following full analysis:

Gas	Per cent
Methane (CH_4)	94.42
Ethane (C_2H6)	1.05
Propane (C_3H_8)	0.28
Butane (C_4H_{10})	0.17
Nitrogen (N)	3.89
Carbon dioxide (CO_2)	0.02
Oxygen (O_2)	0.17
Sulphur (S)	Traces
Water vapour (H_2O)	Negligible

Its calorific value ranges between 8.000 and 8.400 kcal/Nm^3, that is, cubic metres at standard temperature and pressure.

The high proportion of methane in this gas permits comparisons with processes in which methane is cracked for the production of hydrogen gas and soot. It is known that, under imperfect (under-stoichiometrical) combustion, methane dissociates into the constituents hydrogen (H_2), soot (elementary carbon) and water vapour (H_2O). Dissociation takes place rather slowly, however, which is disadvantageous with processes that provide no devices for dissociating the gas outside of the process kiln and which must thus accomplish the dissociation reaction during the actual process; that is, sometimes within the material to be treated.

According to Mayer and Altmayer, the state of equilibrium of this reaction was determined by the following values:

Temperature (°C)	300	400	500	600	700	800	850
Per cent CH_4 (methane)	96.9	86.2	62.5	31.7	11.1	4.4	1.6
Per cent H_2 (hydrogen)	3.1	13.8	37.5	68.3	88.9	95.6	98.4

These figures show that the CH_4 quota decrease is inversely proportional to the increasing H_2 quota during the process. In addition to this transformation, there is a yield of soot, which occurs in hard, granulated form (graphite) when the temperatures during the process are too high.

Particularly with the dissociation of natural gases for subsequent thermal processes such as lime-burning, the formation of graphite can and should be avoided by adequate regulation of the temperatures during the process, because an amorphous carbon will then be produced which, owing to its structure, just as the cracked gas itself, will penetrate without difficulty into the material to be treated and will oxidise there. This general reflection applies in particular to the lime production in the plants considered here, namely those of Sind Alkalis Ltd at Landhi-Karachi and of Ittehad Chemicals, Ittehad Pesticides Ltd at Kala Shan Kaku.

Both plants were visited by the expert, who found, particularly in the plant of the first-named firm, that the lime-burning process used in its three shaft kilns does not meet the requirements for the production of quicklime suitable for the manufacture of soda (sodium carbonate) and sodium bicarbonate.

The carbonic acid (H_2CO_3) resulting from the de-acidification of limestone is also used as a by-product for the manufacture of soda. Moreover, if the de-acidification process is not adequate, a lower volumetric percentage of carbon dioxide (CO_2) in the waste gas must be expected.

Modification of the operation of the kilns at Landhi-Karachi

The expert visited and examined the natural-gas-fired kilns of Sind Alkalis Ltd. On the basis of his observations and findings, he worked out a trial concept for the immediate improvement of their two products, namely quicklime and carbonic acid. He discussed this concept thoroughly, in all details, with the top management and engineers of the plant. The object of this plan is to attain a nearly flameless burning process, with suction draught alone, to produce a better quality of lime based on better conversion. The plan had two aspects: first, the modification of the kiln, which operated with both sucked and pressed draughts, to pressed draught alone, and second, to create a secondary burning process. The scheme for this trial operation is shown in figure I.

Execution

Before beginning the trial operation, the kiln selected should be charged with limestone of uniform size - between 60 and 120 mm. The kiln must be in its normal operating condition, with proper de-acidifying (calcination) temperature levels. The injectors must have been removed from all of the burners so as to return them to their original form.

The design of the burners indicates that these injector tubes do not allow free penetration of the natural gas jets (issuing from tangential ports) into the linearly moving recirculation gas current. The removal of these injectors should promote good mixing of the two currents. (The original design did not include these injectors.)

Owing to the fact that the existing primary air fan has a limited nominal capacity of 2,280 Nm^3/hour, which is greatly below the total requirement for the complete combustion of full natural gas introduced, it is necessary that the natural gas supply be reduced in order to have a stoichiometrical combustion process at the beginning of the trial. With the above output of the primary air fan a maximum of 210 Nm^3/hour of natural gas can be fed for complete combustion in the kiln.

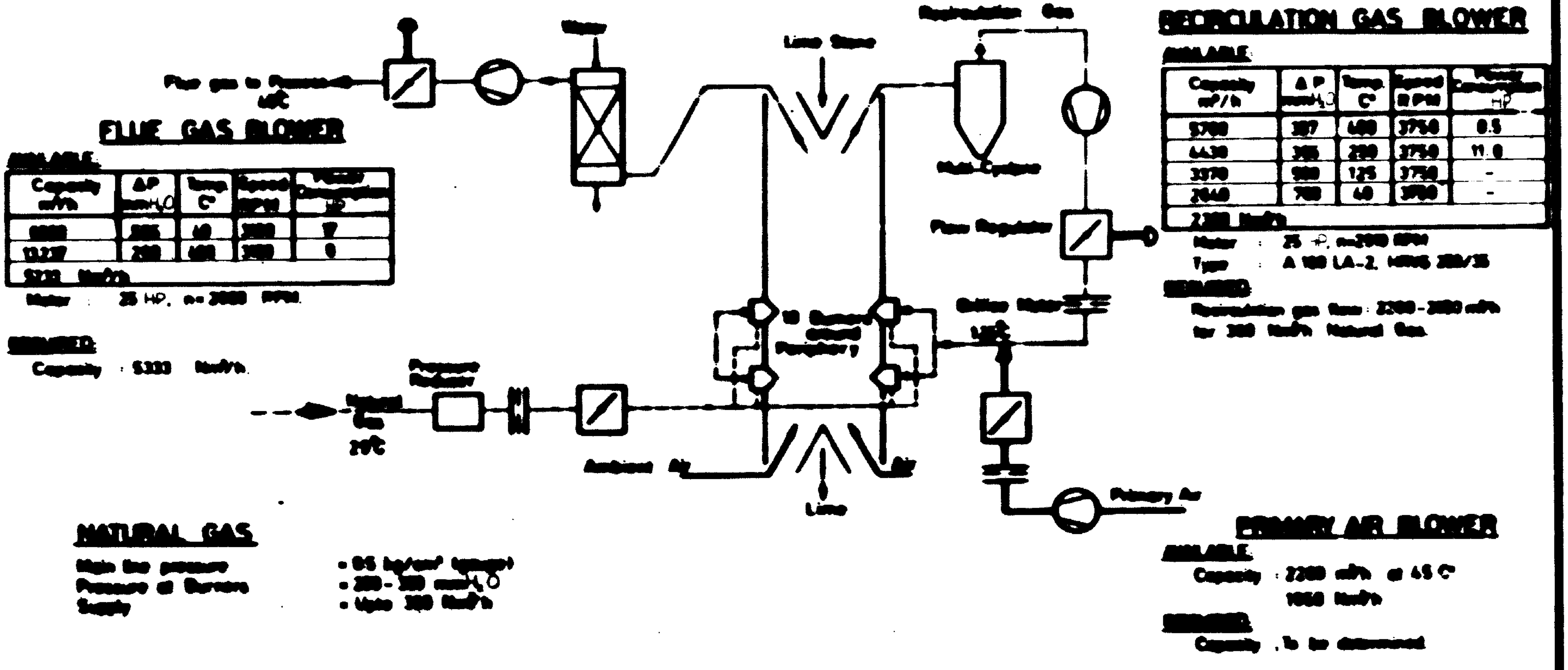


Figure I. Scheme for the trial operation of the modified operation kilns at Landhi-Karachi

The trial

After adjusting the flow rates of natural gas and primarly air (the air being kept in large excess for some time shortly before the commencement of the trial in order to eliminate any explosive gas-air mixture from the kiln), all four vibrator windows must be opened simultaneously in order to expose the bottom of the kiln shaft to the atmosphere. The damper in the delivery line of the flue gas (waste gas) blower should be fully opened before the windows are opened as well with a view to increasing the draught in the kiln so that the flue gas fan will be capable of handling the large volume of gas momentarily available at the opening of the windows. The secondary (fresh or cooling) air blower can now be stopped (that is, when the vibrator windows have been opened) so as to bring the kiln under the influence of induced draught only.

After 10 to 20 minutes of operating in this manner, an analysis of the flue (waste) gas should be carried out in order to determine the values of CO_2, O_2, H_2 and CH_4 for this purpose. The relative values for H_2 and CH_4 should be checked with an Orsat apparatus.

It should also be remembered that exposure of the kiln bottom to the atmosphere and also through all of the existing secondary air distributors and inlets by disconnecting the air inlet pipes from the blower will be helpful in providing good access for the atmospheric air to the remote areas of the kiln, in particular to its eastern and western corners (that is, those on the longer axis).

It is to be feared that the substantial proportion of lime given out in the form of powder along with lump lime might resist the entry of free air and/or its distribution during the sucked-draught operation of the kiln. To avoid such an undesirable effect, it is suggested that all of the upper discharge vibrators be operated in such a way that there would be an almost continuous discharging operation. The provision of an intermediate bunker beneath the kiln shaft should be helpful in storing lime before it is finally discharged out of the lower locks.

The secondary burning process

In order to create a secondary burning process it is necessary gradually to increase the amount of natural gas up to the production feed rate of 368 Nm^3/hour for 50 tons of lime per day. Since the design of certain essential parts of the kiln is suited to the present method of operation, it is not possible either to operate the two levels of the burners independently or to make significant changes in the individual burners with respect to the ratios of primary air and recirculation gas. Only the total supply of primary air can be varied according to the requirements.

As this equipment is not capable of coping with the pure technology of a secondary burning process, the new process tested here can only simulate the original process. The provision of an exact control instrument for natural gas and of an orifice flowmeter in the primary air circuit would make it possible to calculate, to maintain and to register different ratios between the quantities of the two currents.

The first setting should be 0.9, which means that the quantity of primary air should be about 90 per cent of the total quantity of air necessary for complete stoichiometrical combustion of the offered amount of natural gas after a period of one hour, at which time a flue gas analysis should be carried out.

The amounts of H_2 and CH_4 should not increase, since this would indicate a deficiency of air for the secondary burning process and consequently an incomplete combustion. From then onwards, the primary air feed should be reduced stepwise to the lowest possible point, which should theoretically be zero.

However, because of the design of the existing equipment, it was not possible to carry out the necessary cracking of the natural gas outside the kiln. It was also necessary to make a compromise in the trial operations owing to the fact that methane, and hence the natural gas used can be cracked into its parts (H_2, elemental carbon and water vapour), only under certain conditions.

All of this leads to the option of accepting, if necessary, pre-combustion in the form of an under-stoichiometrically burning flame in front of the mouth of the burner. Only by the trials can it be found out which air-gas ratio should be selected. During the trial operation the tendency should be to keep it as low as possible.

It can be expected that the existing equipment, such as the burners, will be capable of dissociating only a small portion of the quantity of natural gas that is offered. For this reason the following points need particular attention:

(a) A pre-burning process in the existing burners with an air-gas ratio to obtain a flame as small as possible is accepted as an alternative to a separating cracking equipment;

(b) As a consequence of (a), a large quantity, between 60 and 80 per cent of uncracked and unburnt natural gas, will enter the kiln;

(c) Because of (b), this quantity of natural gas should be mixed with a large quantity of recirculation gas in order to produce a gaseous mixture with a low calorific value.

Such poor gases are required for two reasons: first, because only they can provide flames that are long and soft; and second, because only they have the necessary volume to bring the ratio of burning gas to cooling and burning air (that is, secondary air) close to the ideal ratio of 1:1 required for optimal distribution of the mixed gases.

On the other hand, this secondary burning process has two disadvantages: first, higher calorific consumption, owing to the necessity to heat the recirculation gas from about 350° to 1,100°C and second, natural gas mixed with carrier gas (recirculation gas, in this case) is difficult to ignite and burn completely.

As mentioned previously, a suitable compromise must be made as there is no separate cracking equipment available with the kilns. The quantity of recirculation gas should be increased to a ratio of 1 part natural gas to 6 to 8 parts recirculation gas. This ratio applies only to pure recirculation gas.

The measurement of the amount of soot expected to be carried over in the flue gas would be done in the filter equipment provided with the gas analyser in the flue-gas line for its subsequent control through the kiln operation. It cannot be stated in advance if the soot produced will have enough time to become ignited and to burn out completely on its way to the top of the kiln, as explained above. For this reason the experiment of reducing the quantity of primary air should be stopped at a point at which the content of free soot in the flue gas becomes unacceptable to the soda ash plant for various mechanical and operational reasons and/or the percentage of unburnt methane exceeds an acceptable limit.

Consecutive analyses of the flue gas will indicate the increasing consumption of cooling air (sucked from the atmosphere as secondary burning air) during the trial operation of the kiln. (This is the registration of the total lambda.)

Precautions

Every precaution should be taken to ensure that explosive gas mixtures do not form anywhere in the system and at any stage of the trial run. Even the possibility of such an accumulation must not be ignored. When it is technologically possible to do so, calculations and measurements should be carried out at each stage of the operation and at each gradual change during the trial run.

After clarification of all technical factors and possibilities and the preparation of a scheme concerning the suggested technology, a conference took place with the responsible managers of the firm. The expert expressed his opinion that, in view of the low efficiency of the kiln and the correspondingly poor results, the execution of the trial for a partial improvement of the quality would be indicated, and also that a reconstruction of the kilns would have to be envisaged as a final solution. A proposal for such reconstruction is annexed to the present report.

Suggestions for improving the kiln at Kala Shan Kaku

As the kiln has an exclusively sucked draught, no corrective measures need be taken in this respect. Here also, natural gas with the addition of primary air is burnt in burners; a certain rarefaction of the natural gas, with the object of reducing the temperatures of the flames, is brought about by adding recirculation gas to the primary air as well as separately. It is obvious that, as a result of the high temperatures of the flames, the lining in the range of the flames is subject to high wear, and that partial hard burning of the lime will occur.

It was therefore suggested that the primary air blower be disconnected, and that the quota of recirculation gas be increased in a ratio of 1:6 or 1:8. Certainly, an increase of the specific heat consumption is to be expected by this procedure, owing to the increased heat consumption for the higher quota of recirculation gas, but on the other hand it will achieve a levelling and reduction of the temperatures and an extension of the combustion zone.

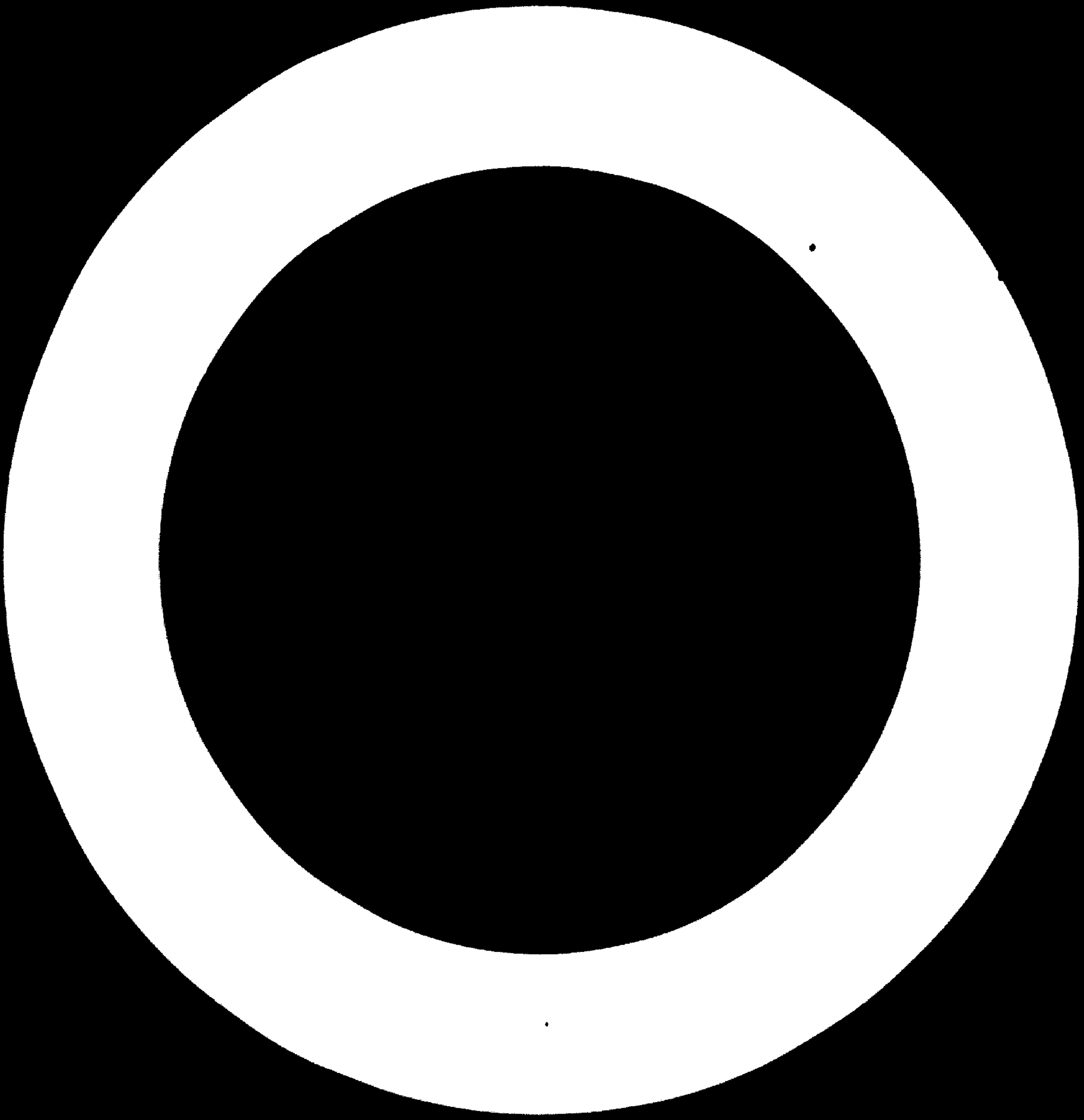
In order to improve the supervision of the burning process the expert suggested the following additions to the measuring devices:

(a) A second measurement of the quantity of natural gas;

(b) A volumetric device for the recirculation gas;

(c) U-pipes for all tapping conduits for gas and recirculation gas before the burners in order to control the pressure because the quantitative measurements for natural gas and recirculation gas are carried out only in the main conduits;

(d) For the supervision of the combustion process, of the excess air and in particular of the quantity of unburnt CH_4, an Orsat apparatus for the production of full analyses in the flue (waste) gas as regards CO_2, O_2, CO, H_2 and CH_4 should be installed.



Annex

PROPOSAL FOR THE RECONSTRUCTION OF THE SHAFT LIME KILNS OF SIND ALKALIS LTD. AT LANDHI-KARACHI

At the request of the management of Sind Alkalis Ltd, the expert explained a technology for the calcination of limestone in sucked low-pressure kilns with gas-cracking reactors. A schematic diagram of this scheme is shown in figure II. The details of this plan, including its probable cost, would be as follows.

Kiln data

Form of the shaft	Elliptical
Major axis	4 000 mm
Minor axis	2 000 mm
Cross-section in the combustion zone	6.20 m^2
At an output of 50 tons/day	7.96 tons/m^2/day
Inner circumference of the shaft	9.94 m
Distance of the axes of the 6 reactors	1.66 m

Specifications of the plant

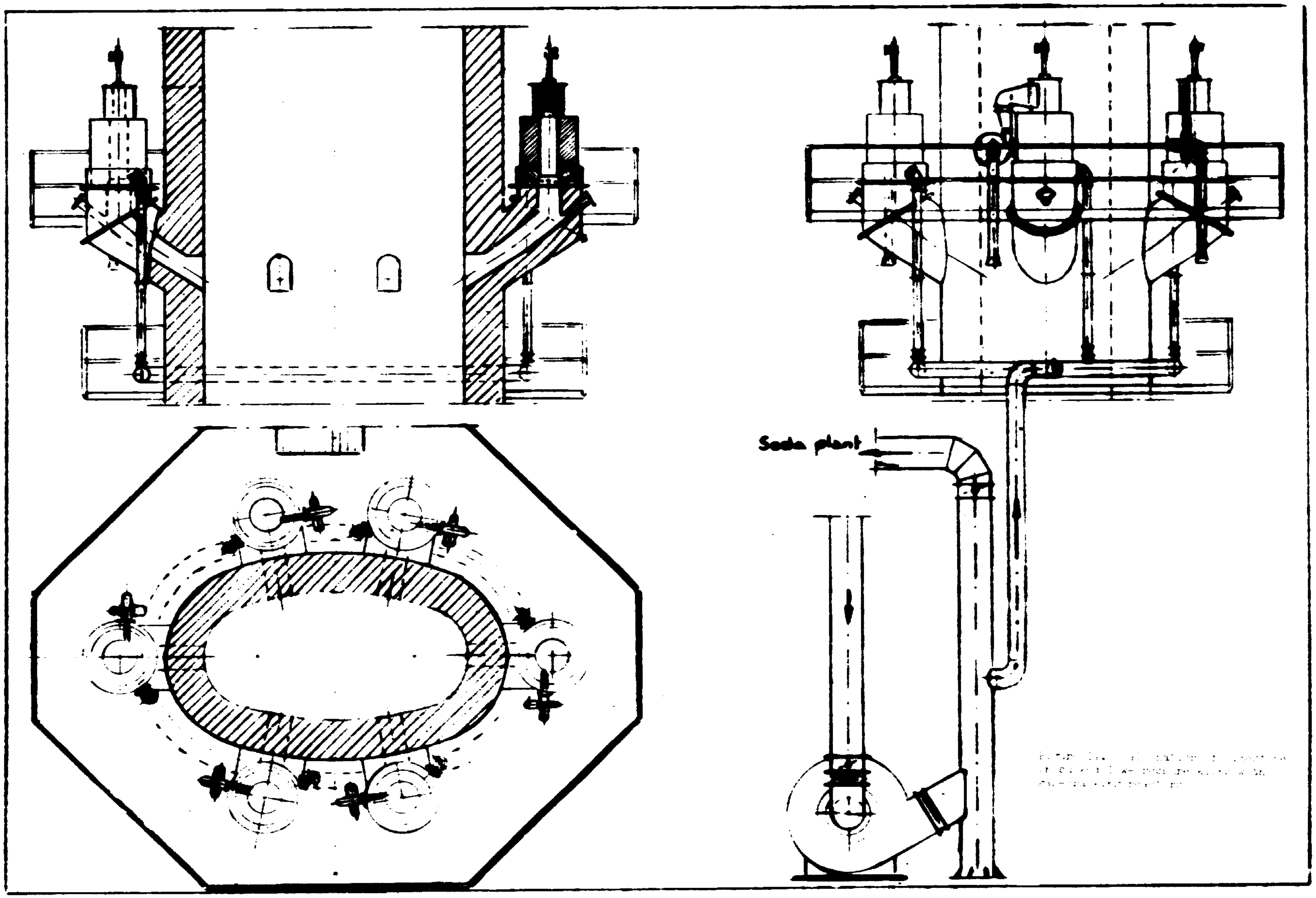
The essential requirements of the plant would be:

- A flue gas (waste gas) and carrier gas plant
- 6 gas-cracking reactors
- 6 sharp-edged diaphragms and 6 ring balances
- A set of four drawings
- Various pipes for natural gas, carrier gas and flue gas (waste gas)
- A licence-fee as settlement for the patented process

All of the above would have to be imported, except the piping, which could be produced and installed on the spot according to the drawings.

Estimated cost of the materials and services

The costs listed do not include transport charges, packing or insurance; they are pure estimates, ex factory Central Europe. They do not include erection and mounting charges.


Soda plant

Item	Cost (US dollars)
Flue gas (waste gas) and carrier gas plant	11 500.00
Gas-cracking reactors ($10,800 each x 6)	64 800.00
Sharp-edged diaphragms and ring balances ($850 each x 6)	5 100.00
A set of drawings, namely 1 DIN AO assembly drawing 1 DIN AI descending pipe-line flue gas (waste gas), with damming device carrier gas and chimney 1 DIN AI ascending pipe-line ring conduit and tapping conduits 1 scheme AI	
Total 375 hours at $15.40/hour	5 775.00
Various pipings for natural gas, carrier gas and flue (waste) gas, estimated weight 12 tons, estimated price for 1 kg mounted $2.40 (x 12,000)	28 800.00
	115 975.00
Licence fee 7 percent of the above	8 118.25
Total	124 093.25

Improvements through reconstruction

The results of the reconstruction are expected to be:

(a) An improvement of the quality of the lime produced, with a residual content of CO_2 in the quicklime of 4 percent;

(b) A reactive soft quicklime owing to the use of poor hydrogen gas as fuel;

(c) An improvement of the specific cross-section output from the present 7.96 tons/m^2/day to 10.0 tons/m^2/day, which would mean an increase in daily output from 50 to 63 tons.

With the installation of a stone-crushing and sifting plant and the use of limestone of 60-to 80-mm diameter, the output could even be increased to 12 tons/m^2/day for an output of 75 tons/day.

The parts of the installation

The waste gas and carrier gas recovery equipment would consist of the suction-line system including the waste-gas pipe-line, with the dynamic pressure device for the carrier gas and a speed-control system together with a throttle valve in front of the exhauster, that would allow the pressure of the atmosphere in the kiln to be regulated in accordance with operational requirements, independently of the quantity of waste gas to be extracted. Carrier gas would be collected by means of an adequately long section in the stack with a remote-controlled damper; the damper position indicator and the remote-control unit would be located in the control room.

The gas produced in the reactors would be added to the carrier gas and the quantity and pressure of the carrier gas would be adjustable by means of the exhaust gas below the speed control and the ram valve in the exhaust gas pipe-line. This control would permit the calorific value of the fuel gases to be adjusted to the optimim for the burning process so that a moderately long-drawn-out combustion zone would be obtained, ensuring the production of soft-burned lime.

The most important components of this equipment are the six gas-producing reactors, which are located around the shaft shell. Each consists of a crossed piece for producing the required turbulence in the primary air and arrangements for obtaining optimal mixing efficiency. It also carries the hole for the ignition, which is performed with a slow match. It also carries the mounting for the burner nozzle assembly and the ultrasonic nozzle, which produces an ultrasonic field for atomising the natural gas.

There follows the actual reactor chamber in which the cracking process takes place. Behind the reactor chamber there is a mixing chamber, and between the two chambers there is a nozzle unit for injecting the carrier gas.

A blower would be mounted on each reactor chamber for the supply of the primary combustion air. It would draw in air from the atmosphere through a measuring section of pipe and force it into the crossed piece through suitable pipes. The reactor would be equipped with all the fittings for natural gas, compressed air and primary air necessary for measurement and control purposes in continuous operation.

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