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ENERGY AUDITS FOR SELECTED ENERGY-INTENSIVE INDUSTRIES IN THE ESCWA REGION

(MUSALMEYEH AND HAMA CEMENT PLANTS, SYRIAN ARAB REPUBLIC)

89-1158

PREFACE

The present technical publication has been prepared in accordance with the ESCWA programme of work and priorities for the biennium 1988-1989. It consists of two major parts. The first covers the Musalmeyeh Cement Plant, which is located 15 kilometres (km) north-east of Aleppo, Syrian Arab Republic, and operated by the Shaba Company for Cement and Building Materials. The energy audit undertaken for this plant was carried out with substantial financial support from the United Nations Environment Programme (UNEP).

The second part of this publication covers the Hama Cement Plant, some 210 km north of Damascus. Work was carried out in close co-operation with the Agence Francaise pour la Maitrise de l'Energie (AFME), which provided the ESCWA secretariat with expertise for undertaking the required energy audit.

Both parts of this publication are intended to assess the use of energy in the various stages of cement manufacturing and other related utilities, examine the effects of the operation of equipment and maintenance practices on energy consumption in the plants under consideration, and evaluate the extent to which the technologies used meet the requirements of energy efficiency.

The proposals formulated in this publication for the consideration of authorities concerned aim primarily at identifying the technical and technological requirements and suggesting performance methods and practices for more efficient use of energy.

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Part One

ENERGY AUDIT FOR THE MUSALMEYEH CEMENT PLANT
ALEPPO, SYRIAN ARAB REPUBLIC

1. INTRODUCTION

1.1. The Shaba Company for Cement and Building Materials operates three plants in the Syrian Arab Republic, the first one at Sheikh Said, 5 km south of Aleppo, the second at Bourj-Islam, 15 km north of Latakia and the third, the subject of this report, at Musalmeyeh 15 km north-east of Aleppo. The Musalmeyeh cement plant has a production capacity of more than 700,000 tons (t) of clinker/yr. It consists of three lines, two of them with up-to-date techniques. Two 1,000 t/day lines were commissioned in the period 1976-1980. One old wet process line (the first line set up in the plant), with a rated capacity of 350 t/day, is scheduled to cease production, so its energy consumption will not be audited. The two first lines use the dry-process.

1.2. Energy consumption - Musalmeyeh plant. The thermal energy consumption for the years 1985, 1986 and the first quarter of 1987 varied from 100-110 kilograms (kg) fuel oil/ton of clinker (dry process). The electric energy consumption for the same period was in the range of 180-190 kWh/ton of cement (dry process). This represents a high rate of energy consumption.

1.3. Energy consumption of fuel oil and electricity in the Syrian Arab Republic

1.3.1. Fuel oil. Consumption ranged from 28 to 33 per cent of the total petroleum products consumption between 1950 and 1970. It then started to decrease until it reached 18 per cent in 1970 owing to the country's growing reliance on gas oil for power generation during 1970-1975 and the opening for operation of the Euphrates Dam in 1974. Fuel oil consumption again increased and reached 31 per cent of the total products consumption in 1985 because the power stations using this fuel were again brought into use; in addition some industries utilized such fuel. This percentage is expected to increase owing to the growing reliance on such power stations and industries.

1.3.2. Electricity consumption. The average annual rate of increase of the country's consumption of electricity during the period 1960-1985 was about 15 per cent. Electricity consumption is growing much more rapidly than petroleum products consumption because of the extensive use of electricity and the expansion in the electrification of rural areas.

The increase of the contribution of electricity is easily noticeable in the industrial sector including the oil industry. It is also noticeable in the residential and commercial and the building and construction sectors. However, this is not the case in the transportation and communications sector, since transportaion in the Syrian Arab Republic depends mainly on either diesel to power locomotives or gasoline and gas oil to fuel cars and heavy-duty vehicles for inter- and intra-city transportation.

1.4. Owing to the Syrian Arab Republic's rapidly increasing consumption of energy, of which industry accounts for the highest percentage, energy conservation has become a major concern, particularly in the energy-intensive industries, such as the cement factories. Hence the particular importance of energy audits.

1.5. The energy audit. An energy audit is the starting point for the implementation and monitoring of any energy conservation programme. Actually, it is a critical examination of an energy-consuming facility.

Typical objectives for conducting an energy audit are the following:

- To set energy conservation goals;
- To develop energy standards;
- To identify and analyse energy saving opportunities;
- To establish an accounting and reporting system.

1.6 The need for reducing energy consumption in the cement industries has led to the development of new processes. Over 20 years, energy consumption, thanks to technological contributions, decreased from 1,500 kilocalories (kcal)/kg of clinker to less than 760 kcal/kg. This development is shown in the following table which indicates, for the periods between 1955 and 1985, the average consumption of selected cement plants.

Heat consumption (kcal/kg clinker)	Year
1,700	1955
1,440	1960
1,200	1965
1,070	1970
930	1975
800	1980
760	1985

Electric energy consumption also decreased in one cement plant; any slight increases would be the result of sophisticated and technologically improved production lines.

2. SUMMARY

A summary of operations to be carried for ensuring energy saving is shown in table 4. The savings have been calculated for both production lines 2 and 3, because the two production lines and their associated production sections are not operating at their design capacities. There are many measures which merit consideration such as: reduction of shut-downs, improvement of operation so that equipment will be operated at 90 percent productivity, increasing the percentage of pozzolana in cement from 10 to 20 percent; power factor improvement; avoiding running big consumers in the peak period whenever possible; improving steam boilers efficiency; and reduction of excess oxygen in the kiln exit gas. These measures will require a minor investment, and they will provide savings of approximately 17,868,953 Syrian pounds (LS).

Other important saving opportunities could be achieved by reaching the plant specific energy consumption targets through proper operation, systematic preventive maintenance, personnel training, observance of safety regulations, quality control, pollution prevention and last but not least, a modified management structure. Savings realized through the above measures would be approximately LS 31,461,000.

The utilization of the waste heat from the clinker coolers to provide heat for heavy fuel oil preheating on lines 2 and 3 is technically feasible. However, because the economic analysis indicates a payout period of some 11 years, this measure cannot be recommended.

The operation of kilns, clinker coolers, cement mills and electrostatic precipitators was investigated. Unfortunately the results were disappointing as the equipment did not appear to operate properly for many reasons; the most important ones are the low level of the operators knowledge and the situation with regard to instrumentation and control equipment. Operating and control methods cannot be enchanced until these problems are remedied. There are many opportunities for energy saving to be gained by further tuning and optimizing of these units.

The great energy saving potential reflects the poor opertion level at the Musalmeyah plant. The lack of energy management structure and sound maintenance practices appears to be the major flaw in the operations of the Musalmeyeh plant.

The Sheba Company, which operates three cement plants in the Syrian Arab Republic, as stated above, will be operating a new company for spare parts manufacturing. Management of plants tends to be very centralized in the case of the Musalmeyeh plant, there is a real need for delegation of managerial functions. The main functions of the Managing Director are to elaborate and develop the company's strategy, and to co-ordinate are support factory activities. Any actual activities should be entrusted to the local factory management.

A suggested management structure organization for Musalmeyeh works is outlined below (figure 1).

3. BACKGROUND

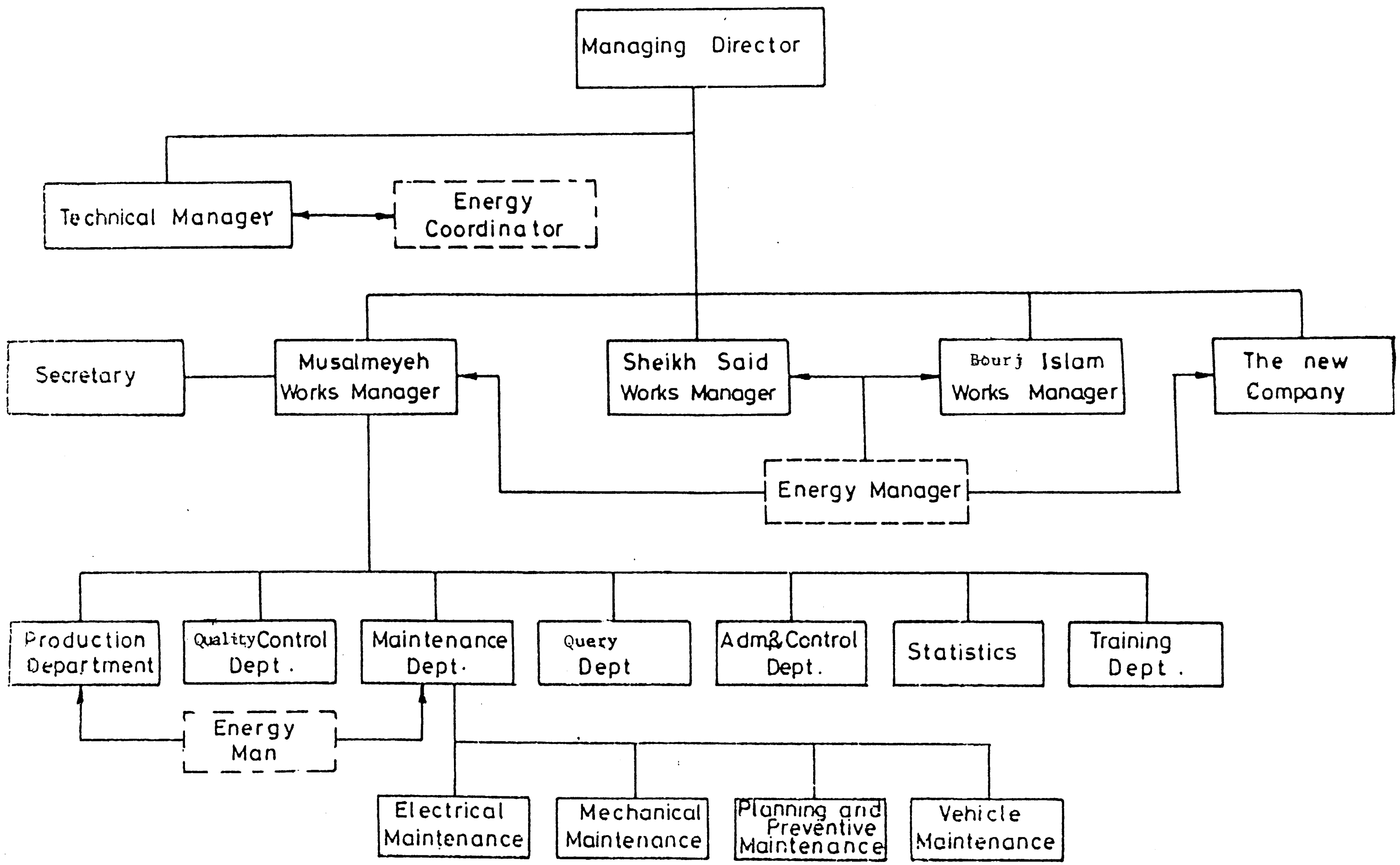
This section covers the procedure and assumptions used to make the necessary analysis for the entire study. It includes the following:

- Methodology
- Units
- Environmental data
- Cost data.

3.1. Methodology

The audit was performed on the basis of the data collected from visits to the plant carried out between 1 and 16 November 1988. Several major objectives were set for the visit in order to create a common understanding with plant management for the study as whole and the audit in particular, and collect the necessary in-plant data for the evaluation of energy usage. Additional information was obtained through meetings with observation of the facilities. The audit concentrated on energy conservation through management, operation and maintenance. The major objectives of the visit were the following:

Figure 1. **Suggested management structure organization for Musalmeyeh Cement Plant**



- To verify or modify the conclusions of the supplied data;
- To collect in-plant data;
- To identify possible measures for conserving energy;
- To study and observe operational and maintenance practices;
- To study and observe energy monitoring and management practices.

In order to accomplish these objectives, meetings and discussions were held with the management at the Musalmeyeh cement plant and the Shaba Company top management.

3.2. Units

1 calorie = 4.18 joule
1 kcal = 1 x 10^{-3} thermie = 1.1628 x 10^{-3} kWh
1 toe (ton oil equivalent) = 1 x 10^{4} thermies = 11,628 kWh

The conversion rate electric kwh/thermic kcal = 860. Although international law recommends the use of joule as an energy unit, the kilocalorie will be used as has been common paractice.

The energy equivalence between commercial units and toe expresses the lower calorific power of a fuel.

As to the electric energy, the equivalence corresponds to the thermal energy amount necessary to the production of a unit of electric energy in a thermo-electric power plant.

3.3. Environmental data

Although environmental regulations concerning air quality standards are not imposed by the Government on industry in the Syrian Arab Republic, self-imposed targets at the Musalmeyah cement plant (200 mg/N m^3) for the two electrostatic precipitator kilns 2 and 3 are up to internationally recognized standards.

3.4. Cost data

The following prices, costs and specifications supplied by the cement plant have been used in this study.

Heavy fuel oil:
Cost LS 821.75/t(ton)
Lower heating value 9,600 kcal/kg
Specific gravity = 0.9735 kg/litre at 20^{o}c.
= 0.953 kg/litre at 25^{o}c.

Electricity. Data provided by the Shaba Company show that since 1 June 1987 the prices charged by the General Organization for Electricity for purchased power were based on the following components:

Day consumption 6 a.m. to 5 p.m., 24 piastres/kWh
Night consumption 11 p.m. to 6 a.m., 19 piastres /kWh
Peak period consumption 5 p.m. to 11 p.m., 32 piastres/kWh
Average price (steady constant load - 24 hr/day), 24 piastres/kWh

Effective 1 December 1987 the prices charged by the General Organization of Electricity for purchased power based on the following components:

Day consumption 6 a.m to 5 p.m., 33 piastres/kWh
Night consumption 11 p.m to 6 a.m., 29 piastres/kWh
Peak period consumption 5 p.m to 11 p.m., 54 piastres/kWh
Average (steady constant load) = 24 hrs/day, 36 piastres/kWh

Power factor penalty:

The power factor penalty cost will be paid according to the formula:

$$\frac{\text{Value paid}}{\text{month}} = \frac{0.85}{\text{actual power factor}} - 1 \times \frac{\text{Total invoice value}}{\text{month}}$$

The electrical energy saving costs will be calculated in this report based on average day/night/peak power prices.

Water	LS 0.5/m^3

Raw materials

Cost at cement plant including loading, haulage and unloading (1986 prices)

Limestone	LS 12.1/t
Basalt	LS 12.1/t
Sand	LS 78.82/t
Pozzolana	LS 38.85/t
Iron ore	LS 49/t
Gypsum	LS 61.7/t

4. TYPOLOGY

4.1. General considerations

In cement factories energy is used in the form of electricity and heat. Electricity is mainly used for lighting and for equipment while heat is used for processes and for space heating or air conditioning.

Energy arrives at the factory as fuel oil by means of railways and is stored heated up to 60° C and then to 120° C and then is brought to the furnace, where it burns and is converted into heat and transferred to the oil heating system (steam) and to the raw meal (clinker burning) and to the raw material for drying. Electric power arrives at the factory from the national high tension grid, is transformed to medium and low tensions and is supplied to the equipment by means of a distribution system. During this process a portion of the energy is lost, and another one is transferred to the final product, which carries a content of energy expressed in term of kcal or kWh per ton of product. The main task of energy managers is to direct actions aimed at the best utilization of energy, decrease losses, increase efficiency of equipment and processes and reduce the amount of energy required without affecting the quality of the end product, or, if possible, even improving it. The cement industry has a wide range of raw materials employed (limestone, basalt, sand, iron ore, pozzolana, gypsum, etc,) and processes involved (crushing, grinding, burning, etc.).

4.2. Plant description

Musalmeyeh started operating with one 350 t/day kiln in 1959/1960; since then it has been expanded two times. In total three kilns and their associated equipment have been built.

Line one is of the wet process type, using excessive energy and has no dust collecting systems.

Line 2 was built in 1976 and line 3 started production early in 1980. The rated capacities of these line are:

Line 2	1,000 t/day clinker
Line 3	1,000 t/day clinker

For convenience, the production lines can be considered in four main groups:
The crushers, the raw mills, the kilns and the cement mills.

4.2.1. Crushers

Three crushers are used to reduce quarried limestone, basalt and gypsum to 0-30 mm grain size prior to stocking. Limestone is crushed with a hammer crusher (double shaft hammer crusher) of a rated capacity of 400 t/hr. The crushed limestone is fed dirctly to two storage silos and, from these silos, limestone is withdrawn by means of a bin discharging carriage (portable and adjustable). Approximately 17 per cent of the crushed/withdrawn quantity of limestone is fed to a 70 t/h drier with a 5 per cent inclination, drying from 12 to 6 per cent H_2O. The dried portion of the limestone and the other non-dried one are stored in a stock pile at the stocking hall, which is covered. The total installed motor power of the crusher is 700 kW. At maximum production levels approximately 3,250 t/day of limestone is required. This would allow for running the limestone crusher outside peak demand period to minimize electricity costs.

Basalt/laterite is crushed in a hammer crusher with a movable crushing apparatus, with an hourly through-put of 100 t/h. The same applies to the gypsum crusher.

Mixing ratio of raw materials components for manufacture of standard Portland cement, type 1, according to ASTM is as follows:

Limestone	71-75	per cent; 73.0 per cent on average.
Basalt/laterite :	23-27	per cent; 25 per cent on average.
Sand	0-3.5	per cent; 2 per cent on average.

The specific energy consumed by the crushers is not calculated, owing to the lack of energy meters for that purpose. Normally the specific energy consumed by the crushers ranges from 1.4 to 1.8 kWh/t of raw material processed.

Allowing for a loss on ignition (LOI) of 35 per cent, this corresponds to a range of 2.15 to 2.77 kWh/t clinker.

4.2.2. Raw mills (Air-swept/central discharge)

Blended raw materials are fed to two raw mills, each dedicated to its own production line. The moisture content can vary from 6 per cent in summer to 12 per cent in winter. Removal of this moisture content occurs during the milling operation through the use of hot exhaust gases from the kiln which, after passing through the preheaters, are cooled to 35^{o} C prior to entering the raw mills.

Operations of the raw mills should be planned to take place outside electricity peak demand period (5 p.m. to 11 p.m.) to minimize electricity costs. During the shutdown period, the kilns are fed from blending and storage bunkers which have sufficient capacity for up to four days operation. The two raw mills operate closed circuit grinding systems. Proportioned quantities of the raw materials (limestone, sand and laterite/basalt) are passed to the bucket elevator rotary mill, in which the materials are reduced and dried in the first chamber.

When the material has been reduced satisfactorily, it is passed through a sieve grate in the central discharge opening and conveyed to the bucket elevator which delivers it to a pneumatic conveyor. From here the material to be ground is passed to the circulating-air separator, in which it is separated into coarse-grained material (grits) and fine-grained material (raw mix). The grits are discharged through a control valve to the first and second grinding chambers. The grits are reduced in the second grinding chamber, then the material is passed through the sieve grate to the central discharge opening and conveyed together with the material from the first grinding chamber by the pneumatic conveyor and bucket elevator to the circulating-air separator. The fine material is carried by waste gases out of the mills and extracted by electrostatic precipitators. It is then removed to the mixing and storage silos prior to release into the preheaters and kilns.

The plant has the following modes of operation:

- Direct operation: (Raw mills are stopped):

The total waste gas goes from the kilns to the electrostatics precipitators via the stabilizers, the connection ducts and the diffusers. Water is injected in the conditioning towers (stabilizers) to reduce the waste gas temperature from 350^{o} C to 120-150^{o} C when the preheater exhaust gases are diverted partially or completely into the electrostatic precipitators.

- Semi-interconnected operation (raw mills are running):

Part of the waste gas goes from the kilns via the raw mills and intermingles in the mixing chambers below the stabilizer gas. The mixed gases go via the connection ducts to the diffusers and the electrostatic precipitators.

- Interconnected operation (raw mills are running):

The total waste gas flows from the kilns via the raw mills and passes through the mixing chambers below the stabilizers, the connection ducts and diffusers to the electrostatic precipitators.

It is possible to operate the raw mills without preheater exhaust gases. Separate fuel oil fired furnaces are installed with sufficient burner capacity to meet the drying loads of the raw mills.

In practice, however, these are never used. Recently, particular attention has been paid to the capture of fine particles, and the exhaust from the electrostatic precipitator of line No. 3 has dust loading considerably higher than the design value of 200 mg/Nm^3 or exhaust gas and this is due to the false air leaking to the system. The E.P. will be more efficient if the false air is prevented from leaking into the system. The electrostatic precipitator of line 2 is running with two fields. The factory staff are repairing the rectifier transformer of field No. 2, after which the electrostatic precipitator will be functioning smoothly if false air is prevented from leaking into the system. Both raw mills are similar in design and output. They are of the horizontally mounted, air-swept, ball mill type (figure 2).

Table 1 summarizes the key data for the raw mills.

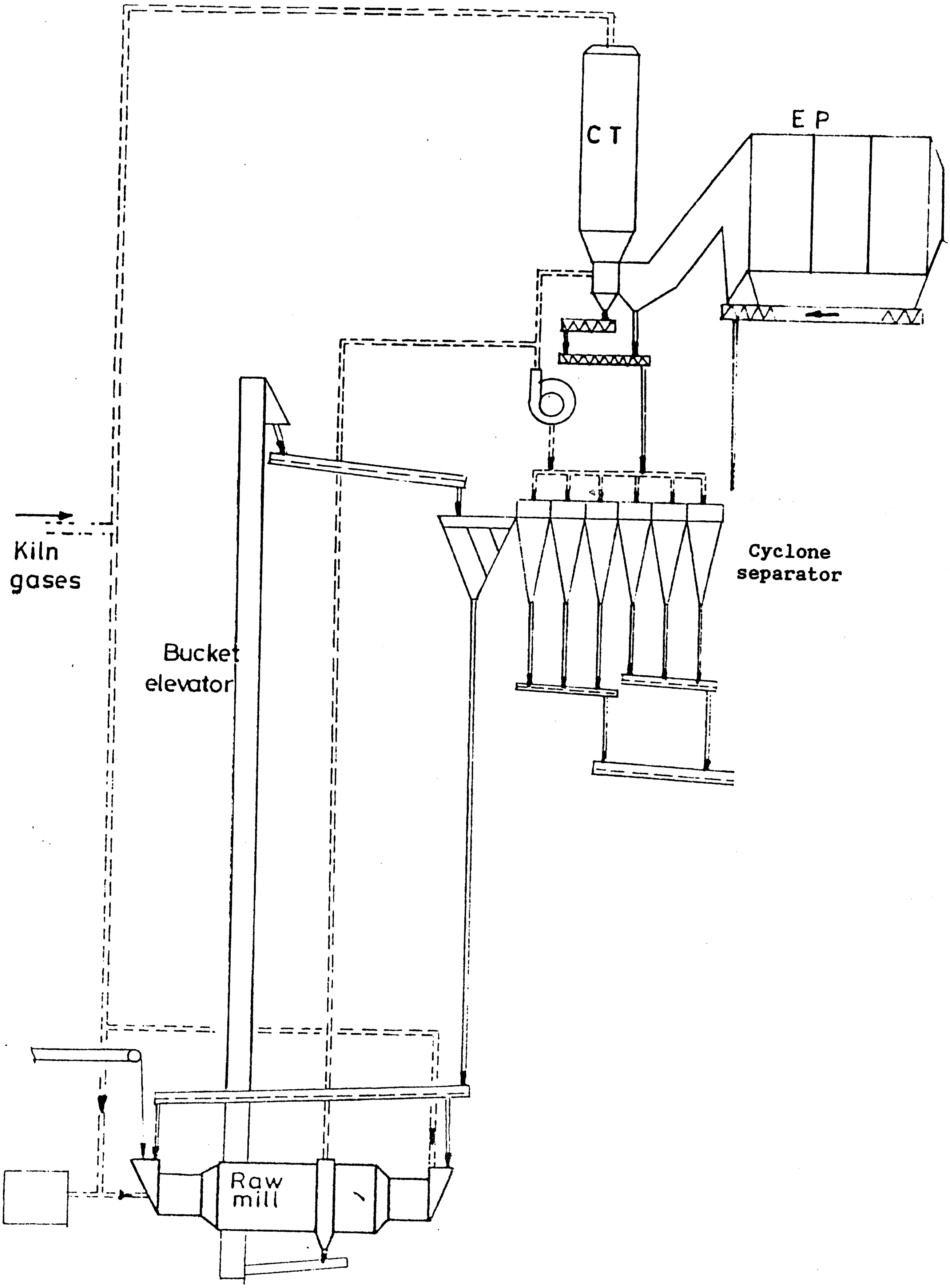
The specific energy consumed by the raw mills is not calculated owing to the lack of necessary energy meters for this purpose. The specific energy consumption of air-swept mills ranges from 20-25 kWh/t of raw meal processed and for a raw meal.clinker factor of 1.6 this will be 32-40 kWh/t of clinker.

Table 1. Raw grinding mills

Line	2	3
	Air-swept ball mill	Air-swept ball mill
Inside diameter of the mill cylinder (mm)	4,000	4,000
Length of the mill cylinder (mm)	10,500	10,500
Inside diameter of the grinding compartment No. 1 (mm)	3,840	3,840
Inside diameter of the grinding compartment No. II (mm)	3,870	3,870
Length of the pre-drying compartment I (mm)	1,000	1,000
Length of the 1st grinding compartment (mm)	5,000	5,000
Length of discharge grate wall (mm)	750	750
Length of second grinding compartment (mm)	3,750	3,750
Rated output (t/hr)	100	100
Drive motor (kW)	2x1120	2x1120
Moisture (percentage)	6-12	6-12
Mill speed (RPM)	15.8	15.8
Fineness	14/R,90	14/R,90
Specific mill power consumption (kWh/t)	22.4*	22.4*

* Total main drive power.

Figure 2. Layout of raw mills 2 and 3 with their associated equipment



4.2.3. Kilns

The layout of the two production kilns, lines 2 and 3, together with their associated equipment, is shown in figure 3. The exhaust gases from these kilns are used to preheat the incoming feed materials in vertical shaft preheaters. As heat in the kiln gases is given up to the charge, the temperature of the kiln gases is lowered from 850° C/950° C to 350° C prior to their passage to the raw mills and/or to the stabilizers where they are further utilized. The two kilns are of the same diameter and length and each kiln has a rated output of 1,000 t/day clinker or 42.5 per cent of total clinker production from lines 1,2 and 3. Each kiln has a special designation reciprocating grate cooler 56 m^2 for cement clinker, manufactured by VEB, German Democratic Republic. The cooler has two stages and five chambers. This type of cooler has a lower power consumption than the travelling grate clinker cooler type. Table 2 summarizes the key kiln data.

4.2.4. Cement mills

At present there are two cement mills (Nos. 2 and 3) in operation. They are closed circuit units, each rated 80 t/hr., and they are tube/ball mills. They have a fixed slot diaphragm separating the two chambers, and material is roughly ground in the first chamber before cascading into the second chamber for fine grinding.

Figure 4 shows the configuration of cement mills 2 and 3 and their associated equipment. Clinker, gypsum and pozzolana are fed at rates of up to 80 t/hr. Exhaust air with extracted fine particles of ground cement passes to a cloth bag filter and hence to an induced draft fan. Cement extracted at a rate of 80 t/hr at a temperature of 100° C passes to storage silos. Oversize material from the mill passes through a bucket elevator into a cyclone separator, manufactured by SKET/VEB, which is a two-stage cyclone separator with a mechanical centrifuge in the main central cyclone. The cyclone separator has its own recirculation fan. Small quantities of fresh air are brought in from the outside atmosphere to cool the system, and a portion of the circulating air is bled off by the induced draught fan via the cement mill bag filter which collects the fine cement and returns it to the cement product line. Cement mills 2 and 3 have 2 x 1,400 kW motors of which more than 2,400 kW manifests itself as heat during grinding. Consequently the recirculation plant can get very hot and cement can exceed its target outlet temperature of 100° C. The situation is even more critical if hot clinker at around 70° C is fed into the cement mill. Pozzolana has a moisture content which provides a useful cooling load. In addition a provision is made for spraying water into the cement mill, if the separator circuit atmosphere air intake is insufficient for cooling purposes; unfortunately, however, the spray system is not working, and it should be repaired. The total power consumption of the cement mill, recirculation fans, separator drive for fan plus dust collector and its induced draught fan can be high. These factors are taken into account when considering savings associated with producing pozzolana Portland cements.

The main cement mill characteristics are listed in table 3. For cement mills 2 and 3 the auxiliary drive motor is rated at 17 kW, the separator circulating fan at 180 kW, the cyclone motor at 225 kW. In practice the auxiliary motors add about 15-20 per cent to the mill motor power consumption figures; specific power consumption for the cement mill is about 40 kWh/t of cement.

Table 2. Kiln data

	Kiln No.	
	2	3
Preheater type	Shaft preheater	Shaft preheater
No. of stages	5	5
Extent of pre-calcining (percentage)	30-40	30-40
Feed exit temperature (° C)	820/850	820/850
Gas entry/exit temperature (° C)	950/350	950/350
Kiln diameter/length (m)	4.0/60	4.0/60
Inside diameter of lining (m)	3.514-3.6	3.514-3.6
Internal volume (m^3)	589	589
Surface area (m^2)	666	666
Rated output (t/day)	1,000	1,000
Specific output/volume	1.698	1.698
Sintering zone temperature (° C)	1,350/1,450	1,350/1,450
Exit zone temperature (° C)	1,200	1,200
Target fuel consumption (kcal/kg cl.)	850	850
Kiln inclination (percentage)	3.5	3.5
Cooler type	Reciprocating grate	Reciprocating grate
No. of grates	2	2
No. of chambers	5	5
Grate area (m^2)	56	56
Clinker exit temperature (° C)	125	125
Waste air temperature (° C)	235	235
Secondary air temperature (° C)	900/1,000	900/1,000
Dust removal	Multi cyclone	Multi cyclone

Table 3. Cement mill data

Parameter	Mill No.	
	2	3
Diameter (m)	3.6	3.6
Chamber length No. 1 (m)	3.724	3.724
Chamber length No. 2 (m)	9.744	9.744
Rated output (Portland) (t/hr)	80	80
PPC output (t/hr)	85	85
Motor power (kW)	2x1,400	2x1,400
Specific mill power consumption (kWh/t)	35*	35*
Blaine fineness (cm^2/gm)	3,000	3,000
Accessories (kW)	550	550

* Main drive.

Figure 3. Kilns 2 and 3 schematic diagram

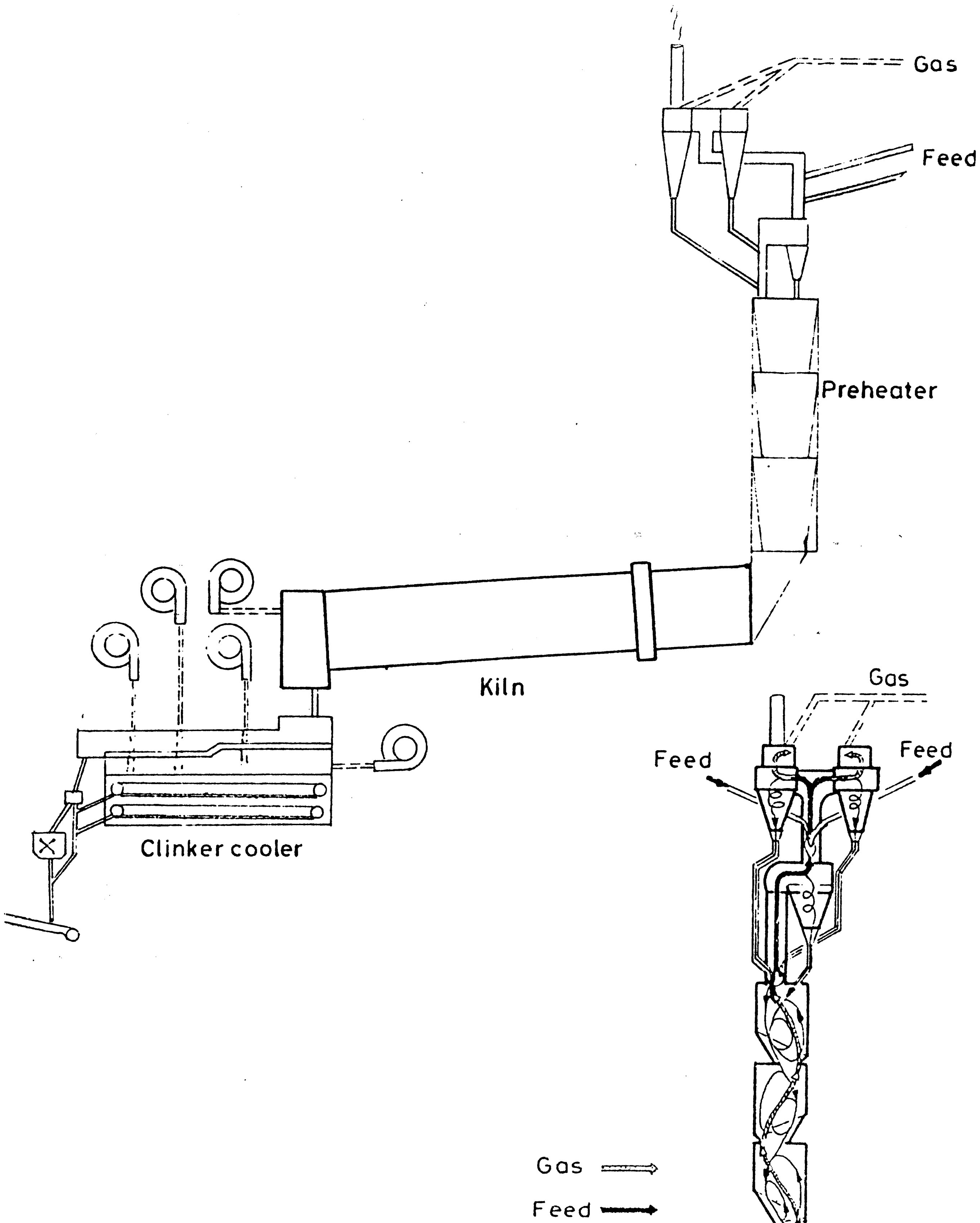
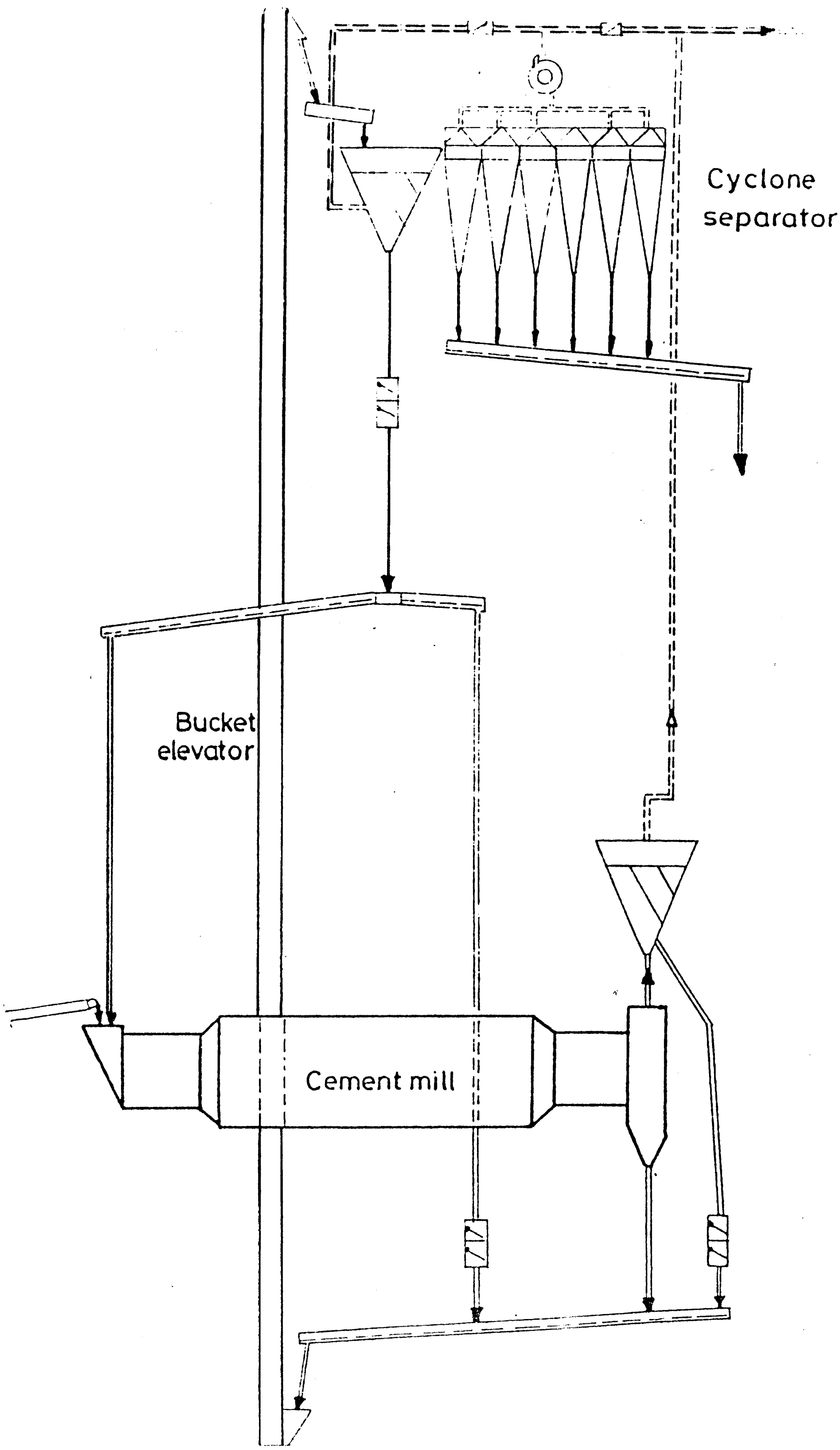


Figure 4. Layout of cement mills 2 and 3 with their associated equipment



5. IN-PLANT OBSERVATIONS AND DATA COLLECTION

Complex manufacturing works cannot attain high levels of production and good energy performance without the support and guidance of top management. Before considering the details of plant design, instrumentation and control, it is always prudent to ascertain management's approach to the questions of plant functioning, preventive maintenance and energy utilization. Knowledge of works operational procedures allows subsequent plant observations to be carried out more effectively.

5.1. Management structure and operation

The operating works management structure of Musalmeyeh is shown in figure 5. The works management has sole responsibility for attaining production and profit targets set by the head office. Line responsibility to the works manager (the managing director) is from two main groups; namely the production and technical affairs department and the personnel and administration department. Maintenance, production, statistics and quality control sections report to the chief of the production and technical affairs department. Considerable attention is paid to building up special teams headed by engineers for particular areas of the plant.

In practical terms, it seems to be very difficult to establish truly functional systems. Most staff view the system from the short term and seem unable to have a long-term perspective. Therefore, in their attitude and behaviour, there is concern for the present, but not for the future which means there are repairs but no modifications leading to improvement. Establishment of a truly functional system can only be achieved by continuous and systematic actions.

Operating works management structure has to be modified and made fully functional. Certain steps should be taken to improve the staff's attitude and activities. Without improving the factory management structure, it is difficult to improve anything else.

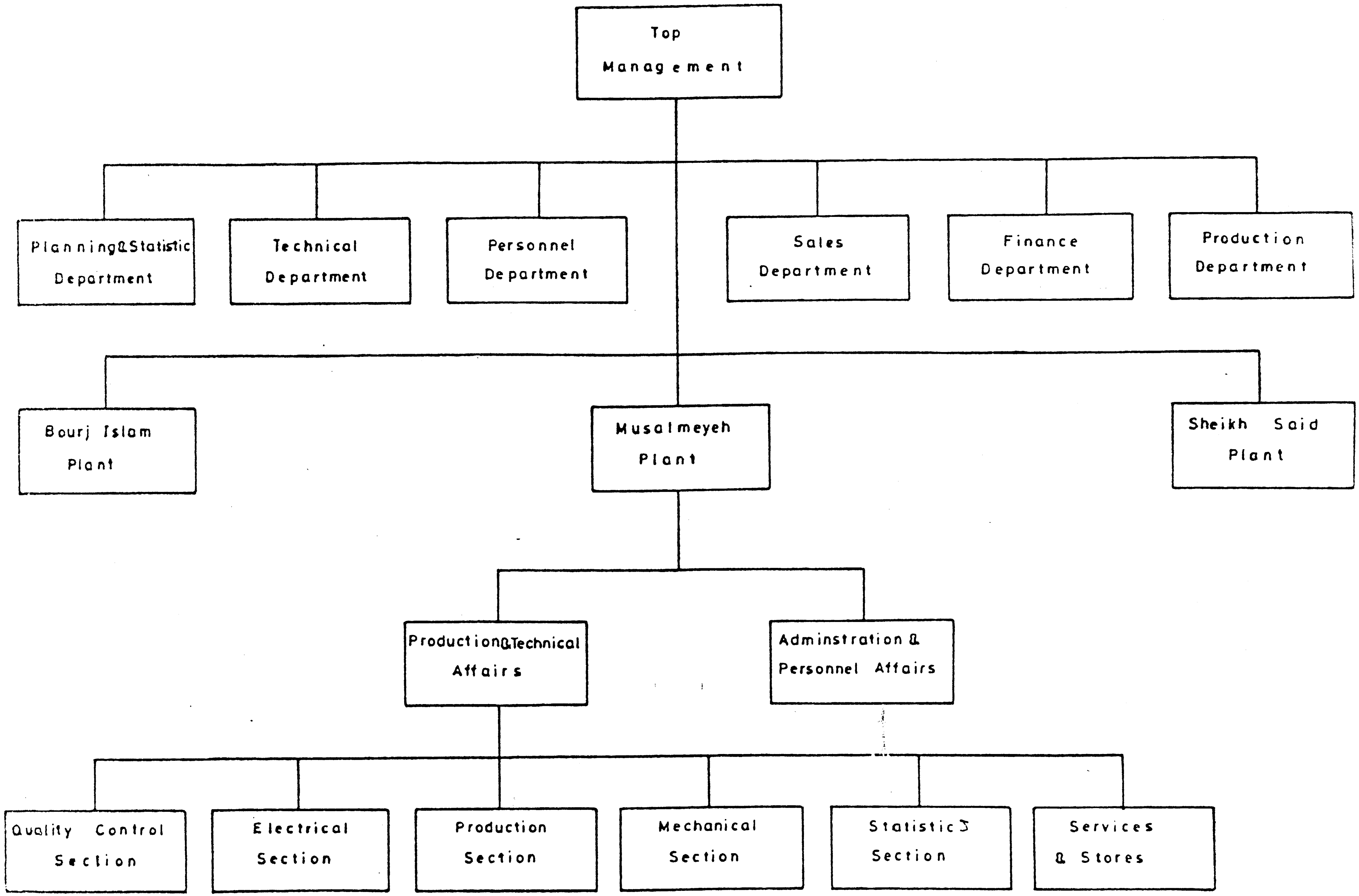
5.2. Maintenance

Maintenance procedures and practices have been examined and found unsatisfactory. Maintenance consists of repairing breakdowns. There is no preventive maintenance and the information system to assist in planning preventive maintenance schedules is not applied.

For most major shutdowns some kind of maintenance programmes are planned and executed, and the work is controlled by the concerned engineers who supervise the activities of the mechanical, electrical and production functions. All the plant and/or sections is inspected during major shutdown periods.

Maintenance staff totals 162 mechanical engineers and fitters and 120 electrical engineers and fitters. Maintenance teams are backed by fully stocked engineering workshops with a comprehensive range of machine tools and metal fabrication facilities. The work is virtually self-sufficient, in that it can undertake most repair operations, including, for example, manufacturing most of the spare parts required locally, motor rewinding and fan impeller rebalancing. However there is a lack of the original spare parts required for comprehensive maintenance. It was noted that a record is kept for the coolers and kiln linings.

Figure 5. Shaba company management structure



5.3. Energy management

An energy management structure is badly needed in the Shaba Company for Cement and Building Materials, and an energy saving committee should be established to set targets for energy consumption and review current performance.

5.4. Instrumentation and control

Inspection of the two production lines showed that, for process control purposes, instrumentation is adequate. All key instrument readings on lines 2 and 3 are conveyed back to a central room.

Although instrumentation is adequate for process control, there are areas in the plant where it is insufficient to enable energy balances and consumptions to be assessed. In addition, some of the existing instruments are not functioning owing to lack of maintenance and/or to the lack of spare parts. Temperature shell measuring equipment have not been erected for kiln 2 or kiln 3.

5.5. Production plant

During the audit of processing equipment and auxiliaries the following points were noted or confirmed by the plant staff.

5.5.1. Line 2

- There is no kiln shell temperature measuring, owing to the lack of apparatus for this purpose.

- 620 cm of the kiln shell at the outlet had been replaced in April 1983 owing to the overheating of the original section which led to an opening in the kiln shell under the third tyre. One roller was replaced under tyre No. 2 owing to cracks in the roller.

- There is a section between tyres 2 and 3 which is deformed and it needs to be replaced for a length of 2.5 m. There are two other deformations under tyre No. 3, 50 x 50 cm each.

- The O_2 gas analyzer reading was more than 6 per cent.

- The CO gas analyser reading was 0.1 per cent at kiln inlet, and 0.25 per cent before electrostatic precipitation.

- Field 2 in the electrostatic precipitator was not working owing to the failure of the rectifier transformer of that field.

- The kiln faced many stoppages owing to brick accidents, electrical and mechanical faults. Several stoppages occured during the audit, all of them owing to electrical and mechanical faults.

- Leaks into the system were detected, especially in the following sections: the pre-heater, the ducts between the pre-heater and the raw mill and the duct between the raw mill and the electrostatic precipitator (EP), and between the pre-heater and the EP and into the EP itself.

- Many parts of the duct between the preheater and the EP are uninsulated.

- A large area of the stabilizer needs to be insulated.

- The duct behind the preheater is deformed owing to overheating.

- The cooler is not working efficiently: the cooling air is not sufficient, the grate plates are of bad quality, there are many damaged plates and many blockages and subsequently many damages to the dragchain. Accidents have led to many kiln stoppages. The dampers between cooler chambers are not working and they were opened and kept open manually; big heaps of clinker built up on the top of the first row of the plates at the cooler inlet ("snow man" phenomenon) which led to the damage of those plates.

- There are several reports of cement mill stoppages owing to mill cylinder problems. Two cracks occurred in the middle of the mill cylinder of 50 cm and 60 cm and they were welded in 1984; the outlet sleeve bearing is leaking oil owing to an opening in the sleeve itself, and the factory management decided to keep it running since cement mill No. 3 stopped because of a major failure, and oil adding is going on. The inlet bearings of the mill were changed in 1986 owing to cracking problems (longitudinal cracks). The inlet section of the mill (175 cm long) and outlet section (120 cm long) had been cut and changed by new parts. There is no stable feeding to the cement mill owing to a technical failure in the clinker feeding carriage. All the above mentioned contribute to the unstable operation conditions of the cement mill and subsequent low productivity (50-60 t/hr) and high energy consumption. Other reasons are the routine breakdowns owing to normal electrical and mechanical faults. The same can be said about the kiln with regard to high energy consumption.

The control room of cement mill 2 is situated at the cement mill location and is not connected to the central control room which controls lines 2 and 3.

5.5.2. Line 3

- No kiln shell temperature measuring.

- 260 cm of the kiln shell between tyres 2 and 3 was replaced in Ocober 1987 owing to deformation that area.

- One roller of tyre No. 2 was replaced in October 1987 owing to cracks in the roller.

- The kiln outlet section is not in alignment with the kiln centre line owing to deformation under tyre No. 3; the Musalmeyeh management is planning to change this section at the end of 1988.

- Leaks and insulation situations are, to a certain extent, similar to what has been observed in kiln No. 2.

- Inlet and outlet sections of cement mill No. 3 were replaced as for cement mill No. 2.

- The cement mill diaphragms in cement mills Nos. 2 and 3 were moved one meter closer to the second chamber.

5.5.3. Compressed air systems

- The pressure of the central compressed air distribution systems and the losses from leakages in the distribution systems were checked. No abnormal problems were noted.

- Regular operation of air compressors and safety valves settings were checked as were leaks in piping, air receivers, valves, fittings, etc. No abnormal problems were noted.

5.5.4. Fuel oil storage system

Documents of all physical and chemical properties of the stored fuel oil, as well as a drawing of the tanks with their heating system and all ancillary equipment and the flow diagrams with all design data (temperature, pressure, pressure drop, viscosity, flow rate, etc.) were available and accordingly all the parameters were thoroughly checked; no abnormality was noted.

The temperature of fuel oil in the storage tank and in the piping system after the outflow heaters was checked, as was pressure drop and correct operation of pumps.

There are three tanks for fuel oil storage; it was checked and found that only the one in service is kept heated, while the others remain cold, to avoid wasting energy.

The condition of existing insulation of piping for oil was checked and found good except for minor pipe sections near the tanks which are in need of insulation repair.

5.5.5. Steam boiler system

- The steam in the Musalmeyeh plant is used for heating fuel oil in the fuel oil storage tanks to 60^{o} C and heating fuel oil used in steam boiler furnaces, kiln burners and drying burners. Three steam boilers are installed for these purposes, one always in operation and the other two on a stand-by basis. One of the three steam boilers is rated 3.2 t/hr and the other two are rated 3 t/hr each.

- Leaks in piping, valves and fittings were checked and it was found that there were too many leaks in the system.

- Insulation of piping, collectors and valves, etc. was checked and found good except in places such as valves, which should be thermally insulated.

- During inspection, it was noted that there were many unused and leaky steam pipes, for example, the steam pipes connected to the cement mills, packing plant buildings and to the raw materials store area.

5.5.6. Electrical system

- Locations of transformers, associated H.V switch gear and main M.V switchgear were checked and found correct. Cable feeders to submain switchboards at local centres to which the final circuits for machines, and distribution boards for lighting and small power are connected were also checked and found correct.

- Size and material of conductors with reference to load length of run and location in relation to other services or plants were checked and found satisfactory.

- The system was checked and it was found that it was installed in compliance with local regulations concerning earthing.

- Power factor compensating elements were checked and found satisfactory both for H.V motors drive and low tension distribution systems; it is possible to improve the power factor by operating these elements up to more than 0.90 but, unfortunately, these elements are not operated effectively, which means that the power factor is almost below 0.85, and consequently the electricity bills always have extra charges, i.e., the cost of reactive power resulting from the power factors which are below 0.85.

- Eight No. - 6KV (kilovolt) drives had been burnt between 1984 and the time of the audit. The total capacity of those drives is 6,560 kW.

- Energy meters erected are not enough for the purposes of calculating the specific power consumption for each production department. The main 6 kV electric drives have energy meters only. There are still 24 to 30 kW meters to be erected to enable the factory staff to determine the power consumption of the different sections. Those energy meters are vital for establishing the energy management in the Musalmeyeh works.

- The importance of safety management in the electrical system should be stressed, since this would lead to minimizing the breakdowns, and consequently to energy saving. Safety is as important as preventive maintenance.

6. ENERGY-SAVING OPPORTUNITIES AND MEASURES FOR SAVING IN THE MUSALMEYEH CEMENT PLANT

One of the most pressing economic factors for any cement plant is the cost of energy. The cost of energy, in the Musalmeyeh cement plant, expressed as a percentage of the variable and of the total production costs respectively, was to reach 50 per cent and 38 per cent in 1986 and about 60 per cent and 44 per cent in the first quarter of 1987. The basic functions of management - planning, organizing, decision making, and controlling - apply to the use of energy as they do to any other manufacturing resource. In the case of energy, the basic information for planning is supplied by the energy audit. During this energy audit for the Musalmeyeh plant, the opportunities for energy saving and the measures needed were summarized as follows:

6.1 Energy management structural organization.
6.2 Efficient utilization of thermal and electrical heat.
6.3 Reducing production costs of cement by introducing the use of blended cement.
6.4 Personnel training.
6.5 Daily energy report.
6.6 Preventive maintenance.
6.7 Clinker coolers' "snow man phenomenon".
6.8 Excess oxygen

6.1. Energy management structural organization

Energy management in the cement industry generally includes all actions aimed at achieving a higher degree of efficiency and reliability in the end use of energy in the system. For that reason any cement plant must have an energy conservation programme in order to improve efficiency and reduce energy consumption. This is as important as other indispensable management units such as the operation management unit, quality control unit and personnel management unit. As with the other management units, energy management units should be as effective and efficient as possible.

Energy management affects almost every major activity of the cement plant: electrical engineering, control system engineering, utility engineering, mechanical engineering, chemical engineering, environmental engineering, operations, maintenance, heating, ventilation, air conditioning engineering and accounting and financial management.

The main problem of energy management is how to organize the energy conservation activities so that all functions are moving in common directions.

In all phases of the cement industry process, a remarkable amount of energy is supplied. Energy conservation is important in this "energy intensive industry" and it can be achieved through the following:

- Proper procedures and maintenance;

- A continuous evaluation of energy conservation opportunities;

- Careful evaluation of the new activities of the enterprise.

An energy management structure is needed and proves its worth:

- During the planning of an energy programme;

- During the execution of the programme;

- When energy management personnel are committed at all levels to success of the plan;

- During the continuous controls which provide the data for evaluation and corrections.

In all cases, independent of the size of the cement plant, the energy management structure should be co-ordinated by a single person, which in a large enterprise would be the energy management co-ordinator. It is he who develops and implements energy management programmes and has authority, accountability, and direct access to the people at the top of the organization chart.

The energy manager's tasks and responsibilities are outlined below:

1. Main duties

The duties of an energy manager may change according to the size and the type of organization in the enterprise he works for, but the managers in general are expected to do the following:

- Develop record keeping and energy accounting systems;

- Give technical advice on energy-saving equipment and procedures;

- Identify possible energy conservation opportunities;

- Co-ordinate the effort of energy users;

- Train energy users and stimulate interest in energy conservation;

- Plan and participate in energy audits;

- Survey and review the literature on energy development, and to disseminate this information to appropriate channels;

- Make plans for energy emergencies or cutbacks.

2. Educational background and hierarchical position

Energy managers, and energy management personnel in general, should have an adequate technical background, including engineering and economics, and an organizational attitude. Hierarchically each energy staffer of the various departments is subordinate to the energy manager of his plant, whereas the energy manager is autonomous within the organization, between those responsible for generation and distribution of services and those responsible for their use.

6.2 Efficient utilization of thermal and electrical heat

6.2.1. Efficient utilization of thermal heat and improvment of overall combustion efficiency in the kilns

The overall efficiency of a combustion unit is defined as the useful heat (i.e., heat transferred to the material) to the total input heat. By applying the energy balance of the kiln (as a combustion unit) in a steady state (which means that the chemical power brought in with the fuel is equal to the sum of the useful power and the lost power), the following equation can be produced:

$1 = \eta + Ps + Pi + Pu$

where:

η : The overall efficiency of the system
Ps : The stack loss.
Pi : The insulation loss.
Pu : The unburnt loss.

The comustion efficiency (1-stack loss) depends on the load (ratio between useful power and its maximum); since it is this that affects the loss values. The combustion efficiency increases (i.e., stack loss decreases) if the fuel rate is reduced. The load is dependent on production need and on the homogenization of the raw meal and these are not constant always. It is of great importance to have an accurate regulation of feed rate and constant feed composition in order to give the proper load.

Cutting down on the use of excess fuel improves combustion efficiency.

The following is a brief explanation of combustion losses and their evaluation:

(a) Stack loss

This loss occurs because the combustion products leaves the stack at a higher temperature than the air and fuel at the inlet.

The stack loss equation as estimated from the energy balance is:

$$Ps = \frac{Cs}{H} (1 + \eta\ Ast)\ (ts-ta)$$

Where:

Cs : Specific heat of combustion products.
H : Net calorific value of fuel.
η : Air index $\left(\frac{\text{actual air}}{\text{theoretical air}}\right)$
Ast: Stoichiometric air mass/fuel mass.
ts : Stack gas temperature.
ta : Ambient temperture.

For each fuel there is a range for the value of η corresponding to its flow rate. The value of η is different from fuel to fuel as it is dependent on the nature of the fuel (for example, gaseous fuel has better mixing qualities than others). Typical values of η are:

Gaseous fuels	1.05 → 1.2
Fuel oils	1.1 → 1.3
Pulverized coal	1.1 → 1.3

A famous formula by Siegert which is widely used for stack loss estimation is:

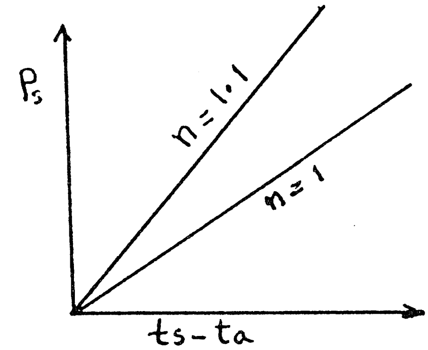
$$Ps = \frac{Ks\ (ts-ta)}{CO_2\ \%\ \text{in vol. dry basis}}$$

Where Ks is the Siegert constant depending on type of fuel and CO_2 percentage in the flue gas. Values for some very commonly used fuels are:

Distillate fuel oil	$0.495+0.0069xCO_2$
Heavy fuel oil	$0.516+0.0067xCO_2$
Natural gas	$0.379+0.0097xCO_2$
Coke	0.67

This formula is worthwhile being plotted for the fuel used in the burner

The stack loss usually lies within the range of 5 - 50 per cent.



This loss can be reduced either by:

1. Reducing η by controlling combustion to the point where unburnt substances begin to appear, or by:

2. Reducing ts:

This can be achieved by the following:

(i) <u>Heat recovery of exhaust gases</u>

The kiln exhaust gases of the Musalmeyeh cement plant are of low grade heat value (100-120° C) so using such low grades of heat to, for example, heat offices or for other purposes would not be feasible; the kiln exhaust gases at 350° C after pre-heating are utilized mostly or totally in drying the raw materials in the raw mills.

Clinker cooler exhaust gases are of a medium grade heat value (200-235° C), and they may be utilized for heating purposes, for example, heating fuel oil from 60° C to 120° C, but the use of kilns 2 and 3 cooler exhaust gases for pre-heating heavy fuel oil is not recommended for the following reasons:

1. This will require an estimated investment of about $US 175,000 and the pay-back period would be more than 10 years, if the rate of exchange is $US 1.0 = LS 11.25 and longer if it is more.

2. The fuel oil is heated, for the time being, in Musalmeyeh by steam, which is available in sufficient quantities. The same source of steam is used to preheat the fuel oil in the oil storage tanks and in the unloading station and the total steam cost used for oil firing plants/yr is about $US 4,000 only (exchange rate of $US 1.0 = LS 11.25).

3. To preheat the fuel from 60° C to 120° C requires a constant source of heat to raise the temperature of the heavy fuel oil being fired in kilns 2 and 3. Because the temperature of the cooler exhaust gas fluctuates fuel oil temperature control by this scheme is not possible.

The only thing that can be done with regard to the high temperature of cooler exhaust gases (220-350° C) and coolers' output clinkers temperature (more than 125° C) is to keep the coolers well-maintained and then try to tune the coolers to improve their efficiency. Output clinker temperature should be reduced and exhaust gases temperature should also be reduced. Secondary air temperature should be increased; this can be achieved by controlling the air flow entering each cold air fan to set points which are fixed by the kiln operator. The speed of the first grate is controlled to keep the pressure constant in the first (hot-end) under grate chamber. The grate speed is reduced if the pressure falls and increased if the pressure rises. The main air is blown in with a pressure of about 500 kg/m^2 into chambers 1, 2 and 3. The air for the additional cooling is supplied by fans, at low pressure. Anyhow, the grain size of clinker, the material percentage passing through the grate and the temperature of the longitudinal girders beneath the grate track affect the optimizing of the cooler operation.

However, the detailed feasibility study of a heat recovery system and calculating a system's efficiency are two important subjects and they can be given to the factory staff as a case-study. Main guidelines can be shown to help the staff to carry out the study by themselves for the purpose of training. The staff could then determine if a heat recovery system would be feasible and try to optimize the system to have a better efficiency if the measurements and calculations made prove that the system's efficiency is below the designed value.

- Heat recovery (use of cooler exhaust gases from kilns 2 and 3 for preheating heavy fuel oil) study: the heat required to heat heavy fuel oil at 4.2 m^3/hr from 60° C to 120° C with specific gravity of 0.93 (at 60° C) and specific heat of 0.465 kcal/kg ° C is:

(120-60) x 4.2 x 1,000 x 0.93 x 0.465 = 108,977 kcal/hr.

The quantity of exhaust gas in kg/hr for each cooler should be measured at the exhaust gas temperature. Static pressure, dynamic pressure and diameter of stack masurements are necessary to calculate gas quantity. This quantity is estimated to be 80,000 kg/hr at an average exhaust gas temperature of 200° C. The heat available from this quantity of exhaust gas per cooler = (200-t) x 80,000 x 0.242 kcal/hr when t is the temperature of the gas leaving the heat exchanger. Therefore, assuming 30 per cent overall efficiency, the exhaust gas temperature can be calculated from the following equation:
(200-t) x 80,000 x 0.242 x 0.30 = 108,977 Hence t = 181° C and the drop in gas temperature = 200-181=19° C. For the above, the annual fuel oil saving would be 82 t per kiln, which is equal to $US 6,000 The total annual saving would be: 6,000 + 6,000 + 4,000 = $US 16,000 Hence the payout period would be roughly: 175,000 ÷ 16,000 = 11 years. So this measure does not merit consideration.

- Cooler system efficiency calculation:

The staff have to carry out a test programme on the clinker coolers of kilns 2 and 3. The advantage of performing such tests over an extended period is that the results will reflect the average performance of the coolers. The following observations can be obtained from an extended test period to be carried out by the staff:

- Flow cold air fans in kg/kg clinker;
- Average cold air temperature in ^{o} C;
- Exhaust air flow (fan inlet) in kg/kg clinker;
- Exhaust outlet temperature in ^{o} C.

After this the cooler efficiency may be calculated from the formula:

$$\text{Efficiency} = \frac{\text{Heat in} - \text{Heat out}}{\text{Heat in}}$$

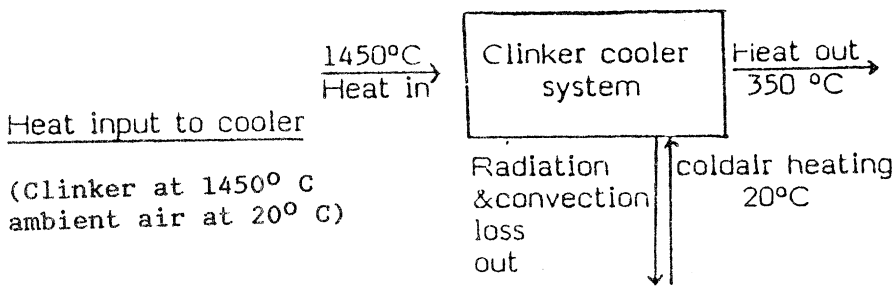
and if it would be possible to calculate or measure the flow rate and temperature of the secondary air, which contains the bulk of the heat recovered the formula

$$\text{Efficiency} = \frac{\text{Heat recovered}}{\text{Heat in}}$$ then can be applied.

To calculate the cooler efficiency from the first formula, one must consider the following data:

- Flow, cold air fans = 2.7 kg/kg clinker (estimated)
- Average, cold air temperature = 20^{o} C
- Exhaust air flow (fan inlet) = 1.7 kg/kg clinker
- Exhaust air temperature (fan inlet) = 350^{o} C
- Clinker outlet temperature : 125^{o} C

If the cooling zone of the kiln is considered part of the cooler, then the temperature of the clinker entering the cooler sytem boundary would be 1,450^{o} C i.e., the sintering temperature of the clinker.



Heat in clinker = mass x specific heat x temperature
= 1 x 0.264 x 1,450 = 382.8 kcal/kg clinker

Heat in cold air = 2.7 x 0.240 x 20 = 13 kcal/kg clinker
Total 395.8 kcal/kg clinker

Heat output from cooler (clinker at 125° C, exit gas at 350° C)

Heat in exit gas = mass x specific heat x temperature
= 1.7 x 0.240 x 350 = 143 kcal/kg clinker

Heat in clinker = 1 x 0.210 x 125 = 26.3 kcal/kg clinker

Radiation and convection loss = 1 per cent of heat in = 4/173.3 kcal/kg clinker

$$\text{Total cooler efficiency} = \frac{395.8 - 173.3}{395.8} = 56.2 \text{ per cent}$$

If the real measurement will lead to such a result then the cooler efficiency is low. Design one is 77 per cent.

To improve the cooler efficiency, as mentioned above, it would be possible to have the clinker outlet at 75° C to 80° C and exit gas at 140° C to 160° C; this would lead to annual savings of more than 3 per cent of the total thermal energy, which would be used to produce 600,000 t of clinker/year and this equals more than 1,000 t of fuel oil/year which equals an annual savings of more than $US 78,000. This is due to the fact that the specific thermal consumption of the kiln itself would be improved owing to the higher value of the heat recovered by the secondary air. To minimize the temperature of the clinker at the cooler outlet would have a positive effect on the cement mills productivity, i.e., low temperature clinker would improve the specific power consumption of cement mills.

(ii) <u>Improvement of heat exchange in the preheater stages</u>

The efficiency of heat exchange is affected by the separation efficiency of the preheater stages.

(b) <u>Unburnt loss (Pu)</u>

Unburnt loss arises in case of incomplete combustion. This loss can be estimated from the following equation:

$$Pu = Ku \frac{CO}{CO + CO^2}$$

Where Ku is a constant depending on type of fuel. Some valves are:

Heavy fuel oil	0.51
Coal	0.59
Natural gas	0.38

This loss is usually in the range of 0.5 to 5 per cent and it can be reduced by proper control on combustion.

(c) <u>Insulation loss (Pi)</u>

This loss is due to heat exchange with the surroundings. Insulation loss is estimated from the following equation:

$$Pi = \frac{\Sigma \; hwi \; Swi \; (twi - tex)}{qF \quad H}$$

[This equation is valid to temperatures up to 300° C.] where hwi accounts for heat transfer coefficient of convection and radiation (hr+hc) from a given surface.

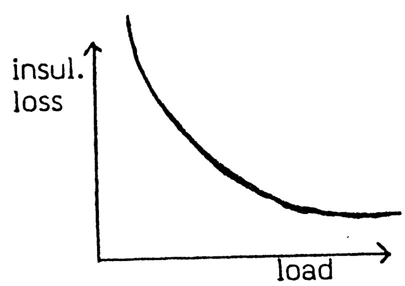
For a horizontal surface $hw = 9.4 + 0.057\ tw$
For a vertical surface $hw = 7.1 + 0.039\ tw$
(hwin $W/m^2\ ^{o}C$, tw in ^{o}C)

Sw is the surface area of the wall
tw is the wall temperature
tex is the external atm. temperature.
qF is the mass flow rate of fuel
H is the calorific value of fuel.

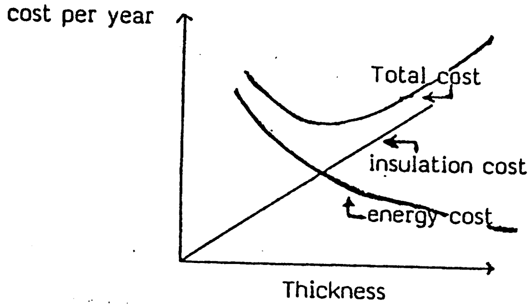
The summation sign is used when different surfaces are involved.

The trend of the insulation loss is a function of the load, which depends on that of the dissipated power, if the latter is constant, i.e if the casing of the combustion unit maintains a constant temperature, the insulation loss increases with reduction of the load in accordance with the hyperbolic law.

The insulation loss is usually in the range of 0.5 to 5 per cent.



The insulation of any thermal system means capital expenditure. Hence, the most important factor in any insulation system is to analyse the thermal insulation with respect to cost and to find the optimum economic thickness. The effectiveness of insulation follows the law of diminishing returns. If one plots the annual cost of insulation and the annual energy cost against the insulation thickness, one obtains the diagram shown below. Finally, if the energy cost and the insulation cost are added and the sum is plotted against the insulation thickness on the same figure, the summation curve (total annual cost) will show a minimum somewhere.



The insulation cost of insulation

C_i* is given by:

$$C_i^* = C_i \frac{(1 + i)^n - i}{(1 + i)^n - 1}$$

Where: Ci = global initial cost of insulation
n = amortization period
i = interest rate

As bricks in cement works are supplied in constant thickness, the analysis can run as follows: Calculate the annual cost of insulation for several lifetimes, such as 6 months, 7 months, and calculate the corresponding annual energy consumption.

The minimum total annual cost can then be found and hence the optimum economic thickness at which insulation should be changed can be found. It should be noted the corresponding wall temperature to that optimum thickness should not exceed the maximum allowable temperature of shell wall.

From the above, it can be seen that it is not feasible to keep the kilns running until the brick thickness has nearly completely deteriorated. This is the case now at the Musalmeyeh cement plant, and if this way of using the bricks continues, red spots and kiln shell deformation will lead to critical or dangerous conditions, especially since the kilns are now operated without kiln shell temperature measuring equipment. The measuring equipment should be made available, and until then, brick thickness, especially in the sintering zone, should be measured from time to time on account of certain kiln stop conditions.

6.2.2. Efficient utilization of electrical power

In addition to thermal energy, the input of electric energy plays a major part in cement manufacture. As opposed to heat consumption, the specific demand for electric energy shows an upward trend in comparison with preceding years. In the early 1960s the level of power consumption for cement-making in the Federal Republic of Germany was about 90 kWh/t, whereas now the average is 106 kWh/t of cement. This increase is due, among other causes, to the increasingly strict requirements of environmental protection that have to be satisfied. The trend will probably continue, because these requirements are bound to become stricter.

In 1986 and the first quarter of 1987, the level of power consumption for cement-making in the Musalmeyeh cement plant was about 180 to 190 kWh/t of cement. This level of power consumption is high compared with other levels of similar plants in other countries, i.e. in selected European plants.

Dry process plants:	Capacity range t/day	Averge kWh/t cement
	< 1,000	90
	1,000 - 1,500	97

The target level of power consumption at Musalmeyeh is 110-120 kWh/t of cement.

A saving of 70 kWh/t of cement would be possible, i.e about a 40 per cent saving. This saving can be achieved through the following measures:

(a) Running all production equipment (crushers, kilns, mills etc) at maximum capacities.

(b) Proper control of fineness. Differences in the fineness of the final products account for 15 to 20 kWh/t for grinding. Maximum possible raw meal size should be applied. An interesting index that can be used to compare cement mills' efficiency is defined as the power per metric ton per strength

$$\frac{\text{kWh/metric ton}}{\text{28 day strength kg/cm}^2}$$

Ratios are approximately 0.05 to 0.1 for efficient systems. The ratios for Musalmeyeh are around 0.55 to 0.58.

(c) Minimizing feed size to mills: savings of up to 40 per cent have been made for plants that pre-crush raw materials to a fairly small size before feeding them to the grinding mills.

(d) Improving the separators' efficiency through proper setting of the separator.

(e) The use of grinding aids: In most countries grinding aids such as ethylene glycol and acetic acid are used to achieve fine product cements with reduced energy consumption. The grinding aids are used in small amounts, typically 0.01 to 0.04 per cent and it is claimed they save as much as 15 per cent of fine-grinding energy.

(f) Proper management of compressed air systems: the compressors should be running according to the demand. A check on pressure, cleanliness of the strainers and leaks in the system is necessary.

(g) Other areas of concern which affect the value of the monthly electricity bill (invoice) i.e. production cost reduction:

- Improvement of power factor: the installed compensating capacitors are enough to have a power factor above 0.85, but those capacitors need to be maintained and operated efficiently;

- Good control on lighting;

- Shut-down of transformers and no unnecessary running of equipment outside working hours;

- Crushers, raw mills and cement mills should not run at the peak period (the high tariff period);

- Low tariff period (11 p.m. to 6 a.m.) should be utilized carefully.

(h) Cleaning, safety and preventive maintenance systems would reduce the different equipment breakdowns, by 50 per cent at least, and that will lead to a lot of energy savings, not only in electrical energy but also in thermal energy.

6.3. <u>Reducing production costs of cement by intoducting the use of blended cements</u>

A relatively great part of energy can be saved by producing blended cements. Blended cements are cements to which are added different (up to 30 per cent) quantities of so-called blended material. This blended material or admixture must be pozzolanic material or latent hydraulic binder. The quality of blended cement must be the same or very similar to the quality of ordinary Portland cement which has the same class. Blended cements can contain about 20 per cent of admixture but in special cases this amount can reach up to 70 per cent.

The admixture materials for blended cements can be divided into two groups:

- The first group is what is called pozzolana.

- The second group is latent hydraulic material which is blast furnace slag.

It is obvious that in view of the very great differences of properties of pozzolanic materials only general instructions can be given for their use. Every specific case must be investigated separately.

Natural pozzolana is a very soft material. In practice by blending it with other materials, energy consumption for cement grinding is diminished. The disadvantage of these other materials is that they can contain a relatively great quantity of moisture. It means that these materials must very often be dried before grinding them with clinker in cement mills.

A couple of years ago silica fume was introduced in blended cement and proved to be very useful in view of the energy saving in the cement industry as well as in the quality of concrete produced. It can be blended by grinding it with clinker or by adding to concrete slurry in concrete plants. Blending up to 10 per cent of silica fume with clinker effects a saving of about 10 per cent of energy of grinding as well as an increase of 10 per cent in mortar strength. By adding up to 30 per cent of silica fume to concrete slurry in concrete plants, the strength of concrete can be doubled. This means lower consumption of cement for the concrete of the same strength. Saving cement means saving energy. Blast furnace slag is also very useful material for blended cement production, and generally is better than natural pozzolana. Grinding the mixture of clinker and blast furnace slag requires slightly more energy than grinding a mixture of clinker and natural pozzolana, but this is compensated for by the better cement quality compared with natural pozzolana; furthermore it is not necessary to dry it before grinding it with clinker. Blast furnace slag could be added up to 30 per cent.

Energy savings in the case of a 20 per cent admixture added to blended cement can be calculated on the basis of the following data:

Blended material: moisture content 20 per cent

Final blended composition

20 per cent dry blended material
75 per cent clinker
5 per cent gypsum

For 1 kg of blended cement the following are necessary:

0.20 kg dry blended material
0.75 kg clinker
0.05 kg gypsum

For 0.20 kg of dry blended material the following are necessary:

$$\frac{0.20}{0.80} = 0.25 \text{ kg of raw blending material.}$$

For 1 kg of blended cement, it is necessary to evaporate:

0.25 - 0.20 = 0.05 kg of water.

Energy for evaporating water for 1 kg of blended cement is:

0.05 kg x 640 kcal/kg = 32 kcal.

Assuming that efficiency of the drying device is 0.85, the actual energy for 1 kg of blended cement is:

$$\frac{32}{0.85} = 37.6 \text{ kcal}$$

If the heat consumption for 1 kg clinker poduced is 850 kcal, then for 1 kg of pure cement it is 850 x 0.95 = 807.5 kcal.

For 1 kg of blended cement (20 per cent admixture) it is necessary: 0.75 x 850 + 37.6 = 675.1 kcal. In this case saving energy is:

$$\frac{807.5 - 675.1}{807.5} = 16.4 \text{ per cent.}$$

If it is not necessary to dry blended material, the saving of energy is:

$$\frac{0.95 \times 850 - 0.75 \times 850}{0.95 \times 850} = 21 \text{ per cent}$$

If kilns 2 and 3 are considered, i.e., 2,000 t clinker/day production, then for cement production without blended material the following will be needed:

$$\frac{2{,}000 \times 10^3 \times 300 \times 850}{10^4 \times 10^3} = 51{,}000 \text{ tons of fuel oil/year (300 workdays per year).}$$

In the case of dry blended material, the fuel oil saving per year will be 51,000 x 0.21 = 10,710 tons of fuel oil/year. In case of moisture content of 20 per cent the fuel oil savings will be 51,000 x 0.165 = 8,364 tons of fuel oil/year. The difference between dry and moist blend material is 37.6 kcal in heat consumption for 1 kg of blended cement. This means that it is acceptable to pay for blending materials an amount of 37.6/(0.2x10,000) = 0.0188 kg of fuel oil per 1 kg of dry blending material. In this case the price of preparation will be equal and it will not be necessary to build a drying device. By production of blended cement a significant amount of energy can be saved. The amount of added blending material depends on its quality. Before using the blending material, a careful investigation of technical and economic pros and cons must be carried out.

Cost of pozzolana = LS 38.85/t

Production cost of clinker = LS 200/t (variable cost)

Another method of comparison can be carried out accordingly. At Musalmeyeh 10 per cent of pozzolana is added to blended cement and it is advised to raise it to 20 per cent to achieve more energy saving.

6.4. Personnel training

The personnel technical level is very good, but this alone is not enough to master heavy-duty plants and to manage energy conservation programmes. Promotion of the cost-consciousness of the employees is very important. It is advisable to have a weekly meeting on cost control at the Musalmeyeh plant. All heads of departments and foremen should attend this meeting. In this connection, various training programmes should be introduced. One programme should be devoted to questions of energy consumption. By holding courses at regular intervals, it will be made clear to the participants by explanation and demonstration how great the influence of energy consumption on operating costs really is. All employees should be called upon to bring forward their own ideas on how the work can be more efficient.

6.5. Daily energy report

The Musalmeyeh plant should develop and introduce a daily energy report with the aim of acquiring an instrument which would make it possible to keep a check on daily energy consumption (in kWh/t, kcal/kg) for the entire plant. In order to ensure immediate readiness for action, the target figures are specified for the following departments: crushing plants, raw grinding, clinker production, cement grinding and the total plant as follows:

Department	kWh/t (main drive)	kWh/t (whole department)*
Crushers	1.2	1.6
Raw mills	18	25
Total raw meal/clinker	30	42
Kilns kWh/t	2	18
Kilns kcal/kg		850
Total clinker/cement (kWh/t)	27	51
Cement mills	30	40
Total plant (without auxiliaries)	57	91
Total plant (including auxiliaries)	63	100

* To keep a check on the daily-energy consumption, the kWh meters referred to in preceding pages should be installed.

For a second important series of figures the optimal utilization of the mills capacity should be considered. Here the ratio of the energy consumption (kWh/h) of each mill and its installed load (kW) should be determined. Then, depending on the values determined, the categories of grinding media would be suitably adapted. It is the writer's opinion that this ratio value is more reliable than measuring the level of the ball charge, as that can prove very awkward on account of certain mill stop conditions. The grinding media in the mills should be topped up at more frequent intervals than at present since this would improve the productivity and reduce the specific power consumption.

6.6. Preventive maintenance

An effective maintenance system, of which preventive maintenance in one facet, should be established as soon as possible. The general belief that preventive maintenance is the answer to all maintenance problems is not accurate. Preventive maintenance is not magic, it will not guarantee instant success and - most significantly - will not replace good maintenance work.

Experience in maintenance shows that a good preventive maintenance system is a very powerful tool, but still only one tool of effective maintenance and it cannot exist without certain other maintenance tools. Depending on the degree of sophistication, one could consider preventive maintenance to be either part of or the highest perfection of a good running system. In other words, preventive maintenance may take different forms from plant to plant and mean different things in different industries.

Normally one will evaluate the direct "return on investment" to decide how far one will go with possible preventive efforts. However, in continuous process industries (chemicals, refineries, cement, etc.) preventive maintenance becomes a means of signalling that work is required before a shut-down occurs and of ensuring that all work preparations are completed when the shut-down, planned or unplanned, does occur.

With the above in mind, it can be concluded that not a specific preventive maintenance system should be designed, but rather an approach to a method of developing an effective maintenance management system. In addition, a step-by-step method should be presented for the use of any group plant to set up or update a preventive maintenance system. However, certain basic things must be achieved to ensure that maintenance work is being controlled. Apart from a compatible organization and skilled work-force, the plant should have a formal work order system, an equipment inventory, an equipment coding system and a written equipment history.

The formal work order system is necessary to control the work being carried out. This may be a simple piece of paper stating what and where the trouble is, the description of equipment, and costing identification or it may be sophisticated to the point of including all the above plus standard problems and be capable of storing these in an electronic data processing (EDP) system.

The equipment inventory is merely a complete up-to-date list of all equipment in the plant. The equipment coding system is a means of quick identification of each specific piece of equipment. It may be as simple as describing by function or as sophisticated as to be used for an EDP system. The equipment history is necessary to ensure continuity in the operation and to assess the effectiveness of the maintenance programme. Some smaller plants successfully rely on the maintenance supervisor's memory for this function; however, if the maintenance supervisor should not be available, it could be next to impossible to continue without being faced with severe poblems. It is, however, to be borne in mind that the various functions must be formalized if an effective preventive maintenance system is desired. The sequence of steps for the establishment of a preventive maintenance system can be found in any textbook on the subject.

It also has to be born in mind that the installation of a preventive maintenance system will result in increased operating costs for the initial period, some minor capital expense and the results will not be apparent in the first few years. Therefore, the enthusiastic support of the plant manager and department heads concerned, including an agreement on what must be done, are required.

6.7. Clinker coolers snowman phenomenon

The snowman phenomenon in clinker coolers means that heaps of clinker are formed and built up on the first row of the coolers' lining, and because of this the plates of this row of lining will be damaged, leading to cooler and kiln breakdowns, i.e. energy loss.

The Musalmeyeh cement faces this problem and it has been one factor among others responsible for the repeated kiln breakdowns. This phenomenon is perhaps due to a high per cent liquid phase or/and a short cooling zone at the kiln outlet. The liquid phase per cent in clinker had been calculated for kilns 2 and 3 and it was noted that they were more than 33 per cent, which is high; to reduce it, it is advisable to increase the silica (SiO_2) and to reduce basalt in the raw mix, and this should be co-ordinated well between the quality control and production sections and the results should be written down. The cooling zone should be checked too; the cooling zone is normally between 1 to 1.5 m long; i.e. the burner nozzle is 40 to 50 cm away from the kiln outlet (inside the kiln).

Per cent liquid calculation

Per cent liquid at 1,450° C = 1.13 C_3A + 1.35 CuAF + MgO + Alkalis
= 1.13 x 8 + 1.35 x 14 + 3.2 + 1.2
= 9.04 + 18.9 + 4.4 = 33.54

Alkalis are not determinded in the clinker chemical analysis so they were estimated.

6.8. Excess oxygen

This was mentioned above but since it is so important, it is advisable to refer to it as a separate item. Ideal operating conditions in the kiln occur when the kiln exit gas contains between 1.1 and 2 per cent oxygen. An excess of air results in excessive heat loss; 1 per cent of excess oxygen in the kiln exit gas consumes 3 to 5 kcal/kg; more than 6 per cent of excess oxygen observed in kilns constitutes exit.

7. POTENTIAL SAVINGS

Data

Clinker production of 600,000 tons/year. Which is equivalent to 800,000 tons of cement/year (if 20 per cent pozzolana and 5 gypsum are added to the clinker in the cement mills).

- Energy consumption for the time being is: 100 to 110 kg fuel oil/ton of clinker. 180 to 190 kWh/ton of cement. The net calorific value of fuel oil used was determined by a third party on 4, November 1987 and it was 9,668 kcal/kg.

- Current productivity of the production units is mostly 70 to 80 per cent, i.e. an increase of energy consumption of 10 to 20 per cent.

- The average of the power factor penalty paid per month for the years 1984, 1985 and 1986 was about LS 25,000.

- One ton of fuel oil = 2,282.64 kWh/cost bases.

- 1,000 t/day kiln one hour shut-down consumes 4.2 m^3 of fuel oil and if the shut-down would be for one day it would consume 30 to 36 m^3 of fuel oil, in addition to the corresponding production loss.

- Exchange rate \$US 1.0 = LS 11.25.

Table 4. Operations to be carried out to ensure energy saving

	Action	Means to be used	Saving toe/yr	% *
1	Excess oxygen in kiln exit gas	- Repair, maintain analysers, probes and sensors complements - Make sure of skilled operating personnel	300	< 1
2	Reduction of shut downs (i.e. 30%)	- Maintenance - Cleaning - Safety	2,400	
3	Improvement of operation so that equipment will be operated at 90 per cent productivity	- Maintenance of production units - Training of persoonel - Prevent leakage air	9,000	15
4	Blended cement	- Add 20% of pozzolana to clinker in addition to gypsum before grinding. - Modify specification standards for cement to allow for 3-4% insolubles.	5,500	9.2
5	Power factor improvement	- Maintain the installed capacitors and operate them efficiently	365	6.1
6	Avoid running big consumers in the peak period where ever it is possible (28% of cement was produced in peak period)	Crushers, raw mills, cement mills should be stopped during the peak periods	4,000	6.7
7	Improve steam boilers efficiency	- Prevent steam leakages through proper maintenance - Insulate steam valves and pipes	180	5+

Notes
* % of total kilns fuel oil consumption.
+ % of heating system consumption.

The above table shows that the total annual saving would be LS 17,868,953 = $US 1,588,351.

Most of the above-mentioned saving opportunities do not need any investment and some need only minor investments (spare parts cost and new kWh meters to monitor electrical energy consumption). Provided that the plant targets of specific energy consumption would be achieved through proper operation and scheduled and preventive maintenance systems, the annual saving would be LS 31,461,000 = $US 2,796,533.

8. CONCLUSIONS AND RECOMMENDATIONS

Energy consumption levels at Musalmeyeh are high compared with worldwide standards or with similar plants in neighbouring countries. During the in-plant observations and data colletion, it was noted that many activities could be carried out to improve the situation and achieve the energy consumption goals: 83-88 kg fuel oil/t of clinker produced and 100-110 kWh/t of cement. These goals can be implemented provided that the following conclusions and recommendations are implemented.

(a) For immediate action, the whole factory area should be cleaned up quickly. The complete clearance of the factory is such a big operation that it is beyond the scope of the present company personnel. It is therefore recommended that an outside contractor be engaged to carry out this task. There are many hundreds of tons of dust and rubbish which have been accumulating for many years and the contractor after discussion with the management should outline a plan of action, acceptable to the company, over a fixed period, say one month, to guarantee the complete removal of all dust and rubbish, inside and outside the buildings and the entire factory area.

(b) No worker should be allowed to dump rubbish indiscriminately, or allow dust of any kind to accumulate. Everything should be cleaned up right away and removed from the factory. This would need considerable organization by the management; clear-cut directives could be circulated and some form of discipline introduced. The responsibility for plant cleanliness could be given to the plant shift foreman who in turn would be responsible to the production manager.

Alternatively, a small labour force of approximately 20 labourers could be employed especially for keeping the factory clean. A foreman in charge of the labour force, and systematically patrolling the whole plant, could be made responsible to the production manager.

(c) An effective maintenance management system of which preventive maintenance is one facet has to be established with skilled operating personnel.

(d) False air leaks in the kiln systems, raw mills system, cement mill systems, electrostatic precipitators, bag filters, etc. should be managed, and immediate action should be taken to prevent all leaks. All systems should be inspected periodically for leaks in order to take the appropriate action at the right time.

(e) Since the standing losses on many processes are more or less constant for a wide variation of loading rates, maximum economy will be achieved at the highest practicable throughput rate. For example, for any production equipment in a cement plant running with a 70 per cent throughput, i.e. 30 per cent below its rated capacity, its energy consumption will be increased by 10 to 20 per cent. Therefore, equipment should be operated near its rated capacity.

(f) Repair and maintenance of O_2 and CO analysers and operating the kilns with the excess air. One per cent of excess oxygen in the kiln exit gas consumes 3 to 5 kcal/kg. Ideal operating conditions in the kiln occur when the kiln exit gas contains between 1.12 and 2 per cent oxygen.

(g) Prevention of steam leaks and insulation of all pipes, valves, etc. which are not insulated in the steam boiler systems.

(h) Thermal insulation of all ducts, conditioning towers, and all other parts or sections which do not have thermal insulation, especially in the following systems: raw mills system, kiln system, cement mill system, etc.

(i) Purchase, set-up and operation of the necessary kWh meters to make it possible to audit the specific power consumption for all production departments starting from crushers up to the dispatching plant.

(j) Purchase, set-up and operation of the necessary equipment for measuring and supervising the kilns' shell temperature along the whole kiln sintering zones to be able to avoid high temperatures and consequently red spots and kiln shell deformations.

(k) Proper maintenance and operation of the whole power factor improvement capacitors, i.e. reducing the monthly invoice of electrical energy, to avoid fines imposed by law.

(i) Crushers, raw mills, and cement mills should not be operated during the peak demand period (high tariff period) in order to reduce the invoice of the electrical energy consumed.

(m) Loss of production is estimated to be about 15 per cent at the Musalmeyeh works while it should not be more than 5 per cent. This could be solved by repairing and controlling the sources of such a loss, such as sources of leakage, electrostatic precipitators, etc.

(n) Development and introduction of an accident analysis system aimed at reducing the breakdowns. This system should answer the following questions: Where the accident happened? When did the accident happen? What happened? Why did this accident happen? What measures should have been taken to prevent this accident? Temporary measures and substantial measures should be taken to ensure that another accident would not occur for the same reasons.

(o) Auxiliaries, belt conveyors and similar energy-consuming equipment should not be operated unless absolutely necessary.

(p) It is advisable to raise the percentage of pozzolana in cement from 10 to 20 per cent. This will save energy. The chemical analysis of the pozzolana used in Musalmeyeh shows that it is of good quality; the insoluble percentage remaining would not be detrimental.

(q) Preparation of a daily energy report, to keep a check on daily energy consumption.

(r) Establishment of energy management structure aiming at achieving a higher degree of efficiency and reliability in the end use of energy in the system.

(s) Thr grinding media in the cement mills should be topped up at more frequent intervals than at present.

(t) To improve the cement mills productivity, it is advisable to mix cold clinker with hot clinker and not to use hot clinker only and the ratio of hot clinker:cold clinker:pozzolana should be kept constant for the longest period possible.

(u) Control of cement mills of outlet air temperature by means of variation in the cold air bleed to the separator should make it possible to keep the feed proportions within a closer range, thus giving a more stable operation.

(v) Tuning and optimizing the operation of cement clinker coolers of kilns 2 and 3.

(w) Pollution prevention is one of the most important issues. Putting a high priority on safety, pollution prevention, and quality is a corner-stone of sound management.

ANNEXES

Annex I

RAW MATERIAL CHARACTERISTICS

(a) Limestone

Elements	Ranges % From	To
L.O.I	41.00	43.50
SiO_2	0.50	2.80
Fe_2O_3	0.08	1.30
Al_2O_3	0.12	0.90
CaO	53.00	55.50
MgO	0	0.80

(b) Basalt

Elements	Ranges % From	To
L.O.I	4.00	17.00
SiO_2	37.00	47.00
Fe_2O_3	8.00	14.50
Al_2O_3	9.00	15.00
CaO	7.00	19.00
MgO	6.00	9.20

(c) Sand

Elements	Ranges % From	To
L.O.I	0.30	4.00
SiO_2	77.80	96.90
Fe_2O_3	0.20	0.40
Al_2O_3	0.30	0.80
CaO	1.00	12.00
MgO	0.10	0.40

(d) Gypsum

Elements	Ranges %	
	From	To
L.O.I	16.80	24.40
SiO_2	2.00	5.00
Fe_2O_3	0.50	1.50
Al_2O_3	0.50	1.00
CaO	30.00	35.00
MgO	3.00	6.00

(e) Pozzolana

Elements	Ranges %	
	From	To
L.O.T	0.00	1.00
SiO_2	38.00	48.00
Fe_2O_3	10.00	15.20
Al_2O_3	9.50	10.90
CaO	9.00	11.00
MgO	12.50	15.90
SO_3	0.00	0.30

Annex II

RAW MEAL CHARACTERISTICS

Elements	Ranges % From	To
L.O.T	33.00	35.50
SiO_2	12.80	13.20
Fe_2O_3	3.20	3.50
Al_2O_3	2.90	3.20
CaO	42.90	43.50
MgO	1.80	2.20
SM	1.95	2.05
AM	1.15	1.25
L.S.F	98	100

Annex III

CEMENT CLINKER CHARACTERISTICS

Elements	Ranges %	
	From	To
L.O.T	0.20	0.60
Insoluble	0.2	0.80
SiO_2	20.00	21.00
Fe_2O_3	4.00	4.50
Al_2O_3	5.00	5.50
CoO	63.50	64.50
MgO	2.80	3.20
SO_3	0.60	0.90
SM	2.10	2.25
AM	1.18	1.30
L.S.F	94.00	96.00
C_3S	55.00	65.00
C_2S	12.00	20.00
C_3A	6.00	8.00
C_4AF	12.00	14.00

Annex IV

MEAN SPECIFIC HEAT OF PORTLAND CLINKER BETWEEN 0^{o} C AND t^{o} C

Temperature (t)	Mean specific heat (kcal/kg/^{o} C)
300	0.2060
500	0.2186
700	0.2278
900	0.2344
1,100	0.2409
1,300	0.2533
1,450	0.2644

Annex V

CHEMICAL-PHYSICAL DATA ON SYRIAN FUEL OIL ACCORDING TO INVESTIGATION BY THE DAMW IN 1971

C	84.3%
H	11.2%
O+N	4.5%
H_2O	0.3%
Ash	0.066%
Ho	10240.8 kcal/kg
Hu	9648.9 kcal/kg
Point of congelation	10° C
Flash point	121° C i.g.t.
Density at 20° C	0.9735 kg/L
Density at 25° C	0.953 kg/L
Density at 60° C	0.929 kg/L
Density at 130° C	0.892 kg/L
Viscosity at 30° C	215 °E
Viscosity at 50° C	36.6 °E
Viscosity at 130° C	2°E

Part Two

ENERGY AUDIT FOR THE HAMA CEMENT PLANT

1. BACKGROUND

Following consultations with the Syrian authorities and discussions held by ESCWA and the Industrial Testing Research Centre of Damascus (ITCR), the Hama Cement Plant (Syrian Company for Cement Industry and Building Materials) was chosen for this audit.

Continuing research aimed at minimizing energy consumption in the cement industry, has led to the development of new processes. This research has revealed that new technologies have reduced energy consumption from 1,500 kcal/kg of clinker to 800 kcal/kg during the last 20 years.

The graph below illustrates the average consumption for cement plants built between the years 1955 and 1983. The average reflects the continuous improvement resulting mainly from the perfecting of machinery and the use of technological sophisticated production lines.

New progress can be expected as a result of shorter conveyer lines and heavy duty machines such as modern fans, or of increased research on the output of milling and crushing machines, which presently account for more than half the electricity consumed in a cement plant. Similarly, the development of a more sophisticated precalciner system would result in a considerable saving of energy and a great increase of output. In this connection, it should be noted that in a dry process cement plant:

- 1 tonne of cement requires approximately 1/45 tonne oil equivalent (toe) electric and 1/12 toe thermal

And in a wet process plant:

- 1 tonne of cement requires approximately 1/56 toe electric and 1/6 toe thermal.

1.1. Units and their equivalences

The list below indicates the units used in this document with their equivalences:

1 kilocalorie (kcal)	= 4,186 kilojoules (kv)
1 kcal	= 3,968 British Thermal Units (BTU)
1,000 kcal	= 1 thermie = 0.86 kWh
1 toe	= 1,000,000 kcal
	= 41.8 x 10^6 kJ
	= 11,600 kWh (th), (thermal kWh)

1 toe = 1.05 of heavy fuel oil
= (9,500 kcal/kg)*
1 toe = 4,500 kWh electricity (e)**
(The conversion rate applied in France for electricity).

Although the international system recommends the joule as an energy unit, the kilocalorie will be used here for this has been the general practice until now.

1.2. Measures identified for improving energy efficiency

1.2.1. On the wet process line

In spite of the low output (300 t/d) of this line, it would be of interest to study a chain system and a more suitable heat exchanger, an also to reduce the quantity of water in the slurry. This could make a saving of nearly 8 per cent.

1.2.2. On the dry process line

(a) Replacement of the clay used presently in the raw meal by a drier material would allow a saving of about 100 kcal/kg of clinker. Taking account of the saving of electricity due to milling the product under consideration, the saving might amount to more than 8 per cent.

(b) Electricity consumption is very high in all the shops because the principal motors are oversized. It should be possible to improve considerably the power factor of the production line by installing capacitors.

(c) The output of the clinker grinding shop is limited by two bottle-necks, at the separator and at the filter. The output could be improved by regulating the shop and then by installing a more adequate separator. The energy savings would amount to respectively 6, and 15 to 20 per cent.

(d) Precalcination would be simplified by installing an auxiliary burner; this would result in a reduction of heat consumption of about 2 to 3 per cent.

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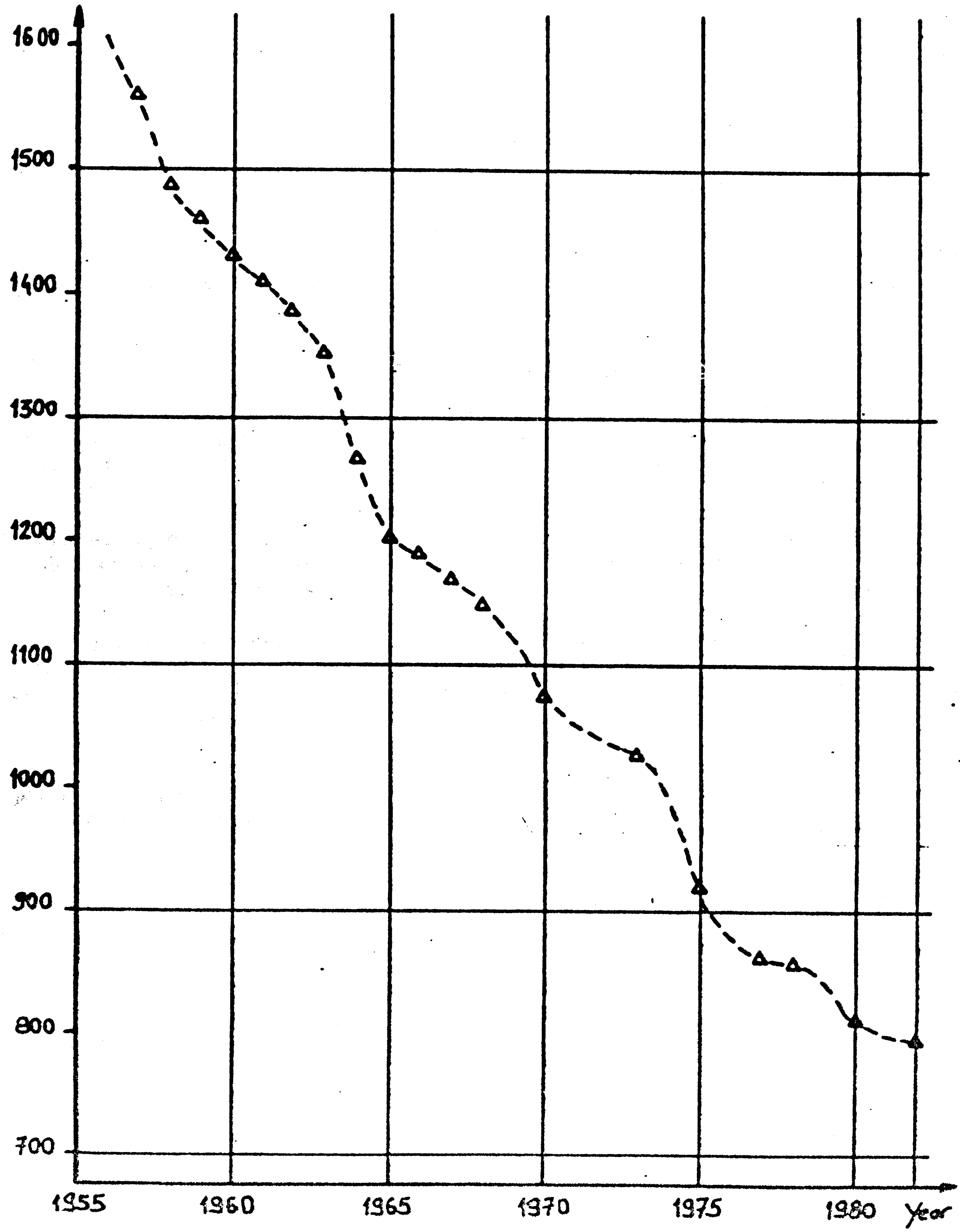
* The figures given for toe and equivalences relate to the net heat value or lower calorific power of a fuel.

** The figures given for electric power relate to the thermal energy needed to generate one unit of electricity in a thermal electric power plant. The figures for heating values given by the Hama Cement Plant are 9,600 kcal/kg of fuel oil so that:

1 toe = 1.04 t of heavy fuel oil (9,600 kcal/kg.)

Heat consumption

(kcal/kg clinker)



(e) The replacement of the first preheater shaft by a cyclone would make a saving estimated at 3 per cent (the proposal for transforming the cement works).

(f) The improvement of output by replacing the preheater lower shaft by a cyclone associated with an auxiliary burner would provide a saving of heat on the order of 7 per cent.

(g) Replacement of the burner by a more efficient apparatus will mean a saving of 4 per cent and will have an effect on the comsumption of lining bricks.

(h) Finally, improvements should be made in the existing instrumentation.

The measures recommended above for the dry process line can be applied in their totality and in any order.

2. SYRIAN COMPANY FOR CEMENT INDUSTRY AND BUILDING MATERIALS

Hama Cement plant

North from Damascus 210 km
North from Homs 47 km
South from Aleppo 121 km

Capacity (clinker)

- 1 wet process (WP) line, 300 t/d : 1966
- 1 dry process (DP) line, 1,000/1,100 t/d : 1977

Cement produced*
(Thousands of tons)

	1983	1984	1985	1/2 1986
Line 1 (WP)	131	128	135	71
Line 2 (DP)	274	290	319	173

* Portland cement: 90%, Pozzolana cement: 10%

Clinker produced

	1983	1984	1985	1/2 1986
Line 1 (wet process)	122	130	127	66
Line 2 (dry process)	278	284	288	155

Note: Manpower on line 1:323; on line 2: 631.

Quarries

	Location	Distance	Transport to Plant
Limestone	Near plant	3 km	Rubber conveyors
Clay	Near plant	3 km	By truck
Silica sand	Alkaryatein	135 km	By truck
Gypsum	Raqqer Jairoud	340 km	By truck
Pozzolana	Shaba	315 km	By truck
Oil	Homs refinery	63 km	By tank
Gas			Not yet
Water	On site		
Power	Muhardeh	30 km	

Sales and cost of production line 1

(In Syrian pounds)

	1983	1984	1985	1986	Percentage	
Sales:						
Portland cement	35,428	34,951	36,749	24,598		
Pozzolana cement	2,487	5,917	4,411			
Total sales	38,417	40,868	41,160	24,598		
Cost of production:						
Raw materials	1,251	2,165	1,980	1,251	5	5
Consumables	2,074	2,426	3,985	679	7	8
Maint. parts	1,556	1,080	1,162	246	3	3
Fuels	16,630	18,661	18,590	8,604	50	51
Electricity	1,178	1,106	1,280	510	3	3
Other utilities	432	568	312	250		
Wages and salaries	5,346	5,454	6,270	366	14	14
Overhead (exc. sal.)	1,028	740	831	400	2	2
Gypsum	347	249	277	153	1	1
Pozzolana	218	249	276	240	1	1
Package mat.	2,406	2,435	2,467	1,342	7	7
Subcontract serv.	99	384	120	18	1	1
Depreciation	203	684	740	400	2	
Total production cost	33,727	35,929	38,290	17,722	%	%
Total less utilities	33,295	35,361	37,978	17,472	97	
Less utilities and depreciation	33,092	34,677	37,238	17,072		97

Sales and cost of production: line SKET

(In Syrian pounds)
A

	1983	1984	1985	1986	Percentage	
Sales:						
Portland cement	73,477	79,255	86,110	61,324		
Pozzolana cement	8,001	4,238	7,272			
Total sales	81,478	83,493	93,382	61,324		
Cost of production:						
Raw materials	3,646	4,446	4,569	2,670	6	7
Consumables	674	819	842	451	1	1
Maint. parts	2,115	3,381	3,269	3,393	5	5
Fuels	25,080	25,884	30,088	14,719	37	43
Electricity	6,064	6,323	6,616	2,030	8	9
Other utilities	13,805	16,475	18,580	1,083		
Wages and salaries	9,966	13,496	15,436	8,000	18	21
Overhead (exc. sal.)	3,737	1,552	1,755	588	3	3
Gypsum	520	546	556	417	1	1
Pozzolana	553	296	728	637	1	1
Package mat.	4,134	4,099	4,769	2,878	6	7
Subcontract serv.	29	224	131	37	0	0
Depreciation	9,658	9,788	10,035	5,100	13	
Total production cost	79,981	87,329	97,344	42,003		
Total less utilities	66,481	71,954	78,796	40,920	99	
Less utilities and depreciation	56,823	62,166	68,761	35,820		98

Sales and cost of production: line SKET
B

	Quantity /t. cem.	Unit cost	Cost/ t. cem	Total cost
RAW MATERIALS				
Limestone ton.	1.104	9.79	262.33	1,461,746
Clay ton.	0.379	6.52		334,618
Other matter. ton.	0.039	34.74		183,259
ADDITIVES				
Gypsum	0.048	42.3		276,687
Pozzolana	0.038	54.20		275,592
CONSUMABLES				
Grinding media kg	0.281	471.3		179,094
Lining plates kg	0.026	14.54		52,331
Refractories kg	0.568	153		117,431
Packaging m. unit/t	20.47	0.89		2,467,000
Other Consumables	0.14	59.95		113,910
FUELS				
Oil	0.155	855.1		17,993,879
Gas				3,811
Diesel oil				682,714
Gasoline				107,000
ELECTRICITY				
Repair and maintenance		0.145		1,567,459
Cost for 1985				27,398,457

2.1. Description of the wet process (Smidth 300 t/d)

The nominal capacity of this production line is 300 t/day; it consists of the following:

- A slurry preparation shop
- Storage silos
- A rotary kiln fitted with Smidth satellite coolers
- A clinker storage facility
- A ball mill of capacity 20 tonnes/hour
- Two cement storage silos.

The rotary kiln is a long kiln, fitted at the input with a chain exchanger. The information gathered on electricity consumption does not differentiate between workshops. Electricity is metered overall for each of the two lines.

This production line is not covered by the present report because the Company is particularly interested in the dry-process production line. Mention is, nevertheless, made of the possibility of energy saving by improving heat exchange in the burning zone.

2.1.1. Kiln heat balance

In the wet process line, heat is required only for the burning shop, whereas electric power alone is needed in the other shops. In spite of the unavailability of comprehensive data on this subject, it is possible that this information can be gained from the tables of production costs and from information on the price of fuel. Tables with additional information are in this section.

Taking the price of LS 855 per tonne with a P.C.I. of 9,700 kcal/kg, the table below has been prepared on the assumption that fuel oil prices remain constant.

	1983	1984	1985	1986
Production 10^{3+}	131	128	135	71
Total fuel cost 10^3 SL	16,630	18,661	18,590	8,604
Cost of fuel/t Clinker	127	146	138	121
kg fuel/kg clinker	0.148	0.171	0.161	0.142
Thermal balance kcal/kg	1,440	1,660	1,562	1,378

The probable figure in fact lies between 1,500 and 1,600 kcal/kg clinker. This is a very high figure and represents the maximum thermal consumption of customary wet processes.

This heat consumption depends on:

1. The percentage of water in the slurry (about 32 per cent);
2. Efficiency of the chain system;
3. The efficiency of the satellite cooler (which is poor);
4. The quantity of excess air in the smoke.

Owing to lack of adequate data on operation of the kiln, a standerd heat balance has been based on assumptions.

How can this cement production line be improved?

1. The quantity of water in the slurry could be reduced by adding a fluidizer such as carbonates, silicates or polyphosphates. The saving will be relatively low, not more than 2 or 3 per cent of water, because the quantity of water is presently 32 per cent. This would mean savings of about 30 kcal/kg of clinker for 2 per cent of water, and 43 kcal/kg of clinker for 3 per cent of water.

If the water can in fact be so reduced, it will be necessary to re-examine the kiln chain system. The heat saving is not insignificant for it represents about 425 tonnes of fuel oil per year and a reduction of costs of fuel of about 2 per cent. However, consideration should be given to the additional additives.

2. Irrespective of the fact that the use of a fluidizer in the slurry would necessarily involve modifying the chain system, efforts could be made to improve the exchanger by means of a thermal study in order to lower the gas temperature at the kiln outlet. This study could be carried out by suppliers specialized in chain systems.

3. When satellite coolers are used for clinker cooling, this often obliges the cement plant operators to allow more air into the kiln than necessary. Excess air in the smoke should, therefore, be reduced to the maximum extent possible, to remain within the limits permitted for clinker cooling.

One per cent of excess oxygen in the smoke consumes 5 to 6 kcal/kg of clinker but also lowers the flame temperature and its efficiency, which adds a few calories to the figure given above for losses. Equipment and efficiency of the satellites designed for clinker cooling should be carefully examined.

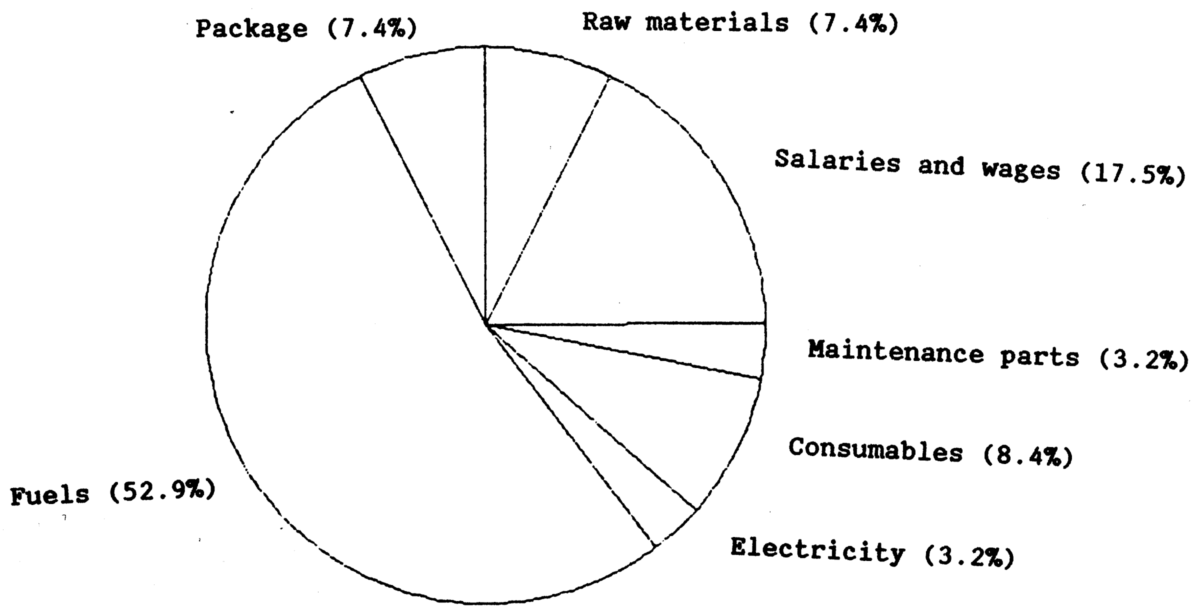
2.2. Line electrical consumption

The figures given represent the total consumption of each line and do not distinguish between individual items of equipment. One may, however, assume that milling consumes 35 to 40 kWh/tonnes of cement produced by comparison with the milling shop of dry process line No. 2.

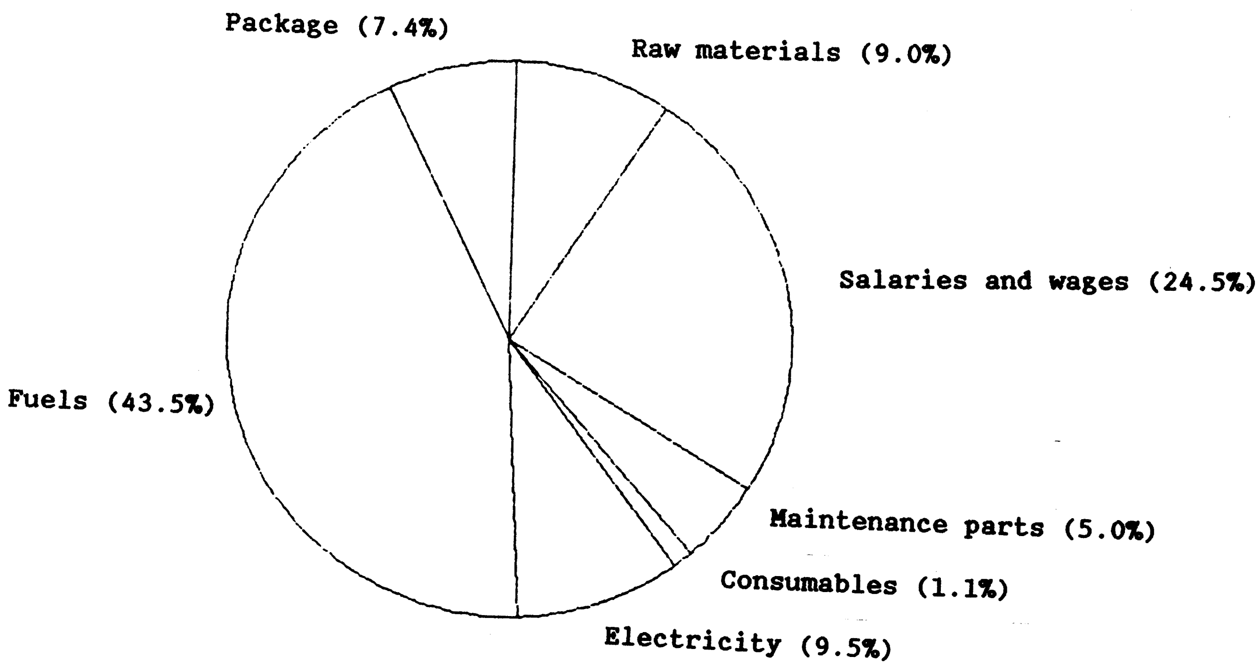
Electric power presently costs LS 0.145 kWh, with no allowance made for peak and normal times. The total cost of electricity consumed in 1985 was LS 1.28 million, representing consumption per tonne of cement over the whole wet process production line of 65.80 kWh/t

Cement milling represents a little more than half of this figure. In spite of the uncertainties and the assumptions which had to be made, the consumption of this production line appears to be reasonable and no significant savings of electricity can be expected.

Line 1


Package (7.4%)
Raw materials (7.4%)
Salaries and wages (17.5%)
Maintenance parts (3.2%)
Consumables (8.4%)
Electricity (3.2%)
Fuels (52.9%)

Line 2


Package (7.4%)
Raw materials (9.0%)
Salaries and wages (24.5%)
Fuels (43.5%)
Maintenance parts (5.0%)
Consumables (1.1%)
Electricity (9.5%)

3. SKET 1,000 t/d

3.1. Description of the dry process

The capacity of the dry process line is 1,000 tonnes/day, that is, about 330,000 tonnes/year. The line consists of a dryer designed to dry clay, with a capacity of 300 t/h working two shifts (16 hours) and controlled from a small separate control room. It is intended for clay of a moisture content up to 26 per cent in winter and 15 per cent in summer. Moisture at the outlet is reduced to 5 per cent at most.

Dimensions are: diameter 3 m, length 24 m, which allows 169 m^3.

The dryer consumes thermal energy of approximately 310 kcal per kg of clay.

Operating characteristics:

Gas inlet temperature	700 to 750° C
Gas outlet temperature	90 to 110° C
Outlet gas volume	26,300 Nm^3/h
Fuel oil consumption	645 k/hour

The plant operators are conducting a study aimed at replacing part or all of the wet clay by basalt taken from a quarry at a greater distance. A considerable saving of heat could be achieved, up to 300 kcal/t of clay, but the effect on raw mix grinding remains to be seen. Electricity consumption might increase owing to the characteristics of the basalt on fragmentation.

3.1.1. Raw-mix grinding shop

This shop consists of a closed-circuit 100 t/h ball mill. Recirculation is 200 to 240 t/hour, which shows that the shop is operating correctly. Three metering units feed limestone, clay and sand to the mill. The limestone particle-size breakdown is as follows:

0 - 10 mm : 50 per cent approx.
10 - 25 mm : 25 per cent approx.
25 - 50 mm : 10 per cent approx.

The mill operates at 15.4 t/min. and is driven by two electric 1,400 kWh, 6,000 V. motors. The same type of motor is installed in the two raw mix and cement grinding shops, for reasons of rationalization. The result is faulty utilization because true consumption is 1,620 kW/h (16.2 kWh/tonne) whereas power installed is 2,800 kWh. The mill is loaded with 146 tonnes of balls of a calibre between 30 mm and 90 mm.

The mill is scavenged by part of the gas from the kiln at 290 to 320° C. Because of the low moisture content of the raw mix, between 8 per cent in winter and 5 per cent in summer, the quantity of gas consumed is about 75 per cent of the total kiln output (when it is operating at 900 t/day).

The possibilities of making savings by increasing the kiln output, and the possibility of limiting production from the burning shop without changing the structure of the grinding shop are examined below. The diagram illustrates gas circulation in the kiln when it operates at 900 t/day which rate was normally achieved during the visit). The figures for gas flow rate were calculated from the information given in the production data sheets.

3.1.2. Burning shop of 1,000 t/d capacity

The shop was supplied by SKET (German Democratic Republic) and lies downstream from a double-silo homogenization unit, which calls for no particular comments and which appears to be operating correctly.

The kiln is fed through two metering units of a capacity of 42 t/hour, with a third on stand-by. The kiln is equipped with a ZAB exchanger with three shafts downstream from two dedusting cyclones.

The clinker is cooled by a cooler with two grilles and five compartments.

The nominal production rate has not been achieved until now and heat consumption exceeds the designed capacity figure.

The observations will therefore be devoted principally to this item of equipment with a view to achieving substantial savings and with two targets:

- To increase output by improving operation of the burning shop;
- To increase output by changing the present equipment.

Further, clogging has been noticed at the junction between the rotary kiln, the smoke box and the preheater, probably due to alkalis. This interferes with operation of the kiln by causing stoppages.

3.1.3. Cement grinding shop

The shop consists of a ball mill fed from three metering units - clinker, gypsum and pozzolana - at 65 t/h, nominal output is 80 t/h.

Annual production is 340,000 t/year, corresponding to a true output of 60.3 tonnes/hour, working 18 hours per day. This produces cement at 2,000 Blaine (oversize 6 to 9 per cent at 90 microns). The mill is associated with a dynamic separator. Fines are recirculated at about 200 t/hour (4.5 times throughput).

The shop is not at present producing 80 t/h, apparently owing to the limitation on operation of the separator and the small size of the bag filter at the scavenging air outlet.

It should also be noted that the motors drive a mill that operates at 980 kWh, whereas the motors are 1,400 kWh. The same observation holds true for the raw materials mill.

3.1.4. Intermediary stocks and silos

The storage and homogenization silos were supplied by Claudius Peter (Federal Republic of Germany), and are supplied with air from compressors of which the motors consume 1,120 kWh and 720 kWh for homogenization and for discharge respectively, carrying the raw mix from the silo to the mill.

3.2. Dryer heat balances

Capacity 25 t/d of dry clay, max. 30 t/d
Outlet moisture: 1 to 5 per cent
Inlet moisture (clay)
Winter: 26 per cent
Summer: 15 per cent

Fuel consumption: 0.032 t/tclay (645 kg/h)
Inlet gas temperature: 700° C/750° C
Outlet gas temperature: 90/110° C, max. 180° C
Gas flow (at 180° C): 43,700 m^3/h

ITEM		Moisture Inlet 15 per cent Outlet 1 per cent	Moisture Inlet 25 per cent Outlet 5 per cent
Exit combustion gas	kcal/kg	53.1	62.3
Water evaporation	kcal/kg	110.7	170
Shell loss (estimation) and "stop loss"	kcal/kg	75	75
Superheating of water vapour	kcal/kg	7.1	14.1
Clay waste heat outlet	kcal/kg	12	12
Total kcal per kg of dry clay	kcal/kg	257.9	333.4
Total kcal per kg of clinker	kcal/kg clinker	103.2	133.4

These figures are similar to those computed from consumption, giving the following mean value:

0.032 x 9,700 = 310.40 kcal/kg clay

The drying unit is built at the plant entrance and is far from the kiln. It is therefore difficult to consider partial utilization of the gas discharged into the atmoshpere especially since the dryer is probably not designed to be efficient if the drying gas is colder than that leaving the auxiliary kiln.

A calculation should, however, be made of the heat balance of the SKET kiln, allowing for the fuel oil used to dry the clay.

3.3. Kiln heat balance

There is not sufficient statistical information available to estimate the heat balance. However, it can be assumed that consumption of fuel oil is about 35,190 tonnes/year, taking the data of the table below and results of the year 1985.

	Sales cost 1985	Sales cost/t*	Production consumption	Thermal balance (9,600 t/t)
Cement	93,382	352	264,200 t	
Fuel oil	30,088	855	35,190 t	1,279

* Prices are those of 1987. There is little risk of error in making the comparison because the price of cement is very often linked to that of fuel oil.

A consumption of 1,279 kcal/kg is arrived at, from which must be deducted consumption by the dryer that was estimated previously at 120 kcal/kg of clinker.

To summarize, from this approximate calculation it can be estimated that the SKET kiln heat balance is 1,160 kcal/kg.

Another comparison can be made from the information given to us on production during the four first months of 1987, listed in the table below:

1987 Month	Clinker production	Plant II Kiln stoppages	Fuel consumption	Thermal balance
January	28,361	30h	3,170	1,073
February	24,760	30h	2,893	1,133
March	19,089	212h	2,391	1,215
April	27,535	73h	3,168	1,116
	tons	h	tons	kcal/kg

This indicates for the year 1987 an average figure of 1,134 kcal/kg, confirming the previous figure.

Further, the heat balance can be estimated from the operating data given below on kiln operation.

DATA	UNIT	KILN		KILN	
Kiln outlet temperature	°C	340		360	
Raw mix moisture content	%	1		1	
Gas cooler outlet temperature	°C	180		180	
Oxygen content in the smoke	%	1		1	
Heating value of the fuel oil	kcal/kg	9,700		9,700	
Clinker output (t/d)	t/d	950		950	
% $CaCO_3$	%	76.3		76.3	
Ratio dry meal/clinker		1.56		1.56	
Heat balance			%		%
Ratio flow of smokes/clinker	Nm^3/kg	1.71		1.84	
Heat lost in CO_2 from raw mix	kcal/kg	41	4	44	5
Clinker waste heat cooler out	kcal/kg	23	3	23	2
Water evaporation	kcal/kg	11	1	11	1
Shell loss (difference)	kcal/kg	146	16	147	15
Super heating of water vapour	kcal/kg	2		2	
Exit combustion gas	kcal/kg	178	19	202	21
Theoretical heat requirement	kcal/kg	437	47	437	46
Cooler exit air	kcal/kg	86	9	88	9
Heat balance		924 kcal/kg	99 %	954 kcal/kg	99 %

Some observations can now be made in this regard. There are three columns of results of the thermal exchange calculations:

The first assumes a thermal balance of about 924 kcal/kg. If this is so, and assuming that the clinker output at the kiln outlet is 40 tonnes/hour (950 t/d), the quantity of gas leaving the preheater is about 1.71 Nm^3/kg of clinker.

The third column indicating more than 950 kcal/kg implies a quantity of gas at the preheater outlet of about 1.85 Nm^3/kg of clinker.

These two images correctly illustrate the excessive consumption resulting from the poor efficiency of the burning shop. There is a deviation of more than 3 per cent. The second column gives percentage consumption by heading.

Leaving aside the irreducible "clinker formation heat", the main losses are:

(a) Gas leaving the pre-heater;
(b) Losses through the walls of the kiln, the cooler and the pre-heater;
(c) Losses due to excess cooling air in the cooler;
(d) Losses due to decarbonization.

Taking (b) above, which supposes less efficiency, the consumption parameter that varies is, of course, linked to the losses through combustion gas which have increased at the same ratio.

It can be stated that an increase of the heating cost aggrevates the thermal losses.

In any case, three figures for the balance are available; the first two are averages because they result from long times of operation over four months of one year and were corrected when estimating the cost of energy due to drying clay.

There is a significant difference between the two first figures, which were:

- Average 1985 figure over one year: 1,160 kcal/kg clinker;
- Average 1987 figure over four months: 1,135 kcal/kg clinker.

and that resulting from the thermal balance calculation which was only:

- 950 kcal/kg of clinker (approximately).

This difference is basically due to the stoppages. No information on either the importance, the durations or the reasons for these stoppages was available. This observation must be taken into consideration when examining the subject of savings, and is noticeable in the above table on plant II in 1987, in which the consumption increase is about 10 per cent (212 hours against 30 to 40 hours on the average), because of the loss of time caused by stoppages during March.

Production stoppages of about one hour lead to consumption of about 3 to 4 m^3/h of fuel oil. Shutdowns of more than 12 hours that require total reheating increase consumption by more than 20 m^3/h of fuel oil for a kiln of equivalent capacity.

3.4. Dry line electricity consumption

The observation made for the wet process can be applied to the dry process. There is no system for metering electricity for each major consumer. It is, however, possible to gain a fairly precise idea of consumption from the electricity consumed production ratio for the year 1985. This indicates an electricity consumption for the whole of SKET line No. 2 of 150 kWh/tonne of cment.

This is confirmed when examining the figures for the previous years in the table below, which includes wet process line No. 1 and also thermal consumption.

Electrical consumption	1983	1984	1985	Mean
Line 1	75	72	76	74 kWh/t
Line 2	150	163	145	153 kWh/t
Thermal consumption				
Line 1	1,425	1,630	1,550	1,535 kcal/kg
Line 2	1,030	1,005	1,050	1,028 kcal/kg

Electricity consumed in auxiliary shops such as the bag manufacturing shop and by normal utilities, such as lighting, must be reduced.

The table below is based on the information made available:

Workshop	kWh/t	kWh/t
Raw milling and transport	40	25 - 30
Homogenization, pumps	5	2
Burning line	38	22 - 25
Cement milling	49	35 - 45
Packing shop	3	3
Dryer and transport	6	6
Miscellaneous	10	10
	151	103 - 121

This shows that electricity consumed in the shops is particularly high, with the following particular features outlined below.

Raw milling shop

The excessive consumption is probably due to the unsuitability of the motors driving the mill and which are oversized - 2 x 810 kWh for power installed of 2 x 1,100 kWh - meaning that consumption is increased to 2,450 kWh/h with an output of 100 t/h of raw mix.

The resulting energy balance is:
25 kWh/tonnes of meal
39 kWh/tonnes of clinker

Homogenization

The motors driving the pumps and compressors also seem to be oversized, which explains why the figure is double that usually encountered.

Burning line

The figure of 38 kWh/kg of clinker is based on 90 per cent of power installed and on verification of the figures for consumption of at least the most important item such as exhaust fan and cooler fan. This is a high figure, particularly when considering that the pre-heaters normally consume little, meaning that electricity consumption should be about the lowest of the figures indicated in the above table, i.e., around 22 kWh/kg of clinker.

One of the main reasons for this excessive consumption is probably the fact that the output of the burning shop is distinctly less than the nominal output under normal conditions (900 to 950 t/d for 1,000 - 1,000 t/d) and that the stoppages of varying length and number worsen the balance. When stoppages are limited to a few hours, a certain number of machines must be kept in operation for reasons of safety and protection of equipment, such as the kiln turning gear, the exhauster, the cooler outlet fan, the cooler input fans and the grilles. Similarly, the auxiliary equipment is not shut down; this includes the fuel oil heater, the metering equipment, the dedusters, the primary air fan for the purpose of protecting the burner and the fuel oil pumps. When shutdown times are short, a supply of fuel oil to the kiln is maintained.

In the case of a month like March 1985, when stoppages totalled 73 hours, which can be assumed as 50 stoppages lasting one and one-half hours each, and because one hour may be needed to start up again after every stoppage, average energy consumption was 40 kWh/tonne whereas, when operating for 24 hours per day with no stoppages, electric energy consumption would be reduced to about 34 kWh/t of clinker.

Of course, here again the production figure has an effect, and it is probable that the electrical energy balance would be about 30 kWh/tonne of clinker at an output of 1,000 t/day because an increase of clinker flow rate does not increase consumption proportionally.

4. PROCESS LINE SURVEY

4.1 Kiln gas utilization

As can be seen from the flow sheet below, the kiln gases are not used entirely to dry the raw mix at the present output of 900 t/d of clinker per kiln. This is due to the low moisture content of the raw materials. The gas that is not used is bypassed through a conditioning tower to the electro-filter. The figures on the flow sheet (see below) illustrate the reserve capacity of the principal machines (see also the two following tables below),

The distance between the dry process line and the drying shop is too great to allow the recovery of gas at 320° C in order to dry part of the clay. This is a method that must therefore be abandoned because of the relatively important modifications needed.

Gas flow Clinker output	Outlet preheat.	Inlet condit. tower	Outlet condit. tower	Inlet raw mill	Outlet raw mill	Outlet electro filter
900 t/d	58,000	15,200	16,900	42,800	77,500	94,500
1100 t/d	71,000	27,000	31,000	44,000	80,000	111,000
Limits	95,000					165,000

Cooler air flow Clinker output	1	2	3	4	Exit cooler	Grates speed
900 t/d	39,000	39,000	22,000	22,000	110,000	15.5/20
1100 t/d	45,000	45,000	25,500	25,000	130,000	19/22.5
Limits	45,000	47,000	33,000	53,000	158,000	22.5

4.2. Present performance of dry line

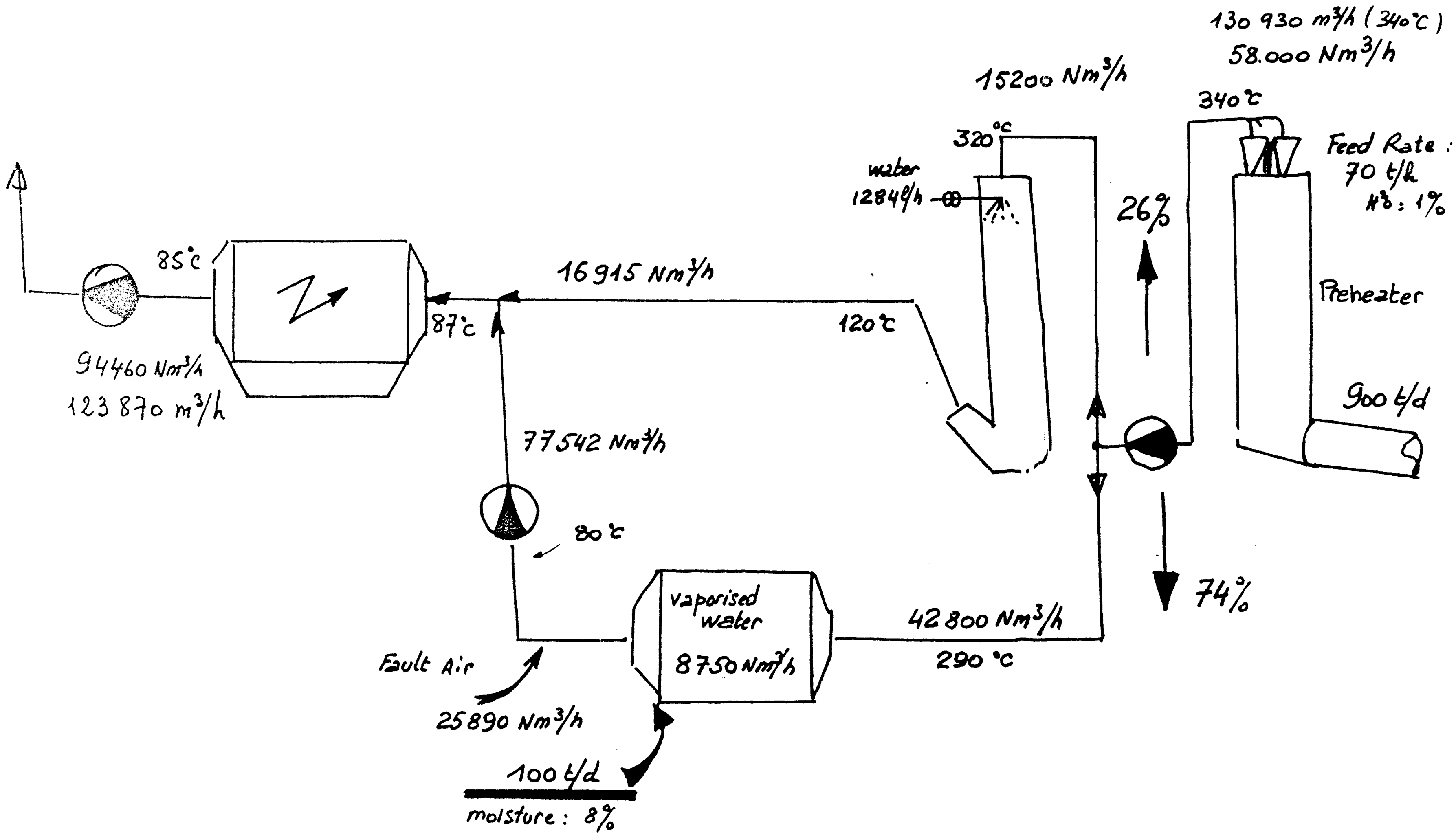
The production line presently operates at a maximum output of 950 tonnes/day, and 1,000 tonnes when working for short times, owing to a number of reasons:

- Difficulties of flow of raw materials caused by caking rings at the junction between the kiln and the ZAB pre-heater;

- Caking rings at the inlet to the burning zone partly due to the chemical composition of the raw mix, to a liquid phase which is perhaps excessive, and also to variations of flame geometry;

- Unexpected power cuts that cause stoppages and thermal shocks that are difficult to avoid.

FLOW SHEET OF GAS



The fans - the kiln exhauster fan, the cooler fan and the air cooling fans - are correctly designed and allow more advantageous operation of the burning line, as can be seen from table 15. The raw mix grinding shop is able to prepare raw mix for a clinker tonnage of about 1,100 to 1,200 tonnes per day, on the condition of constant output of 100 t/h over a longer operating time (18 hours).

4.3 How to save thermal energy

There are several ways to achieve savings in an industrial process. Different ways of saving can be achieved simultaneously. These consist of taking action on the factors that are fixed in a balance or on the variable items. In the present case, if the production of clinker is increased, it would save thermal energy because the losses through the walls are practically constant.

If the efficiency of combustion is improved, a thermal saving can be made by changing the flame profile and by improving the gas/material exchange.

If exchanges in the pre-heater are improved by modifying structures and reorganizing the thermal levels, thermal energy can be saved by reducing the losses at the pre-heater outlet and by improving preparation of the material at the rotary kiln inlet.

It is therefore proposed to effect improvements by implementing all these suggestions.

The efforts for energy saving will therefore concentrate of the following:

(a) Combustion efficiency;

(b) Exchanges between kiln and pre-heater - the thermal profile;

(c) Improvement of exchanges in the pre-heater with two proposals for restructuration of the heat exchanger;

(i) Replacing an upper section of the shaft by a cyclone exchanger;

(ii) Replacing a lower section to allow the later addition of a precalcination unit;

(d) Better distribution of the combustion points - an attempt at precalcination;

(e) Improvement of measuring and test facilities for the purpose of improved operation;

(f) Improvement of production.

Combustion efficiency

A number of parameters have an influence on combustion efficiency, which has a great effect on the thermal profile in the rotary kiln. It can been seen from the data made available that the quantity of primary air is very high when compared with modern and efficient systems. The quantity of primary air is about 20 per cent, whereas modern burners operate with 4 to 6 per cent of primary air.

If it were possible to employ such modern burners, much less primary air would be needed.

When fuel oil is of the quality available at HAMA, the volume of air is 11.3 Nm^3/kg of fuel oil (with 1 per cent of added oxygen).

It will in fact be necessary to burn 100 kg of 9,600 kcal/kg fuel oil to produce 1 tonne of clinker and to provide 50,000 Nm^3/h of primary air, which is fitted to the burner at about 10,000 m^3/h with the additional quantity supplied in the form of secondary air at 800° C (the hoped-for temperature) entirely from the primary ventilation system (36,000 m^3/h) with a small part from the secondary system (6,000 m^3/h). It is noted that the temperature of the combustion air within the burning zone is 689° C and not 800° C.

The flame is therefore less powerful than it should be with a burner receiving a low percentage of cold primary air. The thermal saving due to the use of the burner is thus already 26 kcal/kg of clinker.

The calculations below relate to this.

Calculation of energy saving due to the use of a high-performance burner

General conditions		
Kiln output	:	900 t/day
Fuel oil	:	9,650 t/day
Air/fuel oil ratio	:	11.3 Nm_3/kg fuel oil (including 1 per cent of added oxygen)
Secondary air temp.	:	800° C
Present thermal balance	:	950 kcal/kg clinker
Present burner	:	15 per cent of primary air at 20° C (6,250 m^3/h)
Combustion air temperature	:	0.15 at 60 + 0.85 at 800 = 689° C
Nozzle with 5 per cent added air	:	0.05 at 60 + 0.95 at 800 = 763° C
Additional energy supplied by secondary air	:	

$$\frac{1.30 \times 0.25\ (763 - 689) \times 11.3 \times 950}{9,650} = 26.75 \text{ kcal/kg clinker}$$

Resulting thermal balance : 923 kcal/kg clinker

Resulting fuel oil consumption : 0.096 kg/kg clinker

A real economy results from adjustment of the necessary air:

$$\frac{1.30 \times 0.25\ (763 - 689) \times 11.3 \times 923}{9{,}650} = 26 \text{ kcal/kg clinker}$$

The thermal saving achieved is 3 per cent.

Daily saving: $0.03 \times \frac{923}{9{,}650} \times 900 \times 855 = \text{LS } 2{,}453$

Payback time - 105 days

This is not the only advantage of a modern burner, it can be adjusted more precisely and we can expect a better stabilized burning zone temperature and to benefit from an evident saving of refractory lining bricks.

For reasons of flame instability and thermal shocks that the operators are not able fully to control because they are often caused by the unexpected power cuts, the present consumption of kiln lining bricks is:

- In the 4 - 11 m zone (burning zone)
  4/5 months, material: magnesia

- In the 11 - 22 m zone
  6/7 months, material: 80 per cent alumina

- In the 22 - 35 m zone
  12 months, material: 30/60 per cent alumina

- In the 35-60 m zone
  (7 years) not replaced, material 50/60 per cent alumina

These figues are excessive and it is believed that they can be reduced considerably by installing a better burner.1/ It should be possible to attain a lifespan of bricks of about 12-16 months in the burning zone under conditions of regular operation, particularly at Hama where the clogging is uniform and relatively significant.2/ The resulting flame would allow a slight slowing down of the kiln operating speed, or at least maintaining the same speed with a production of 1,100 t/d, complementary to the following modifications.

1/ The results achieved at Tartous witha Pillard burner should be followed with interest.

2/ Another reason for unexpected wear is the number of stoppages caused by power cuts.

4.4. How to increase output

The present output of the burning shop is about 950 tonnes/day while its nominal capacity is 1,000 tonnes/day. However, there are two reasons that prevent a desirable increase to 1,100 t/d:

- The frequent caking rings that form at the junction between the kiln and pre-heater;

- The poor thermal efficiency and therefore the insufficient preparation of the raw mix together with the resulting low decarbonization that makes burning difficult in the kiln with avalanches or difficulties of flow (caking at the zone inlet and outlet).

It therefore appears essential to better prepare the raw materials, to increase decarbonization and also to prevent excessive temperature defferences at the kiln-pre-heater junction by checking the quality of the seal).

It is, however, not possible to burn a fuel containing less sulphur. The fuel oil presently burned contains 3.5 per cent of sulphur and one has to wait until gas from the Palmyra basin is available at Hama; this gas is sufficiently desulphurated to resolve this problem and would result in considerable savings.

One means of reducing caking at the rotary kiln inlet would be to change the thermal profile and modify the layout of the fuel oil feed system, for which purpose it would be of interest to provide additional fuel oil at the position where the raw material enters the rotary kiln by placing an auxiliary burner there.

It must be understood that such an addition would not immediately provide an improvement of the thermal balance, because the thermal efficiency of the SKET tower will not be improved, and working in the burning zone with excess air will render thermal exchanges less efficient. However, there would be a more regular operation and therefore an improved flow rate.

Losses through the walls are about 147 kcal for the production of about 1,000 kcal/kg of clinker. These losses include those due to stoppages and also to operation of the burning shop, and should amount to less than 30 kcal.

In compensation, the kiln output could be increased by:

- Improving preparation of the raw mix at the kiln input because the combustion gas temperatures are higher and decarbonization is more important in the exchanger;

- Reducing the alkaline clogging by uniformizing the thermal profile.

It is therefore probable that operation will be more regular leading to an increase of output. Finally, certain production difficulties are due to the method of operation. For example, one operating day (2 October 1987) has two shutdowns, one probably due to a power cut or to a mechanical incident lasting one hour and 45 minutes, and the second due to the difficulties of the previous start-up and lasting 30 minutes.

The thermal balance of the first shift was 981 kcal/kg for the whole 8 hours; the balance was decreased by an unexpected stoppage for one and one half hours.

The thermal balance for the second shift was improved with 958 kcal/kg of clinker in spite of the 30 minute stoppage.

During the third shift, production was regular with a thermal balance of 924 kcal/kg clinker.

The overall thermal balance for the day was therefore 953 kcal/kg, producing 915 tonnes of clinker.

With regard to breakdown of consumption, assuming the same smoke temperature of 340° C, smoke temperature at the kiln inlet is about 850° C, a figure that appears to be low and proves the poor thermal efficiency of the ZAB pre-heater and the high thermal load in the rotary kiln. The installation of a burner at the junction should raise the temperature at the back of the kiln and should relieve the rotary kiln by better preparation of the raw material of which the present decarbonization can scarcely be more than 10 per cent at the kiln inlet.

Consideration can also be given to the placing of a burner at the bottom of the last ZAB shaft, offsetting the flame in order to increase its vertical flow.

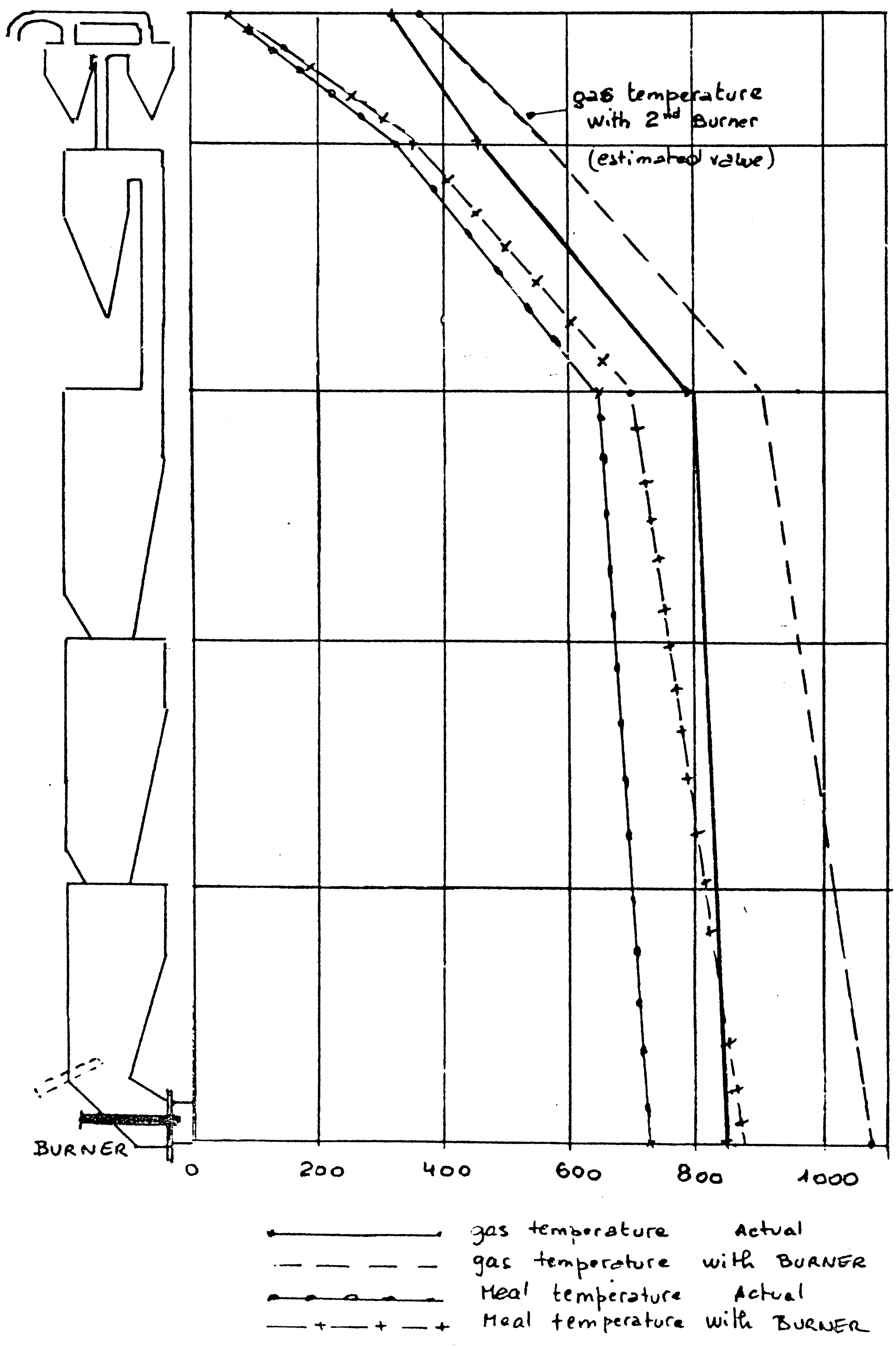
This is a conversion that can be carried out by the operators at low cost. It would allow an improvement of the burning shop output through more regular operation. Because of the reduced kiln thermal load, it should be possible to increase the kiln output to a minimum of 1,000 t/day. The thermal balance would then be significantly improved in spite of the slightly higher smoke temperatures.

<u>To what degree can production be thus increased without major transformations?</u>

The table below lists the parameters of the principal machines together with their values at present production rates. It would appear to be possible to increase production of clinker to 1,100 t/day without extensive transformations.

The exhauster is probably able to operate at higher capacity provided that there is no change in the pressure loss through the exchanger when the motor driving it will be near to its limits at 1,100 t/day.

The kiln is at present operating at its limits. A new filling rate should therefore be set, which seems to be not impossible because the motor driving the kiln has a power reserver. The cooler ventilation system is sufficient and air distribution would be slightly changed, particularly in compartments 2 and 3. It will be necessary to make sure that the grille mechanical system is able to support an additional load of 10 per cent, with reinforcement of the base frame if needed.


gas temperature with 2nd Burner (estimated value)
BURNER
0
200
400
600
800
1000
gas temperature Actual
gas temperature with BURNER
Meal temperature Actual
Meal temperature with BURNER

4.4.1. Improvement of heat exchanges in the pre-heater

The thermal profiles of the above figure illustrate the poor exchange efficiency of the ZAB shafts. A shaft might well be replaced by a better exchanger. The cyclone that ensures good contact by increasing gas turbulence should increase exchange efficiency.

The Hama cement plant has taken an interest in this transformation that consisted in replacing the upper shaft by a cyclone identical to that of stage 2. The builder was unwilling to give a warranty (the position taken by SKET). It is nevertheless certain that this transformation would result in improvements with regard to both the clinker flow rate and thermal savings.

This is illustrated in the table below, which indicates the thermal balance resulting from replacement of the first shaft by a cyclone and increasing the kiln output to 1,100 tonnes/day.

Because of improvement of exchanges, the outlet temperature is near to 320^{o} C. Increased production limits losses and allows operation with a thermal balance of about 884 kcal/kg of clinker. It has been assumed that losses through the walls will be no different from those at present. The savings in this case will therefore amount to about 70 kcal/kg.

Consideration must be given to the fact that this very important saving will be reduced by a loss of electric power caused by the increase of pressure loss between 120 and 170 mm WG depending on the cyclone. This leads to the replacement of the exhauster fan or, perhaps preferably, to the installation of a series of a fans with a motor operating at fixed speed to back up the original fan.

A study will have to be made to make sure that the duct connecting the pre-heater to the exhauster is sufficiently strong mechanically and is designed to withstand the forces due to the increased negative pressure caused by raising the pressure loss through the new pre-heater.

The other parameters in principle remain unchanged:

- The kiln speed remains at its present maximum figure. For greater flexibility of adjustment, one might examine the possibility of providing a more powerful motor;

- The cooler is guaranteed to operate at 1,000 t/d but is designed for a load of about 17.7 t/m which corresponds to a maximum output of clinker of 1,100 t/d at its maximum advance (0.12 m/rotation). At this rate the motor driving each grille reaches its maximum permissible consumption (38 kWh); this represents an operating limit.

In spite of the improved exchange in the pre-heater due to the replacement of the upper shaft by a cyclone and also to the increased temperature of the material entering the kiln, clogging may occur and hold up the flow of the raw mix.

If this is so, the previously recommended precaution of feeding part of the thermal energy through an auxiliary burner at the bottom of the pre-heater should be implemented.

The expected balance would be near to that illustrated in the table below, on burner back and rotary kiln, which shows, in comparison with that of the table below, on thermal balance resulting from replacement of the first shaft by a cyclone, that a slight increase of the thermal balance (15 to 16 kcal/kg) may be necessary to achieve sufficient output of clinker.

4.4.2. Replacement of last lower shaft by a cyclone/duct assembly

This method, which may be more difficult to implement, has the advantage, when compared with the previous one, of better preparing the passage to future precalcination. But if it should prove possible to install a sufficiently long connecting duct between the kiln and the lower cyclone inlet, it would worthwhile to increase the percentage of fuel and to distribute it on the basis of 200 kcal/kg in the connecting duct and 680 kcal/kg in the kiln, to give an example.

This method would increase decarbonization in the pre-heating system, probably to nearly 50 per cent. The combustion of fuel oil in the duct will have to be very efficient, necessitating considerable pre-heating of the fuel oil so that its viscosity is about 2 - 3° C at the burners (spray pressure 35 - 40 bar).

- Gas at smoke box : 1.22 Nm^3/kg
- Gas temperature : 1,150° C
- Oxygen : 5 per cent

One of the tables below, on three-stage cyclone - two shafts, lists the figures for the thermal balance that might be achieved by such an organization and which might be improved still more if the other measures specified in this report are implemented,

Nevertheless, to attain an output of raw materials of 1,200 t/day, a certain number of changes will have to be made in the shop, in particular:

(a) Change of the kiln exhaust fan and its drive motor or placing, in a series between the exhaust duct and the present fan, a second fan operating at fixed speed and able to compensate for the pressure loss;

(b) Study of the mechanical characteristics of the exhaust fan and replacing it if necessary;

(c) Strengthening of the mechanism of the cooler grilles, checking that with an extra load of 10 per cent the increased pressure does not involve changing the air blowing fans;

(d) Changing the grille operating motors.

All the calculations relating to the above modifications will have to be based on an output limitation of 1,400 of 1,500 t/d in order to allow future increases. It will then be possible to increase the kiln/precalcination ratio in the breakdown of fuel.

Thermal balance resulting from replacement of the first shaft by a cyclone

Data	Unit	Kiln	
Kiln outlet temperature	°C	320	
Raw mix moisture content	%	1	
Gas cooler outlet temperature	°C	180	
Oxygen content in the smoke	%	1	
Heating value of the fuel oil	kcal/kg	9,700	
Clinker output (t/d)	t/d	1,100	
% $CaCO_3$	%	76.3	
Ratio dry meal/clinker		1.56	
Heat balance			%
Ratio flow of smokes/clinker	Nm3/kg	1.63	
Heat lost in CO_2 from raw mix	kcal/kg	41	5
Clinker waste heat cooler out	kcal/kg	23	3
Water evaporation	kcal/kg	11	1
Shell loss (Difference)	kcal/kg	166	19
Super heating of water vapour	kcal/kg	2	-
Exit combustion gas	kcal/kg	118	13
Theoretical heat requirement	kcal/kg	437	49
Cooler exit air	kcal/kg	86	10
Heat balance		884 kcal/kg	100%

Burner back and rotary kiln

Data	Unit	Kiln	
Kiln outlet temperature	°C	320	
Raw mix moisture content	%	1	
Gas cooler outlet temperature	°C	180	
Oxygen content in the smoke	%	1	
Heating value of the fuel oil	kcal/kg	9,700	
Clinker output (t/d)	t/d	1,100	
% $CaCO_3$	%	76.3	
Ratio dry meal/clinker		1.56	
Heat balance			%
Ratio flow of smokes/clinker	Nm3/kg	1.64	
Heat lost in CO_2 from raw mix	kcal/kg	41	4
Clinker waste heat cooler out	kcal/kg	23	3
Water evaporation	kcal/kg	11	1
Shell loss (difference)	kcal/kg	166	18
Super heating of water vapour	kcal/kg	2	-
Exit combustion gas	kcal/kg	132	15
Theoretical heat requirement	kcal/kg	437	49
Cooler exit air	kcal/kg	88	10
Heat balance		900 kcal/kg	100%

Three-stage cyclone - two shafts

Data	Unit	Kiln	
Kiln outlet temperature	°C	330	
Raw mix moisture content	%	1	
Gas cooler outlet temperature	°C	180	
Oxygen content in the smoke	%	1	
Heating value of the fuel oil	kcal/kg	9,700	
Clinker output (t/d)	t/d	1,200	
% $CaCO_3$	%	76.3	
Ratio dry meal/clinker		1.56	
Heat balance			%
Ratio flow of smokes/clinker	Nm3/kg	1.57	
Heat lost in CO_2 from raw mix	kcal/kg	45	5
Clinker waste heat cooler out	kcal/kg	23	3
Water evaporation	kcal/kg	11	1
Shell loss (difference)	kcal/kg	165	19
Super heating of water vapour	kcal/kg	2	-
Exit combustion gas	kcal/kg	116	13
Theoretical heat requirement	kcal/kg	437	49
Cooler exit air	kcal/kg	88	10
Heat balance		882 kcal/kg	100%

Comparison of thermal balances

		Actual	Previous table*	2nd Burn.
Thermal Balance	Kcal/KK	924	884	900
Raw meal flow rate	t/h.	60	73	73
Raw meal work in	t/h.	67.5	82.5	81.5
Outlet gas flow	Nm3/h.	64,000	75,000	75,200
	T^{o} C	340	320	350
Gas flow to raw mill	Nm3/h.	45,000	49,000	44,000
	T^{o} C	290	280	300
Gas flow to stabil.	Nm3/h.	19,000	26,000	21,000
	T^{o} C	320	305	330
Gas flow after stab.	Nm3/h.	21,300	28,300	23,300
	T^{o} C	120	120	125
Gas f. out raw mill	Nm3/h.	77,500	90,000	80,000
	T^{o} C	80	80	80
Gas f. out. elec. pre.	Nm3/h.	98,800	118,300	103,300
	T^{o} C	85	90	90

* Table on thermal balance resulting from replacement of the first shaft by a cyclone.

5. PROCESS CONTROL

Achievement of energy savings also depends on examination of the facilities and the methods of operation of the cement plant.

It has been shown that substantial savings can be made by improvements of equipment but more details should be given on the effect of the stoppages of which the principal causes are:

- Electrical and mechanical faults;

- Difficulties due to physico-chemical factors such as flow rates, clogging, variation of liquid phase, composition of raw mix and of the fuel;

- Production details.

The purpose of this paragraph is to examine production details, for which only the information appended in the form of the Rotary Kiln Plant Daily Log and a copy of the data are available.

However, the following points must be taken into account:

(a) Readings relating to the day of 2 October 1987 are not very recent;

(b) They give the figures relating to the process but not to the settings, except the essential ones for raw materials and fuel;

(c) The operators are highly experienced in correcting operational deviations, as the graph below illustrates;

(d) The long response time in receiving signals on operational parameters is due to the lack of latest modern instruments.

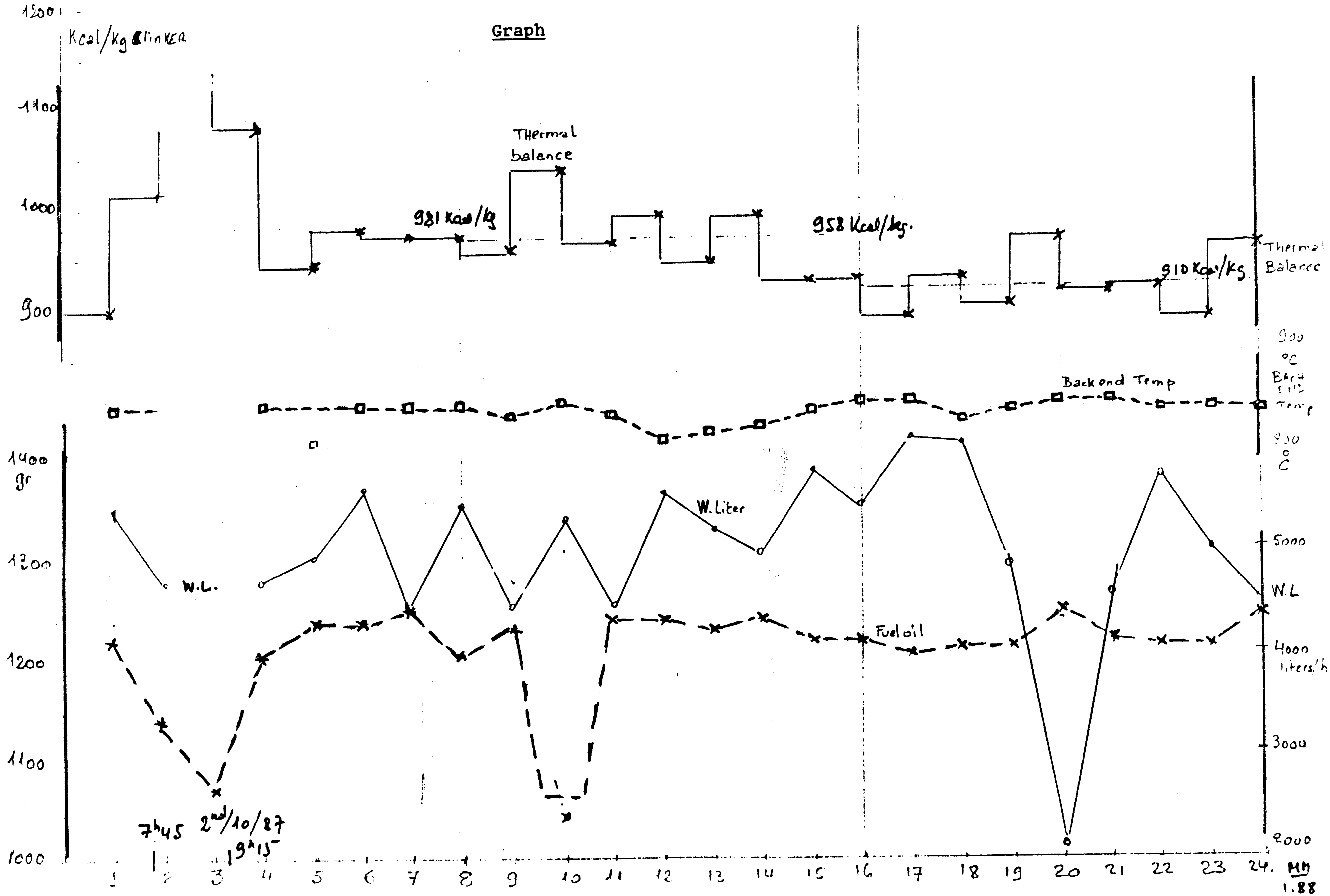
Further to this last point it should be noted that the instruments are not sufficient. There is no operating recorder and no, or very few, regulation instruments to maintain the set-points. Position measurements are transmitted pneumatically and are very slow. Distances are very long and the signals are attenuated; this blurs changes of parameters. We see from the "data" that the pressure in the firing hood is constant at -1mm WG, which is not possible when we read the figures for gas flow at the pre-heater outlet.

This is an example that justifies the use of more sophisticated instruments to operate the shops.

<u>Observations contained in graph below</u>

Only the figures below were taken from this graph; they originated in the table below on thermal balance and were calculated for the balances. The balances are based on mean values and their accuracy remains to be gauged.

Graph


Kcal/Kg Clinker
1200
1100
1000
900
Thermal balance
981 Kcal/kg
958 Kcal/kg.
910 Kcal/kg
Thermal Balance
900 °C
Back end Temp
Backend Temp
1400 gr
1300
1200
1100
1000
W.L.
W.Liter
Fuel oil
5000
W.L
4000 liters/h
3000
2000
7h45 2nd/10/87 19h15
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24.
1.88

Thermal balance: one-day evolution

Hour	K. output	Q. fuel m^3	Thermal balance
7	42.8	4.2	893.0
8	30.6	3.4	1,816.0
9		2.7	
10	33.9	4.0	1,076.0
11	41.7	4.3	940.0
12	40.6	4.3	965.0
13	41.7	4.4	961.0
14	41.1	4.0	887.0
15	41.1	4.3	953.0
16	21.1	2.4	1,034.0
17	41.7	4.4	961.0
18	40.6	4.4	989.0
19	41.7	4.3	940.0
20	40.6	4.4	987.0
21	41.7	4.2	916.5
22	41.7	4.2	916.5
23	41.7	4.0	875.0
24	40.6	4.1	920.0
1	42.8	4.1	872.5
2	41.7	4.4	961.0
3	41.7	4.2	916.5
4	41.1	4.1	909.0
5	41.1	4.1	909.0
6	41.1	4.3	953.5
Mean	38.1	4.1	967.3
	Tons K.	m^3/hour	kcal/kg

Figures taken from the above graph

1. Thermal balance, taken hour by hour (at end of shift);

2. Temperature of klin outlet;

3. Rate of one litre of clinker (average of samples or weight of sample taken during one hour of operation). The sample is corrected between two particle sizes and in principle represents the content of free lime and the burning process;

4. Fuel consumption during one hour of operation.

The data and the graph illustrate the above-mentioned two disturbances that occurred during 24 hours (three shifts). The first occured during the second hour of the first shift and was evidently due to a sudden power cut; it lasted from 7.45 a.m. to 9.15 a.m. during which time the burning shop was shut down.

The second apparently resulted from the first and must have occurred because of an avalanche that cut off the supply of raw mix and fuel to the kiln, though it did not hold up the flow of materials for the kiln rotating speed was maintained.

These two disturbances causing shutdowns are going to considerably modify the instantaneous thermal balance as can be seen from the mean figures of the thermal balances taken hourly over eight hours. Here there is proof that shutdowns lead to overconsumption. Without claiming that the second shutdown might be prevented, it must be pointed out that better knowledge of operating conditions supplied by more sophisticated instruments and automatic operating facilities, which exist today, will allow elimination of these faults and will aid in improving the thermal and energy balances.

It can be seen from the graph that the lines plotted for the hourly thermal balance and the kiln outlet temperature are consistent. Concordance is good between weight per litre and fuel oil flow rate. This is a postulate that requires examination of the average figure needed for reconsideration of operational savings. Leaving aside the drop of weight per litre at 8 a.m. the average weight during the day was 1,316 g/litre.

Although the weight per litre may be arbitrary and depends on a great number of factors, it seems to be relatively high and it would probably be sufficient to operate at a figure of about 1,250 g/litre. If it proves possible to reduce the difference of weight per litre, this could save some 10 kcal/kg of clinker.

A more careful study carried out by the plant operators of the free lime present in the clinker should allow this saving. It is important to make sure that the parameters are as consistent as possible. It should be pointed out again that this implies new instruments and new technologies for the purpose of automation.

The figures below on modifications required show that considerable capital outlay is needed for the buying of equipment and also for the training of personnel.

6. MODIFICATIONS REQUIRED TO IMPROVE THE ENERGY BALANCE OF THE HAMA CEMENT PLANT

Wet process

- Study of slurry improvement	20 to 40 kcal/kg
- Adjustment of temperature at clinker outlet	15 kcal/kg
- Increase of chain density (at the same time as the previous study)	40 to 100 kcal/kg

Dry process

- Study of use of basalt to replace the present clay. The price of transportation is unknown. Basalt contains a little moisture and can be dried in the present mill where heat is available, up to an output of 1,500 t/d. This idea was put forward by the Hama technicians and appears to be very promising. 100 kcal/kg

Compensation of reactive energy by the installation of capacitors

- On the power input
- On every consuming machine

This step must be taken to avoid the penalties which are or will be imposed by the power company, and to improve operation of the motors. The study can be carried out by questioning the power company and the main equipment suppliers, without cost.

Clinker grinding

The mill output is less than its nominal figure for two reasons:

- Inefficiency of the dynamic separator
- Saturation of the bag filter

To save the 15 tonnes required to operate at nominal capacity, the following measures are necessary:

1. The builder or a similar company could adjust the separator and the shop, re-examine the load in the mill and improve the surface area of the bag filter by installing a second filter.

2. The present separator should be replaced by a separator of better efficiency such as the OSEPA separating devices*

Expected saving 5 kWh/t

With regard to elctric power, the same observation applies as to the raw mix mill. This step is essential and must be undertaken.

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* OSEPA is an active separator for which the manufacturing licence has been granted for the region to CLE TECHNIP of Paris, a builder of cement plants.

Intermediate stocks and silos

The compressor consumes too much electricity, probably at least twice that normally needed, though there are no data on the circuits and their dimensions. No solution to the problem is foreseen other than to study the connection of one circuit to the other.

Dry process kiln

Consumption may be improved by the following:

1. Improving preparation of the raw mix (indicated in section 1).

2. Reducing burning in absolute values by introducing an auxiliary burner at the end of the kiln (increasing the kiln operating time).
20 kcal/kg K

3. Increasing output by transforming the exchanger, replacing the first shaft by a cyclone.
25 kcal/kg K

4. Increasing output by transforming the exchanger, replacing the third shaft by a cyclone.
45 kcal/kg K

5. Fitting a high-performance burner.
40 kcal/kg

6. Improving the instruments, improving operational stability, reducing stoppages due to difficulties of operation.
30 kcal/kg.

7. MAJOR ACTIONS FOR IMPROVING ENERGY EFFICIENCIES

Wet process kiln (Smidth)	kcal kW/h	Ton/ day	Fuel/ year ton	Work cost KF	Pay back time M.th
1. Decreasing moisture of slurry using slurry thinners: 30% H_2O	45		530	150 (Stud)	6
2. Output clinker temperature satellite cooler study	40		480	1,800	40
3. Kiln chain system study, modification and furniture	80		950	1,500	24
Dry process kiln (SKET)					
4. Basalt in place of clay, geological and chemical studies	20/ 100		750/ 3,750	250	4 1
5. Optimization of raw milling and cement milling	6 Kwh		2 M.kWh	200	12
6. Setting up of pre-heater auxiliary burner	18	980	680	140	6
7. Cyclone as a substitute for first shaft of the pre-heater	25	1,050	850	2,600	36
8. Cyclone as a substitute for third shaft of the pre-heater	40	1,100	1,550	4,100	32
9. New high efficiency burner	40	1,000	1,500	450	8
10. Instrumentation and automation (process automation)	15	1,050	550	2,500	22
11. New cyclone pre-heater (four stages)	120	1,200	2,590	10,000	24
12. New cyclone pre-heater with precalciner and tertiary air	140	1,500	7,140	19,000	18

* With simple precalcination.

Calculation of the profit of proposal

	Expected output	Gain by output		Gain by energy saving	
	Tons/day	Tons/day	FF*	kcal/k	FF*
6	980	20	213	20	360
7	1,050	90	1,060	25	450
8	1,100	140	1,600	40	820
9	960	-	-	40	795[a/]
10	1,000	40	425	110	2,000
11	1,200	240	2,650	105	2,200
12	1,500	550	5,845	140	7,100[b/]

Notes: * FF = French Francs.

Energy saving (difference of thermal balance)
Kcal/kg* Coef TH =
Coef TH = Cost of fuel oil (855 LS)* Change LS/FF(0.62)= Coef TH = 530

Cost saving same amount for each component of cost price except salaries and wages.
Coef CS = Cement price (LS) * Change (LS/FF=0.62)*
Working day (330) * Part of salaries (actual condition 24.5%).
Coef CS = 10,627

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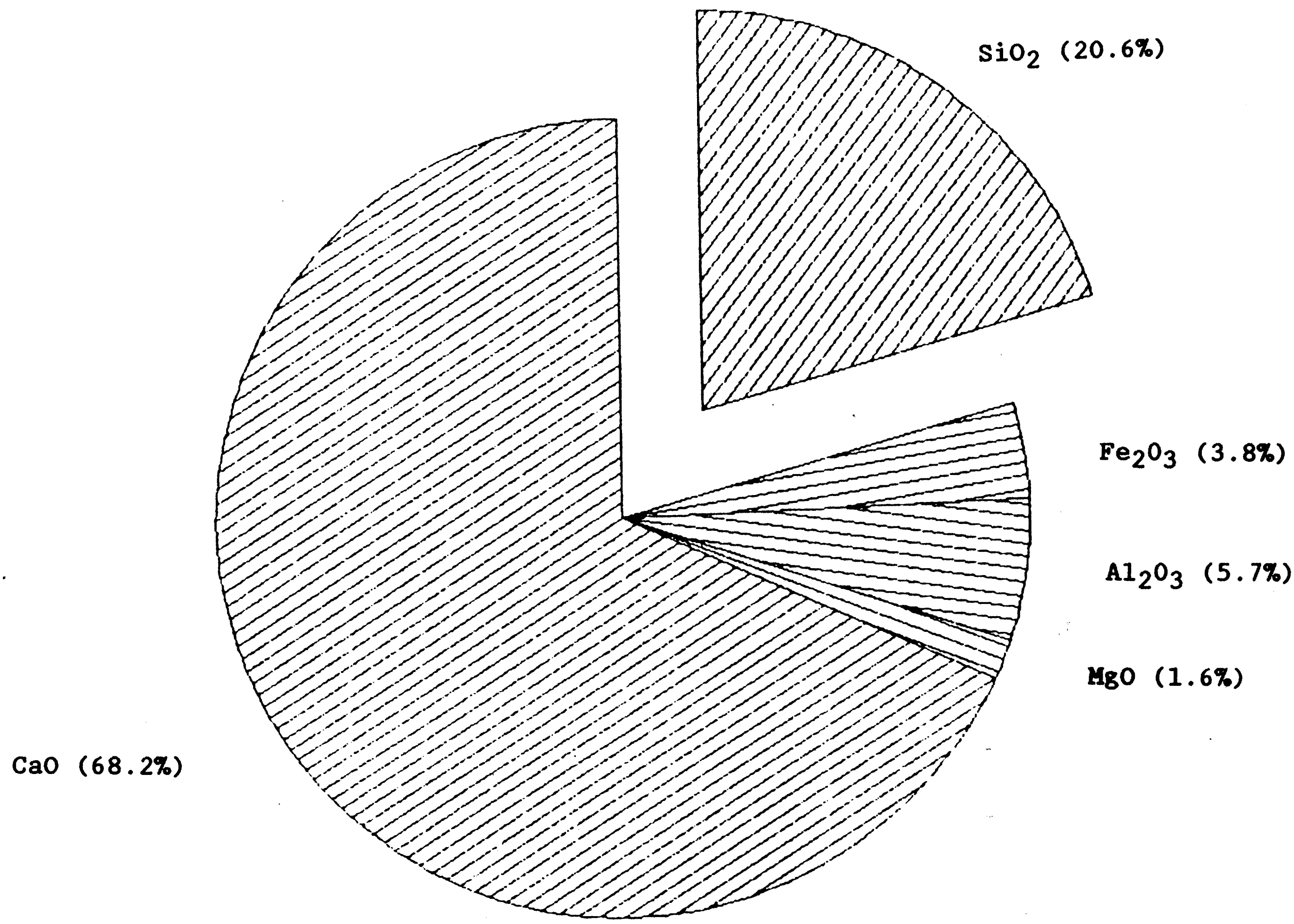
a/ May be added with : (6), (7), (8), (9), (10), (11).

b/ With precalciner : max. capacity: 2,000 ton/d.

Break influence on output and consumption

	1st shift By h./shift		2nd shift by h./shift		3rd shift by h./shift		Total and average by 24 h.
Fuel consumption (m^3)	3.66	29.3	4.08	32.6	4.21	33.7	95.63
Fuel consumption (ton)	3.44	27.51	3.83	30.61	3.96	31.64	89.8
Raw mix consumption (ton)	61.25	490	69.7	558	74.88	599	1,647
Clinker output	34.03	272	38.7	310	41.6	332	915
Breaks and stops (h)		1/2		1/2			
Average balance (kcal/KK)	981		958		925		952


SiO2 (20.6%)
Fe2O3 (3.8%)
Al2O3 (5.7%)
MgO (1.6%)
CaO (68.2%)