3. RESULTS OF THE STUDY ON THE CEMENT INDUSTRY

3. RESULTS OF THE STUDY ON THE CEMENT INDUSTRY

3.1 Results of the Study at Sepahan Cement Company

3.1.1 Outline of the Plant

(1) Plant name

Sepahan Cement Company

(2) Plant address

Esfahan City

(3) Number of employees

1,375 including about 30 engineers

(4) Major products

Portland cement and clinker

(5) Production capacity (nominal)

Cement: 10,000 t/d
Clinker: 7,000 t/d

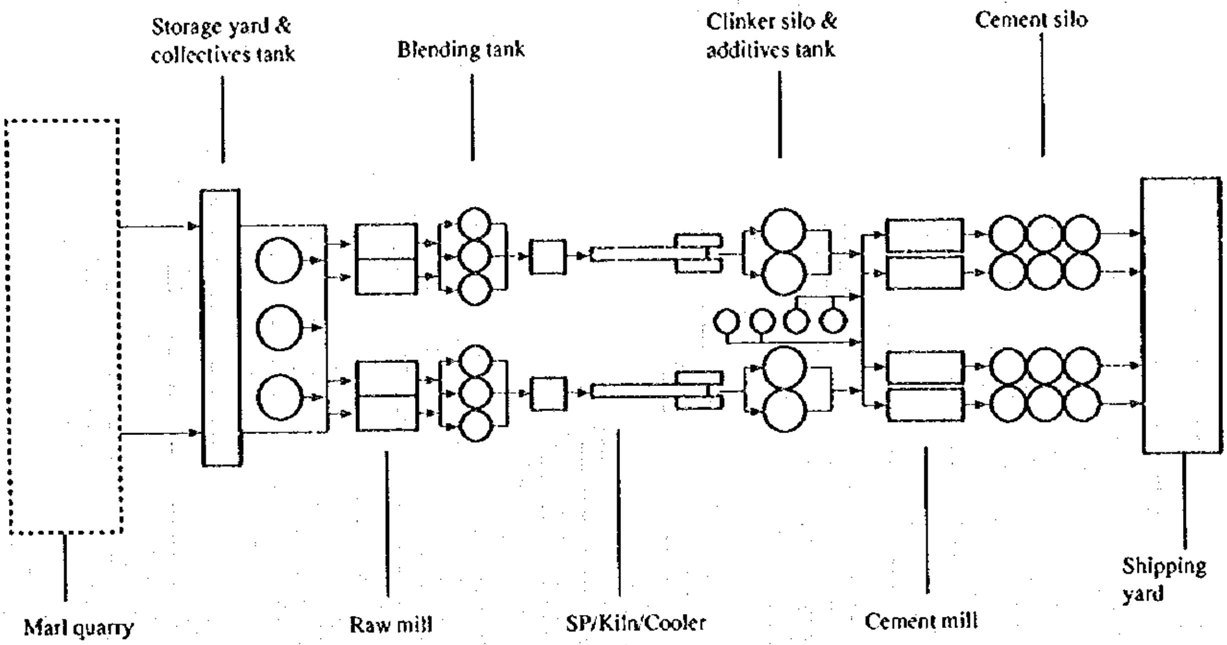
(6) Production process of cement

This cement company digs out marl for raw material at the adjacent quarry. This raw material is made into the blended ore in the indoor yard using the ore bedding system. The components are then adjusted by adding 2 to 3 % of limestone, silica, and iron, to be used.

The tandem method, which is a combination of the secondary crusher and the air swept mill, is adopted for dry crushing of the raw material. The pre-heater exhaust gas is used as a drying heat source after adjusting the moisture. The suspension pre-heater (SP) kiln with satellite cooler is used for the burning process. The closed circuit type ball mill is used as the finish grinding system. The final product is manufactured by mixing 4 to 5 % of gypsum and 7 to 18 % of slag in the clinker on the design basis.

Figure 3.1.1 shows the manufacturing process flow of the entire plant.

Figure 3.1.1 Process Flow



(7) History of the plant

1973: This company was established.

1978: No. 1 line started operation.

1981: No. 2 line started operation.

Now, as a single factory, it has a production scale next to Tehran Plant of Tehran Cement Company and Abyek Plant of Fars and Khuzestan Cement Company, and is one of modern representative cement plants in I. R. Iran.

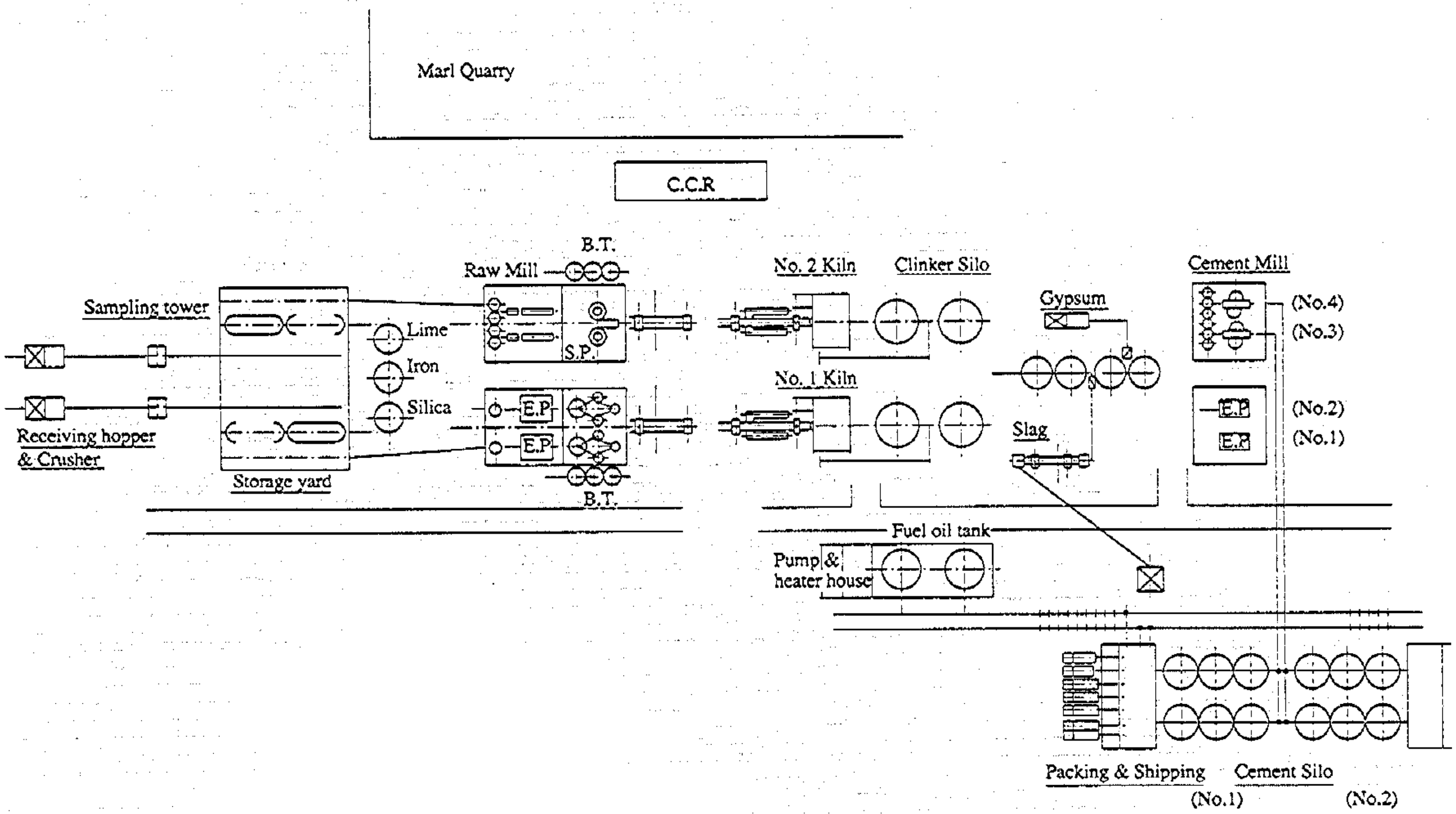
(8) Plant layout

Figure 3.1.2 shows the plant layout.

(9) One line diagram

Figure 3.1.3 shows the electric power one line diagram.

Figure 3.1.2 Plant Layout



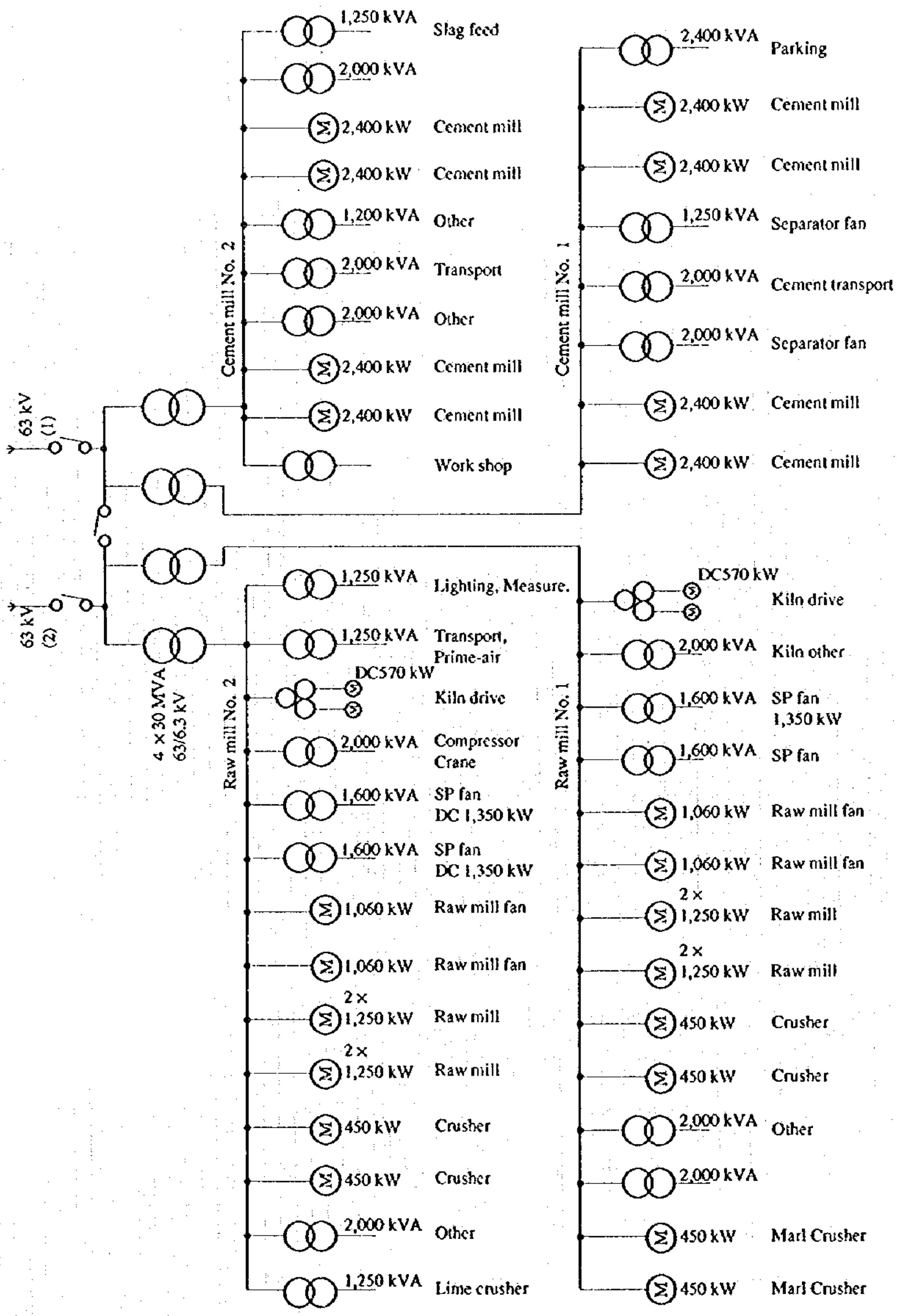


Figure 3.1.3 One Line Diagram

(10) Outline of major facilities

The facilities consist of 2 lines of kiln with the same specifications, which main equipment are shown in Table 3.1.1.

Table 3.1.1 Major Equipment

Department	Equipment	Dimensions [m]	Number [set/-]	Capacity [t/h]	Motor [kW]	Note
Raw material drying & grinding	Hammer crusher	Tip speed 40 m/s	1/mill	140 (raw meal)	450 6 p	Moisture 5 to 8 %
	Ball mill	4.6 $\phi \times$ 8.86 14.7 rpm	2/kiln	140 (raw meal)	2,500 6 p	1,250 twin
	Mill fan	6,200 m³/min -640 mmAq	1/mill		1,060 6 p	90 °C
Clinker preheating & burning	Suspension preheater	Twin 4 stage cyclone type	1/kiln	230 (raw meal)		Supplied by KHD
	SP fan	6,200 to 5,200 m³/min -830 mmAq	2/kiln		1,350	150 to 350 °C
	EP fan	4,570 to 5,200 m³/min -70 to -77 mmAq	2/kiln		1,350 6 p	150 to 90 °C
	Rotary kiln	5.8 $\phi \times$ 88	2/plant	137.5 (clinker)	DC 570	
	Satellite cooler	2.4 $\phi \times$ 19.7	10/kiln			150 °C
Finish grinding	Ball mill	4.4 $\phi \times$ 15.7 2 compartments	2/kiln	130 (cement)	4,800	2,400 twin water-injection
	Classifier		2/mill		120	dynamic-separator

(11) Energy prices

Energy prices are as follows:

		(September 1995)	(July 1996)
Natural gas		25 Rial/m³	24.5 Rial/m³ (10,000 kcal/m^3_N)
Heavy oil		15 Rial/L	35 Rial/L (9,100 kcal/L)
Electric power	Demand charge		3,200 Rial/kW
	Energy charge		38.3 Rial/kWh
	Total charge	39.5 Rial/kWh	

Since the cost of energy fluctuates within short periods, it seems to make adjustments in order to make up the gap with international market prices.

(12) Study period

a. Preliminary study: September 30, 1995

b. Plenary study : July 6 to 10, 1996

(13) Members of the study group

a. JICA team

Leader	: Norio Fukushima
Process management technology	: Hisashi Ikeda
Heat management technology	: Katsuhiko Kaburagi
Heat management technology	: Masami Kato
Heat management technology	: Jiro Konishi (Preliminary study)
Electricity management technology:	Toshio Sugimoto
Electricity management technology:	Kazuo Usui (Preliminary study)
Economic evaluation	: Shigeaki Kato (Preliminary study)

b. PBO team

Energy conservation	: Mr. Mazhari
Energy conservation	: Mr. Akhavan (Preliminary study)
Micro level energy management	: Mr. Mianji
Instrumentation	: Mr. Shayesteh (Preliminary study)
Macro level energy management	: Mr. Azizi
Macro level energy management	: Mr. Moosavi
Ministry of Industry	: Mr. Parsi (Preliminary study)
Advisory commitee	: Mr. Alavizadeh (Preliminary study)

(14) Interviewees

Mr. Dayani	: Factory Manager
Mr. Safaie	: Head of Electric Department
Mr. Shirzadi	: Head of Electronics
Mr. Shane Sazzadeh:	Manager of Production Affairs
Mr. Nazemi	: Maintenance Engineer
Mr. Hashemi	: Maintenance Engineer of Production Line
Mr. Pourghasemi	: Maintenance Department (Preliminary study)
Mr. Tavanger	: Electric Department
Mr. Khozestani	: Head of Operation Line
Mr. Mahbod	: Electric Manager, Production Line

Mr. Abedi	:	Material Preparation Section
Mr. Sadeghiyan	:	Head of Technical Office
Mr. Hajsadeghia	:	Technical Office (Preliminary study)
Mr. Ghondagi	:	Operation Line 2
Mr. Shekarchi	:	Mechanical Department (Preliminary study)

3.1.2 State of Energy Consumption

(1) Trend of production, energy consumption, and energy intensity

Table 3.1.2 and Figure 3.1.4 indicate the production and energy consumption between 1989 and 1995. After some degree of improvement, it seems that the production and energy intensity have reached a limit in the present conditions.

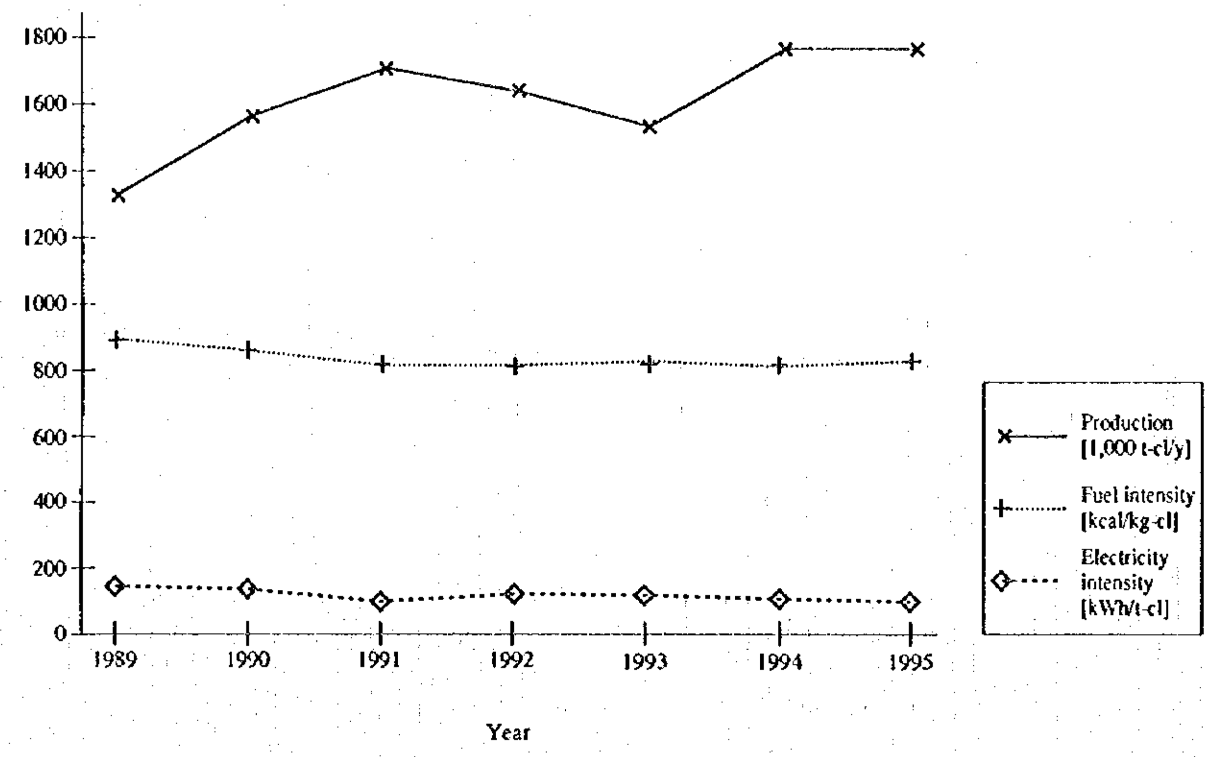
The clinker production is at a level of 75 to 90 % for the nominal capacity of 2,000,000 t/y.

On the other hand, cement production is over 2,000,000 t/y, but hourly production is only about 100 t/h, which is 77 % of rated capacity of 130 t/h.

Table 3.1.2 Production, Energy Consumption and Energy Intensity

	Year	1989	1990	1991	1992	1993	1994	1995
Production								
Clinker	t/y	1,332,700	1,567,516	1,715,365	1,647,681	1,553,188	1,779,378	1,785,733
	h/y	11,004	12,915	13,565	13,407	12,489	12,970	13,432
	t/h	121.1	121.4	126.5	122.9	124.4	137.2	132.9
Cement	t/y	1,556,240	1,749,149	2,073,624	1,888,943	2,039,740	2,081,203	1,905,798
	h/y	16,528	18,023	20,738	18,890	21,658	20,344	19,655
	t/h	94.2	97.1	100.0	100.0	94.2	102.3	97.0
Energy consumption								
Fuel oil	L/y	73,769,576	102,776,784	79,042,975	75,645,330	81,684,680	87,240,300	96,679,780
Natural gas	m^3/y	52,463,911	41,751,042	70,415,397	67,585,130	55,001,615	69,827,646	65,711,427
Sub total	Gcal/y	1,195,942	1,352,779	1,423,415	1,364,224	1,293,347	1,492,163	1,536,900
	equivalent to kL/y	131,422	148,657	156,419	149,915	142,126	163,974	168,890
Electricity	kWh/y	205,188,365	234,602,730	209,553,853	238,938,667	214,496,714	239,188,418	224,275,235
Energy intensity								
Fuel	kcal/kg-cl	897.38	863.01	829.80	827.97	832.70	838.59	860.66
	kcal/kg-cem	768.48	773.39	686.44	722.22	634.07	716.97	806.43
Electricity	kWh/t-cl	153.96	149.67	122.16	145.02	138.10	134.42	125.59
	kWh/t-cem	131.85	134.12	101.06	126.49	105.16	114.93	117.68

Figure 3.1.4 Production and Energy Intensity



(2) Energy intensity in each process

Table 3.1.3 indicates the recent state of operations for each month and for each process. Figure 3.1.5 illustrates the production for each process. It seems that system downtime due to maintenance has affected the quantity of raw material and clinker production. The required amount of raw material is in proportion to the clinker production and is approximately 1.6 times of the clinker production. The reason why cement production changes without regard to the clinker production may be the difference of the slag mixing percentage. The average monthly clinker production is approximately 150,000 t/month which is 90 % of the nominal capacity.

Table 3.1.3 Plant Operation Record

Year	Month	Raw Mill Department		Kiln Department				Cement Mill Department	
		Production [Raw tons]	Electricity consumption [kWh]	Production [t-cl]	Fuel Consumption Oil [L]	Fuel Consumption Gas [m³]	Electricity consumption [kWh]	Production [t-cem]	Electricity consumption [kWh]
1995	4	250,369	7,000,859	161,327	6,810,200	7,696,160	n.a.	128,336	6,609,177
	5	197,305	5,606,369	114,471	5,343,000	4,968,375	n.a.	163,789	6,889,358
	6	267,009	7,550,945	169,050	8,765,490	6,448,475	n.a.	162,823	7,475,430
	7	264,583	7,261,766	167,957	7,056,310	8,327,500	4,305,900	154,108	6,913,508
	8	265,306	7,477,303	166,323	6,948,800	7,778,930	4,291,200	200,726	9,271,129
	9	245,903	7,255,831	149,856	7,716,300	5,664,970	3,740,700	230,460	10,367,404
	10	200,277	5,865,121	129,909	5,563,500	6,348,675	3,834,500	168,460	7,897,977
	11	287,053	7,795,035	178,201	7,676,750	8,317,375	4,583,400	194,806	9,196,037
	12	166,019	4,638,087	103,388	5,985,400	3,427,090	2,815,300	151,697	7,124,444
1996	1	169,668	5,091,218	110,177	9,426,450	849,300	2,688,600	130,478	6,378,320
	2	268,261	5,088,800	162,389	14,914,300	0	3,929,800	92,742	6,377,295
	3	266,572	7,796,870	172,685	15,473,350	0	3,989,600	127,115	4,799,592
	4	259,981	7,498,200	154,152	14,041,000	0	3,752,972	170,198	6,224,433
	5	200,471	7,126,127	124,302	11,423,600	0	3,096,549	158,392	8,658,179
	6	289,226	5,323,251	180,647	16,632,100	0	4,512,000	170,051	7,964,163
Total (1995.7 - 1996.6)		2,883,320	78,217,609	1,799,968	122,857,860	40,713,840	45,540,521	1,949,233	91,172,481
Monthly average		240,277	6,518,134	149,999	10,238,155	3,392,820	3,795,043	162,436	7,597,707
Energy intensity		1.60	27.13	1.00	68.25	22.62	25.30	1.08	46.77
Total	Electricity	[kWh/t-cl]							119.41
		[kWh/t-cem]							110.26
		[kWh/t-ref]					(1.6R+Cl)+C:		115.53
	Fuel	[kcal/kg-cl]			[kcal/kg]	[kcal/m³]			856.12
				[LHV]	10,180	10,049			
				[kg/L]	0.905				

Figure 3.1.5 Monthly Production by Process

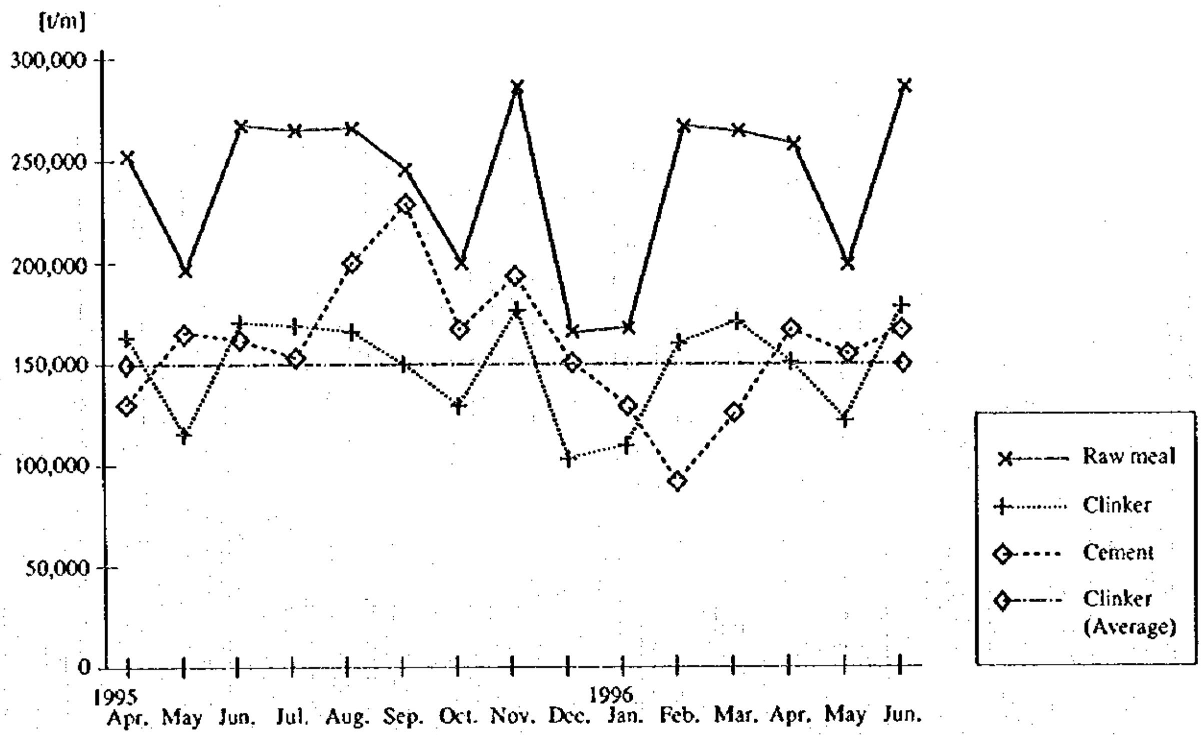


Figure 3.1.6 shows the monthly energy intensity. Although both natural gas and fuel oil are used concurrently as fuel, the intensity is indicated by calculating the fuel amount in terms of fuel oil for simplification in this figure. The fuel intensity is about 92 to 95 L/t-cl. The average amount is 856 kcal/kg-cl in terms of heat value. It should be noted, however, that the fuel consumption for drying the slag is not included in this amount.

The electric power intensity is indicated on the value per production of each department. For example, to show the electricity intensity of the raw material department per clinker ton, it is necessary to multiply this value by 1.6. Sometimes the electricity intensity is given per cement ton. As in this factory, however, when large quantities of mixtures are added into cement and moreover if the quantities of the mixtures are not constant, the electricity intensity indication per cement ton may be in error. Therefore, such an indication method should be avoided due to management reasons.

Figure 3.1.6 Monthly Energy Intensity

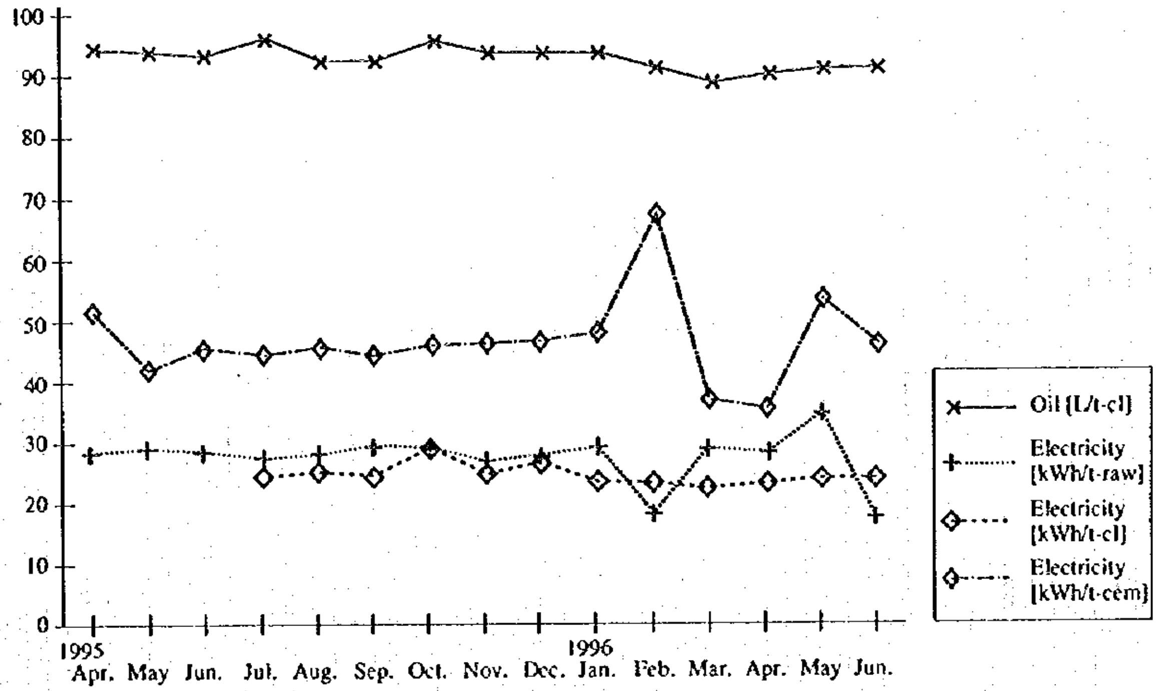
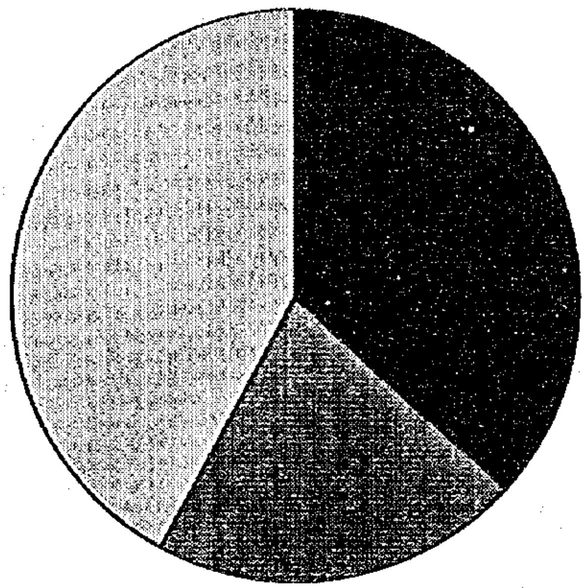


Figure 3.1.7 shows the electricity consumption for each department. As shown in the figure, the electricity consumption of the raw mill department is 36.4 %; that of the kiln department is 21.2 %; and that for cement mill department is 42.4 %. If the electricity consumption of the raw mill and kiln departments is calculated per clinker ton, it will be 44 kWh/t and 25.3 kWh/t respectively. It will be 46.8 kWh/t per cement ton for the cement mill department. In Japan, for example, the percentages of electricity consumption are: 40 % for the cement mill department; 27.5 % each for the raw mill and kiln departments; and 5 % for other departments. It is better to avoid a simple comparison of the electricity consumption with Japan by ignoring the differences in raw material characteristics and difference of equipment used according to those raw material characteristics. However, the high percentage of electricity consumption of the raw mill department is conspicuous.

In the case of this plant, there are 2 raw material mill lines per 1 kiln line which impose a load of approximately 3,000 kW each. The exhaust fan load at each mill is 930 kW. It is noteworthy that 31 % of the electricity consumption in the raw mill department is taken up by this fan.

Figure 3.1.7 Departmental Electricity Consumption



(3) Heat balance

Table 3.1.4 shows the heat balance calculated using actual measured values and indicated values of the measuring instrument for operation on the date of the study.

Table 3.1.4 Heat Balance (No. 2 SP Rotary Kiln) (1/2)

1. Precondition

Item	Unit		Remarks
1.1 Raw meal			
1) Charged raw material	t/h	239	125 + 114
2) Temperature	°C	100	
3) Specific heat	kcal/kg·°C	0.20	
1.2 Clinker			
1) Yield of material	t-cl/t-raw material	0.59	
2) Dusting loss	%	5	
3) Clinker output	t/h	134.30	239 × 0.59/1.05
4) Termperature on the conveyor	°C	164	
5) Heat for clinkering	kcal/kg-cl	430	
6) Specific heat	kcal/kg·°C	0.192	
1.3 Fuel in kiln			
1) Kind	–	Fuel oil	
2) Low heat value	kcal/L	9,207	
3) Temperature	°C	100	
4) Consumption in kiln	L/h	12,500	
5) Specific gravity	kg/L	0.905	
6) Specific heat	kcal/kg·°C	0.45	
1.4 Exhaust gas at preheater outlet			
1) Temperature	°C	320	
2) O_2 content	%	2.8	
3) Specific heat	kcal/m^3_N·°C	0.338	
4) Specific gas volume of fuel oil	m^3_N/kg-cl	1.63	
5) Specific gas volume by clinkering of materials	m^3_N/kg-cl	0.27	
1.5 Radiation loss from kiln surface			
1) Average temperature	°C	282	
2) Surface area	m^2	1,604	
3) Convection coefficient	kcal/m^2·h·°C	10.9	
4) Radiation coefficient	kcal/m^2·h·°C	15.9	
5) Emissivity	–	0.95	
1.6 Radiation loss from cooler surface			
1) Average temperature	°C	455	
2) Surface area	m^2	1,379	
3) Convection coefficient	kcal/m^2·h·°C	13	
4) Radiation coefficient	kcal/m^2·h·°C	29.7	
5) Emissivity	–	0.95	

Table 3.1.4 Heat Balance (No. 2 SP Rotary Kiln) (2/2)

2. Heat balance

Item	kcal/kg-cl	%	Remarks
Input heat Q1			
1) Qa : Heat of combustion of fuel	857.0	96.9	
2-1) Qb_1: Sensible heat of fuel	2.7	0.3	
2-2) Qb_2: Sensible heat of raw material	24.9	2.8	
Total	884.5	100.0	
Output heat Q2			
3) Qc : Heat for clinkering	430.0	48.6	JIS
4) Qd : Sensible heat of clinker at cooler outlet	25.7	2.9	
5) Qe : Sensible heat of preheater exhaust gas	135.8	15.3	
6) Qf : Radiation loss	226.2	25.6	
7) Qg : Other heat loss	66.8	7.6	
Total	884.5	100.00	

1) $12,500 \times 9,207 / 239 / 0.59 \times 1.05 / 1,000 = 857.0$

2-1) $12,500 / 239 / 0.59 \times 1.05 \times 0.905 \times 0.45 \times (100 - 30) / 1,000 = 2.7$

4) $0.192 \times (164 - 30) = 25.7$

5) $(1.115 + 0.270) \times 0.338 \times (320 - 30) = 135.8$

6) Cooler 177.5 + Kiln 76.8 = 226.2

3.1.3 State of Energy Management

(1) Setting the energy conservation target

No specific target seems to be set up. It is absolutely necessary to set a target which can be achieved rationally in accordance with the actual conditions at the plant. Also, energy conservation measures are closely related to plant productivity and antipollution measures and these factors must be in harmony. It is desirable to understand the present situation completely, make a certain level of forecast on the improvement results, analyze the cause and reason if the result is unsatisfactory, and continue to make step-by-step efforts.

At present, the target fuel intensity should be 800 kcal/kg-cl as suggested by the plant supplier. In reality, the measures for improving productivity have priority over energy conservation. If the plant can constantly achieve the rated capacity of 137.5 t/h, a reduction of fuel intensity can be expected to follow. Therefore, the approach may not be exactly wrong.

There is no clear target for the electricity intensity either. 100 kWh/t seems to be one of the guidelines, but without specific reason. It is recommended that the possibilities of power saving should be pursued by each department. The improvement of efficiency of the raw milll department should have priority over all other departments. Although the raw material mill is operating with low load at present, the optimal operating conditions must be studied.

(2) Systematic activities

To our understanding, around March 1995 the energy committee was established and related activities started. The achievements of the committee's activities cannot be detected yet from the operation data. The engineers, however, are highly interested in the activities. A number of questions were positively put forward by them and we were asked for our views when we visited the plant. We expect the committee to make significant achievements in the future.

(3) Management based on data

Judging by the quick responses to our questions, the engineers have a good understanding of equipment and facilities related to individual machines and the overall operating conditions.

It is, however, necessary to continue to make various arrangements for a summing up method and communication of information in order to make optimal use of these data for process analysis and improvement. The measuring instruments and recorders must be upgraded in accordance with the purpose.

For example, we have asked the company this time to sum up the operation results according to department and for each month. It will be a reference example. To find keys for improvement by grasping of the actual state of energy consumption, it is always necessary to sort the summed up data according to each process and understand the trends of change.

(4) Education of employees

It is commendable that the facilities for training of young workers are provided at the same plant site. It is recommended that energy conservation measures be included in their curriculum. Grading up of the engineer level may be also needed in order to assure the results of productivity improvement and energy conservation. Since the operations of the kilns were started one after another until now, the engineers at the plant must have had well-established contacts with overseas engineers and received considerable encouragement from them. From now on, it is necessary to offer such opportunities to a greater extent to gain better overall knowledge.

(5) Equipment maintenane

The factory is clean and has an almost ideal layout according to plan. The equipment and facilities are very well maintained. The concept of preventive maintenance has been partly introduced. For example, a spare assembly is prepared for the satellite cooler (which goes through severe wear and tear) during its operation.

The annual operation hours is limited to the 6,500 hours level according to Table 3.1.2. This is equral to only 270 days when calculated in terms of days. It is advisable to increase the annual operation to 7,200 hours or operation of 300 days.

According to Figure 3.1.5, there are sharp changes in the monthly production. It appears that these changes are caused by system downtime due to troubles besides the scheduled shutdowns. Since a sudden system shutdown will cause big energy losses and secondary troubles of equipment, such shutdowns should be avoided by all means. It is necessary to reinforce upgrading of equipment and facilities related with the raw material mills and cement mills.

3.1.4 Problems and Measures on Energy Use

(1) Comparison with a Japanese excellent factory

The fuel intensity is within 830 to 860 kcal/kg-cl, except during the initial year of operation. These are very excellent figures in this country. However, it is still 4 to 8 % higher than the international level of SP kilns of an equal scale which is annual fuel intensity of 800 kcal/kg-cl. The causes of difference are shortage of gas flow volume, operation change by gas flow and clinker cooler type.

The electric power consumption shifts between 125 and 145 kWh/t-cl. In the case of SP kilns, it is not unusual for the electricity intensity to be about 20 to 30 kWh/t-cl higher than that of other systems. Even considering this fact, however, intensity is still 30 % higher than the international level of 100 kWh/t-cl. The reason of the difference may be the troubles of cement mills.

Among all critical problems faced by this plant, both the productivity improvement of the kiln and the hourly production improvement of the cement mill have a close relationship with energy conservation and must be resolved as quickly as possible. For the kiln, it is necessary to implement, one after another, the measures given in the following inprovement of kiln draft. For the improvement of the cement mill, implementation of item (4) will be effective. All of these measures can be executed by allotting the priority of daily maintenance costs as a management-oriented matter without drastically changing the process.

(2) Improvement of kiln draft

The following 2 points are considered as the factors which prevent a kiln from improving its hourly production.

a. Insufficient cooling performance of the satellite cooler

Outlet clinker temperature:
Design value: 150 °C
Actual value : 200 to 250 °C

b. Generation of unburned gas at the kiln outlet

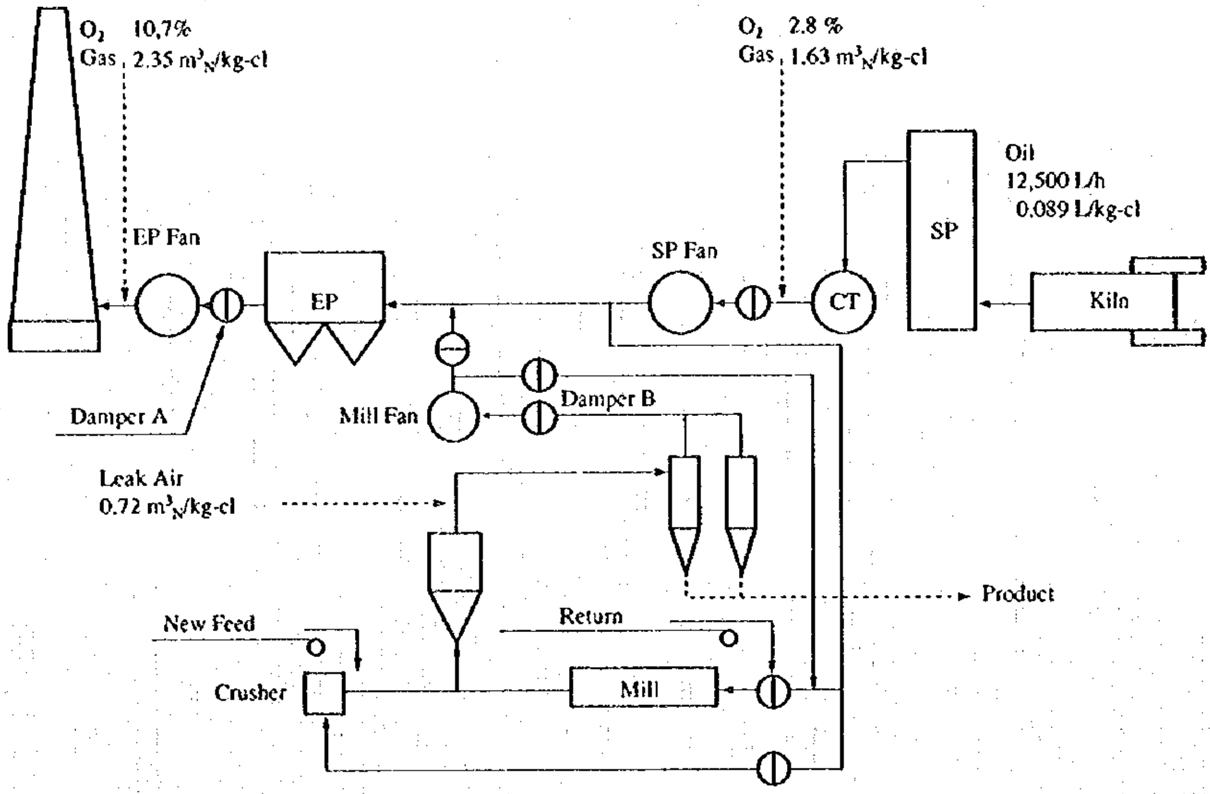
CO gas sensor (setting 0.5 %) detects CO from time to time.

The cause for both cases is insufficient draft capacity of the entire process.

As shown in Figure 3.1.8, the gas flow from cooler through kiln, pre-heater, and EP are located on a single line connected in series, and the raw material dry grinding system is installed parallel to the middle of this line. Both SP fans and mill fans exceed the draft capacity of the EP fan. When a large volume of leakage air is brought in through the raw material mill with the kiln being almost in a state of full operation, the kiln draft volume is limited to the capacity of the EP fan.
As a first step, the following measures are available for increasing draft capacity.

The EP fan currently in use is driven by V belt. Therefore, the draft capacity of the fan should be easily increased 5 to 15 % by increasing the rotation speed. At this time, even if the motor is replaced, it should pay well. This measure should sharply improve the operability of the kiln.

Figure 3.1.8 Gas Flow (Kiln No. 4)



Basically, it is important to reduce a lot of leakaged air through a raw material mill.

The oxygen content measured at the EP outlet was 10.7 %. This means that air volume equal to the theoretical exhaust gas volume of the pre-heater must have leaked into the process. Since the oxygen content at the pre-heater outlet is less than 3 %, most of the oxygen must have been brought in from the periphery of the raw material mill. The locations from which air leaks in the process are mainly in the periphery of outlet and inlet of the raw mill and high negative pressure sections of the gas duct.

Many portions repaired by welding are found on the duct. Besides these parts, we also detected a large number of small holes and cracks. From these openings, a large overall volume of air is leaking in. It is obvious that immediate repair of the abrasion portions is necessary. However, it looks as if the abrasion is actually progressing quite fast and the repair work cannot catch up.

As a drastic measure, the size of a pipe can be enlarged to reduce the air flow velocity. However, obviously an air volume far exceeding the design value is flowing through the pipes. Therefore, the air volume and air pressure must be reduced down to the limit at first by adjusting the damper opening (Figure 3.1.8 Damper B) located at the inlet of the mill fan.

When the capacity of the fan is proven to be more than enough, finally the electric power intensity can be reduced sharply together with capacity optimization of the fan by providing either one of the following modifications.

1) Cut off the blade edge of the impeller of the fan to make the blade diameter smaller.

2) Replace the impeller with a more suitable one.

3) Change the motor control system to a rotation speed control system.

Using the above methods, the gas volume at the EP inlet will be reduced. Though the gas temperature will rise, reduction of the gas volume will have an excellent effect and the desirable results must be achieved on the dust collecting efficiency.

When the proper draft is performed, the problem of shortage of cooling capacity in the clinker cooler will be resolved.

If capacity allowance is produced for the EP fan as a result of improvement measures above, the automatic control for stabilizing the SP fan outlet pressure will be possible by operating the EP fan inlet damper (Figure 3.1.8 Damper A) regardless of the operating status of the mill. The actual construction work required will only involve the installation of a damper opening setting device.

This improvement will remove one of the important factors of daily fluctuation, making the kiln and pre-heater operations stable and allowing the optimum status to be maintained.

(3) Screen plate replacement of cement mill

All 4 cement mills of this plant use a closed circuit system of identical size, and a part of these is modified to the open circuit system. The inside of each mill is divided into 2 chambers. A screen plate is provided at the partitions of the chambers and the outlet portion of the material to be ground. Mills have the most popular structure and the appropriate dimensions. Therefore, if the charge amount of a ball is appropriate, the full load is imposed on this mill according to calculations and an output close to the rated capacity should be obtained. On the other hand, the actual production is around 100 t/h while the rated capacity is 130 t/h. The motor load is 3,600 kW and is therefore in a light load status against the rated output of 4,800 kW.

The possible cause is that the slits of the screen plates are clogged. Due to this, the material to be ground is obstructed from passing through the screen plates and the pile up inside the mill is steadily increasing. In this condition, the additional charge of a ball (grinding media) cannot be carried out and the passing speed of the material becomes slower. Thus, optimal use of the superb features of a closed circuit system is not possible here.

After checking the inside of 1 mill among 4, the chips of a ball and clinker were found to be clogging the slits of the screen plate between chambers 1 and 2 and the plate was slightly deformed. Over 50 % of the opening of the chamber 2 outlet portion was blocked by concrete along with ball chips. The concrete was produced by an insufficient evaporation of water sprayed inside of the mill for cooling. Since the airflow will be insufficient in this condition, evaporation of water will become more and more difficult and the situation will become worse.

The usual 2-chamber type mill is operated by a 100 to 200 % circulating load. On the other hand, the mill at this plant is operated by a 20 to 30 % or zero % circulating load. There is a possibility that the screen plate design may not have been suitable from the initial stage. It is recommended that arrangements should be made for replacement of the screen plate by consulting the mill supplier.

The most appropriate value of a circulating load varies depending on the process design concept, separator (classifier) performance, mill dimensions, and characteristics of the material to be ground. At first, it is necessary to ask the original mill supplier for an opinion. Barring a few exceptions, measuring the actual circulation amount is difficult in most cases. Therefore, instead of measuring the actual circulation amount, the following method is used for normal operation. This method estimates the circulation amount based on the mill sound, separator load, and bucket elevator load, and then confirms this estimation in accordance with a grain size analysis of the sample collected at the separator outlet and inlet.

(4) Effects of improvements

a. Improvement of clinker production

The improvement of hourly production corresponding to the increase of the air volume can be expected by increasing the rotation speed of EP fan. This improvement level should be considered as 3 % at present. This is equivalent to the ratio of the average hourly production between fiscal 1994 and fiscal 1995, and it is the level already attained within a short period. Due to this, a production increase of 60,000 t/y has been achieved. Supposing that the marginal return is 2,000 yen/t, an annual profit of 120,000,000 yen/t will be possible.

By the reduction of leakage air in the raw material mill, the kiln operation can be maintained at a steady high level. The average hourly production will be increased further and the fluctuation of the heat load will also be suppressed. As a result, the wear and damage of the equipment and refractory will be reduced and the annual operating hours will be increased. The present operating hours of this plant is limited to a 6,500 h/y level. It should be easy to increase the operation hours by 3 % in the same way as above. This is also within the range of difference between fiscal 1995 and fiscal 1994, and the increase of annual profit same as above can be expected.

Resources for energy conservation, can be produced in this way, which will further improve the profit rate of the company.

b. Reduction of fuel consumption

After the fuel intensity was recorded in 1992 as 828 kcal/kg-cl, it has increased to 860 kcal/kg-cl, which is going against the increase of production. This increase can be analyzed as one o the symptoms of the equipment operating at the limits of their capacity by exceeding the optimal point. This problem, however, can be solved by the improvement measure of kiln draft. The recent monthly fuel consumption was detected to have a fluctuation width of approximately 7 % for the average value. If stable operation is carried out by the improvement measure of draft control, it should become closer to a level better than the average value.

It is pertinent to expect a reduction of at least 7 % by the synergistic effect of the above 2 matters.

At this time, the fuel intensity shall reach the plant supplier's guaranteed value of 800 kcal/kg-cl.

The fuel saving amount is approximately 13,200 kl/y calculated in terms of fuel oil. The profit to be gained will be yen 224 million annually if the price of fuel oil is assumed to be 17,000 yen/kl or equal to the price in Japan. For convenience of calculation, each effect is divided into 2 % and 5 % in Table 3.1.6.

$$\frac{860{,}000 \text{ kcal/t-cl} \times 7\,\% \times 2{,}000{,}000 \text{ t/y}}{9{,}100{,}000 \text{ kcal/kl}} \doteq 13{,}200 \text{ kl/y}$$

c. Reduction of electric power cost

Three different methods for the reduction of electricity intensity of EP fan are provided in item (2). The effect varies depending on the method to be adopted. The actual volume of gas that can be reduced is unknown at present. Supposing the gas volume of raw mill can be reduced by 15 %, the result of improvement can be estimated as follows.

	(Method)	(Effect)	(Saving power)
1)	Only damper control	10 %	186 kW
2)	Cutting of the blade of the impeller	15 %	279 kW
3)	Impeller replacement	20 %	372 kW
4)	Speed control	25 %	465 kW

Supposing that the impeller replacement (item 3)) is carried out, the saving electricity of 372 kW is equivalent to 2.7 kWh/t-cl (= 372 kW/137.5 t/h) and the annual saving of electricity will be 5,400 MWh (= 2.7 kWh/t × 2,000,000 t/y). Supposing that the electricity rate is 10 yen/kWh, it will result in annual profits of 54,000,000 yen.

A simple calculation of the improvement effect of the cement mill as a result of item (3) will yield 6.77 kWh/t-cem, which is the difference between the current electricity intensity 46.77 kWh/t-cem and the actual record of 40 kWh/t-cem of the normal closed circuit method. This figure, however, should be estimated as 5.0 kWh/t-cem level in view of the fact that the customer may demand higher product quality in the future. The annual electricity saving amount will be 10,000 MWh/y (5.0 kWh/t × 2,000,000 t/y) and the profit will be 100,000,000 yen/y (10 yen/kWh × 10,000 MWh/y) when the production is 2,000,000 t/y.

d. Increase of profits due to increase of cement production

If the screen trouble is solved for the cement mills currently operating at 100 t/h, operating these mills at the rated capacity of 130 t/h will be easy. In this case, an annual increase of 600,000 tons or more will be possible with 4 mills. If the sales expansion amount at present is estimated at 300,000 t/y and a profit of 500 yen/t is anticipated by considering the availability of slag mixing, it can lead to an annual surplus profit of yen 150,000,000. This is equal to the profit resulting from the above energy conservation and thus it can encourage the target of energy conservation.

(5) Power-receiving/distributing facilities

a. Measurement and its results

We measured the electricity of the process equipment at the power-receiving substation and plant as follows.

1) Measurement of receiving power at the power-receiving substation

2) Measurement of consumed power of each equipment at distribution panels

Raw mill of both process : Crusher, raw mill and mill fan
Kiln of both process : SP fan
Cement mill of both process: Cement mill and transportation equipment

3) Investigation of load fluctuation by continuous measurement

Total electric power used by process No. 1 at the power-receiving substation
Raw mill, SP fan and cement mill of process No. 1
Raw mill and cement mill of process No. 2

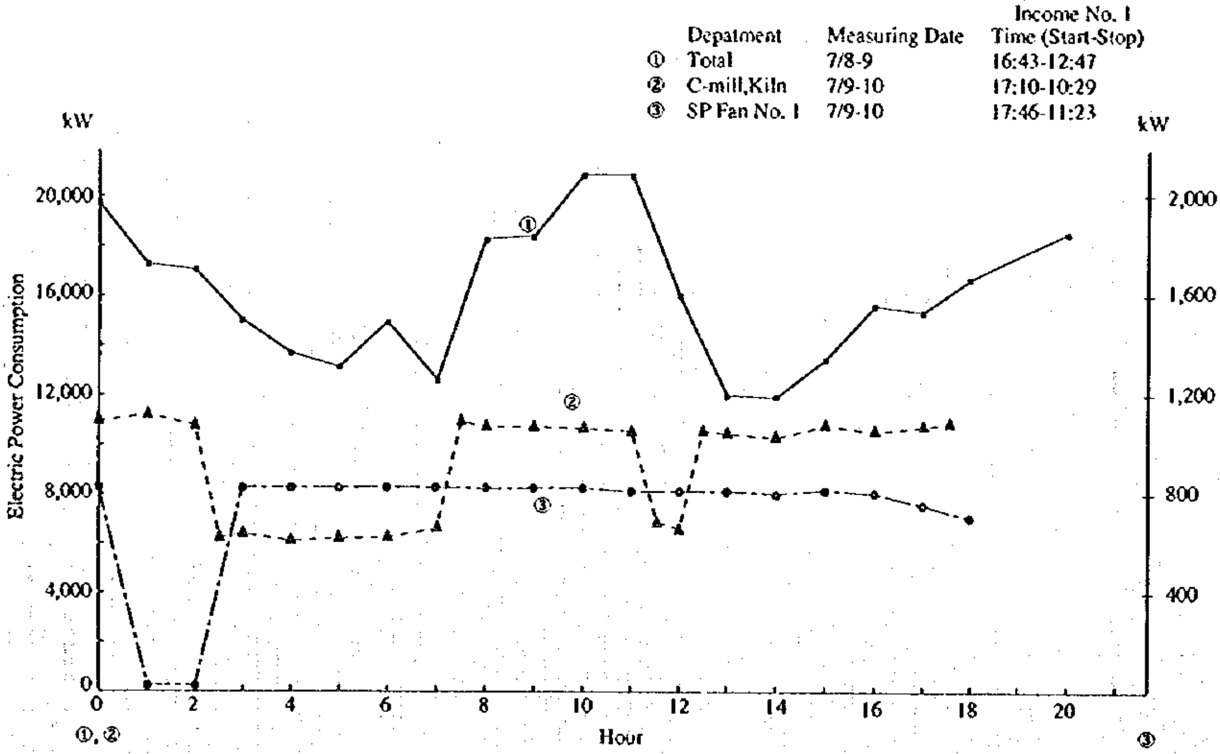
4) Investigation of demand record

Table 3.1.5 and Figure 3.1.9 indicate these measurement results. Since the measurement values change long and frequently and the measurement time is different, the total value of the electricity consumption of load and power supply value are different.

Table 3.1.5 Electricity Consumption

Process	No. 1			No. 2		
	Rating kW	Electricity kW	Cosϕ %	Rating kW	Electricity kW	Cosϕ %
Crusher	450	234	94	450	176	95
Crusher	450	153	94			
Raw-mill	2 × 1,250	2,335	98	2 × 1,250	2,459	96
Raw-mill	2 × 1,250	2,473	100	2 × 1,250	2,410	97
Mill fan	1,060	938	96	1,060	887	94
Mill fan	1,060	870	98	1,060	1,015	100
Mill drive (DC)	570	338	39	570	493	48
Kiln others (compressor etc)		977	61		1,000	94
SP fan	1,350	843	67	1,350	716	68
SP fan	1,350	688	58	1,350	711	60
Raw mill Total		10,327	89.1		11,904	80.6
Cement mill	2 × 2,400	3,539	98	2 × 2,400	3,777	95
Cement mill	2 × 2,400	3,512	100	2 × 2,400	3,725	97
Transport		1,038	87		1,065	90
Cement mill Total		8,948	93		11,100	97
Process Total		19,269	91		23,005	89
Factory Total			42,274	Cosϕ:90		

Figure 3.1.9 Operation Record of Electricity Consumption



b. Reduction of contract demand

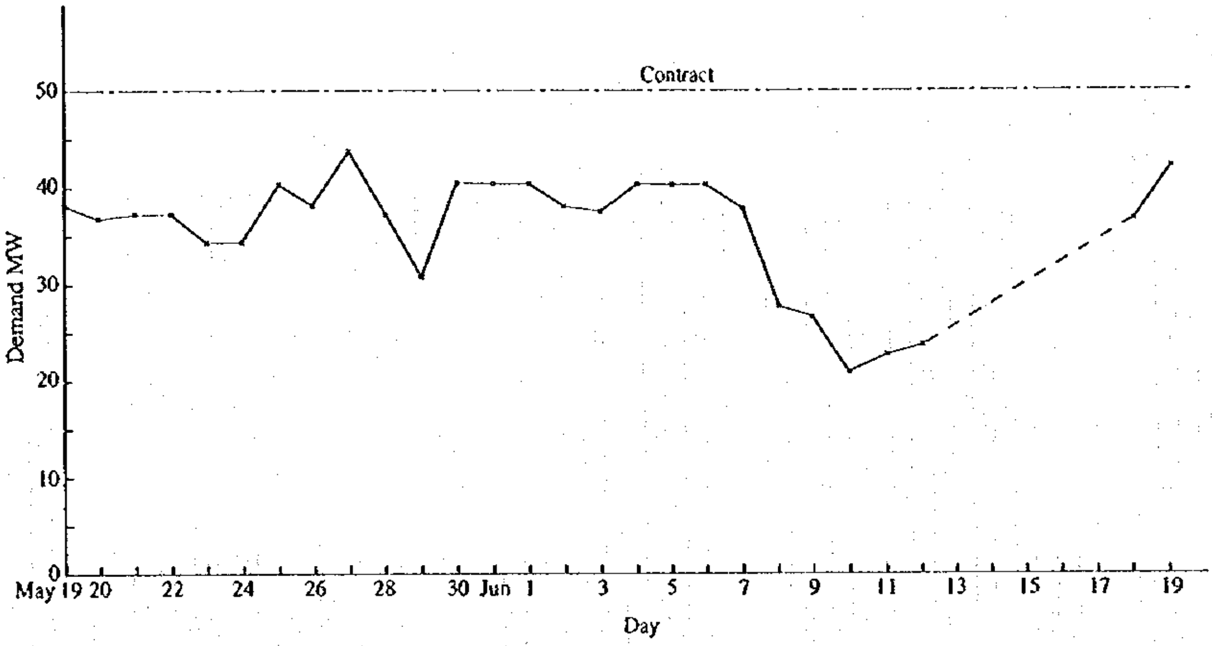
The demand specified in the power-receiving contract is 50,000 kW (actually 45,000 kW) and the electric charge in June 1996 is 38.3 Rials/kWh.

There are the charges such as energy charge, demand charge, and loss charge for the peak time and for the off-peak time. Among these expenditures, the charge for peak time is 37 % and the demand charge occupies approximately 19 %. The expenditures can be cut down by reducing the peak power and lowering the demand charge by stabilizing the production operation.

According to the demand record of this factory (Figure 3.1.10), the value exceeds 43 MW once or twice a month. If this is a normal condition, it is recommended to lower the contract demand to 48 MW from the current 50 MW, and investigate and provide measures so that the demand can be made lower than the current value (43 MW).

In this case, the demand charge can be reduced by 76.8 × 10^6 Rials annually (2,000 kW × 3,200 Rial/kW × 12 month/y).

Figure 3.1.10 Electricity Maximum Demand of Everyday



(6) Summary of proposals

Table 3.1.6 summarizes the above-mentioned proposals.

Improvement concerning the above 4 items is expected to bring about the following effects.

Increase in the production of clinker	: 120,000 t/y (6 %)
Increase in the production of cement	: 300,000 t/y (15 %)
Reduction of fuel consumption	: 13,231 kL/y (7 %)
Reduction of power consumption	: 15,400 MWh/y (7 %) (= 7.7 kWh/t/115 kW/t)
Reduction of demand charge	: 76.8 Million Rial/y

The investment amount for this purpose, 107 million yen, can be recovered within a short period by the increase in the annual profit of 769 million yen.

Table 3.1.6 Summary of Proposals

(Japanese Yen base)

Item	Expected Saving: Fuel kL/y	Fuel Million yen/y	Fuel %	Electricity MWh/y	Electricity Million yen/y	Electricity %	Total Million yen/y	Investment Million yen	Payback Period Year
Capacity up of EP IDF	3,780*1	64.3 120.0*3	2.2*5	-			64.3 120.0	9.6	0.1
Raw mill fan operation				5,400*8	54.0	2.4*10	54.0	43	0.8
Total process draft control	9,451*2	160.7 120.0*4	5.6*6	-			160.7 120.0	6	0.02
Cement mill screen plate				10,000*9	100.0 150.0*7	4.5*11	100.0 150.0	48.5	0.5
Total	13,231	465.0	7.8*7	15,400	304.0	6.9*12	769.0	107.1	0.1

(Iran Rial base)

Item	Expected Saving: Fuel F.oil kL/y	Fuel Million Rial/y	Fuel %	Electricity MWh/y	Electricity Million Rial/y	Electricity %	Total Million Rial/y	Investment Million Rial	Payback Period Year
Capacity up of EP IDF	3,780*1	284 2,100*3	2.2*5	-			284 2,100	168	0.6
Raw mill fan operation				5,400*8	540	2.4*10	540	753	1.4
Total process draft control	9,451*2	709 2,100*4	5.6*6	-			709 2,100	105	0.1
Cement mill screen plate				10,000*9	1,000 2,625*7	4.5*11	1,000 2,625	849	0.8
Total	13,231	5,193	7.8*7	15,400	4,165	6.9*12	9,358	1,707	0.2

*1 $\frac{860 \text{ kcal/kg-cl} \times 0.02 \times 2{,}000{,}000 \text{ t/y}}{9{,}100 \text{ kcal/L}} = 3{,}780 \text{ kL/y}$

*2 $\frac{860 \text{ kcal/kg-cl} \times 0.05 \times 2{,}000{,}000 \text{ t/y}}{9{,}100 \text{ kcal/L}} = 9{,}451 \text{ kL/y}$

*3 Production increase merit resulting from improvement of hourly production: 60,000 t/y × 2,000 yen/t = 120 Million yen/t
*4 Production increase merit resulting from the extension of the operation time: 60,000 t/y × 2,000 yen/t = 120 Million yen/t
*5 3,780 / 168,890 × 100 = 2.2 %
*6 9,451 / 168,890 × 100 = 5.6 %
*7 13,231 / 168,890 × 100 = 7.8 %
*8 2.7 kWh/t × 2,000,000 t/y = 5,400 MWh/y
*9 5.0 kWh/t × 2,000,000 t/y = 10,000 MWh/y
*10 5,400 / 224,275 × 100 = 2.4 %
*11 10,000 / 224,275 × 100 = 4.5 %
*12 15,400 / 224,275 × 100 = 6.9 %

Energy price in Japan:
Fuel price: 17,000 yen/kL
Electricity price: 10 yen/kWh
Energy price on Iran Rial base:
Fuel oil: 75 Rial/L
Electricity: 100 Rial/kWh
Exchange rate: 1,750 Rial = 1 US Dollar = 100 Japanese Yen
Calorific value of fuel: Oil: 9,000 kcal/kL
Investment cost is based on that in Japan.

3.2 Results of the Study at Tehran Cement Company

3.2.1 Outline of the Plant

(1) Plant name

Tehran Cement Company

(2) Plant address

Serah Afsarieh - Jadeh Khavaran - Serah Avarezi - POB 18/745 - 4148, Tehran

(3) Number of employees

About 2,000

(4) Major products

Portland cement and clinker
ASTM Type 2 and Type 5

(5) Production capacity

9,600 t/d (including No. 7 kiln)

(6) Production process of cement

This cement company digs out the limestone as raw material in an adjoining quarry. The limestone is transported by trucks over a 7 km route. After the secondary crushing, the limestone is placed in the ore bedding yard. Clay is also dug out from an area of the same quarry and delivered to the plant. The normal blending ratio is 70 % limestone to 30 % clay. Sometimes, however, a small amount of iron ore is added as compensation for iron content.

The production line consists of 7 kiln groups. Four lines including kilns No. 1 to No. 3 and No. 5 are wet process kilns, and 3 lines including kilns Nos. 4, 6, and 7 are dry process kilns. Kilns No. 1 to No. 4 share the raw materials and clinker storage. Kilns No. 5 to No. 7 are separated and have individual stockyards. Particularly among these, kiln No. 7 is located at another site near the mine and is an independent plant. This plant was excluded from the study made at this time since it was difficult for us to adjust the schedule.

All dry processes use the suspension pre-heater (SP). Three types of clinker coolers are used. Kiln No. 3 uses a rotary cooler, kiln No. 6 uses a grate cooler, and the other 5 kilns use satellite coolers. Natural gas and fuel oil is used concurrently for fuel.

(7) History of the plant

Kilns No. 1 and No. 2 have been operating since 1956 and 1958 respectively. Therefore these kilns have been operating for almost 40 years. Kilns No. 5 and No. 3 were built in 1962 and 1968. Kiln No. 5 is older than kiln No. 3 and was originally built by a different company. Later, this kiln was incorporated in the Tehran Cement Company after the operation of kiln No. 4 was started. Because of this reason, the designation number and the order of operation do not match and the layout also appears unnatural. These 4 kilns are wet process kilns.

The operation of kiln No. 4, which is the first dry process kiln, was started in 1972, followed by kilns No. 6 and No. 7, which were completed in 1979 and 1984 respectively. Kiln No. 7 was built by another company like kiln No. 5 and was merged with the Tehran Cement Company later.

The production capacity including kiln No. 7 is 9,600 t/d. The clinker production capacity as a single plant is the largest in I.R. Iran. The clinker production capacity by wet process is 1,500 t/d and that by dry process without kiln No. 7 is 6,100 t/d. If the production of kiln No. 7 is included, the capacity is 8,100 t/d. The ratio of the dry process is overwhelmingly large.

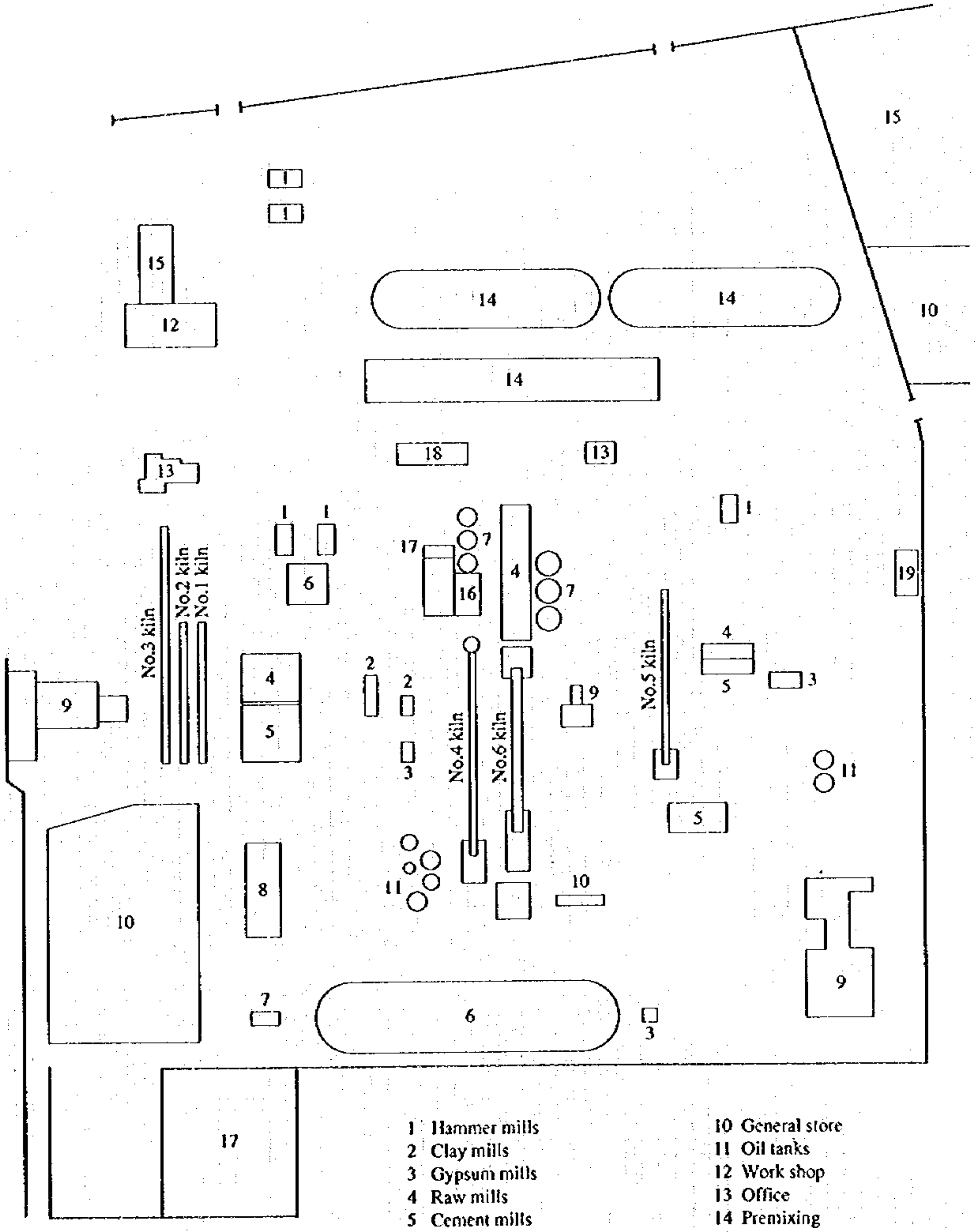
(8) Plant layout

Figure 3.2.1 shows the plant layout, where No. 7 is excluded.

(9) One line diagram

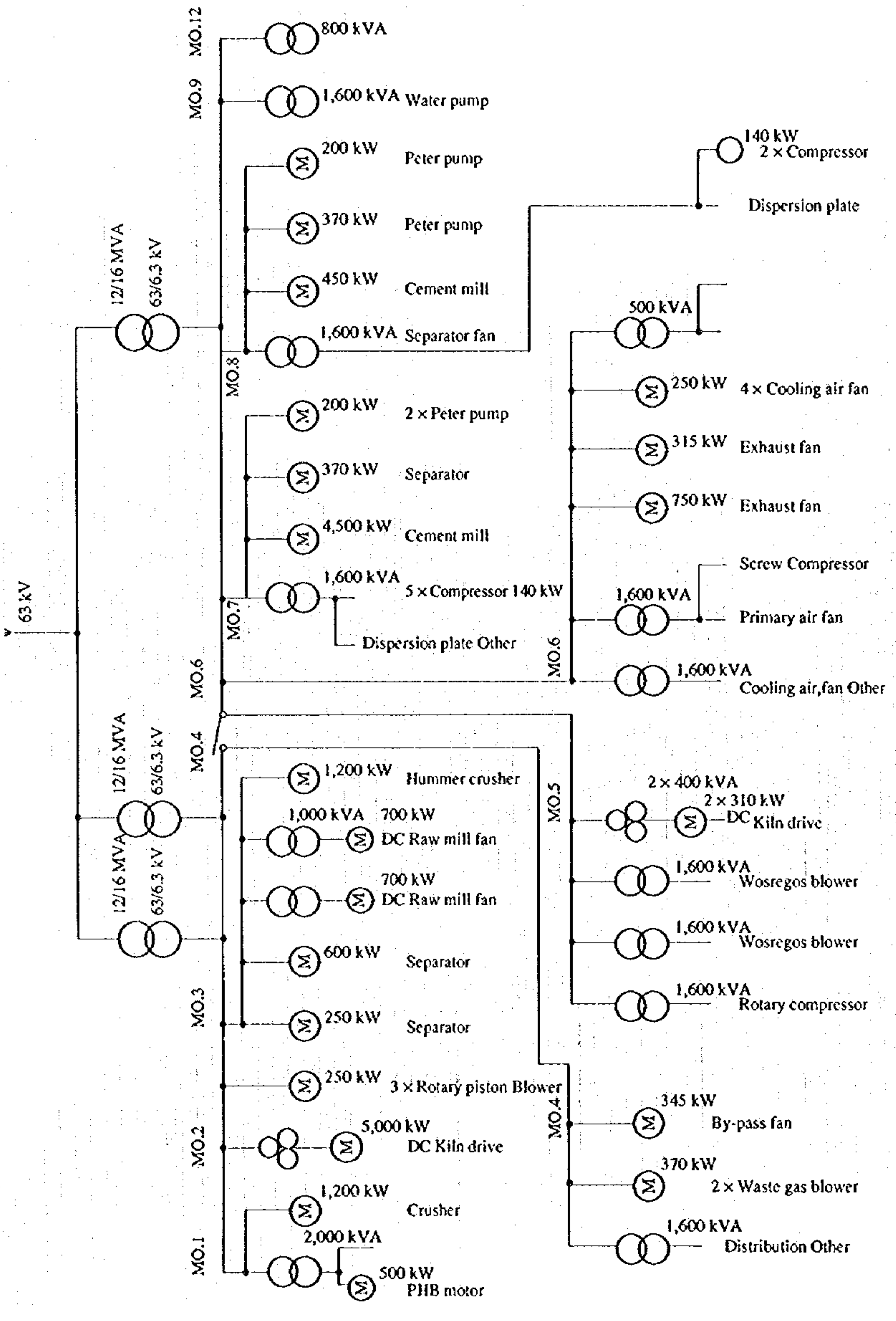
Figure 3.2.2 shows the electric power one line diagram.

Figure 3.2.1 Plant Layout



1 Hammer mills
2 Clay mills
3 Gypsum mills
4 Raw mills
5 Cement mills
6 Clinker store
7 Silos department
8 Power station
9 Packing plants
10 General store
11 Oil tanks
12 Work shop
13 Office
14 Premixing
15 Garage
16 Compressor
17 Substation
18 Laboratory
19 Gas station

Figure 3.2.2 One Line Diagram



(10) Outline of main production lines

Table 3.2.1 shows the main specifications of each kiln.

Table 3.2.1 Production Lines

Line No.	Type of Process	Capacity (t-cl/d)	Kiln Size (L × D m)	Clinker Cooler	Supplier	Year in Service
1	Wet	300	100 × 3	Satellite	F.L.Smidth	1956
2	Wet	300	100 × 3	Satellite	F.L.Smidth	1958
3	Wet	600	150 × 3.75	Satellite	F.L.Smidth	1968
4	Cyclone SP	2,100	80 × 5	Satellite	F.L.Smidth	1972
5	Wet	300	100 × 3	Rotary	G.H.H.	1962
6	Cyclone SP	4,000	95 × 5.8	Grate	Polysius	1979
7	Tower SP	2,000	n.a.	Satellite	Perage Inv.	1984

(11) Energy price

As of September 1995, we have obtained the following information.

Natural gas : 10 Rial/m³ (9,600 kcal/m³)

Heavy oil : 20 Rial/L (10,500 kcal/L)

Total electric power: 53 Rial/kWh (63 kV)

(12) Study period

a. Preliminary study: September 24, 1995

b. Plenary study : July 14 to 17, 1996

(13) Members of the study

a. JICA team

Team leader : Mitsuo Iguchi (Preliminary study)
Leader of factory diagnosis : Norio Fukushima
Process management technology : Hisashi Ikeda
Heat management technology : Katsuhiko Kaburagi
Heat management technology : Jiro Konishi (Preliminary study)
Energy policy : Toru Kimura (Preliminary study)
Energy policy : Shin-ya Udo (Preliminary study)
Database and energy utilization plan: Kaoru Yamaguchi (Preliminary study)
Economic evaluation : Shigeaki Kato (Preliminary study)

b. PBO team

Energy conservation : Mr. Mazhari
Factory management : Mr. Sajadifar
Micro level energy management: Mr. Toofangchi (Preliminary study)
Electrical energy management : Mr. Maboodi (Preliminary study)

(14) Interviewees

a. Preliminary study

Mr. A. Farahi Jahromi : Electric Engineer
Mr. Nasser Bahadori : Head of Electronic & Electrofilters
Mr. Mohammad-Reza Artan Nejad: Electric Engineer
Mr. Abolghasem Rastegar : Production Manager

b. Plenary study

Mr. Amini Yekta: Vice President of Factory
Mr. Shahverdi : Deputy Manager of No. 1 Plant, Head of Energy Committee
Mr. Arian Nejad : Senior Electric Manager, Head of Electric and Electronics
Mr. Jahromi : Deputy Manager of Electric Engineer of Kiln No. 4
Mr. Salimi : Deputy Manager of Production

3.2.2 Situation of Energy Consumption

(1) Transition of production, energy consumption, and energy intensity

Data of the production and energy consumption for every fiscal year and for each kiln was not obtained.

The fuel intensity has changed within the following range.

Wet process: 1,600 to 1,700 kcal/kg-cl

Dry process: 850 to 950 kcal/kg-cl

We have not obtained definite information on electric power intensity.

Table 3.2.2 and Table 3.2.3 show the investigation results of monthly operation records of kilns No. 4 and No. 6 for each process during the last 16 months.

Table 3.2.2 Operation Record of Kiln No. 4

Year	Month	Raw Mill Department		Kiln Department				Cement Mill Department	
		Productoin [Raw tons]	Electricity Consumption [kWh]	Production [t-cl]	Fuel Consumption Oil [L]	Fuel Consumption Gas [m³]	Electricity Consumption [kWh]	Production [t-cem]	Electricity Consumption [kWh]
1995	1	89,813	2,711,929	54,791	2,655,000	2,614,300	1,434,816	52,801	2,798,885
	2	90,478	2,519,081	52,277	1,043,000	4,243,304	1,376,907	52,032	2,341,357
	3	72,640	2,313,164	47,719	800,000	4,314,716	1,282,390	47,127	2,557,626
	4	79,239	2,337,032	45,278	549,000	4,187,591	1,259,061	48,938	2,597,942
	5	69,873	2,254,201	46,098	715,000	4,540,125	1,313,941	49,198	2,174,361
	6	84,650	2,676,910	51,659	684,000	5,000,965	1,428,407	49,022	2,446,999
	7	4,280	355,280	90	0	69,805	157,753	48,313	2,028,060
	8	39,784	1,418,114	29,034	418,000	2,550,331	844,169	42,954	2,143,533
	9	96,253	2,757,656	59,573	897,000	5,263,290	1,578,437	58,384	2,947,780
	10	72,819	2,125,585	40,833	550,000	3,566,130	1,077,945	35,395	1,610,343
	11	72,734	2,221,452	45,985	723,000	4,106,572	1,241,532	59,912	2,666,088
	12	37,321	1,272,401	21,720	998,000	1,276,031	640,248	37,886	1,708,902
1996	1	97,415	2,671,416	60,096	2,205,000	3,540,697	1,475,684	58,857	2,724,253
	2	87,425	2,614,040	52,261	3,989,000	1,021,506	1,376,133	40,338	1,908,744
	3	81,219	2,492,914	48,311	1,521,000	3,375,320	1,277,383	44,104	1,922,761
	4	83,201	2,377,889	49,685	1,065,000	4,136,423	1,306,139	34,951	1,575,696
Total (1995.1 - 1996.4)		1,159,144	35,119,064	705,410	18,812,000	53,807,106	19,070,945	760,212	36,153,330
Monthly average		72,447	2,194,942	44,088	1,175,750	3,362,944	1,191,934	47,513	2,259,583
Energy intensity		1.64	30.30	1.00	26.67	76.28	27.04	1.08	47.56
Total	Electricity	[kWh/t-cl]							128.07
		[kWh/t-cem]							118.84
		[kWh/t-ref]				(1.6R+Cl)+C:			124.38
	Fuel	[kcal/kg-cl]			[kcal/kg]	[kcal/m³]			950.80
				(LHV)	9,845	9,350			
				[kg/L]	0.905				

Table 3.2.3 Operation Record of Kiln No. 6

Year	Month	Raw Mill Department		Kiln Department				Cement Mill Department	
		Productoin [Raw tons]	Electricity Consumption [kWh]	Production [t-cl]	Fuel Consumption Oil [L]	Gas [m³]	Electricity Consumption [kWh]	Production [t-cem]	Electricity Consumption [kWh]
1995	1	157,260	3,585,600	102,531	5,144,000	3,687,055	3,825,640	104,948	5,328,500
	2	136,192	3,359,200	77,870	1,934,000	4,966,776	3,114,270	49,393	2,375,650
	3	71,850	1,758,900	43,975	1,777,000	2,380,911	2,072,750	43,628	2,262,500
	4	157,925	4,221,800	107,300	0	9,804,205	3,866,750	52,609	2,687,100
	5	128,616	3,439,100	73,232	0	7,258,928	2,972,180	93,116	4,445,400
	6	46,716	1,312,900	41,171	0	4,115,398	1,650,980	73,337	3,581,900
	7	138,656	3,568,000	95,954	284,000	8,790,248	3,486,040	74,751	3,790,300
	8	143,463	3,360,900	76,979	2,118,000	4,952,012	3,122,670	84,635	4,408,100
	9	120,956	2,919,500	81,888	0	7,629,722	3,178,400	99,779	4,938,500
	10	112,555	2,538,000	62,824	0	5,817,910	2,450,080	76,513	3,704,600
	11	76,370	1,779,000	52,132	0	5,077,504	2,033,150	63,178	2,892,100
	12	127,649	3,031,000	90,188	2,747,000	5,319,643	3,517,330	80,991	3,743,100
1996	1	157,715	3,687,700	96,154	3,956,000	4,592,089	3,750,000	82,656	3,684,800
	2	143,713	2,939,500	92,156	5,000,000	3,161,092	3,594,150	74,883	3,718,200
	3	87,514	1,997,300	65,444	3,800,000	1,868,541	2,552,316	68,924	3,225,700
	4	133,290	3,317,200	76,772	5,225,000	1,629,319	2,994,108	65,846	3,118,700
Total		1,940,440	46,815,600	1,236,570	31,985,000	81,051,353	48,180,814	1,189,187	57,905,150
Monthly average		121,278	2,925,975	77,286	1,999,063	5,065,710	3,011,301	74,324	3,619,072
Energy intensity		1.57	24.13	1.00	25.87	65.55	38.96	0.96	48.69
Total	Electricity	[kWh/t-cl]							123.65
		[kWh/t-cem]							128.58
		[kWh/t-ref]				(1.6R+Cl)+C:			125.52
	Fuel	[kcal/kg-cl]			[kcal/kg]	[kcal/m³]			843.31
				[LHV]	9,845	9,350			
				[kg/L]	0.905				

Note: Some amount of clinker are exported.

According to these tables, the average values of the fuel intensity of kilns No. 4 and No. 6 are 950 kcal/kg-cl and 843 kcal/kg-cl respectively. Since the above values of fuel intensity of the wet process kiln are at a normal level, it seems that the information obtained indicates a reasonable value. By calculating the weighted average in accordance with the kiln capacity, it is estimated that the average fuel intensity of the entire plant is 1,038 kcal/kg-cl.

The electricity intensity of kiln No. 4 is 128 kWh/t-cl and that of kiln No. 6 is 124 kWh/t-cl. Supposing that the electricity intensity of the wet process kiln is 110 kWh/t-cl and the electricity intensity of kiln No. 7 is at the same level as that of kiln No. 4, the electricity intensity of the entire plant can be presumed to be 123.5 kWh/t-cl.

(2) Energy intensity for each process

Table 3.2.2 and Table 3.2.3 given earlier show the production and energy consumption of kilns No. 4 and No. 6 for every month and for each process. Figure 3.2.3, Figure 3.2.4, Figure 3.2.5, and Figure 3.2.6 illustrate the above data.

We have omitted the investigation on the wet process kilns and kiln No. 7 kiln due to the lack of time. We could perform the actual measurement of the operating conditions of kiln No. 4 only due to various reasons.

Figure 3.2.3 Monthly Production of Kiln No. 4

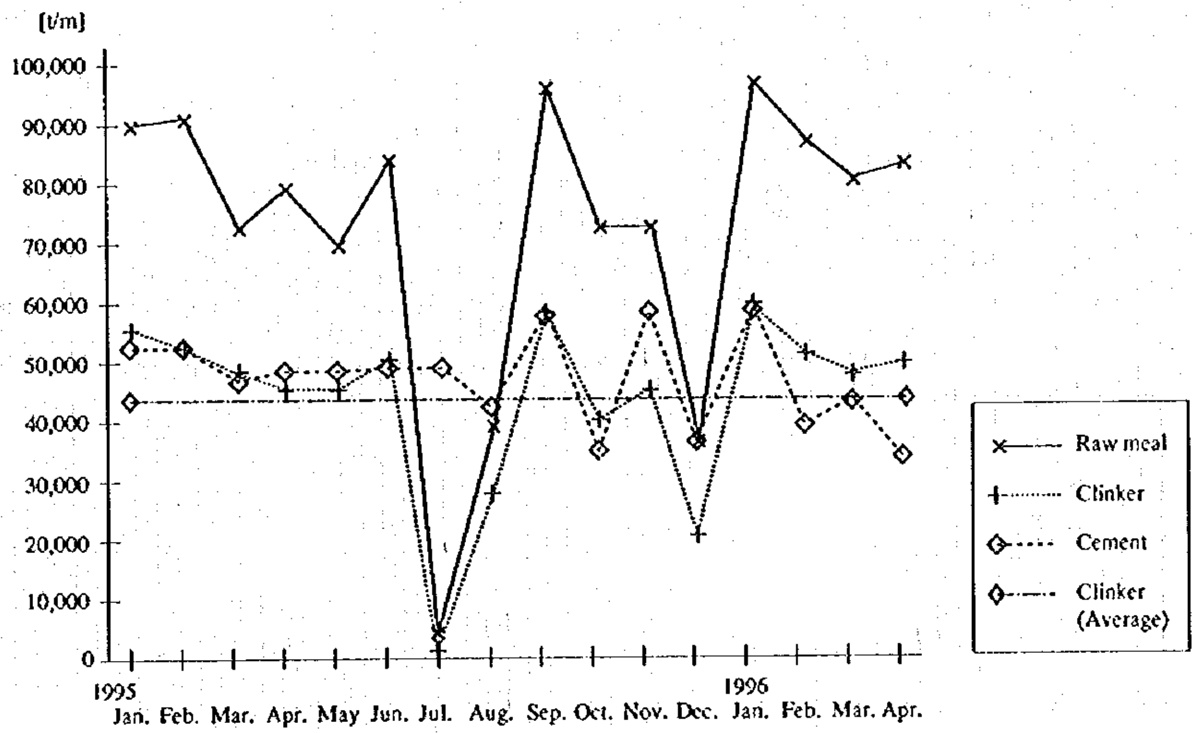


Figure 3.2.4 Monthly Energy Intensity of Kiln No. 4

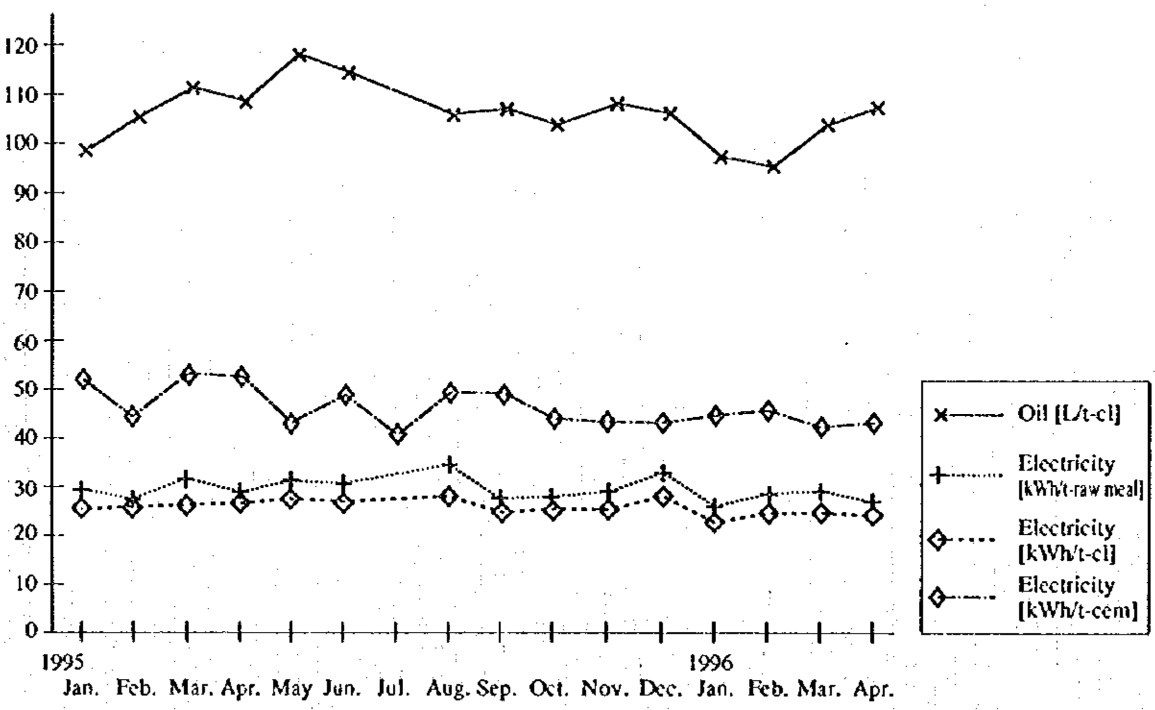


Figure 3.2.5 Monthly Production of Kiln No. 6

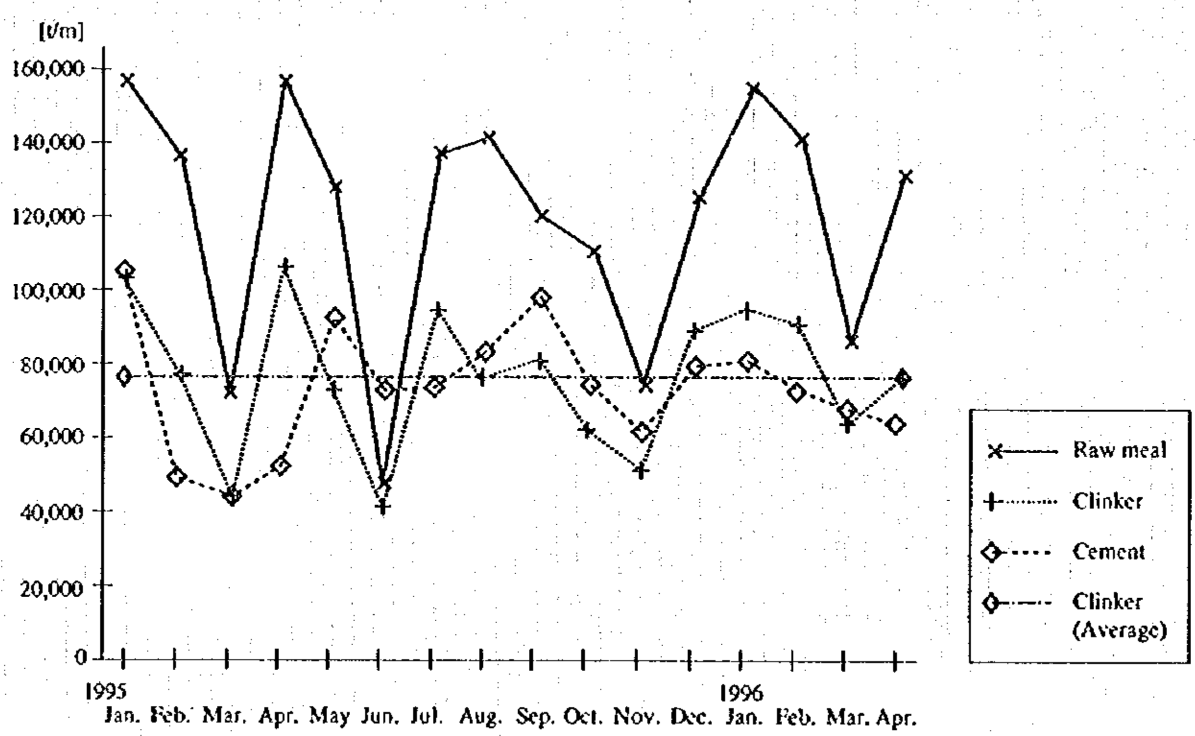
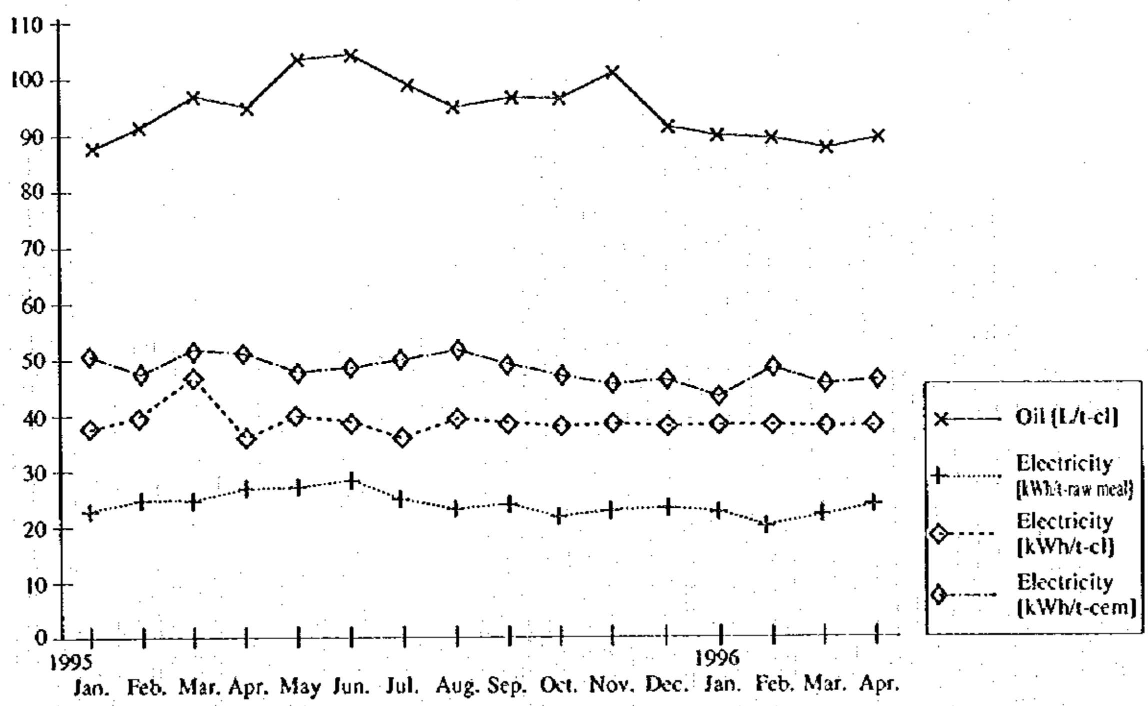


Figure 3.2.6 Monthly Energy Intensity of Kiln No. 6



The electricity intensity of the raw mill department of kiln No. 4 is approximately 6 kWh/t higher than that of kiln No. 6 in spite of the fact that the same raw materials are used. The difference in the system alone should not account for this much disparity. On the other hand, the electricity intensity of the kiln department of kiln No. 6 is approximately 12 kWh/t higher than that of kiln No. 4. Kiln No. 6 uses the grate cooler and therefore it is understandable that the electricity intensity of this kiln is slightly higher. This difference, however, is too large. It is very doubtful that there may be some errors in the sorting of the electricity consumption records of each kiln or each department, and thus the actual situation is not indicated correctly.

A part of the clinker of kiln No. 6 is exported, and therefore the cement production is less than the clinker production. If the electricity intensity of the entire plant is indicated per cement ton under these circumstances, the result does not carry any profound validity. Therefore, it is necessary to always know the actual consumption by each department and by each product.

(3) Heat balance

Table 3.2.4 indicates the heat balance calculated using the actual measured values and indicated values of the operation measuring instrument on the date of the investigation.

Table 3.2.4 Heat Balance (No. 4 SP Rotary Kiln) (1/2)

1. Precondition

Item		Unit		Remarks
1.1	Raw meal			
	1) Charged raw material	t/h	155	
	2) Temperature	°C	100	
	3) Specific heat	kcal/kg·°C	0.20	
1.2	Clinker			
	1) Yield of material	t-cl/t-raw material	0.59	
	2) Dusting loss	%	5	
	3) Clinker output	t/h	87.10	155 × 0.59/1.05
	4) Temperature	°C	150	
	5) Heat for clinkering	kcal/kg-cl	430	
	6) Specific heat	kcal/kg·°C	0.192	
1.3	Fuel in kiln			
	1) Kind	–	Natural gas	
	2) Low heat value	kcal/m^3_N	9,500	
	3) Temperature	°C	30	
	4) Consumption in kiln	m^3_N/h	7,500	
1.4	Fuel in preheater			
	1) Kind	–	Fuel oil	
	2) Low heat value	kcal/L	9,207	
	3) Temperature	°C	100	
	4) Consumption in preheater	L/h	1,500	
	5) Specific gravity	kg/L	0.905	
	6) Specific heat	kcal/kg·°C	0.45	
1.5	Exhaust gas at preheater outlet			
	1) Temperature	°C	360	
	2) O_2 content	%	3.25	
	3) Specific heat	kcal/m^3_N·°C	0.338	
	4) Specific gas volume by natural gas	m^3_N/kg-cl	1.24	
	5) Specific gas volume by fuel oil	m^3_N/kg-cl	0.24	
	6) Specific gas volume by clinkering of material	m^3_N/kg-cl	0.27	
1.6	Radiation loss from kiln surface			
	1) Average temperature	°C	284	
	2) Surface area	m^2	1,257	
	3) Convection coefficient	kcal/m^2·h·°C	11.4	
	4) Radiation coefficient	kcal/m^2·h·°C	16	
	5) Emissivity	–	0.95	
1.7	Radiation loss from cooler surface			
	1) Average temperature	°C	244	
	2) Surface area	m^2	625	
	3) Convection coefficient	kcal/m^2·h·°C	11.9	
	4) Radiation coefficient	kcal/m^2·h·°C	13.7	
	5) Emissivity	–	0.95	

Table 3.2.4 Heat Balance (No. 4 SP Rotary Kiln) (2/2)

2. Heat balance

Item		kcal/kg-cl	%	Remarks
Input heat Q1				
1) Qa :	Heat of combustion of fuel	976.6	97.5	
2-1) Qb_1 :	Sensible heat of fuel	0.5	0.0	
2-2) Qb_2 :	Sensible heat of raw material	24.9	2.5	
Total		1,002.0	100.00	
Output heat Q2				
3) Qc :	Heat for clinkering	430.0	42.9	JIS
4) Qd :	Sensible heat of clinker at cooler outlet	23.0	2.3	
5) Qe :	Sensible heat of preheater exhaust gas	195.2	19.5	
6) Qf :	Radiation loss	139.1	13.9	
7) Qg :	Other heat loss	214.7	21.4	
Total		1,002.0	100.00	

1) $((7{,}500 \times 9{,}500) + (1{,}500 \times 9{,}207)) / 155 / 0.59 \times 1.05 / 1{,}000 = 976.6$

2-1) $1{,}500 / 155 / 0.59 \times 0.905 \times 0.45 \times (100 - 30) / 1{,}000 = 0.5$

4) $0.192 \times (150 - 30) = 23.0$

5) $(1.24 + 0.24 + 0.27) \times 0.338 \times (360 - 30) = 195.2$

6) Cooler 39.1 + Kiln 100.0 = 139.1

3.2.3 Situation of energy management

(1) Setting the energy conservation target

Reflecting the history of this plant, 7 kilns of different production styles are connected in a complicated manner and old and new equipment are operating in parallel here. The task of only maintaining the rate of operation at a constant level at this plant requires considerable effort. In such a situation, partial change is buried under the entire flow and the actual condition is difficult to grasp. Therefore, to follow up the result, it is advisable that the data for each system and each process should be summed up, and by using the data as the clues for an approach, the attainable target should be set for each item. The following items have been investigated at this plant as problem at present.

a. Achieving a kiln operation rate of 92 %

b. Increasing the capacity of kiln No. 6 from 4,000 t/d to 6,000 t/d

c. Additional installation of raw material transportation belt conveyors and crushers

d. Application for ISO-9000 approval

All of the above matters are closely related to energy consumption.

(2) Systematic activities

The energy management committee has been set up by appointing the representatives in charge of machines, electricity, and production of the 7 kiln production lines. The activities have just been started. At present, data collection is performed mainly by electrical engineers on a daily basis. They are working on energy management with fuel, cost and environmental issues besides electricity.

(3) Data-based management

Right now, the company is in the stage of data collection through the above committee. Since the types and numbers of equipment operating at the plant are very numerous, it must be difficult to sort the information related to the specifications and features of the equipment, transmit this information to each personnel in the workshops, and make the most use of this information. As mentioned earlier, since there is the equipment in the raw mill department of kiln No. 4 which is shared with kilns No. 1 to No. 3, the electricity consumption cannot be grasped clearly for each kiln. We expect that these problems will be clarified and improvement measures provided as the activities of the committee progress.

(4) Education of employees

We do not have specific information regarding this matter.

For production conditions and also for a stable product quality and improvement of the operation rate, the operators must thoroughly learn the correct operation standards. This will lead to the improvement of energy intensity.

(5) Equipment maintenance

At the old plants, a large amount of dust is emitted from everywhere. Whenever there is a sudden gust of wind or a truck passes, the dust piled in the passages scatters again. It cannot be denied that the scattered dust is a possible reason for equipment damage and for shorter equipment life. The cleanup of a plant is not only favorable in terms of appearance and the welfare of the employees but also for assuring profit in operation.

Old and new equipment are installed complicatedly in the plant and the present layout of the plant is far from being ideal as far as equipment maintenance is concerned. The reasons described in the section "History of the plant" are involved in this matter. The engineers at the workshop must be putting in tremendous efforts to maintain the specified rate of operation. There will be continued investment for various equipment to reinforce the production capacity of the plant. It is recommended that efforts should be made to improve facilities for equipment maintenance. Looking back at the history of this plant, it can be said that now is the time for integration of equipment.

3.2.4 Problems and measures on energy use

(1) Comparison with a Japanese excellent factory

As mentioned in Section 3.2.2 (1), the fuel intensity of the entire plant is estimated at 1,038 kcal/kg-cl, which is approximately 30 % higher than 800 kcal/kg-cl of the recent international level.

This difference of approximately 30 % in fuel intenisty results from the difference of approximately 21 % in the process, the difference of 4 % in the cooler type and the difference of 5 % in the operating conditions.

As mentioned earlier, there are 4 lines of wet process kilns namely kilns No. 1 to No. 3 and No. 5 among the 7 production lines of this plant. Theoretically, a wet process kiln requires approximately twice the fuel intensity of a modern dry process kiln (NSP method). The production capacity of each wet process kiln is small. To modernize the entire plant, now is the time to transform production styles and to concentrate production simultaneously.

The main reason why the fuel intensity of kilns No. 4 and No. 6 differs sharply among all dry process SP kilns is probably the difference in the clinker cooler types. The satellite cooler provided in kiln No. 4 has the advantage of a simple structure and easy operation. It is disadvantageous, however, from the energy conservation point of view. The difference of fuel intensity between the kilns will be reduced by replacing the clinker cooler of kiln No. 4 with the grate cooler.

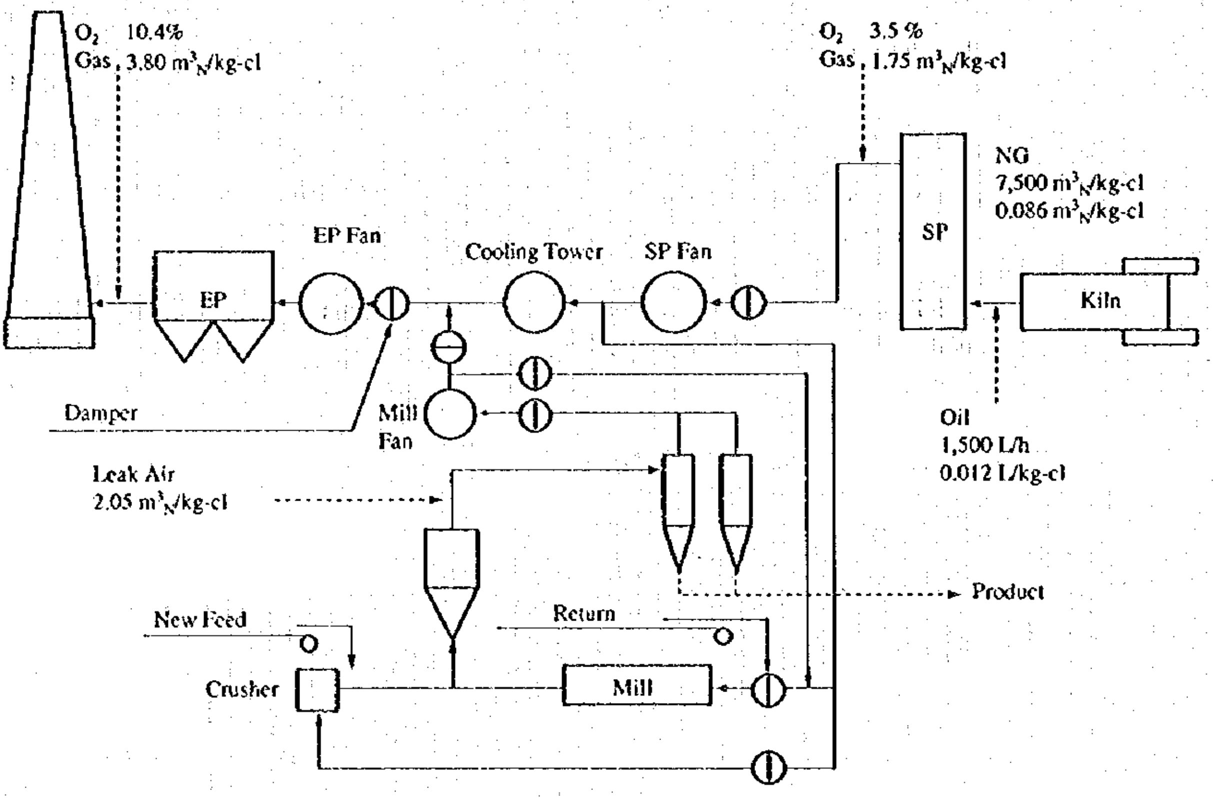
The fuel intensity of kiln No. 6 is good as compared with the other kilns. It still has room for improvement if the rate of operation improves.

Electricity intensity, 123.5 kWh/t-cl, is also approximately 23 % higher than the equivalent international level 100 kWh/t-cl for the cement particle size in I.R. Iran. Considering that there are not so many pullution control facilities, the difference will be still about 3 to 5 % larger. This difference arises mainly from light load operation and the differences of the mill operation control.

(2) Kiln No. 4 clinker cooler modification

Kiln No. 4 is a dry process kiln with a suspension pre-heater, same as kiln No. 6. The fuel intensity of kiln No. 4 is 100 kcal/kg-cl higher than that of kiln No. 6. The main cause for this seems to be the difference in the cooler type. About 3.5 % of oxygen content was detected in the exhaust gas at the kiln outlet of kiln No. 4. When using the grate cooler, this is normally less than 1 %. The difference is caused by bringing the total volume of air used for cooling the clinker into the kiln regardless of the air volume required for fuel combustion. It is one of the characteristics of the satellite cooler. 3.5 % of oxygen content in the exhaust gas is equivalent to about 15 % of surplus air volume which is a ratio of excess air volume to the thoretical combustion air volume (See Figure 3.2.7). If we risk increasing the supply of fuel, the heat load of the kiln sintering zone and the temperature of exhaust gas will increase, and various troubles will occur in the operations. If the heat efficiency of the burning system improves, the theoretical air volume required for combustion will be decreased. Therefore, this excess air ratio will become bigger. The combination of a suspension pre-heater and satellite cooler is obviously disadvantageous except for the simplicity of equipment. At present, satellite coolers are not operating in Japan.

Figure 3.2.7 Gas Flow (Kiln No. 4)



The number of operating days of kiln No. 4 is 21 d/month. The health condition of the kiln itself seems to be a problem. The wear and damage of the satellite coolers and kiln shell near them is highly noticeable. It appears that the problem has been eased by reducing the heat load of the sintering zone and then preventing the pre-heater coating trouble caused by the temperature rise at kiln outlet, after shifting approximately 15 % of the fuel amount supplied to the kiln burner to the auxiliary burner at the pre-heater inlet section. The problem, however, has not been eliminated at the source.

This kiln can be modified into the same type as kiln No. 6 which has excellent heat efficiency. First, the kiln shell on the downstream side of the current third support point should be dismantled together with the satellite cooler. This part of shell must be replaced with a new shell which has the same diameter but a slightly longer body. Then, the new grate cooler must be installed at the clinker outlet portion of the new shell. A number of similar modifications have been carried out in Japan. Normally installation work of the new cooler is carried while operation is continued.

By the above modifications, the extreme wear and damage of the kiln sintering zone and the health condition of the cooler can be recovered all at once. At the same time, the excessive secondary air which is more than air volume required for fuel combustion is no longer brought into the kiln. This will allow the kiln exhaust gas volume to decrease, and the heat efficiency will be improved. Also, the clinker is rapidly cooled down at the cooler inlet section after it is sintered at a higher temperature, which will improve the clinker quality.

Fortunately, both kiln shell and cyclone of pre-heater are large enough. Therefore, significant increase of production capacity can be expected depending on the draft capacity of the pre-heater exhaust fan. Since the plant has performed a record of 2,100 t/d sometimes, it is very possible to increase the daily production to the 3,000 t/d level.

It is necessary to increase the capacity of the raw mill and cement mill departments by approximately 50 % each. For the raw mill department, this goal can be achieved simply by adding 1 vertical roller mill to this department. By adopting the above method, the electricity intensity of the raw mill department will be equal to at least the level of kiln No. 6. In the same manner, adopting the vertical roller mill for the cement mill department as the pre-grinding system will allow the capacity-oriented balance to be maintained and at the same time the electric power intensity can be improved.

(3) Modification of kiln No. 3

The dimensions of kiln No. 3 are larger than the other 3 wet process kilns. The inner diameter of the shell is 3.75 m. If the length is shortened to 65 m and it is modified to use the NSP method, this kiln will be transformed into a modern piece of equipment with a daily production capacity of approximately 2,000 t/d. Once the modification of this kiln is completed, the operations can be consolidated in this kiln and the operations of the remaining 3 wet process kilns which require high fuel intensity can be stopped. However, since the operation of kiln No. 3 is stopped while the kiln is modified, this modification should be started after completion of the kiln No. 4 modification.

The kiln No. 3 will be relocated near kiln No. 4 or No. 6 after it is temporarily disassembled. A series of equipment including the electric precipitator, raw material mill, blending silo, suspension pre-heater with calciner, and grate cooler must be installed newly. Therefore, a large amount of investment capital is required. The existing support unit and driving unit of the kiln can be re-utilized after slight modifications. If all existing grinding mill used for the wet process kilns are utilized for cement mills and if all wet process raw material mills are charged into cement mills, the balance should be retained.

The construction costs can be significantly reduced by making such arrangements, compared with the cost of a full new construction. From another standpoint, the electricity intensity can be positively reduced by adopting the pre-grinding system using the roller mill, or the equipment can be revived by newly installing a large-size mill. This report, however, is based on the assumption that the existing mill can withstand continuous use at the present time.

(4) Improvement of kiln No. 6

Kiln No. 6 still has room for improvement with regard to its production capacity. The average monthly production of 77,286 t/month corresponds to only 19.3 d/month calculated in terms of operating days per month at 4,000 t/d.

There were occasions, however, when the monthly production exceeded 100,000 t/month, such as in January and April 1995. If the monthly production is improved and always exceeds 100,000 t/month, the amount of increased production will be equal to the total production of the 3 wet process kilns. Since the kiln was stopped when we visited the plant, we could not make measurements. A trouble with the raw material mill seems to be one of the reasons of law operation rate. We would like to assume that there are no severe technological defects and this goal can be achieved by a complete maintenance.

The electricity intensity of the raw material mill of kiln No. 6 is better than that of kiln No. 4. The fuel intensity of kiln No. 6 is also low. Therefore, if the rate of operation of this kiln is improved, it can contribute further to the improvement of the entire plant's profit rate.

The electricity intensity of the kiln department and cement mill department is high. For the kiln department, it is supposed that the operation of the clinker cooling fan of the clinker cooler may not be adequate.

The electricity consumption of the cement mill department of both kilns No. 4 and No. 6 must be reduced by about 20 %. Troubles often occur in the mill motors of both the raw mill and cement mill departments at this plant. Some of the mill motor is operated by partial load. Since the efficiency of a ball mill has a characteristic of decreasing in the operation with a lighter load than the design value, it is not favorable to continue or repeat such a situation.

The plant is carrying out studies on a plan for increasing the production capacity by 50 % to achieve 6,000 t/d through modification of the present SP kiln into an NSP kiln. We don't agree with this idea.

A calciner with its excellent performance has the natural capacity to absorb a process fluctuation in itself if properly used. This feature is a major contributing factor in achieving stable operation of a large-sized kiln. The modification under consideration by the company is something like adding a pre-heater with a calciner which has different characteristics with the existing pre-heater. From such a modification, one cannot expect the above effect. On the contrary, such a modification may make the operation difficult due to problems such as coating trouble at the existing preheater. If by chance the kiln condition worsens after the modification, and if the kiln is repeatedly shut down even temporarily, the production loss incurred during this period can be made up. Thus, because the production capacity of kiln No. 6 is significantly larger than the other kilns, the company will be obliged to take the larger risk in terms of management. These are the reasons why we cannot agree with the modification plan being considered by the company at present.

(5) Consolidation of equipment

If the above-mentioned measures are applied, the production capacity of 3 kilns of this plant, excluding No. 7 kiln, can amount to 9,000 t/d in terms of daily production. Kilns No. 1 and No. 2 can be used for other purposes. We also suggest dismantling kiln No. 5 and building a common cement silo and shipment facilities in this area. The clinker storage should be transformed into a silo system from the present open yard system to prevent dust from scattering. A suitable space for clinker silo system can be created near the existing yard used for kiln No. 6. The limestone yard for kiln No. 6 can be used as the common yard if it is necessary to expand the existing yard. When the new crusher and belt conveyor under consideration are used in this manner, the investment made for these devices will be more worthwhile. The limestone yard for kiln No. 4 can be transformed to the common clay yard. The old small-sized cement mills will be replaced with a large-sized, high-efficiency cement mill. When this takes place, it is recommended that for better management all cement mills should be installed together; for example, near the cement mill of kiln No. 6.

In this way, equipment and facilities can be consolidated and the material flow will become simpler. As a result, various merits should be gained for managerial tasks. The number of operating equipment and systems will be reduced by half. The management resources including man-power and funds can be put to use in a more centralized manner. The operation rate and product quality will improve and the energy consumption will be reduced. These improvements, however, should be strategically carried out with the right timing not only simply for the purpose of energy conservation, but also as a part of a long-term future vision for the plant. Therefore, the merits to be gained from these improvements and the investments made are not included in the economical review to be provided later.

(6) Modification of kiln No. 7

It is difficult to improve the heat efficiency by modifying the existing pre-heater. However, it can be replaced with the cyclone type suspension pre-heater with a calciner. Also, the satellite cooler can be replaced with the grate cooler.

By carrying out the above modifications, it is expected that the present 2,000 t/d production capacity of kiln No. 7 will increase to 3,000 t/d, and the fuel intensity will be reduced to 800 kcal/kg-cl.

According to the improvement measures suggested for No. 1 to No. 6 earlier, a production increase of 1,400 t/d has already been seen as a possibility. The further production increase in No. 7 kiln does not always result in immediate increase of profit. Therefore, we have decided to exclude this modification from the proposal to be submitted this time. Whether or not this modification can be applicable is subject to regional market demand and a study for another time.

(7) Effects of improvements

The production form of the plant is drastically changed. As indicated in Table 3.2.5, the operations of the 3 wet process kilns No.1, No. 2, and No. 5 are stopped. Production is consolidated in kilns No. 3, No. 4, No. 6, and No. 7. The following effects will be gained by adopting these improvement measures.

For the following investigations, 300 days is assumed, for convenience' sake, as the annual standard operating days.

Table 3.2.5 Rationalization of Production

Heat consumption

Kiln No.	Existing Production [t/d]	Existing Intensity [kcal/kg-cl]	Existing Consumption [Mcal/300ds]	After Modification Production [t/d]	After Modification Intensity [kcal/kg-cl]	After Modification Consumption [Mcal/300ds]
1	300	1,700	153,000,000	0		0
2	300	1,700	153,000,000	0		0
3	600	1,600	288,000,000	2,000	800	480,000,000
4	2,100	950	598,500,000	3,000	800	720,000,000
5	300	1,700	153,000,000	0		0
6	4,000	850	1,020,000,000	4,000	800	960,000,000
		Average			Average	
Total	7,600	1,038	2,365,500,000	9,000	800	2,160,000,000
					[kL/y]	[Mcal/y]
Saving based on the original capacity:					59,505	541,500,000

Electricity consumption

Kiln No.	Existing Production [t/d]	Existing Intensity [kWh/t-cl]	Existing Consumption [kWh/300ds]	After Modification Production [t/d]	After Modification Intensity [kWh/t-cl]	After Modification Consumption [kWh/300ds]
1	300	110	9,900,000	0		0
2	300	110	9,900,000	0		0
3	600	110	19,800,000	2,000	110	66,000,000
4	2,100	128	80,640,000	3,000	115	103,500,000
5	300	110	9,900,000	0		0
6	4,000	124	148,800,000	4,000	112	134,400,000
		Average			Average	
Total	7,600	122	278,940,000	9,000	113	303,900,000
						[kWh/y]
Saving based on the original capacity:						22,313,333

a. Improvement of clinker production

After the modifications are carried out, the total production capacity of 3 kilns, No. 3, No. 4, and No. 6, will be 9,000 t/d. This figure is 1,400 t/d higher than the existing capacity of 7,600 t/d. When the 2,000 t/d production capacity of kiln No. 7 is added to this figure, the total production capacity will amount to 11,000 t/d. We believe that this figure can fully meet the present demands.

Supposing the marginal profit is 2,000 yen/t, an annual profit increase of 840,000,000 yen/t (2,000 yen/t × 1,400 t/d × 300 d/y = 840,000,000 yen/t) will be possible according to calculations as a result of the above production increase. Equipment reliability will improve due to the modifications. At the same time, the production plan and preventive maintenance will become easier to carry out due to the consolidation of the production. The rate of operation in general including kiln No. 6 will improve. Therefore, the actual profit increase will be much larger than the above value.

b. Reduction of fuel consumption

The fuel intensity of the wet process kiln No. 3 itself will be reduced by half simply by modifying it into an NSP kiln. It is not difficult to achieve 800 kcal/kg-cl on this scale by adopting the 5-stage type pre-heater. Furthermore, the effect, which will allow stopping the operations of the other wet process kilns that use high heat intensity, will be large. The annual fuel consumption can be cut down to approximately 42,527 kL/y* calculated in terms of fuel oil.

If the existing satellite cooler of kiln No. 4 is replaced with the grate cooler, it will become possible to freely control the volume and temperature of the secondary air for combustion. The heat efficiency of kiln No. 4 will improve and the auxiliary combustion in the pre-heater being carried out at present will no longer be necessary. The production capacity of kiln No. 4 will be improved also so that the percentage of the radiation heat will be somewhat reduced. As a result, the fuel intensity shall reach the international level of 800 kcal/kg-cl, and the annual fuel consumption can be cut down by approximately 10,385 kL/y* calculated in terms of fuel oil.

The present fuel intensity of kiln No. 6 is 840 to 850 kcal/kg-cl and this value is quite a good record in I.R. Iran. The fuel intensity of a similar sized kiln equipped with the grate cooler is normally less than 800 kcal/kg-cl. If the low rate of operation is the obstacle, maintenance will be improved at the point when a margin of production is gained due to the series of modifications given above from the entire production capacity, and the fuel intensity will automatically improve. As a result, the annual fuel consumption can be reduced by approximately 6,593 kL/y* calculated in terms of fuel oil.

Summarizing the above, the annual fuel cut-down amount equivalent to the rated production capacity will be approximately 60,000 kl/y. The profit gained will be approximately 1,000,000,000 yen** per annum if the price of fuel is assumed to be 17,000 yen/kL. The fuel intensity after modifications will be 800 kcal/kg-cl while the present average fuel intensity is 1,038 kcal/kg-cl. Kiln No. 7 was excluded from this calculation.

* : See Table 3.2.6.

**: Addition in Table 3.2.6.

c. Reduction of electricity consumption

Not much can be expected from the reduction of electricity intensity due to the kiln No. 3 modifications. Since the pre-heater and grate cooler are used in the kiln department, the electricity consumption increases on the contrary. If the existing ball mill is used in the new cement grinding section to save construction costs, it will be difficult to reduce electricity consumption here. The increased electricity consumption indicated above can be canceled only if the vertical roller mill is adopted as a new raw material mill.

Although the electricity intensity of the kiln department will increase slightly by applying grate cooler, if the vertical roller mill is used wisely for reinforcement of the production capacity of the raw material mill and cement mill, considerable improvement can be expected from these departments. Judging from the equipment and facilities, the reasonable electricity intensity level is 115 kWh/t-cl. It will be possible to reduce the electricity intensity by approximately 10 % from the present value. This value is equivalent to 8,190 MWh/y calculated in terms of annual consumption.

On the whole, the electricity consumption of kiln No. 6 can be reduced 5 % by continuing the long-period operation. In addition, 3 kWh/t-cl each can be reduced by improving the operating conditions of the clinker and cement mill. A total of 12 kWh/t-cl reduction can be achieved. This value is equivalent to 14,400 MWh/y calculated in terms of annual consumption.

Summarizing the above, the present average intensity 122 kWh/t-cl is reduced to 113 kWh/t-cl. Approximately 22,000 MWh/y of electricity is cut down annually. The profit increase will be 220,000,000 yen annually if the electricity unit price is assumed to be 10 yen/kWh.

d. Reduction of environmental load

As mentioned earlier, integration of production facilities allows increasing the production capacity by approximately 18 % over the present capacity even if 3 wet-type kilns stop operation. As clearly shown in Table 3.2.6, the annual fuel consumption on the other hand is reduced by about 10 %. As a result of the measure for energy conservation, this should be natural, and at the same time it is vitally important in terms of reducing the exhaust of air pollutants.

Unavoidably, the combustion of the oil- and coal-type fuels causes the occurrence of harmful substances such as SO_x, NO_x, etc. Hence, the development of a technology for inhibiting the occurrence of these substances is currently a subject of international concern. This is also a problem that the cement industry, a representative example of fuel-intensive industries, must not avoid. Fortunately, however, the current wide use of SP and NSP systems provides a satisfactory solution to this problem.

More specifically, in the suspension preheater, most of SO_x content in the exhaust gas is absorbed by the material particle in the course of direct contact of the raw material and the combustion exhaust gas, since the rate of the SO_2 gas discharged in the air is extremely low as compared with the long kiln. Besides, an NSP system of excellent performance can reduce NO_x to 50 % or less as compared with the converntional kiln. Moreover, the reduction of the passing gas amount contributes to the improvement of the efficiency of the electrical dust collector. In addition to this, further improvement of the maintenance due to the integration of production facilities can inhibit the occurrence of dust. Thus, the implementation of this meausure will remarkably reduce the environmental load.

Such a measure as this has been, in many cases, implemented in the course of promoting energy conservation in the cement industry of industrially advanced countries, including Japan, for the purposes of improvement of both productivity and environment. This has been highly evaluated as one of typical measures for the modernization of plants. This plant, which is also located in the urban area, has the advantage economically, while at the same time it should take a great responsibility for the environmental load. In this respect, it is placed under similar conditions to industrialized countries. Hence, relevant governmental organs should positively offer their organizational, financial or technical support as required.

(8) Summary of proposals

Table 3.2.6 summarizes the above proposals.

The following effects can be expected by the modification of kilns No. 3 and No. 4 and by the improvement of No. 6.

Integration of production lines : 3 kilns among 7 stop operating.

Clinker production increase : 420,000 t/y

Reduction of fuel consumption : 59,505 kl/y

Reduction of electric power consumption: 22,590 MWh/y

Therefore, the investment amount of 6,903,000,000 yen can be recovered within 4 years by the annual profit increase of 2,077,500,000 yen.

Table 3.2.6 Summary of Proposals

(Japanese Yen base)

Item	Expected Saving: Fuel kL/y	Fuel Million yen/y	Fuel %	Electricity MWh/y	Electricity Million yen/y	Electricity %	Total Million yen/y	Investment Million yen	Payback Period Year
No. 3 Kiln:modification to NSP	42,527*1	723.0	16.4*7	–			723.0	4,550	2.9
		840.0*4					840.0		
No. 4 Kiln:replacement of cooler	10,385*2	176.5	4.0*8	8,190*11	81.9	2.9*13	258.4	2,280	2.9
		54.0*5					540.0		
No. 6 Kiln:improvement of operation	6,593*3	112.1	2.5*9	14,400*12	144.0	5.2*14	256.1	73	0.3
No. 1, 2, 5 Kiln:shut down		–540.0*6					–540.0		
Total	59,505	1,851.6	22.9*10	22,590	225.9	8.1*15	2,077.5	6,903	3.3

(Iran Rial base)

Item	Expected Saving: Fuel F/oil kL/y	Fuel Million Rial/y	Fuel %	Electricity MWh/y	Electricity Million Rial/y	Electricity %	Total Million Rial/y	Investment Million Rial	Payback Period Year
No. 3 Kiln:modification to NSP	42,527*1	3,190	16.4*7	–			3,190	79,625	4.5
		14,700*4					14,700		
No. 4 Kiln:replacement of cooler	10,385*2	779	4.0*8	8,190*11	819	2.9*13	1,598	39,900	3.6
		9,450*5					9,450		
No. 6 Kiln:improvement of operation	6,593*3	494	2.5*9	14,400*12	1,440	5.2*14	1,934	1,278	0.7
No. 1, 2, 5 Kiln:shut down		–9,450*6					–9,450		
Total	59,505	19,163	22.9*10	22,590	2,259	8.1*15	21,422	120, 803	5.6

*1 $\dfrac{\{(300 + 300 + 300)\ \text{t/d} \times (1{,}700 - 800)\ \text{kcal/kg-cl} + 600\ \text{t/d} \times (1{,}600 - 800)\ \text{kcal/kg-cl}\} \times 300\ \text{d/y}}{9{,}100\ \text{kcal/L}} = 42{,}527\ \text{kL/y}$

*2 $\dfrac{2{,}100\ \text{t/d} \times (950 - 800)\ \text{kcal/kg-cl} \times 300\ \text{d/y}}{9{,}100\ \text{kcal/L}} = 10{,}385\ \text{kL/y}$

*3 $\dfrac{4{,}000\ \text{t/d} \times (850 - 800)\ \text{kcal/kg-cl} \times 300\ \text{d/y}}{9{,}100\ \text{kcal/L}} = 6{,}593\ \text{kL/y}$

*4 Merit by production increase : (2,000 – 600) t/d × 300 d/y × 2,000 yen/t = 840 Million yen/y
*5 Merit by production increase : (3,000 – 2,100) t/d × 300 d/y × 2,000 yen/t = 540 Million yen/y
*6 Demerit by production decrease: –300 t/y × 3 sets × 300 d/y × 2,000 yen/t = –540 Million yen/y
*7 Annual fuel consumption: 2,365,500 Gcal/y / 9.1 Mcal/kL = 259,945 kL/y
42,527 / 259,945 × 100 = 16.4
*8 10,385 / 259,945 × 100 = 4.0
*9 6,593 / 259,945 × 100 = 2.5
*10 59,505 / 259,945 × 100 = 22.9
*11 2,100 t/d × (128 – 115) kWh/kg-cl × 300 d/y / 1,000 = 8,190 MWh/y
*12 4,000 t/d × (124 – 112) kWh/kg-cl × 300 d/y / 1,000 = 14,400 MWh/y
*13 8,190 / 278,940 × 100 = 2.9
*14 14,400 / 278,940 × 100 = 5.2
*15 22,590 / 278,940 × 100 = 8.1

Energy price in Japan:
Fuel oil price: 17,000 yen/kL
Electricity price: 10 yen/kWh
Energy price on Iran Rial base:
Fuel oil: 75 Rial/L
Electricity: 100 Rial/kWh
Exchange rate: 1,750 Rial = 1 US Dollar = 100 Japanese Yen
Calorific value of fuel: Oil: 9,000 kcal/kL
Investment cost is based on that in Japan.

3.3 Results of the Study at Soufian Cement Company

3.3.1 Outline of the Plant

(1) Plant name

Soufian Cement Company

(2) Plant address

33 km. Tabriz-Marand Rd. Tabriz

(3) Number of employees

1,075

(4) Major products

Portland cement ASTM Type 1 and 2

(5) Production capacity

4,600 t/d

(6) Production process of cement

This cement company digs out the limestone in a nearby mine for raw material. The limestone is transported to the plant by truck. For the clay component, raw materials of 2 different properties are used in proportions of approximately 20 %. These raw materials can be obtained from a nearby site about 5 km from the plant. Besides these substances, a small quantity of silica sand and iron ore are mixed as required. The moisture content in the clay is high all year around and reaches up to 30 % in some seasons. This high moisture content is one of the difficulties in mixing the raw material properly.

The production line consists of 4 kilns.
Kilns No. 1 to No. 3 are long-type dry process kilns, and the heat of the kiln exhaust gas (temperature 420 to 450 °C) is not utilized. A raw material mill and cement mill each of corresponding capacity are used for these 3 kilns. The equipment and facilities are partly shared. All clinker coolers are satellite coolers.

On the other hand, the No. 4 production line has a suspension pre-heater (SP) kiln with a satellite cooler. This kiln is built completely separate from the above 3 kilns. The plant site layout has a large enough space for the installation of another set of the same kiln type. Unfortunately the expected capacity of the clay grinding and drying system cannot be utilized and it remains idle. The plant is standing on the problem of anomalous raw material composition.

Since natural gas is not available, only fuel oil is used for fuel.

Figure 3.3.1 shows the process flow of kilns No. 1 to No. 3. Figure 3.3.2 shows the process flow of kiln No. 4.

Figure 3.3.1 Process Flow of Units 1 to 3

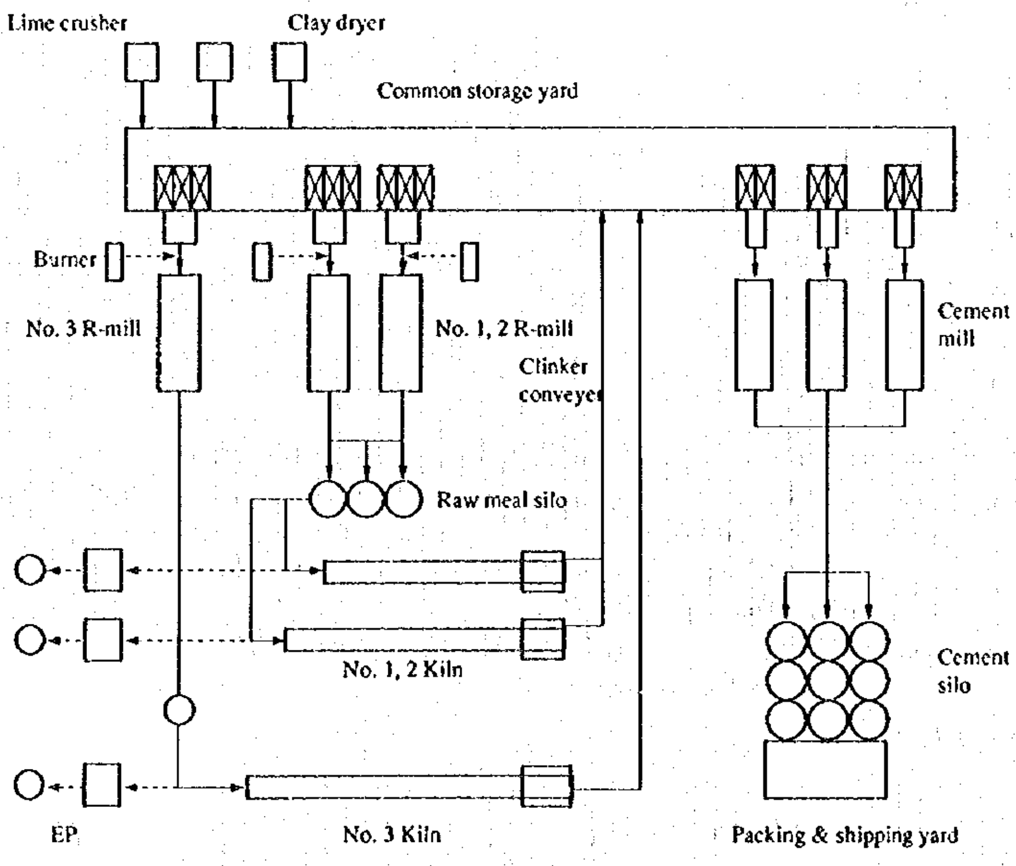
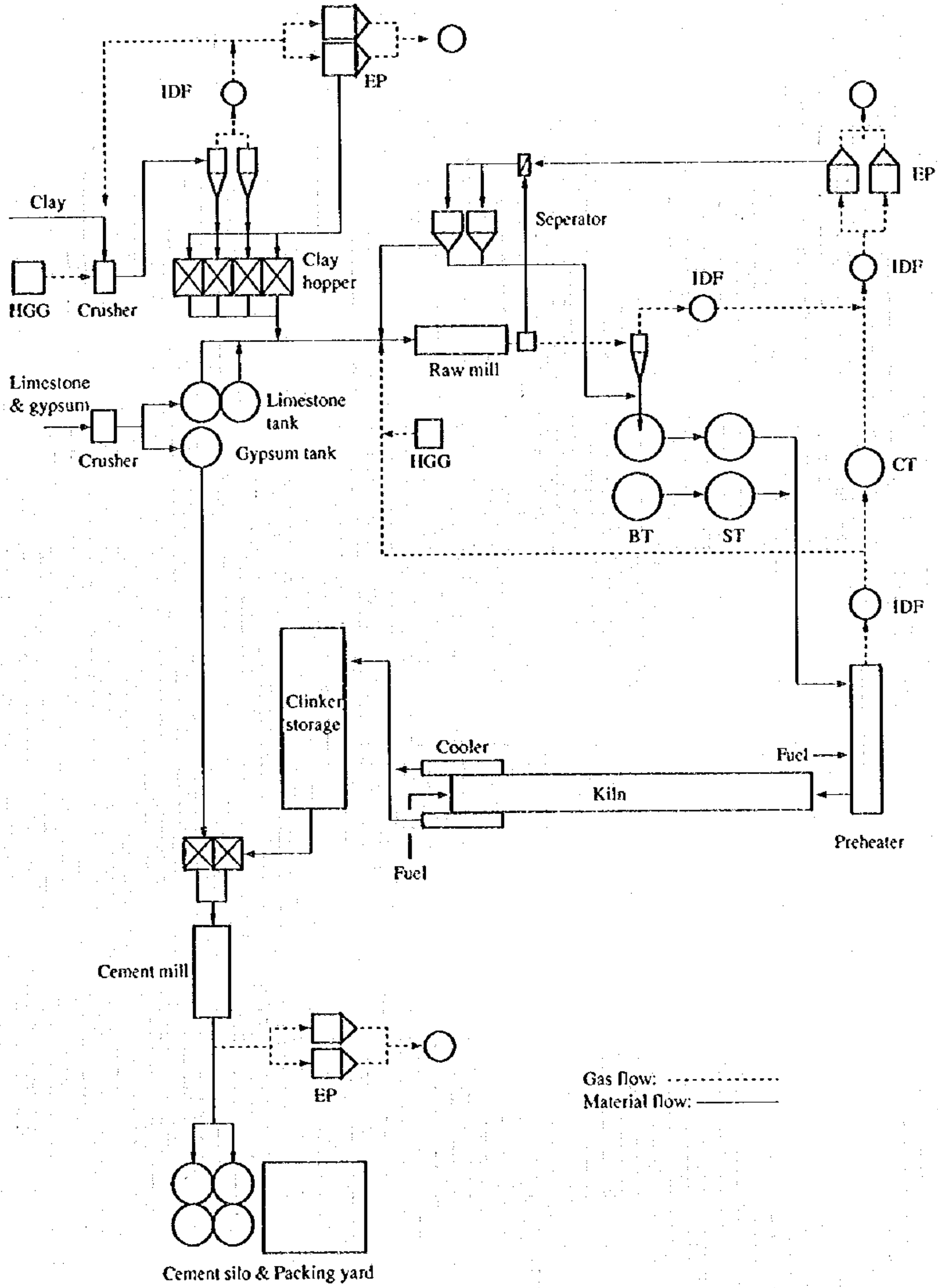


Figure 3.3.2 Process Flow of Unit 4



(7) History of the plant

The Soufian Cement Company was founded in 1967. Kiln No. 1 was completed in 1969 and has been operating from 1970. Subsequently, kilns No. 2 to No. 4 were built in 1971, 1978, and 1987 respectively. The present production capacity of this plant is 4,600 t/d and as a single plant it is the 4th largest in I.R. Iran. This plant is unique in I.R. Iran because it was planned for dry process right from the beginning and has continued to maintain a high rate of operation.

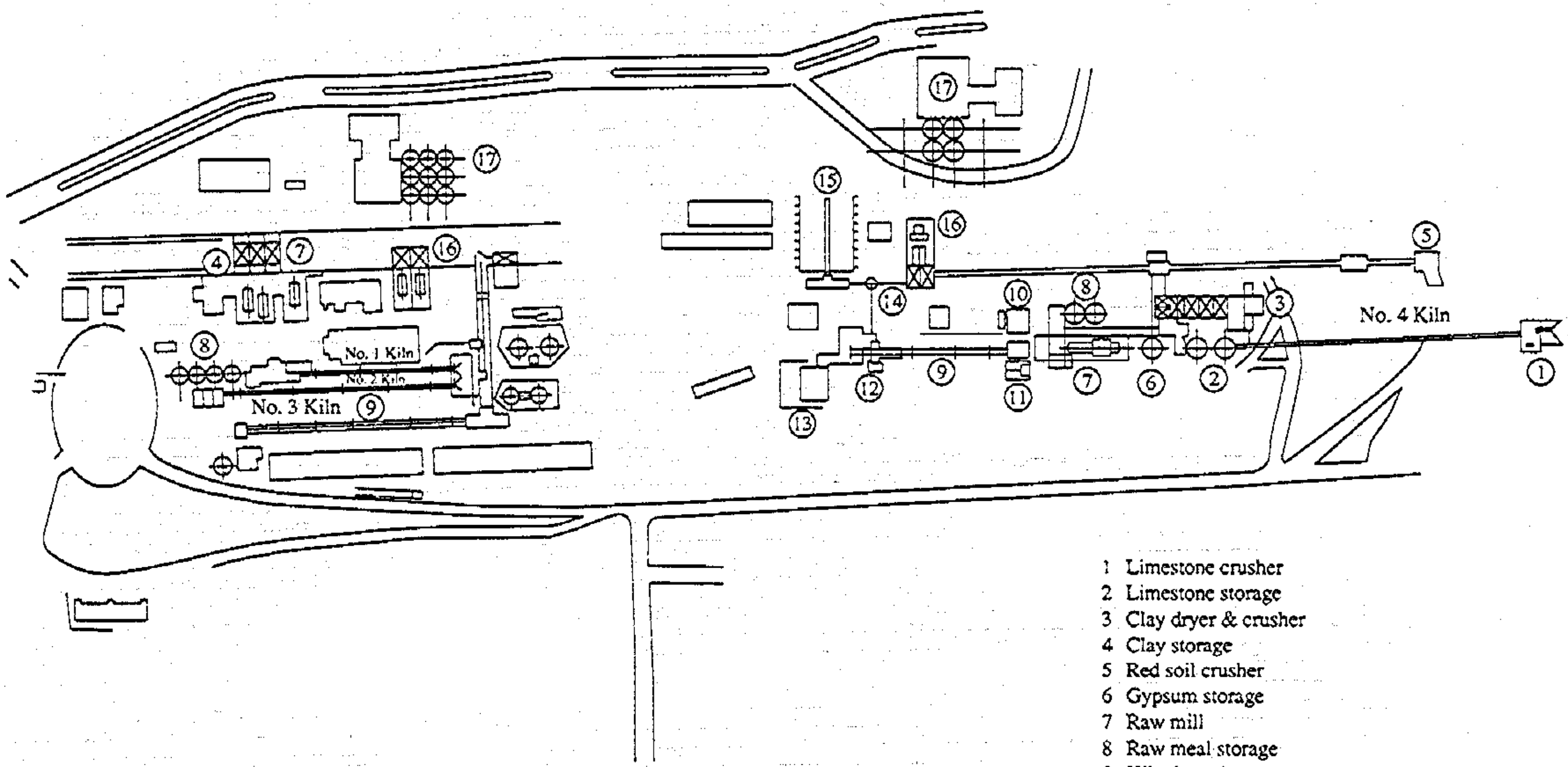
(8) Plant layout

As shown in Figure 3.3.3, the 3 long kilns and 1 SP kiln are completely separated. The independent old plant and a new plant have been constructed in the plant site. There may be some management-oriented inconveniences in such a layout. However, one can interpret this plant layout as an intention of the company to break away from the old and move on to a modern plant.

(9) Electric power one line diagram

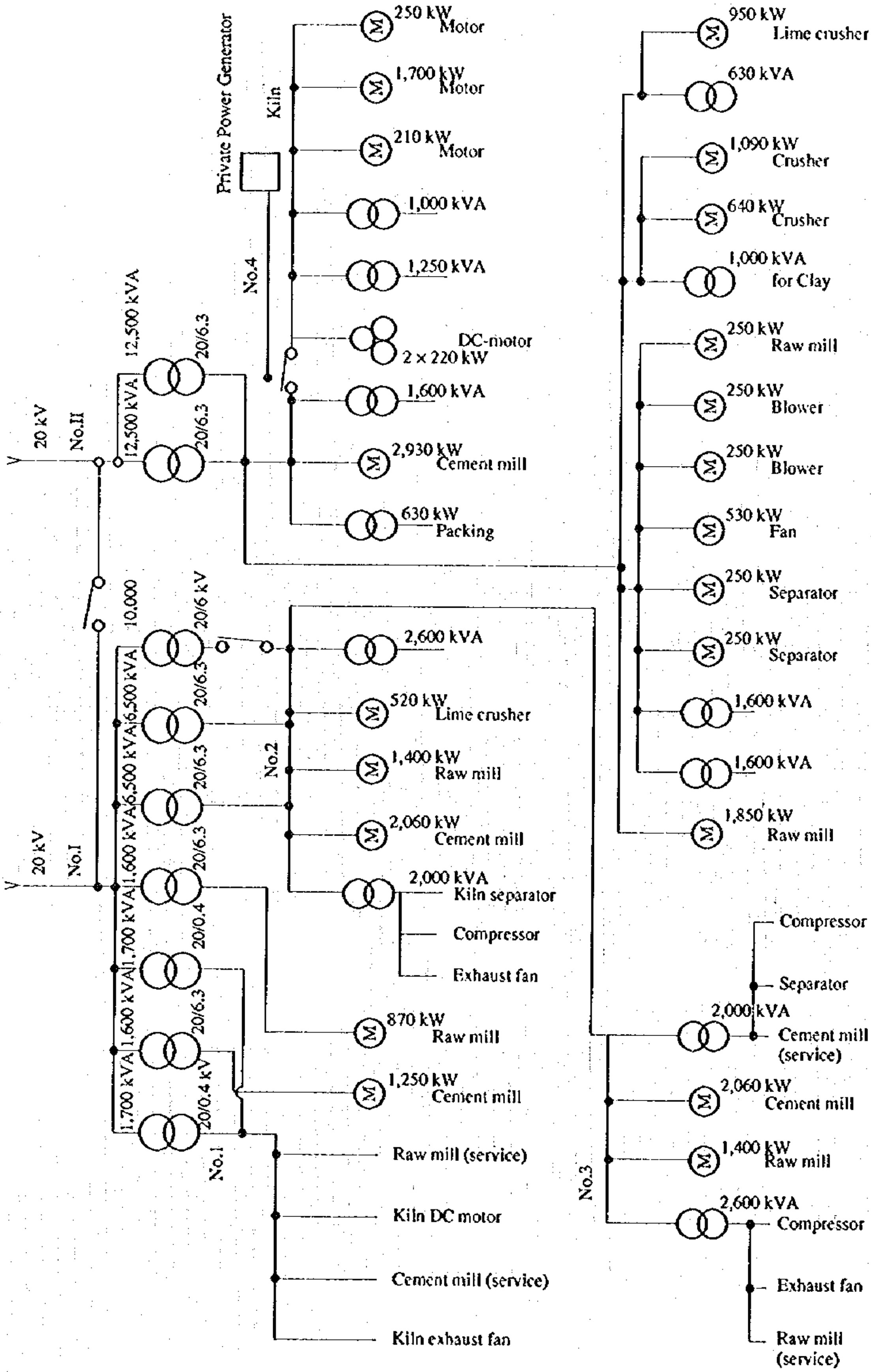
Figure 3.3.4 shows the electric power one line diagram.

Figure 3.3.3 Plant Layout



1 Limestone crusher
2 Limestone storage
3 Clay dryer & crusher
4 Clay storage
5 Red soil crusher
6 Gypsum storage
7 Raw mill
8 Raw meal storage
9 Kiln & cooler
10 EP for kiln
11 EP for by-pass
12 Burner floor
13 Central control room
14 Clinker conveyer
15 Clinker storage
16 Cement mill
17 Cement storage & packing plant

Figure 3.3.4 One Line Diagram



(10) Outline of main equipment

Table 3.3.1 gives the main equipment and facilities of each production line. The special characteristics of the equipment are as follows:

- All 4 kilns are dry process kilns.
- All clinker coolers are satellite coolers.
- The open circuit system is used throughout except in one cement mill.

Table 3.3.1 Major Equipment

Equipment	No.	Type	Dimension [m]	Capacity [t/h]	Motor [kW]	Supplier	Year in Service
Raw mill	1	Tube, Closed, 2c	7.0 × 3.2	60	870	F.L.S	1970
Raw mill	2	Tube, Closed, 2c	7.0 × 3.8	100	1400	F.L.S	1975
Raw mill	3	Tube, Closed, 2c	7.0 × 3.8	100	1400	F.L.S	1977
Raw mill	4	Tube, Closed, 1c	8.3 × 5.0	200	1850	F.L.S	1984
Rotary kiln	1	Dry long	120 × 3.95	600 (t/d)	170	F.L.S	1970
Rotary kiln	2	Dry long	162 × 4.75	1000 (t/d)	2 × 184	F.L.S	1975
Rotary kiln	3	Dry long	162 × 4.75	1000 (t/d)	2 × 184	F.L.S	1977
Rotary kiln	4	Dry SP 4 stage	80 × 5.00	2000 (t/d)	2 × 220	F.L.S	1984
(All are equipped with satellite cooler.)							
Cement mill	1	Tube, Closed, 3c	10.2 × 3.2	32	1250	F.L.S	1970
Cement mill	2	Tube, Open, 3c	11 × 3.66	60	2060	F.L.S	1975
Cement mill	3	Tube, Open, 3c	11 × 3.66	60	2060	F.L.S	1977
Cement mill	4	Tube, Open, 3c	13 × 4.40	116	2930	F.L.S	1984

Note: 2c: 2-chamber type
3c: 3-chamber type

(11) Energy prices

As of September 1995, we have obtained the following information.
Fuel Oil : 20 Rial/L
Electricity: Demand charge 3200 Rial/kW
Energy charge 50 Rial/kWh

(12) Study period

a. Preliminary study: September 26, 1995
b. Plenary study : July 20 to 24, 1996

(13) Members of the study group

a. JICA team

Team leader	: Mitsuo Iguchi (Preliminary study)
Leader	: Norio Fukushima
Process management technology	: Hisashi Ikeda
Heat management technology	: Katushiko Kaburagi
Heat management technology	: Masami Kato
Heat management technology	: Jiro Konishi (Preliminary study)
Electricity management technology	: Toshio Sugimoto
Energy policy	: Toru Kimura (Preliminary study)
Energy policy	: Shin-ya Udo (Preliminary study)
Database and energy utilization plan	: Kaoru Yamaguchi (Preliminary study)
Economic evaluation	: Shigeaki Kato (Preliminary study)

b. PBO team

Energy conservation	: Mr. Mazhari
Micro level energy management	: Mr. Mianji
Factory management	: Mr. Sajadifar
Micro level energy management	: Mr. Toofangchi (Preliminary study)
Electrical energy management	: Mr. Maboodi (Preliminary study)
Ministry of Industry	: Mr. Ali Mohamadzadeh (Preliminary study)

(14) Interviewees

Mr. Khosroshahi	: Managing Director
Mr. Khatibi	: Deputy of Factory Manager
Mr. Geitanchi	: Production Manager of New Units
Mr. Hamadanian	: Production Manager of Old Units
Mr. Mousavi	: Manager of Training (Preliminary study)
Mr. Ganbarian	: Head of Raw Material (Old Units)
Mr. Asgarnejad	: Head of Kiln (Old Units)
Mr. Dolatabadi	: Deputy of Production Manager (Old Units)
Mr. Jahangiri	: Process Engineer (Old Units)
Mr. Elliun	: Process Engineer, Deputy of Operating Manager (New Units)
Mr. Pourebrahimian	: Electrical Manager of New Units
Mr. Farniam	: Electrical Manager of Old Units
Mr. Behzadi	: Electrical Engineer
Mr. Saidnia	: (Preliminary study)

3.2.2 Situation of energy consumption

(1) Trend of production, energy consumption, and energy intensity

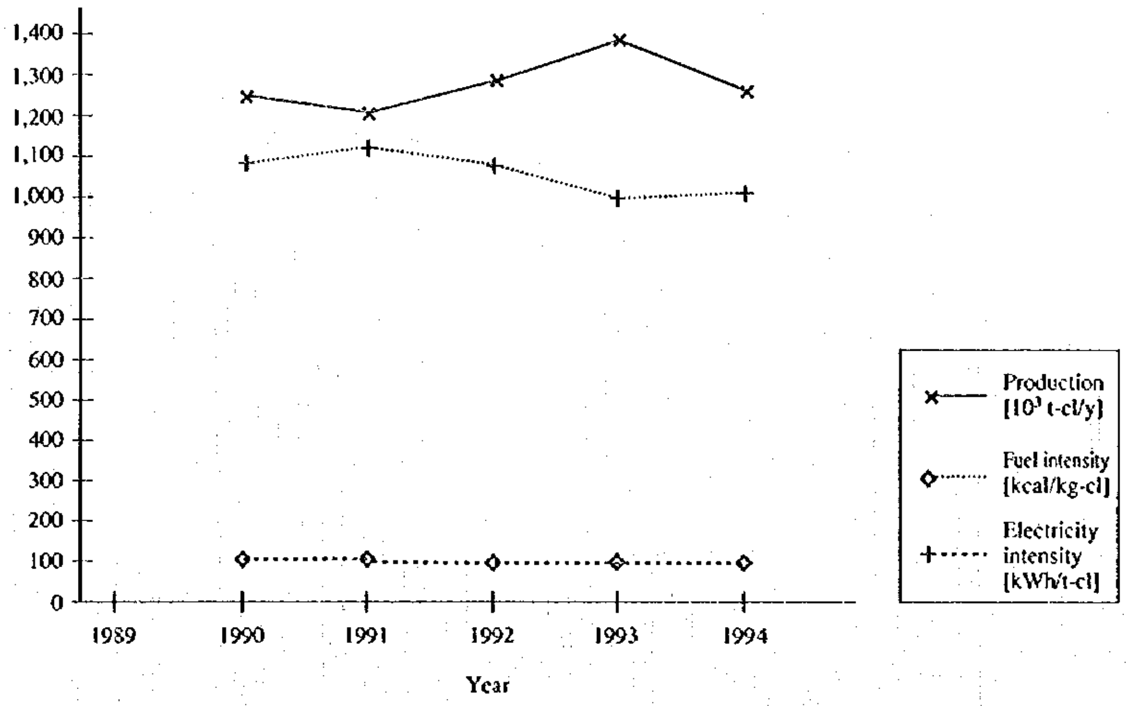
Table 3.3.2 and Figure 3.3.5 show the annual production, energy consumption, and energy intensity of the entire plant.

Table 3.3.2 Production, Energy Consumption and Energy Intensity

	Year	1989	1990	1991	1992	1993	1994
Production							
Clinker	t/y	n.a.	1,250,568	1,209,202	1,293,946	1,388,760	1,261,206
	h/y	n.a.	6,602.0	6,567.0	6,762.0	7,295.0	6,554.5
	t/h	n.a.	189.4	184.1	191.4	190.4	192.4
Cement	t/y	n.a.	1,313,839	1,255,736	1,329,551	1,403,147	1,337,944
	h/y	n.a.	5,599.5	5,504.0	5,168.0	5,593.5	5,243.5
	t/h	n.a.	234.6	228.1	257.3	250.9	255.2
Energy consumption							
Fuel oil	L/y	139,609,769	149,491,358	149,977,150	153,513,775	152,238,525	140,378,544
Natural gas	m³/y	0	0	0	0	0	0
Sub total	Gcal/y	1,270,449	1,360,371	1,364,792	1,396,975	1,385,371	1,277,445
	equivalent to kL/y	139,610	149,491	149,977	153,514	152,239	140,379
Electricity	kWh/y	119,492,400	136,184,282	130,956,202	135,037,079	143,966,822	129,922,024
Energy intensity							
Fuel	kcal/kg-cl		1,087.80	1,128.67	1,079.62	997.56	1,012.88
	kcal/kg-cem		1,035.42	1,086.85	1,050.71	987.33	954.78
Electricity	kWh/t-cl		108.90	108.30	104.36	103.67	103.01
	kWh/t-cem		103.65	104.29	101.57	102.60	97.11

HI value: Fuel oil 9,100 [kcal/L]
9,845 [kcal/kg]
Natural gas 10,000 [kcal/m³]

Figure 3.3.5 Production and Energy Intensity



The plant has maintained a stable and high clinker production for years. The nominal production capacity is 4,600 t/d and is 191.7 t/h calculated in terms of hourly production. The actual recorded value is around 190 t/h. In fiscal 1994, it was recorded as 192.4 t/h. The highest annual production was recorded in fiscal 1993 and was 1,388,760 t/y. The hours of operation this year were 7,295 h/y and 304 d/y calculated in terms of days. This is also an excellent record compared with other plants in I.R. Iran.

These achievements are regarded as a result of the efforts made at the plant. However, we cannot afford to overlook the fact that there is also a very competent design base. For example, the shell inner volume of kiln No. 3 is 2,870 m^3. If the production per inner volume is calculated in accordance with this data, it is 0.35 t/d.m^3. This value is lower than the 0.45 t/d.m^3 of a normal wet process kiln design base. Moreover, the exhaust gas of the kiln is discharged into the atmosphere without utilizing its heat as the raw material drying heat source. This design is such that the troubles of mill operation do not affect the kiln operation. Although these matters are favorable in improving the rate of kiln operation, they are disadvantages in the aspect of energy consumption.

(2) Energy intensity for each process

Table 3.3.3 and Table 3.3.4 summarizes the recent operation record for each process for kilns No. 2 and No. 4 as typical examples.

Figure 3.3.6 to Figure 3.3.9 show the monthly energy intensity and monthly production for kilns No. 2 and No. 4.

Table 3.3.3 Operation Record of Kiln No. 2

Year	Month	Raw Mill Department		Kiln Department				Cement Mill Department	
		Production [Raw tons]	Power Consumption [kWh]	Production [t-cl]	Fuel Consumption Oil [L]	Fuel Consumption Gas [m³]	Power Consumption [kWh]	Production [t-cem]	Power consumption [kWh]
1995	1	37,396	826,940	27,321	3,547,580	0	444,360	22,820	1,012,000
	2	30,519	750,820	13,346	1,886,933	0	230,115	22,817	972,900
	3	47,623	899,600	29,391	4,049,158	0	485,760	27,643	1,133,900
	4	39,427	736,980	27,051	3,435,352	0	434,010	25,807	1,104,000
	5	41,666	946,310	28,343	3,500,536	0	461,265	22,315	1,014,300
	6	49,093	920,360	27,449	3,585,879	0	458,160	33,052	1,278,800
	7	38,829	759,470	21,864	2,977,522	0	366,045	23,140	963,700
	8	41,861	878,840	30,084	3,745,606	0	478,515	24,704	906,200
	9	42,149	866,730	21,670	3,192,097	0	367,770	35,621	1,329,400
	10	24,248	525,920	24,248	3,041,700	0	390,885	27,901	1,120,100
	11	29,483	641,830	31,145	3,634,066	0	460,575	22,196	864,800
	12	40,765	918,630	29,239	3,950,041	0	430,215	34,474	1,382,300
1996	1	40,905	825,210	20,552	2,740,056	0	351,210	22,806	966,000
	2	36,870	775,040	28,142	3,530,797	0	438,150	28,053	975,200
	3	37,450	807,910	20,571	2,455,534	0	363,285	28,894	1,122,400
Total		578,284	12,080,590	380,416	49,272,857	0	6,160,320	402,243	16,146,000
Monthly average		38,552	805,373	25,361	3,284,857	0	410,688	26,816	1,076,400
Energy intensity		1.52	20.89	1.00	129.52	0.00	16.19	1.06	40.14
Total	Power	[kWh/t-cl]							90.39
		[kWh/t-cem]							85.49
		[kWh/t-ref]			(1.6R+Cl)+C:				88.09
	Fuel	[kcal/cl-kg]			[kcal/kg]	[kcal/m³]			
				[LHV]	9,845	-			1,154.02
				[kg/L]	0.905 at 94 °C				

Table 3.3.4 Operation Record of Kiln No. 4

Year	Month	Raw Mill Department		Kiln Department				Cement Mill Department	
		Productoin	Power Consumption	Production	Fuel Consumption		Power Consumption	Production	Power Consumption
		(Raw tons)	(kWh)	(t-cl)	Oil (L)	Gas (m^3)	(kWh)	(t-cem)	(kWh)
1995	1	87,512	1,188,537	46,171	4,741,679	0	1,380,303	46,573	1,658,429
	2	71,558	1,012,832	45,075	5,047,747	0	1,323,600	53,079	1,950,723
	3	75,651	1,040,430	45,910	4,822,156	0	1,305,397	49,181	1,972,067
	4	79,013	1,076,827	47,001	4,880,749	0	1,384,065	47,710	1,748,052
	5	90,058	1,264,289	55,515	5,423,013	0	1,635,958	62,043	1,215,022
	6	75,578	1,291,715	48,426	5,358,190	0	1,450,661	51,341	2,028,512
	7	87,386	1,509,600	52,177	5,792,695	0	1,549,050	46,706	1,861,400
	8	51,330	892,800	29,351	3,366,834	0	894,700	33,359	1,529,300
	9	74,331	1,310,400	45,869	5,333,224	0	1,359,300	52,397	2,177,100
	10	86,143	1,533,600	48,114	5,923,405	0	1,438,650	48,986	2,070,500
	11	37,252	679,200	21,940	2,493,573	0	646,300	41,446	1,697,400
	12	69,650	1,238,400	46,402	4,650,670	0	1,346,650	47,756	2,054,100
1996	1	86,790	1,408,800	47,420	4,223,100	0	1,361,600	45,301	1,972,100
	2	66,648	1,257,600	39,376	4,184,000	0	1,140,800	31,543	1,266,900
	3	63,712	1,149,600	41,822	5,312,156	0	1,225,900	39,611	1,709,700
Total		1,102,612	17,854,630	660,569	71,553,191	0	19,442,934	697,032	26,911,305
Monthly average		73,507	1,190,309	44,038	4,770,213		1,296,196	46,469	1,794,087
Energy intensity		1.67	16.19	1.00	108.32	0.00	29.43	1.06	38.61
Total	Power	(kWh/t-cl)							97.20
		(kWh/t-cem)							92.12
		(kWh/t-ref)			(1.6R+Cl)+C:				95.07
	Fuel	(kcal/kg-cl)			(kcal/kg)	(kcal/m^3)			
				(LHV)	9,845				965.11
				(kg/L)	0.905				

Figure 3.3.6 Monthly Production of Kiln No. 2

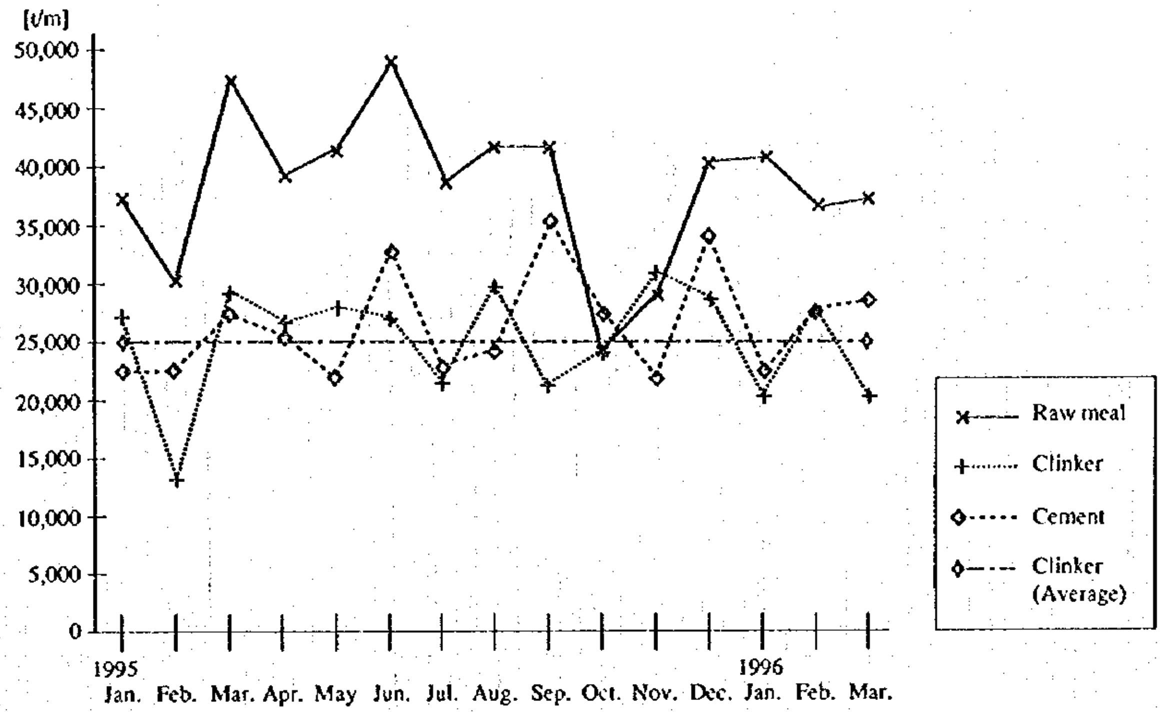


Figure 3.3.7 Monthly Energy Intensity of Kiln No. 2

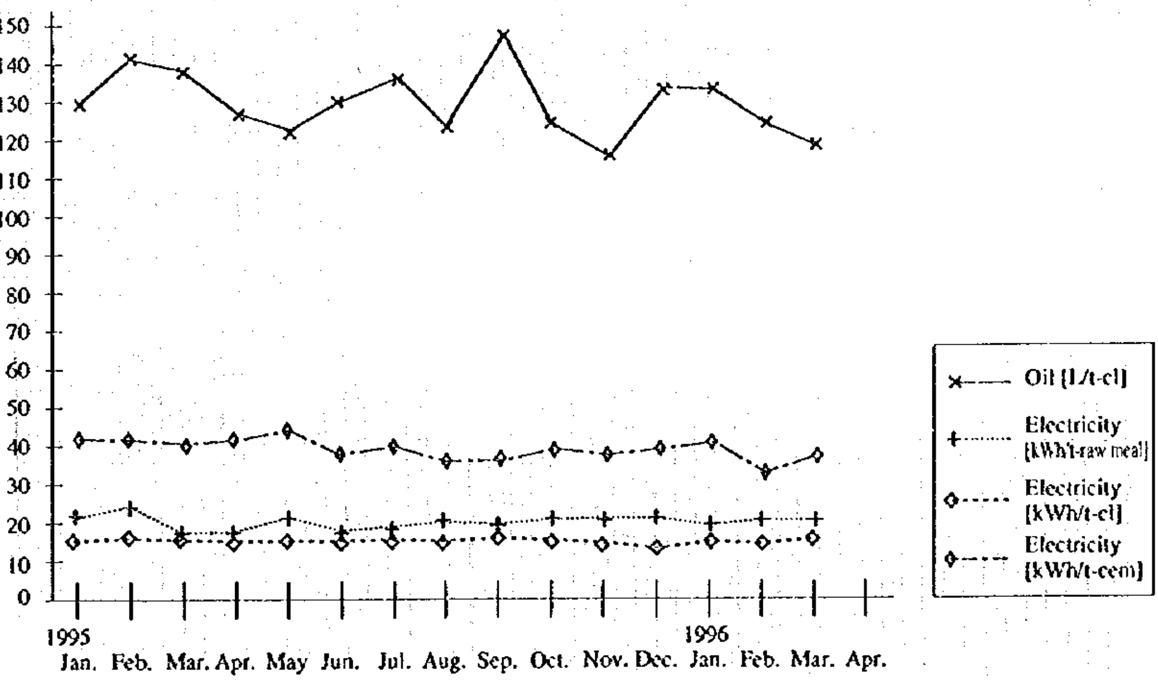


Figure 3.3.8 Monthly Production of Kiln No. 4

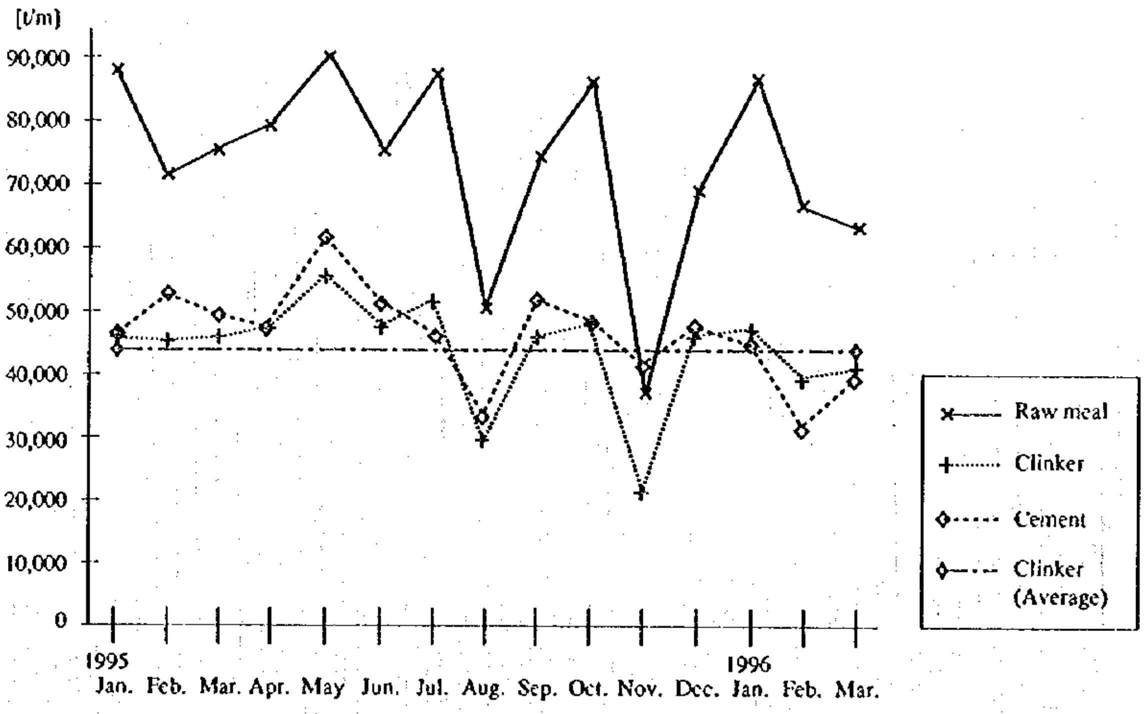
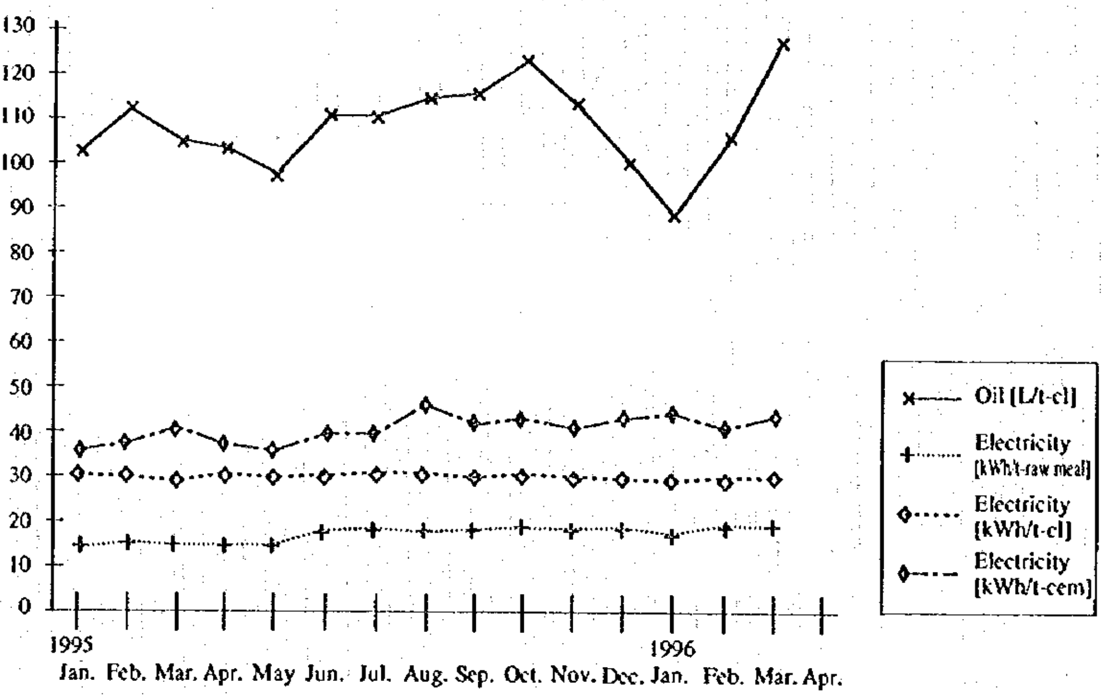


Figure 3.3.9 Monthly Energy Intensity of Kiln No. 4



The fluctuation of the production amount is high, depending on the month. The months in which the production dropped sharply show that there were periods in those months when operation was stopped for maintenance. If this maintenance is repeated periodically every 3 to 4 months and if the production achievement of other months reach the peak value, productivity will be improved further and the energy intensity will be lowered.

(3) Heat balance

Table 3.3.5 gives the heat balance calculated using the actual measured values and the indicated values of the operation measuring instrument on the date of the investigation.

Table 3.3.5 Heat Balance (No. 4 SP Rotary Kiln) (1/2)

1. Precondition

Item		Unit		Remarks
1.1	Raw meal			
	1) Charged raw material	t/h	145	
	2) Temperature	°C	100	
	3) Specific heat	kcal/kg·°C	0.20	
1.2	Clinker			
	1) Yield of material	t-cl/t-r	0.59	
	2) Dusting loss	%	5	
	3) Clinker output	t/h	81.48	145 × 0.59/1.05
	4) Temperature	°C	253	
	5) Heat for clinkering	kcal/kg-cl	430	
	6) Specific heat	kcal/kg·°C	0.192	
1.3	Fuel in kiln			
	1) Kind		Fuel oil	
	2) Low heat value	kcal/L	9,207	
	3) Temperature	°C	100	
	4) Consumption in kiln	L/h	7,500	
	5) Specific gravity	kg/L	0.905	
	6) Specific heat	kcal/kg·°C	0.45	
1.4	Fuel in preheater			
	1) Kind		Fuel oil	
	2) Low heat value	kcal/L	9,207	
	3) Temperature	°C	100	
	4) Consumption in preheater	L/h	1,020	
	5) Specific gravity	kg/L	0.905	
	6) Specific heat	kcal/kg·°C	0.45	
1.5	Exhaust gas at preheater outlet			
	1) Temperature	°C	320	
	2) O_2 content	%	2.1	
	3) Specific heat	kcal/m^3_N·°C	0.338	
	4) Specific gas volume by fuel oil	m^3_N/kg-cl	1.44	
	5) Specific gas volume by clinkering of materials	m^3_N/kg-cl	0.27	
1.6	Radiation loss from kiln surface			
	1) Average temperature	°C	272	
	2) Surface area	m^2	1,257	
	3) Convection coefficient	kcal/m^2·h·°C	11.3	
	4) Radiation coefficient	kcal/m^2·h·°C	15.3	
	5) Emissivity		0.95	
1.7	Radiation loss from cooler surface			
	1) Average temperature	°C	330	
	2) Surface area	m^2	1,150	
	3) Convection coefficient	kcal/m^2·h·°C	11.9	
	4) Radiation coefficient	kcal/m^2·h·°C	19.1	
	5) Emissivity	–	0.95	

Table 3.3.5 Heat Balance (No. 4 SP Rotary Kiln) (2/2)

2. Heat balance

Item	kcal/kg-cl	%	Remarks
Input heat Q1			
1) Qa : Heat of combustion of fuel	962.8	97.2	
2-1) Qb_1: Sensible heat of fuel	3.0	0.3	
2-2) Qb_2: Sensible heat of raw material	24.9	2.5	
Total	990.7	100.0	
Output heat Q2			
3) Qc : Heat for clinkering	430.0	43.4	JIS
4) Qd : Sensible heat of clinker at cooler outlet	42.8	4.3	
5) Qe : Sensible heat of preheater exhaust gas	167.6	16.9	
6) Qf : Radiation loss	219.6	22.2	
7) Qg : Other heat loss	130.6	13.2	
Total	990.7	100.00	

1) $(7{,}500 + 1{,}020) \times 9{,}207 / 145 / 0.59 \times 1.05 / 1{,}000 = 926.8$

2-1) $(7{,}500 + 1{,}020) / 145 / 0.59 \times 1.05 \times 0.905 \times 0.45 \times (100 - 30) / 1{,}000 = 3.0$

4) $0.192 \times (253 - 30) = 42.8$

5) $(1.44 + 0.27) \times 0.338 \times (320 - 30) = 167.6$

6) Cooler 125.1 + Kiln 94.5 = 219.6

3.3.3 Situation of energy management

(1) Setting the energy conservation target

The energy management committee has set up the following items as the targets of energy conservation:

- Operation of the equipment and facilities according to the designed capacity.
- Reduction of the downtime of equipment and facilities.
- Prevention of compressed air leakage.

The committee has not set up the intensity target values.

The plant does not have any plans for new equipment installation. They are planning the streamlining of management and energy conservation by fully utilizing and reinforcing the existing equipment and facilities.

The long kilns and SP kilns are running in parallel operations; therefore, efforts are required to maintain the constant rate of operation. It is advisable to collect data on each production line and on each process, determine the important points, set up targets for individual items, and follow up the results so that energy conservation can be pushed forward with.

(2) Systematic activities

An energy management committee has been set up and it meets twice a month. The chairman of the committee is Factory Manager of the plant, and committee members include Department Managers and personnel in charge of energy management. The committee has demonstrated its usefulness by introducing a data login system and setting up energy conservation targets.

(3) Data-based management

Computers are used to collect data for the purpose of operation and plant maintenance. In particular, adequate data management of power-receiving/distributing station is being carried out with data.

(4) Education of employees

A training center is set up in the plant. It is evident that the management has a high interest in education and training. Factory Manager of the plant gives a speech to the employees about energy conservation. The company encourages the engineers to participate in seminars held outside the company to improve the technology and uplift morale.

The company has introduced an achievement award system to improve productivity which also includes energy conservation.

The operators must thoroughly learn correct operation standards to achieve better production conditions and also for a stable product quality and improvement of the operation rate. This will lead to the improvement of energy conservation.

(5) Equipment maintenance

The equipment maintenance is not adequate enough.

A large amount of dust is scattered and piled on the passages. Construction for paving the passages in the plant site is being carried out at present. Such construction is effective for the improvement of the operation environment.

Since the monitoring of the motor temperature measurements and dust preventive measures of surroundings are unsatisfactory, there are many burnouts of motors.

The old and new equipment are used together in the plant and the current layout of the plant is not ideal. The conditions are making equipment maintenance difficult.

3.3.4 Problems and measures on energy use

(1) Comparison with an excellent factory

This plant aims at the modernization of equipment and facilities including the purpose of energy conservation. Among the 4 kilns, kilns No. 1 to No. 3 use the long dry process which requires high fuel consumption, and these are older models. Therefore, the decision for modernization is well-timed.

In the process, it will be prerequisite to solve several problems mainly in the raw material mixing for a new kiln No. 4 employing an SP system, master the smooth operation of modern equipment, and achieve the expected result.

The fuel intensity has been fluctuating around 1,100 kcal/kg-cl and is an unexpectedly good record. The reason for the good results, i.e. less than 1,000 kcal/kg-cl, obtained in 1993 is probably the high production. There is a slight doubt, however, about the reliability of this data.

As shown in Table 3.3.3, the recent average fuel intensity of kiln No. 2 is 1,154 kcal/kg-cl. The fuel consumption for raw material drying and boiler are not included in this value. A value of 30 to 50 kcal/kg-cl must be added to the above value. Therefore, actual value is presumed to be about 1,200 kcal/kg-cl.

As shown in Table 3.3.4, the average fuel intensity of kiln No. 4 is 965 kcal/kg-cl. This value is not good enough for a SP kiln of this scale. The monthly average production is 44,038 t/month. The number of monthly operation days, which is calculated by dividing the above production by the rated capacity of 2,000 t/d, is 22 d/month, and the number of annual operation days is 264 d/y. The average number of operation days of the entire plant is 304 d/y in 1993. Therefore, that of kiln No. 4 is considerably poor. If the rate of operation is improved, the fuel intensity should decrease also. In that case, it is very possible that the raw material blending system is not at peak performance, along with the structural problem of the kiln.

The electricity intensity has been fluctuating between 103 and 109 kWh/t-cl and a stable good result has been recorded. This result may be explained by the fact that the raw materials have excellent grindability and the structure of the long kiln is simple and its draft resistance is less.

The electricity intensity of No. 2 kiln is 90 kWh/t-cl, which is an excellent achievement. The electric power intensity of the kiln department has contributed to this excellent record. The electric power intensity of the kiln department is approximately 10 kWh/t-cl less than the normal level. This phenomenon may be also a feature of a long kiln.

The electricity intensity of No. 4 kiln is 97 kWh/t-cl, which is excellent for this type of a kiln. The low electricity consumption of the raw mill department is noticeable. The clay grinding and drying system of 1,090 kW was in a bad condition and was not operating. This misfortune might have actually contributed to the good result. If the raw materials can be crushed without trouble under this condition, there is no need to use the clay grinding drying system.

The electricity intensity of the cement mill department of No. 4 kiln is 38.6 kWh/t-cem. If the current Blaine value of 2,700 cm^2/g is increased to the normal quality standard which is 3,050 cm^2/g, the electricity consumption will increase by 4 to 5 kWh/t-cem. If the clinker quality improves, however, mixing components such as pozzolan can be used in the future, and the profit can be increased by expansion of sales. Therefore, there will be no loss.

Compared with an excellent factory, the fuel intensity, 1,098 kcal/kg-cl is higher by approximately 37 %, of which 28 % is caused by the use of a dry long system, 5 % is caused by the type of clinker cooler and the remaining 4 % is caused by operation factors such as combustion control, air leakage, etc.

Although electricity intensity is nearly close to the level of the excellent factory, there is some difference in the grindability of raw material and the Blaine value of the product cement, which may possibly cause the electricity intensity to increase in the future.

The following 4 items are suggested for improvement of energy intensity.

Items (2) and (3) among the 4 suggestions given below are problems related to the improvement of supplementary equipment. Item (4) is related to the change of process. Item (5) can be carried out as a part of the daily management tasks. These suggestions can be carried out on an individual basis. However, it is desirable to implement them as a series of projects in order to get maximum effect out of the investment. Item (5) offers improvement measures which can be carried out any time, and a couple of actual examples of these measures are given.

(2) Kiln No. 4 cooler modification

In kiln No. 4, damages were detected at several locations on the body from the sintering zone to the connection portion with the satellite cooler. The body of the cooler is considerably deformed. These damages must have been made because of the temporary excessive heat load.

The heat load was probably reduced and the problem moderated by adopting Pyroclone system which is a combustion system in addtion to kiln burner. However, this measure has caused a large difference between the volume of air introduced into the cooler for cooling the clinker and the volume of air used by fuel combustion, which is having an adverse affect on both heat efficiency and product. Regarding the damaged portions, major repairs including replacement may be required in order to continue the high efficiency operation for a long period. It is recommended, for the purpose of gas balance, that the cooler should be replaced with a grate cooler suitable for the SP kiln instead of replacing kiln shell if the above repairs are carried out. Also, it is sensible to carry out this replacement as early as possible for economical reasons.

The main unit of the kiln is of the same size as kiln No. 4 (present capacity 2,100 t/d) of the Tehran Cement Company. The difference between the kilns of the two companies is that the cyclone of the pre-heater of this company is a 1 line system. The production capacity, however, is the same. Therefore, if the satellite cooler is replaced with the grate cooler to improve the heat efficiency, it is highly possible that the production capacity in this case can increase up to 3,000 t/d. The heat intensity will be reduced from 965 kcal/kg-cl to 800 kcal/kg-cl. The grate cooler can be installed while continuing operation by temporarily relocating the clinker transportation facility.

Fortunately, the grindability of the raw material is excellent. Also, the existing mill has already been capable of producing 200 t/h. Therefore, it is not necessary to install another new raw material mill. The cement mill should adopt the pre-grinding system by a roller mill (different from a roll press) so that it can reinforce the capacity and improve efficiency at the same time.

It seems that the plant has been considering the modification, and at the same time that this modification will involve replacement of the coolers and conversion of the system to NSP. However, adding the pre-heater with calciner to the existing pre-heater which has different characteristics will make the operation more difficult because of problems such as coating troubles. Since the risk is too big, we cannot recommend this plan. For the time being it is advisable to stick to the cooler replacement alone, and to design another method for improving the production capacity. The improvement of the raw material blending system is the premise for increase of kiln production.

(3) Improvement of raw material blending system

The selection of a clay dryer and the design of the clay storage facility to be used after the drying process were not appropriate in view of the physical properties of the clay. These are the reasons why the raw material blending system of kiln No. 4 was unsuccessful. The "clay" (as it is commonly known) which was originally planned for use is a cohesion of fine particles, and the physical properties of the clay will be radically changed depending on the amount of moisture content. The existing facility is not suitable for such raw materials. It will be rather easier to dry the clay with a rotary dryer, store it in the open yard, and reclaim it from the surface.

Although a new rotary dryer may be purchased, kiln No. 1 can be temporarily used or the remaining portion of the kiln shell acquired when kiln No. 3 is modified (to be discussed in the next item) can be used. The plant can obtain a good storage facility for dried materials by diverting the common storage yard of the old production line or clinker yard of kiln No. 4. It is advisable to construct a new silo to prevent the dust scattering in the clinker yard. Moreover, a smooth raw material blending operation will be possible by modifying the clay tank, now in an idle state, into a dedicated blending hopper that does not produce flushing at minimum storage level. If improvements such as these are carried out in advance, the pre-blending system using the ore bedding yard, currently being planned by the plant, will be able to produce good results.

The improvement of the raw material blending system is a requisite for stable operation of the kiln and improvement of product quality. However, the energy conservation effect cannot be assessed by this improvement itself. It is assumed that the expenditure and effect are included in item (2) or (4).

(4) Modification of kiln No. 3

The diameter of kiln No. 3 is 4.7 m, and the length is 162 m. Kiln No.3 can be converted into an NSP kiln by reducing the length to 80 m and installing a suspension pre-heater with a calciner and a grate cooler. The remaining kiln shell can be used as the rotary dryer of the clay. The dust collector, raw material mill, and blending silo must be newly installed. An existing mill and raw material mill can be diverted to the cement mill, and a new roller mill can be installed as the pre-grinding system.

If the above modifications are carried out, kiln No. 3 will become a powerful kiln and will be able to achieve a production capacity of 3,000 t/d or more. Its fuel intensity will be 800 kcal/kg-cl and the electric power intensity will be 100 kWh/t-cl. This kiln alone can exceed the total production capacity of 2,600 t/d of the existing 3 long kilns. It is recommended that the space adjacent to kiln No. 4 should be selected as the installation site to fully utilize the investment made until now and to make the future management tasks easier.

(5) Present improvement items

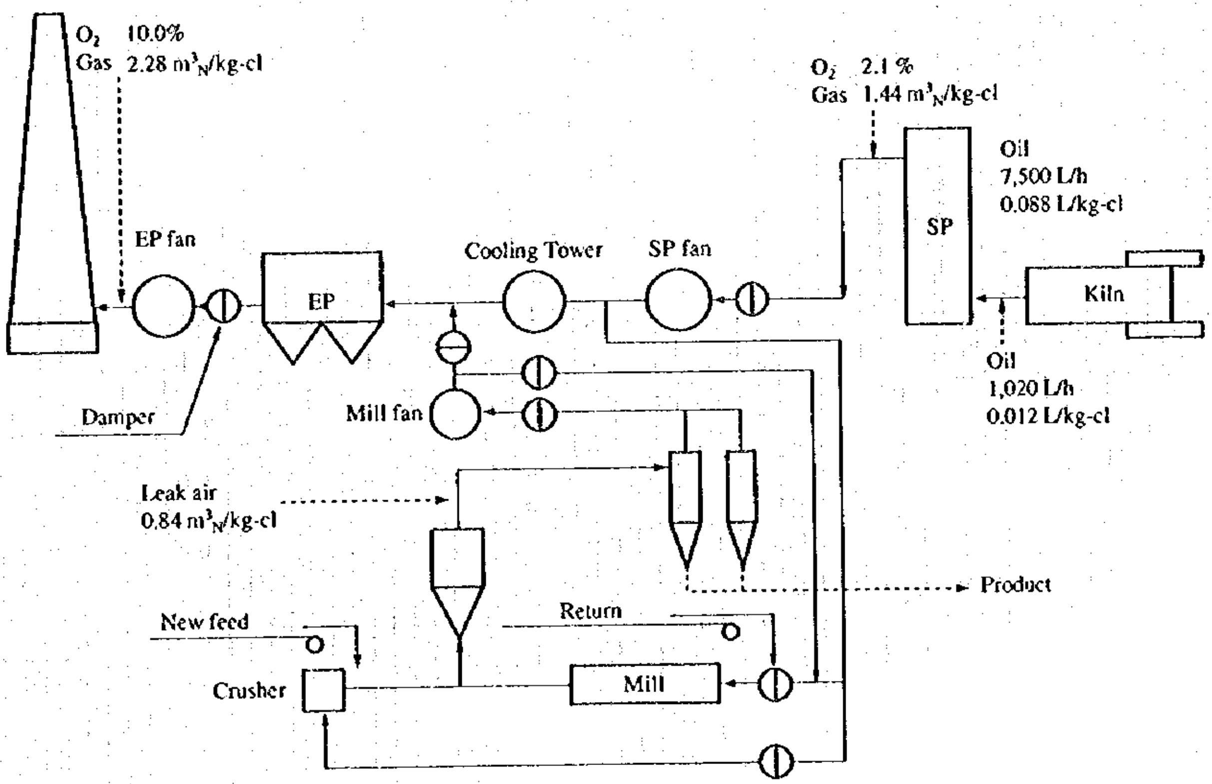
a. Prevention of air leakage

The plant premises are extremely dusty. This condition is connected to the frequent trouble occurrences of the large-size motors. The first step of preventive maintenance is the prevention of dust generation. If there is an imperfect sealed location in a part of the process, dust is blown out each time when the system starts and stops, and leakage air is taken in during normal operation. This can lower the efficiency of the dust collector or cause power loss. Since the leakage air locations and volume can be detected by measuring the exhaust gas temperature and oxygen content at various points during operation, measures should be provided each time leakage air is detected.

As a result of actual measurement of kiln No. 4, the oxygen content in the exhaust gas was found to be 2.1 % at the pre-heater outlet. This oxygen content increased to 10.0 % at the EP outlet. It is obvious that the large amount of leakage air is coming in from the raw material mill section. In that case, the leakage air preventive measures can directly influence the operation of the kiln.

Figure 3.3.10 shows the gas flow.

Figure 3.3.10 Gas Flow



b. Improvement of kiln burner combustibility

When we checked, the main burner of kiln No. 4 lacked flame brightness and the burning speed of fuel was slow. It appeared that a long flame was being formed. In a case such as this, the temperature of the sintering zone may be too low. It is recommended that the blowing out speed of air at the tip of the burner nozzle should be compared with other kilns after confirming the specifications of the primary air fan and burner. If it is determined that the air flow is sufficient, the combustion condition should improve by adjusting the speed of the swirling flow. When the temperature of the flame rises, the heat transmission efficiency will improve. Furthermore, the production will increase, the exhaust gas temperature at the kiln outlet will become lower, and the product quality will improve. If the plant has intentionally set the temperature to low as a preventive measure for the sintering zone and clinker cooler, it amounts to a reversal of the logical order of priority.

c. Increasing the EP fan capacity

The draft capacity of the entire process of No. 4 kiln can be reinforced on a proportional basis by increasing the EP fan rotation speed 5 to 10 % and providing the above air leakage preventive measures. As the EP fan rotation speed increases, the air flow from the satellite cooler will increase and the damages in the periphery of the cooler inlet will be reduced. In addition, it will become possible to control the static pressure of the pre-heater outlet constant. Therefore, the kiln can maintain a high level operating condition with less load fluctuation. It is recommended that this measure should be executed together with the improvement measure suggested in Items a and b above.

d. Utilizing the kiln exhaust gas

If a header for receiving the exhaust gas of each kiln is constructed in a suitable site near the raw material mill chamber of the old system, the operation of the hot air generator used for drying the raw material will no longer be required, and the dust collector efficiency will improve along with energy conservation. For kiln No. 3, there is a possibility of the investment being doubled. Therefore, the implementation of this suggestion should be decided by taking future plans for the plant into consideration.

(6) Effects of improvements

The operation method of the plant will be significantly changed by the improvements suggested in (2), (3), and (4) above. Production that was achieved by the 4 kilns can be consolidated into 2 kilns i.e. No.3 and No. 4 as far as the normal operation is concerned, and the following effects will be gained.

Table 3.3.6 Rationalization of Production

Kiln No.	Existing Production [t/d]	Existing Intensity [kcal/kg-cl]	Existing Consumption [Mcal/300ds]	After Modification Production [t/d]	After Modification Intensity [kcal/kg-cl]	After Modification Consumption [Mcal/300ds]
1	600	1,200	216,000,000	600	1,200	216,000,000
2	1,000	1,200	360,000,000			
3	1,000	1,200	360,000,000	3,000	800	720,000,000
4	2,000	965	579,000,000	3,000	800	720,000,000
Total	4,600	Average 1,098	1,515,000,000	6,600	Average 836	1,656,000,000
					[kL/y]	[Mcal/y]
Saving based on the original capacity:					39,650	360,818,182

(alternative)

Kiln No.	Existing Production [t/d]	Existing Intensity [kcal/kg-cl]	Existing Consumption [Mcal/300ds]	After Modification Production [t/d]	After Modification Intensity [kcal/kg-cl]	After Modification Consumption [Mcal/300ds]
1	600	1,200	216,000,000	0	1,200	0
2	1,000	1,200	360,000,000			
3	1,000	1,200	360,000,000	2,300	800	552,000,000
4	2,000	965	579,000,000	2,300	800	552,000,000
Total	4,600	Average 1,098	1,515,000,000	4,600	Average 800	1,104,000,000
					[kL/y]	[Mcal/y]
Saving based on the original capacity:					45,165	411,000,000

a. Increase of clinker production

After the modifications of kilns No. 3 and No. 4, the production capacity will increase to 2,000 t/d even though kiln No. 2 is shut down. Supposing the marginal income is 2,000 yen/t, an annual profit increase of 1,200,000,000 yen/y (2,000 t/d × 300 d/y × 2,000 yen/t) will be possible. Since the use of a pozzolan will become possible and the sales route will be expanded by resolving the raw material mixing problem (a big obstacle at present) and by improving the product quality, the actual profit increase will be even higher than the above figure.

The scope of manufacturing a higher value-added product will be gained by kiln No. 1. This profit can be added to the above figure.

b. Reduction of fuel intensity

The fuel intensity of kiln No. 3 will be reduced from 1,200 kcal/kg-cl to 800 kcal/kg-cl or less by modifying the current long kiln into an NSP kiln. The annual fuel consumption will be cut down by 312 Tcal/y {(1,200 – 800) kcal/kg-cl × 2,600 t/d × 300} based on the production capacity of the previous kilns No. 1, No.2. and No.3 (2,600 t/d). This figure is 34,300 kl/y (312 × Tcal/y / 9,100 kcal/L) calculated in terms of fuel oil.

If the existing satellite cooler of kiln No. 4 is replaced with a grate cooler, the reduction of fuel intensity will be 165 kcal/kg-cl (965 -800 kcal/kg-cl). Therefore, it will be a reduction of 10,880 kL/y (165 kcal/kg-cl × 2,000 t/d × 300 / 9,100 kcal/L) calculated in terms of fuel oil and based on the previous production capacity (2,000 t/d).
Total reduction of the fuel intensity of these kilns will be 45,180 kL/y.
The profit gained will be approximately ¥ 768,400,000 per annum (17,000 yen/kL × 45,180 kL/y) if the unit price of fuel oil is assumed to be 17,000 yen/kL.

c. Reduction of electric power consumption

A long kiln is a type which consumes less electric power among various kiln types. The existing kiln in particular discharges the kiln exhaust gas into the atmosphere without making use of it, and thus it can achieve low electricity intensity as mentioned earlier. Therefore, it is extremely difficult to reduce the electricity intensity any further. If kiln No. 3 is modified into an NSP kiln, the electricity consumption of kiln department will increase.

If the raw mill department of kiln No. 4 starts using clay as a substitute for red soil which is harder to grind, the electricity intensity will be reduced. On the other hand, the electricity intensity of the kiln department will increase by the replacement of a cooler. The cement mill department can avoid the increase of electricity intensity even if the degree of product fineness improves by adopting the pre-blending system using the roller mill.

It is difficult to offer up a detailed evaluation for each matter at this point. In this report, we assume that the increased amount of electricity intensity will be offset by the improvement effect and therefore the intensity will be neither increase nor decrease.

d. Improvement effect by employing measures for the time being

It is assumed that the improvement measure described in Item (5) will be carried out separately before the improvement measures of the other 3 items are performed. The effect of Item (5) cannot be assessed together with the other effects. However, the effort made to achieve these improvements is necessary to a better understanding of the characteristics of the SP kiln or NSP kiln in order to prepare for the future.

If kiln No. 4 can achieve stable operation and if the number of annual average operation days of the plant improves to 304 d/y, one can expect an annual production increase of at least 80,000 t/y based on the daily production of 2,000 t/d, due to the increase of 40 operation days. The fuel intensity will be also improved to 900 kcal/kg-cl level from the current record of 965 kcal/kg-cl. It is quite possible that 4,340 kL/y of fuel oil (65 kcal/kg-cl × 2,000 t/d × 304 d/y / 9,100 kcal/L) can be reduced annually. An annual profit increase expected from these improvements will be 234,000,000 yen/y (2,000 yen/t × 80,000 t/y + 17,000 yen/kL × 4,340 kL/y), and supposing the marginal income is 2,000 yen/t, the unit price of fuel oil is assumed to be 17,000 yen/kL. The investment amount is presumed to be less than ¥ 100,000,000. Therefore, the above improvement can be carried out regardless of the schedule of the radical measures suggested in the other 3 items.

(7) Electric equipment

a. Measurement results

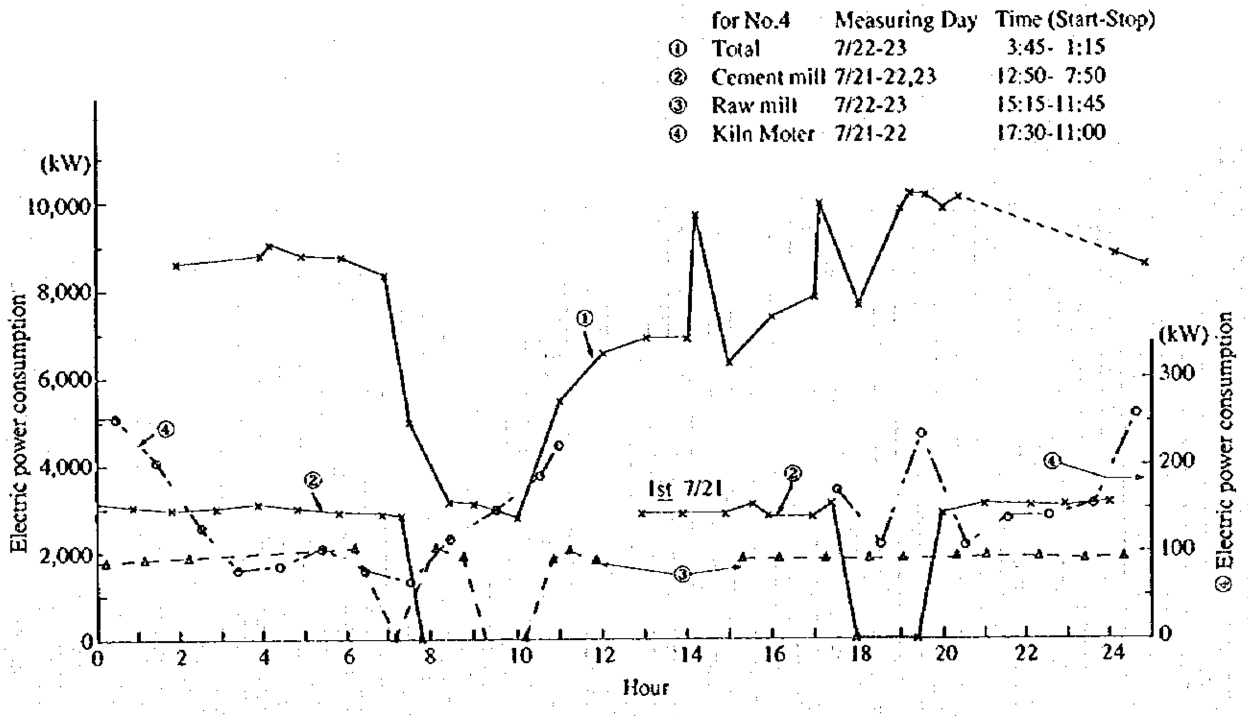
Table 3.3.7 and Figure 3.3.11 show the results of measurement of the transformer input and load of large-size equipment. Since the measured values were fluctuating and the measurement time was different, the values are often different from that of the power supply.

Table 3.3.7 Electricity Consumption of Each Equipment

Process	No. 1			No. 2, No. 3		
Load	Rating kW	Electric Power kW	Cosϕ %	Rating kW	Electric Power kW	Cosϕ %
Crusher				520	124	71
Raw mill	870	888	99	1,400	1,284	92
Raw mill				1,400(for No. 3)	1,074	79
Transformer	1,700 kVA	513	67	2,600	393	83
Transformer				2,000(for No. 3)	306	95
Raw mill Total		1,401			3,181	
Cement mill	1,250	1,153	96	2,060	2,007	94
Cement mill				2,060(for No. 3)	2,038	92
Transformer	1,700 kVA	599	69	2,000kVA	728	89
Transformer				2,600(for No. 3)	309	69
Cement mill Total		1,752			5,082	
Process Total		3,153			8,263	

	Process No. 4			Total
Load	Rating kW	Electric Power kW	Cosϕ %	
Crusher				
Raw mill	2,060	1,930	96	
Blower	2 × 250	174	94	
Fan	530	327	86	
Separater	2 × 250	288	82	
Separater	250	120	68	
Transformer	2 × 1,600 kVA	396	89	
Raw mill Total		3,115		7,697
Fan	250	209	80	
Exhaust	1,700	1,120		
Transformer	1,000	234	48	
Transformer	1,250	167	70	
Kiln drive	2 × 220	289	64	
Cement mill	2,930	2,990		
Transformer	1,600 kVA	243	91	
Transformer packing	630			
Cement mill Total		5,252		12,086
Process Total		8,367		19,783

Figure 3.3.11 Operation Record of Electric Power Consumption



b. Study of the measurement results

1) 3-phase unbalance

As a result of continuous recording measurement, the electricity consumption of the No. 4 cement mill motor (2,930 kW) during operation fluctuated between 2,820 and 3,060 kW. The current of each phase was continuously off balance, such as 370 A, 294 A, and 367 A.

This condition will lead to overheating of the motor and reduction of torque, and it is assumed that the loss is increasing. Although the actual cause is uncertain, factors such as an unbalanced motor secondary side impedance and bias of radiation heat because of dust can be taken into account since there is only a slight voltage fluctuation. It is recommended that the related locations should be checked and the matter should be taken up with the equipment manufacturer.

2) Reduction of electricity intensity and electricity charges

The electricity consumption between April 1995 and March 1996 for kiln No. 2 was 27,629 MWh. The ratio of the usage amount for raw mill, kiln, and cement mill were 35 %:18 %:45 %, respectively.

On the other hand, the consumption for kiln No. 4 was 51,126 MWh. The ratio of usage amount for the raw mill, kiln, and cement mill were 28 %:30 %:42 %, respectively.

The electricity intensity of kiln No. 2 and No. 4 was 87 kWh/t and 96 kWh/t, respectively.

The demand charge is about 18.9 % of the entire charge where the electric charges in July to September 1995 was 38.3 Rial/kWh. As this company is conducting a study, it is necessary to provide improvement measures as follows to prepare for future price revisions.

- Improvement of load factor
- Reduction of demand charges
- Reduction of load during peak time
- Increase of load at night

(8) Summary of proposals

Table 3.3.8 summarizes the above proposals.

The following effects can be expected by the improvement measures of kiln No. 4.

Clinker production increase : 80,000 t/y

Reduction of fuel consumption: 4,300 kL/y

The investment amount of 94,500,000 yen can be recovered within 1 year by an annual profit increase of 233,000,000 yen.

Besides the above, the following effects can be expected by the modification of kilns No. 3 and No. 4 and associated improvements.

Consolidation of production lines: Establishing a production system using 2 kilns (or 3 kilns).

Clinker production increase : Max. 2,000 t/d

Reduction of fuel consumption: 45,200 kL/y

The investment amount of ¥ 7,050,000,000 can be recovered within 4 years by an annual profit increase of ¥ 1,967,800,000.

Table 3.3.8 Summary of Proposals

(Japanese Yen base)

Item	Expected Saving						Total	Investment	Payback
	Fuel			Electricity			Million	Million	Period
	kL/y	Million yen/y	%	MWh/y	Million yen/y	%	yen/y	yen	Year
Tentative:improvement of operation	4,343*1	73.8	2.6*8		–		73.8	95	0.4
		160.0*4					160.0		
No. 3 Kiln:modification to NSP	34,286*2	583.9	20.6*9		–		583.9	5,720	3.2
		1,200.0*5					1,200.0		
No. 4 Kiln:replacement of cooler	6,593*3	112.1	4.0*10		–		112.1	1,323	1.9
		600.0*6					600.0		
No. 2 Kiln:shut down		-600.0*7					-600.0		
Total	45,222	2,129.8	27.2*11		–		2,129.8	7,138	3.4

(Iran Rial base)

Item	Expected Saving						Total	Investment	Payback
	Fuel			Electricity			Million	Million	Period
	F.oil kL/y	Million Rial/y	%	MWh/y	Million Rial/y	%	Rial/y	Rial	Year
Tentative:improvement of operation	4,343*1	326	2.6*8		–		326	1,663	0.5
		2,800*4					2,800		
No. 3 Kiln:modification to NSP	34,286*2	2,571	20.6*9		–		2,571	100,100	4.2
		21,000*5					21,000		
No. 4 Kiln:replacement of cooler	6,593*3	494	4.0*10		–		494	23,153	2.1
		10,500*6					10,500		
No. 2 Kiln:shut down		-10,500*7					-10,500		
Total	45,222	27,191	27.2*11		–		27,191	124,916	4.6

*1 $\frac{(965 - 900)\ \text{kcal/kg-cl} \times 2{,}000\ \text{t/d} \times 304\ \text{d/y}}{9{,}100\ \text{kcal/L}} = 4{,}343\ \text{kL/y}$

*2 $\frac{(1{,}200 - 800)\ \text{kcal/kg-cl} \times (1{,}000 + 1{,}000 + 600)\ \text{t/d} \times 300\ \text{d/y}}{9{,}100\ \text{kcal/L}} = 34{,}286\ \text{kL/y}$

*3 $\frac{(900 - 800)\ \text{kcal/kg-cl} \times 2{,}000\ \text{t/d} \times 300\ \text{d/y}}{9{,}100\ \text{kcal/L}} = 6{,}593\ \text{kL/y}$

*4 Merit by production increase : 2,000 t/d × 40 d/y × 2,000 yen/y = 160 Million yen/y
*5 Merit by production increase : (3,000 – 1,000) t/d × 300 d/y × 2,000 yen/y = 1,200 Million yen/y
*6 Merit by production increase : (3,000 – 2,000) t/d × 300 d/y × 2,000 yen/y = 600 Million yen/y
*7 Demerit by production decrease: –1,000 t/d × 300 d/y × 2,000 yen/y = –600 Million yen/y
*8 Annual fuel consumption: 1,515,000 Gcal/y / 9.1 Mcal/kL = 166,484 kL/y
4,343 / 166,484 × 100 = 2.6
*9 34,286 / 166,484 × 100 = 20.6
*10 6,593 / 166,484 × 100 = 4.0
*11 45,222 / 166,484 × 100 = 27.2

Energy price in Japan:
Fuel oil price: 17,000 yen/kL
Electricity price: 10 yen/kWh
Energy price on Iran Rial base:
Fuel oil: 75 Rial/L
Electricity: 100 Rial/kWh
Exchange rate: 1,750 Rial = 1 US Dollar = 100 Japanese Yen
Calorific value of fuel: Oil: 9,000 kcal/kL
Investment cost is based on that in Japan.