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PRELIMINARY ENERGY AUDIT REPORT
FOR
LA CEMENTO NACIONAL C.A.
GUAYAQUIL, ECUADOR

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FOREWORD

This audit report is part of an Industrial Energy Conservation Program undertaken by the Institute Nacional de Energia (INE), with the cooperation of La Escuela Superior Politecnica del Litoral (ESPOL).

This multi-phase program was launched by INE in association with the U.S. Agency for International Development in 1984. The program includes, in these initial stages, extensive training of young engineers in the basics of energy management principles and practices, including on-site training in energy audit techniques.

The major objective of Phase I is to develop the energy auditing skills necessary to be able to implement a nationwide program of industrial energy conservation.

This report details the findings of a preliminary energy audit conducted at La Cemento Nacional C.A. during September 1984. The plant was selected to participate in the training program based on its suitability for auditing, relevance to the Ecuadorian industrial sector, and the willingness of the plant management to open the plant to the training program.

The energy-consuming systems examined during the audit are common to many industrial plants. It is envisioned that similar audit evaluations can be conducted in other industrial facilities in Ecuador, resulting in major conservation savings.

ACKNOWLEDGEMENTS

The energy audit detailed in this report was performed under a program sponsored jointly by the following organizations:

Instituto Nacional de Energia, Quito, Ecuador

La Escuela Superior Politecnica del Litoral, Guayaquil, Ecuador

The Bureau for Science and Technology, U.S. Agency for International Development, Washington, DC

U.S. AID Mission to Ecuador, Quito, Ecuador

Technical assistance was provided by consultants from Hagler, Bailly & Company, Washington, DC and Reliance Energy Services, New York, New York.

We would like to express our appreciation to the management of La Cemento Nacional C.A. for allowing their plant to be used for training purposes.

The Cerro Blanco plant of La Cemento Nacional C.A. is situated 18 km from Guayaquil and has a design capacity of 1 million tonnes of clinker per year, using the dry production process. The plant is relatively new (1978) and well-managed, and is operating at a level of 900,000 tonnes per year with employment of 400. Limestone is quarried and crushed on the premises. The plant produces mainly type I portland cement, with some type II portland and oil well cements as well. Production of a pozzolan-modified portland cement is currently being studied.

Maintenance is a key function in the plant, and is staffed by 120 persons. The standard of housekeeping and maintenance is very high.

Capital expenditures policy takes a long-term view, and considers intangible benefits as well as financial criteria. Process technology is continually updated, and capacity was doubled in 1981 with the addition of a second production line. The plant benefits from the technology of the Swiss Holderbank Group, who share ownership of the company with the state.

Although Cerro Blanco has no formal energy management program, energy efficiency has improved steadily as a result of an effective cost control program supported by capital expenditures. Planned projects indicate that the practice of improving process technology, plant services, and environmental protection will continue, with concurrent benefits for energy efficiency.

The plant's total energy bill is S/56 million per month, which is 33.5 percent of production cost. This relatively low cost share compared to international values is due to the low local energy prices. (Residual oil costs S/13 per gallon, and the marginal cost of electricity is S/1.26 per kWh.)

Energy consumption in 1982 was 94.1 thousand tonnes of residual oil, 1.6 thousand tonnes of diesel oil and 115,380 MWh of electricity. Residual oil is used primarily to fire the two kilns, while the major consumers of electricity are the four ball mills. Diesel oil is used by mining equipment, and for firing the fuel oil preheaters.

Energy-related instrumentation includes an electrical demand recorder, extensive submetering of electrical consumption in branch circuits, and metering of residual oil consumption for each kiln. Specific consumption of fuel is calculated monthly, and averaged 997 kcal/kg clinker (Line 1) and 822 kcal/kg clinker (Line 2) January-August 1984. Both are below the international index of 1,010 kcal/kg. Specific consumption of electricity is in line with the international index of 113 kWh/tonne cement.

In view of the satisfactory level of specific energy consumption, the newness of the facilities, the high standard of maintenance, and planned projects to improve energy efficiency, a detailed energy audit is not recommended. Nevertheless, there appear to be low-cost opportunities to reduce lighting and air conditioning energy consumption and to reduce maximum electrical demand through load shedding and rescheduling of operations.

Also, a formal energy management program is needed at the Cerro Blanco plant to achieve maximum energy efficiency, particularly in view of expected fuel price increases.

Background

La Cemento Nacional is the largest of the four cement companies operating in Ecuador, with an installed capacity of .35 million tonnes of clinker per year (two plants). Company ownership is shared between the state and the Holderbank Group (Switzerland). The company operates two cement plants, "Cerro Blanco" and "San Eduardo," located about 18 km from Guayaquil. Cerro Blanco, which began operation in 1978, is the newer of the two.

The Cerro Blanco plant has a design production capacity of 1 million tonnes of clinker per year, divided equally between two lines that began operation in 1978 and 1981, respectively. A plot plan of the installations is shown in Exhibit 2.a. The plant uses the dry process in which blending and grinding of raw materials are carried out without addition of water.

Current employment is 400, of which 120 are maintenance personnel.

Limestone is quarried on the plant premises, while red clay and sand are trucked in from sources within 150 km of the plant. Gypsum is imported from Mexico. The moisture content of the raw material mix entering the pyroprocessing stage (at the preheaters) is 0.9 percent.

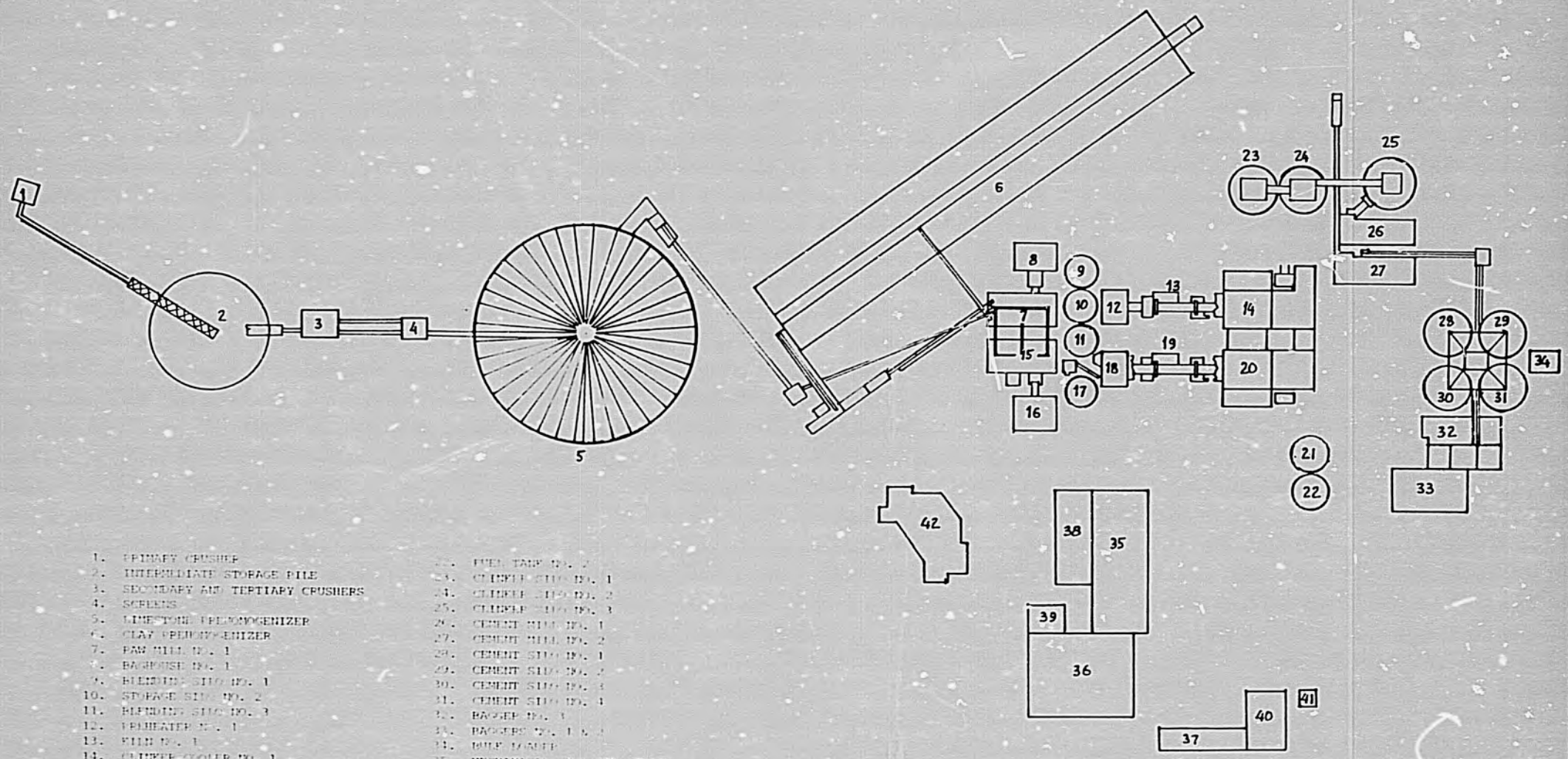
Key data concerning production, fuels, electrical power, and energy consumption are shown in Exhibit 2.b. Since 1983 was not a typical year, data are shown for 1982 as well. Unusually heavy rainfall during the first 7 months of 1983 disrupted production significantly by increasing raw material moisture content to abnormal levels. (See environmental data in Chapter 3.)

Despite lower production in 1983, which would normally entail lower energy efficiency, Exhibit 2.b indicates that specific consumption of residual oil declined 2 percent in that year. This was due to continual actions to improve process technology.

Organization

The Cerro Blanco plant organization is outlined in Exhibit 2.c. The fact that the maintenance department is one of the three departments reporting to the plant manager, with 30 percent of the total employment, indicates the great emphasis placed on this function.

Exhibit 2.a
Plot Plan of the Cerro Blanco Plant
La Cemento Nacional C.A.



1. PRIMARY CRUSHER
2. INTERMEDIATE STORAGE PILE
3. SECONDARY AND TERTIARY CRUSHERS
4. SCREENS
5. LIMESTONE PREHOMOGENIZER
6. CLAY PREHOMOGENIZER
7. RAW MILL NO. 1
8. BAGHOUSE NO. 1
9. BLENDING SILO NO. 1
10. STORAGE SILO NO. 2
11. BLENDING SILO NO. 3
12. PREHEATER NO. 1
13. KILN NO. 1
14. CLINKER COOLER NO. 1
15. RAW MILL NO. 2
16. BAGHOUSE NO.
17. BLENDING SILO NO. 4
18. PREHEATER NO. 2
19. KILN NO. 2
20. CLINKER COOLER NO. 2
21. FUEL TANK NO. 1
22. FUEL TANK NO. 2
23. CLINKER SILO NO. 1
24. CLINKER SILO NO. 2
25. CLINKER SILO NO. 3
26. CEMENT MILL NO. 1
27. CEMENT MILL NO. 2
28. CEMENT SILO NO. 1
29. CEMENT SILO NO. 2
30. CEMENT SILO NO. 3
31. CEMENT SILO NO. 4
32. BAGGER NO. 1
33. BAGGERS NO. 1 & 2
34. BULK LOADER
35. MECHANICAL SHOP AND STORES
36. VEHICLE SHOP
37. [illegible]
38. OFFICE
39. OFFICE
40. [illegible]
41. [illegible]
42. CANTEEN

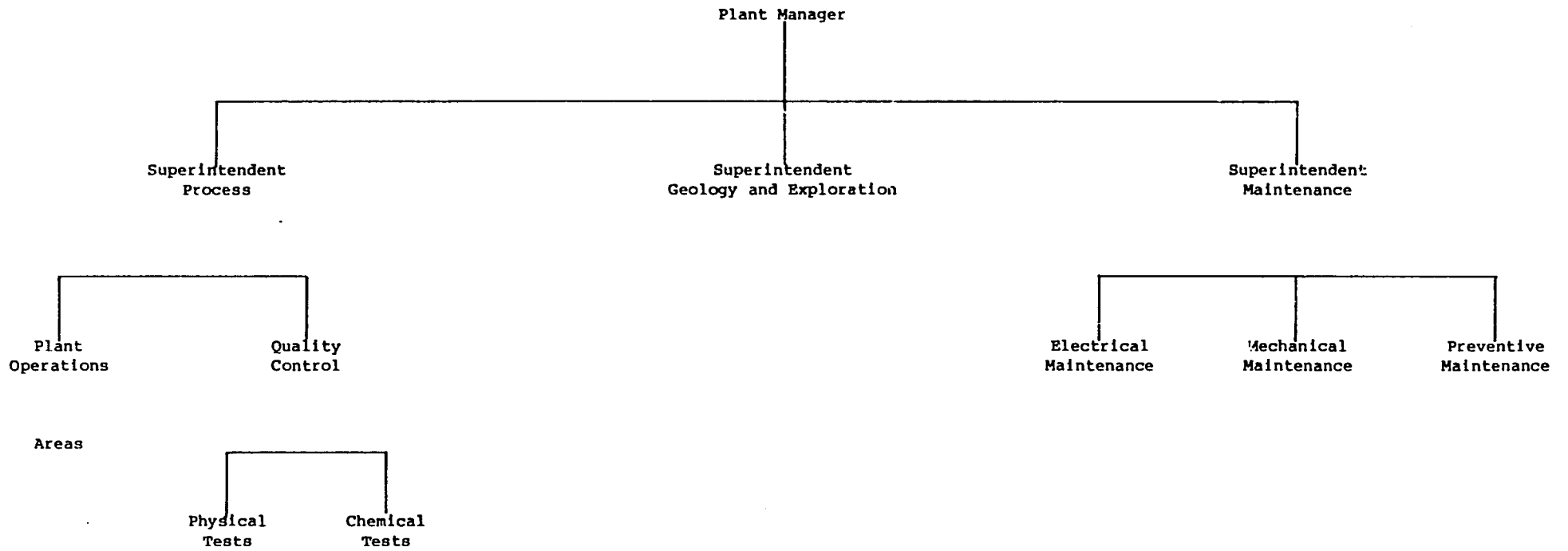
Exhibit 2.b

Energy Profile: Cerro Blanco Plant
La Cemento Nacional C.A.

	1982	1983
Clinker production, tonnes/year	947,902	835,806
Cement production, tonnes/year	1,142,717	904,912
Energy consumption:		
Residual oil, tonnes/year	94,071	78,983
GJ/year	3,856,911	3,238,303
Diesel oil, tonnes/year	1,647	1,608
GJ/year	69,668	68,018
Electricity, MWh/year	115,380	109,152
Specific energy consumption (residual oil):		
Line 1, kcal/kg clinker	978	963
Line 2, kcal/kg clinker	862	845
Electrical power system:		
Grid voltage (Empresa Electrica del Ecuador)	69,000V	
In-plant systems:		
AC motors: 200-4,200 hp	4,160V	
AC motors: large motors to 200 hp	480V	
General service	110V/220V	
DC compound motors: 250-1,250 hp	500V/550V DC	
(DC power supply: thyristor banks)		
Stand-by diesel-electric plant	1,037 kW	
Power factor (July 1984)	0.87	

Exhibit 2.c

La Cemento Nacional C.A.:
Cerro Blanco Plant Organization



SOURCE: La Cemento Nacional, C.A.

There is no formal energy management organization in the plant.

Financial Data

Financial data for the company were not available.

Project Evaluation Criteria

The management of La Cemento Nacional takes a long-term view in evaluating projects. Generally, a payback period within 3 to 5 years, and a 20 percent return on investment are desired; however, intangible aspects that cannot be measured are taken into account. Financial criteria are not applied to necessity projects (safety, environmental, etc.).

Product Information

The product program consists of type I and type II portland cements, and type 6 oil well cement. 1983 production was 96 percent type I and 4 percent type II. No oil well cement was produced in that year.

The company is considering the addition of a pozzolan-modified portland cement to the product line. The product would make use of a pozzolan overburden in the plant's quarry, where this material is currently discarded The pozzolan would replace some clinker content, thereby conserving energy.

Existing and Future Plans

Most planned projects are at the system component level, and will provide equipment to (1) replace old or inefficient equipment, (2) improve reliability of operation, (3) reduce air pollution, (4) improve process control, or (5) improve clay moisture content and homogenity. Further details of the projects are given in Chapter 3 under "Energy Management Organization."

Most of the projects envisioned will improve energy efficiency, including the use of pozzolan to replace a portion of energy-intensive clinker.

There are no major expansion plans at this time. Cerro Blanco will continue to operate as near to full capacity as possible, and production will be supplemented by the nearby San Eduardo plant, which will adjust production to meet variations in market demand.

Energy Management Organization

There is no formal energy management program at La Cemento Nacional; nevertheless, energy efficiency has improved steadily over the years as a result of the plant's overall cost control program:

Specific Energy Consumption

	1979	1982	1983	8 months 1984
Residual oil kcal/ kg clinker:				
Line 1	981	978	963	997
Line 2	--	862	845	822
Electricity kWh/tonne cement:	125	118	131*	113 (est)

*Due to extraordinary rainfall.

SOURCE: J. Jasiewicz and La Cemento Nacional, C.A.

Energy efficiency will be improved further by several planned projects:

- Improvement of red clay drying and homogenization
- Replacement of pneumatic conveyor system to raw feed silo, with a bucket conveyor system
- Centralization of compressed air production and improved distribution system
- Replacement of old air conditioning water chiller
- More precise measurement of kiln temperature through NO_x analysis
- Centralized electronic information and automatic control system for overall process control of Line 1

- Electrostatic filters on clinker cooler stacks for dust recovery
- Capacitors to improve power factor to 1.0
- Production of pozzolan-modified portland cement.

ENERGY CONSUMPTION AND COSTS

The plant's primary source of energy is residual oil, followed by electricity and diesel oil, as follows (1983 data):

	Annual consumption		
Energy source	GJ	%	Major consumer
Residual oil	3,234,613	87.5	Kilns
Diesel oil	68,018	1.9	Mining vehicles
Electricity	392,947	10.6	Raw and cement mills
Total	**3,695,578**	**100.0**	

Residual oil consumption declined from 94,071 tonnes in 1982 (a record production year) to 78,983 tonnes in 1983. Consumption of electricity decreased from 115,380 MWh to 109,152 MWh over the same period. These changes in consumption reflect an 11.8 percent reduction in clinker production from 1982 to 1983. Details of energy consumption and costs are presented in Exhibits 3.a (1982) and 3.b (1983).

Energy costs are currently approximately S/56 million per month, or 33.5 percent of production costs.

Fuels and Energy Rate Analysis

In July 1984, the price of residual oil was S/13 per gallon, and the price of diesel oil was S/17 per gallon.

The average cost of electricity (July 1984) was S/2.7989 per kWh, and the marginal cost was S/1.2614 per kWh. The bill calculation takes into account:

- kWh consumed
- Power factor

Exhibit 3.a

Energy Consumption and Costs (Year 1982)
Cerro Blanco Plant

	Residual oil	Diesel oil	Electricity	Total
Consumption, tonnes	94,071	1,647		
Consumption, gallons	26,130,878	494,179		
Consumption, MWh			115,380	
Consumption, GJ	3,856,911	69,668	415,368	4,341,947
Cost, sucres				
Unit cost, sucres/gallon				
Average unit cost, sucres/kWh				
Marginal unit cost, sucres/kWh				
Average unit cost, sucres/GJ				
Marginal unit cost, sucres/GJ				
Maximum demand, kW				
Power factor				

SOURCE: La Cemento Nacional, C.A.

Exhibit 3.b

Energy Consumption and Costs (Year 1983)
Cerro Blanco Plant

	Residual oil	Diesel oil	Electricity	Total
Consumption, tonnes	78,983	1,608		
Consumption, gallons	21,939,738	482,543		
Consumption, MWh			109,152	
Consumption, GJ	3,238,303	68,018	392,947	3,695,578
Cost, sucres				
Unit cost, sucres/gallon				
Average unit cost, sucres/kWh				
Marginal unit cost, sucres/kWh				
Average unit cost, sucres/GJ				
Marginal unit cost, sucres/GJ				
Maximum demand, kW				
Power factor				

SOURCE: La Cemento Nacional, C.A.

- Maximum demand in peak period (6:00 p.m.-9:00 p.m.)
- Maximum demand relative to maximum demand over the prior 12-month period.

Billing is on the basis of industrial tariff I-4, which applies to users with a connected load greater than 5,000 kW.

The consumption tariff comprises three blocks as follows:

a. kW demand x 200 hours x S/2.3825
b. kW demand x 200 hours x S/2.1873
c. (kWh consumption - (maximum demand x 400 hours)) x S/1.1467.

In addition, a rural electrification surcharge of 10 percent is levied, as well as a S/30 surcharge for fire protection.

The rates are programmed to increase automatically 2 percent per month.

Prior to 1984, there was no power factor penalty. Effective January 1, 1984, the utility (Empresa De Electricidad del Ecuador) established a power factor target of 0.9, above which a penalty is imposed in the proportion (0.9/power factor) x total bill. In 1985, the target will increase to 0.95. In response to this development, La Cemento Nacional will install capacitors to increase the plant's power factor to a level of 1.0 within 2 years.

Exhibit 3.c illustrates the calculation of the plant's electricity bill.

Production Data

In 1982, production of clinker and cement reached record levels of 947,902 tons and 1,142,717 tons, respectively. Following a significant decline in 1983, owing to production problems caused by heavy rains, production has now recovered to 1982 levels (near capacity). Historical data on production and hours worked are presented in Exhibit 3.d.

While the plant as a whole operates 24 hours per day, 7 days per week, the crushing and packaging/shipping departments operate on a different schedule. The following table summarizes the plant's operating schedule:

Exhibit 3.c

Electricity Bill Calculation
Cerro Blanco Plant

Basic Data and Factors

DM = maximum demand = 19,440 kW.

DM_{6-9} = maximum demand 6 p.m.-9 p.m. = 19, 440 kW.

Consumption = 9,072,000 kWh.

Fc = time of day factor = (DM_{6-9}/DM) = 1.0.

D 0.7 $DM_{12\ months}$ = no adjustment of demand.

F_p = power factor = 0.87.

Power factor penalty = $((0.9/F_p)-1)$ = ((0.9/0.87) - 1) = 0.03448 (applied to total bill).

Calculation

(a) DM x S/157.4437 x Fc
(b) + DM x 200 hrs x S/2.3825
(c) + DM x 200 hrs x S/2.1873
(d) + (consumption - DM x 400 hrs) x S/1.1467
Subtotal
(e) + 10 percent rural electrification surcharge
Subtotal
(f) + fire protection fee S/30
(g) + power factor penalty
Total

(a)	19,440 kW x S/157.4437 x 1.0 =	S/3,060,706
(b)	19,440 kW x 200 hours x S/2.3825 =	9,263,160
(c)	19,440 kW x 200 hours x S/2.1873 =	8,504,222
(d)	(9,072,000 kWh - 19,440 x 400) x S/1.1467 =	1,486,123
	Subtotal	S/22,314,211
(e)	0.10 x S/22,314,205 =	2,231,421
	Subtotal	S/24,545,632
(f)		30
(g)	0.034482758 x S/24,545,655 =	846,402
	Total	S/25,392,064

SOURCE: La Cemento Nacional, C.A. and Empresa de Electricidad del Ecuador.

Exhibit 3.d

Production and Hours Worked
Cerro Blanco Plant

Period	Clinker (tons)	Cement (tons)	Hours worked	
			Kiln 1	Kiln 2
1979	429,368	447,258	6,939	--
1980				--
1981				
1982	947,902	1,142,717	7,272	6,312
1983	835,806	904,912	7,416	6,672
January	81,538	69,101	560	714
February	74,482	47,298	571	635
March	60,039	84,432	352	574
April	65,169	65,359	605	437
May	70,208	77,678	448	643
June	77,311	84,619	520	681
July	29,987	36,425	285	210
August	74,604	95,274	630	569
September	67,117	80,493	513	543
October	74,238	90,581	569	510
November	77,033	78,357	525	570
December	85,080	97,238	738	595
1984*	598,948	687,705	4,503	4,798
January	52,295	75,727	493	374
February	70,983	81,405	518	478
March	87,197	82,489	723	730
April	78,203	79,742	635	641
May	85,542	101,427	619	683
June	55,829	80,449	480	589
July	70,884	90,566	504	569
August	87,015	95,900	531	734

*For period January-August.

SOURCE: Jasiewicz and La Cemento Nacional, C.A.

	Shifts/day	Days/week
Primary crushing	2*	5
Secondary crushing	3*	5
Raw reed production	3	7
Clinker production	3	7
Cement production	3	7
Packaging & shipping	1	5*

*Variable.

Environmental Data

Rainfall affects production in that it increases the moisture content of raw materials. The moisture content of clay has reached 35 percent at times, which prevented its use in Line 1 owing to material handling problems. Environmental data for the years 1980-1983 are shown in pages 3.9-3.12. The heavy rainfall in 1983 (4.1 meters) disrupted production seriously.

Process Description

The Cerro Blanco plant uses a dry manufacturing process, comprising the following steps:

- Crushing of limestone and clay
- Drying, homogenization, mixing, and grinding of raw materials
- Clinker production
- Mixing and grinding of cement
- Packaging and shipping.

Following is a description of the process that is outlined in the flow chart (Exhibit 3.e).

Crushing. Limestone is transported from the quarry in 35-ton trucks and dumped into a gyratory primary crusher, where it is reduced to 6-inch rocks. The material is transported on belt conveyors through screens to secondary and tertiary crushing stages, which reduce it to a mill feed size of ½ inch. It is then conveyed to a covered stockpile fitted with homogenization equipment. Subsequently, the material is homogenized and drawn from stock as required. Clay is dried at the nearby San Eduardo plant and trucked to Cerro Blanco, where it follows a process similar to that of limestone, but with only one crushing/screening stage.

ESCUELA SUPERIOR POLITECNICA DEL LITORAL – LAB. FUENTES ALTERNAS DE ENERGIA EST.METEOROLOGICA

AÑO: 1980

MESES.	LLUVIA mm	HUMEDAD RELATIVA %					0° DIRECCION DEL VIENTO 360°				VELOCIDAD DEL VIENTO Km/h.				TEMPERATURA EN °C					
		07 Hora	13 Hora	19 Hora	24 Hora	Máx.	07 Hora	13 Hora	19 Hora	24 Hora	07 Hora	13 Hora	19 Hora	24 Hora	07 Hora	13 Hora	19 Hora	24 Hora	Máx.	Mín.
Enero																				
Febrero																				
Marzo																				
Abril	301	98.6	56.5	80.2	92.7	99.4					4.2	7.1	7.4	6.5	26.3	34.9	29.2	26.3	37	25.6
Mayo	28.5	99	59.7	80.8	87.5	99.6					5.8	5.7	7.6	9.7	25.5	33.6	29.6	25.5	35.4	25.2
Junio	5	100	62.5	79.9	96	100	304.8	247.5	315.6	360	7.3	5.7	8.3	9.9	25	31.8	28.6	25.1	34	24.2
Julio	1	100	56.6	74.5	95.4	100	297.2	261.8	299.1	339.1	8.2	6.6	8.6	10.8	23	32.3	28.5	24	34.9	23
Agosto	.	100	53	74.2	96.5	100	360°	289.3	349.5	360	7.9	6.5	9.7	10.7	23	32	27	23.4	34.1	23
Septiembre	.	99.8	47.2	72.4	98.8	99.7	350	250	355	360	7.6	7.3	11.1	10.1	23.3	33.3	27.6	23.7	35.3	23
Octubre		97.8	52.1	71.3	93.6	98.3	360	267.6	360	360	8.6	7.9	10.5	10.6	24.1	33.4	27.6	24.5	34.5	23.8
Noviembre	.	98.1	48.2	70.7	94.4	99.2	342.5°	245	355	360	7.6	7.2	10.5	10.1	20.9	30.9	26.6	21.9	33	20.4
Diciembre	4	98.5	49.1	67.5	95.1	99.4	357.9	260.1	357.1	360	7.1	6.5	10.4	10.3	20.5	29.2	25.3	21.5	31.4	20.9
TOTAL	339.5	99.	53.8	74.5	94.2	99.5	338.9	260.2	341.6	357	7.1	6.7	9.3	9.9	23.5	32.3	27.7	23.9	34.4	23.2

ESCUELA SUPERIOR POLITECNICA DEL LITORAL – LAB. FUENTES ALTERNAS DE ENERGIA EST.METEOROLOGICA

AÑO: 1981

MESES.	LLUVIA mm	HUMEDAD RELATIVA %					0° DIRECCION DEL VIENTO 360°				VELOCIDAD DEL VIENTO Km/h.				TEMPERATURA EN °C					
		07 Hora	13 Hora	19 Hora	24 Hora	Máx.	07 Hora	13 Hora	19 Hora	24 Hora	07 Hora	13 Hora	19 Hora	24 Hora	07 Hora	13 Hora	19 Hora	24 Hora	Máx.	Min.
Enero	73.5	94.4	44.2	62	84.1	95.8	263.5	195.5	331.1	331.1	5.8	6.2	8.3	8.9	21.5	30.6	25.9	22.8	32.6	21
Febrero	308.7	99.7	56.1	78.5	92.1	99.9	208	186.6	273.3	295	5.1	5.3	6.7	6.9	21	29.1	25	22.5	30.9	20.7
Marzo	185.	98.1	52.7	74	95.7	99.4	223.2	172.2	259.3	303.2	5	6	6.5	7.2	22.1	29.9	26	23.4	32.3	21.9
Abril	99.	97.5	54.8	78.7	89.4	95.9	229.	202.6	308	318.	5.	6.2	7.8	10.4	22.5	29.7	26.1	22.7	31.9	22.2
Mayo	.	97	51.5	75.4	93.9	99.8	325.8	230.3	287.2	359	7.4	5.7	7.8	10.3	20.5	29.3	25.3	21.4	30.6	20.3
Junio	.	97.3	53.8	75.3	95.5	99.8	360	260	324.3	360	1.2	5.9	7.9	10.3	19.6	27.8	23.9	20.2	29.6	19.5
Julio	.	98.9	51.5	70.8	94.7	99.8	351.3	268.7	335.5	360	7.7	6.6	8.6	10.6	19.7	27.6	23.6	20.3	29.7	19.5
Agosto	.	99.3	48.2	71.9	94.4	99.4	360	262.3	325.8	360	7.6	7.3	8.7	10.3	18.1	26.9	22.8	18.8	29.3	18.
Septiembre	.	98.5	42.7	66.7	94.9	99.6	316.9	245.6	341.7	359.5	6	6.4	10.5	9.5	18.8	29	23.3	19.3	30.8	18.7
Octubre	.	98	46.8	70.1	91.8	99.4	360	256.3	339.6	359.6	7	7.2	10.5	10	19.4	28.6	23.3	19.1	30.1	19.2
Noviembre	12	98.1	44.5	69	95.4	99.8	327.6	263.7	341.3	360	7.1	6.4	10.9	10.4	20	29.2	24.1	20.3	30.8	20
Diciembre	61.5	91	38.8	60.8	81.9	95.7	327.3	226.1	323.5	351.3	5.1	5.9	8.7	9.4	21.3	30.5	25.7	22.3	32.1	20.9
TOTAL	739.7	97.5	49.6	71.1	91.9	98.7	303.9	231.6	315.9	343.	6.4	6.3	8.6	9.43	20.4	29	24.6	21.1	30.9	20.1

ESCUELA SUPERIOR POLITECNICA DEL LITORAL – LAB. FUENTES ALTERNAS DE ENERGIA EST.METEOROLOGICA

AÑO: 1982

MESES.	LLUVIA mm	HUMEDAD RELATIVA %					0° DIRECCION DEL VIENTO 360°				VELOCIDAD DEL VIENTO Km/h.				TEMPERATURA EN °C					
		07 Hora	13 Hora	19 Hora	24 Hora	Máx.	07 Hora	13 Hora	19 Hora	24 Hora	07 Hora	13 Hora	19 Hora	24 Hora	07 Hora	13 Hora	19 Hora	24 Hora	Máx.	Mín.
Enero	84.8	94	43.3	60.4	83.7	96.3	301.3	201.6	313.7	336.3	4.9	4.9	7.4	8.2	27.1	30.6	26.2	23.	32.2	21.9
Febrero	26.5	94.6	48.5	67.6	81	97.8	194.6	180	231.2	336.9	4.6	6.3	5.2	7.4	22.4	30.3	26.3	23.7	32.1	22.2
Marzo	1	91.9	40	62.2	77.2	96.2	161.6	182.4	265.6	292.7	4.5	7.1	7	8.3	22.7	31.5	27	24	33.1	22.5
Abril	·	88.6	45.4	67.2	83.2	96.2	192.9	181.7	281	318.3	4.3	6.1	7.9	8.2	22.5	31	25.8	22.8	32.5	21.6
Mayo	1.5	95.9	45.1	69.9	87.3	97.7	305.2	233.6	310	360	7.2	7.5	8.4	11.2	21.1	29.9	25.2	22	31.6	20.7
Junio	·	97.3	48.2	73.6	97.7	98.5	334	250.3	324	360	7.3	7.6	9.2	11.2	19.8	28.3	23.9	20.3	30.1	17.6
Julio	·	96.8	47.6	69.5	93.2	97.8	360	274.7	339.7	360	9.1	8.2	10.9	11.6	19	27.6	23.2	19.5	29.5	18.8
Agosto	·	96.6	44.1	64.8	94	97.8	360	260.4	356.7	360	9	8.6	11.9	12.7	18.3	28.4	23	18.6	30	18
Septiembre	·	96.1	39.5	63.4	92.7	98.	243.2	245.4	335	360	6.3	7.9	13.3	11.4	19.8	29.7	24	20.1	31.3	19.4
Octubre	·	98.1	42.5	67.3	91.7	99.1	327.6	250.3	341.6	360	7.1	7.3	11.6	10.1	21.4	29.1	24.4	21.8	30.5	21
Noviembre	111	95.9	41	64.6	92.7	97.8	248.6	219.3	323.2	326.4	5.7	5.4	8.1	8.7	22.2	30.3	24.7	22.5	31.9	21.8
Diciembre	98.5	95.7	52.6	78	93.9	97.5	237.2	184.5	277.5	288.8	4.7	5.5	8.8	7	22.3	29.1	25.1	23.3	30.9	22.1
TOTAL	323.3	95.1	44.8	67.4	89	97.6	272.3	222.	308.3	338.3	6.2	6.86	9.14	9.7	21.1	29.7	24.9	21.8	31.3	20.8

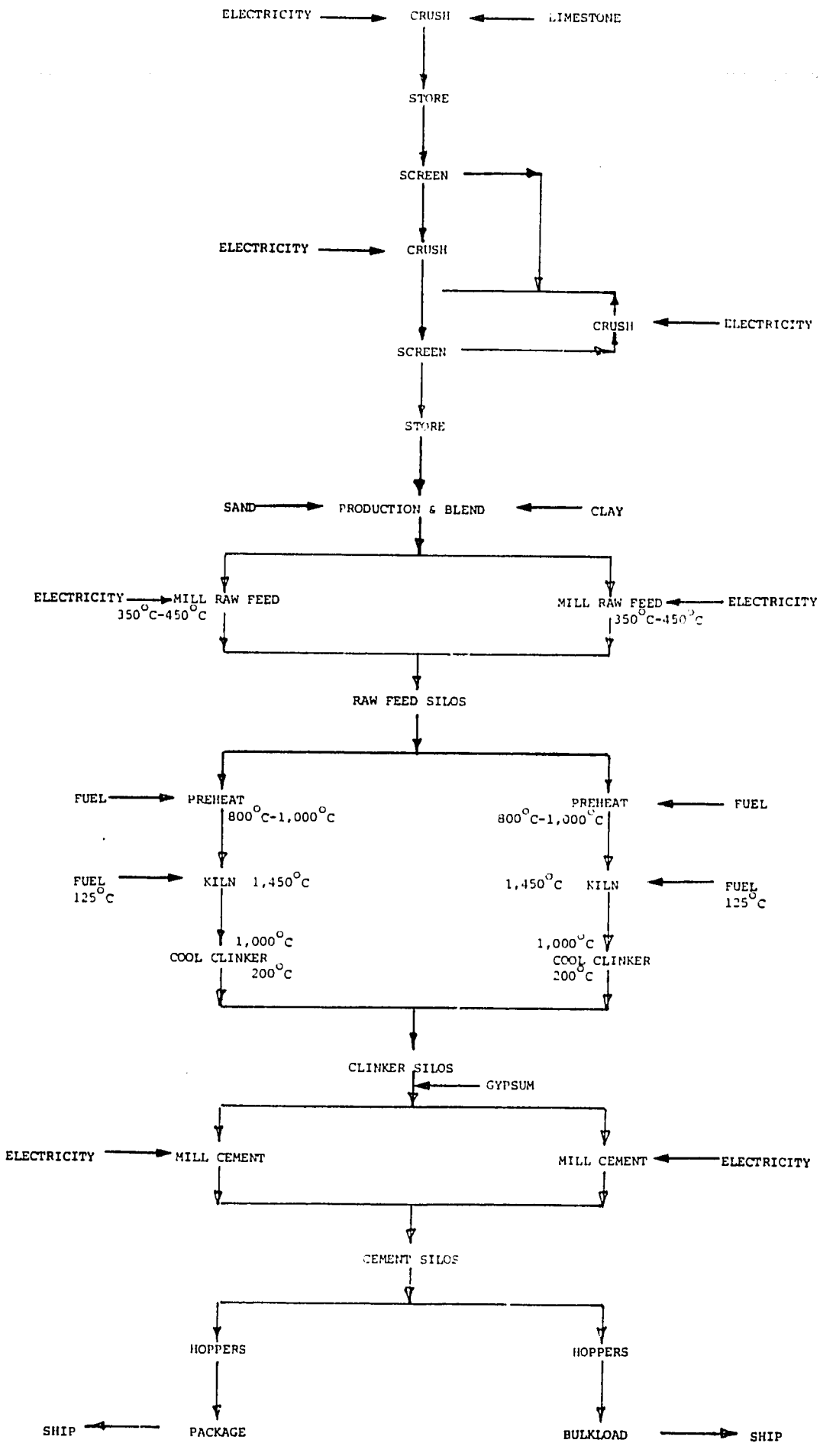
ESCUELA SUPERIOR POLITECNICA DEL LITORAL – LAB. FUENTES ALTERNAS DE ENERGIA EST.METEOROLOGICA

AÑO: 1983

MESES.	LLUVIA mm	HUMEDAD RELATIVA %					0° DIRECCION DEL VIENTO 360°				VELOCIDAD DEL VIENTO Km/h.				TEMPERATURA EN °C					
		07 Hora	13 Hora	19 Hora	24 Hora	Máx.	07 Hora	13 Hora	19 Hora	24 Hora	07 Hora	13 Hora	19 Hora	24 Hora	07 Hora	13 Hora	19 Hora	24 Hora	Máx.	Mín.
Enero	563	97.2	61.4	88.2	96.9	98.6	164.2	178.6	153.2	125.4	5.1	6.5	6.9	3.7	22.2	28.6	24.4	22.9	30.8	22.8
Febrero	697	97.5	56.5	82.3	96.2	98.6	191.3	191.1	133.1	110.7	4	6.2	6.5	4.3	22.1	29.3	24.9	23.5	31.7	21.8
Marzo	782.5	97.7	53.4	83.1	97.6	98.7	156.1	210.3	124.5	134.7	3.4	6.4	6.9	4.9	22.5	29.4	24.9	23.2	32.6	21.9
Abril	579	96.5	56.5	87.3	96.9	98.5	151.6	219.1	112.8	177	3.6	7.2	7.3	6.3	22.6	29.7	24.6	23	31.9	21.9
Mayo	620.5	95.7	46.8	82.	96.	97.9	158.4	211.9	135.5	188.4	4.3	6	6.8	4.3	22.4	30.7	24.9	23.	32.8	21.9
Junio	487.5	95.5	48.9	80.2	95.6	97.9	235.4	187.5	100.4	149.5	3.5	6.7	7.5	4	20.1	28	23.3	21.2	29.8	19.7
Julio	373	93.9	48.1	72.3	93.3	96.9	171.6	205.4	95.3	128.8	3.9	6.2	13.5	6.7	19.5	27.8	22.7	19.7	29.6	19.3
Agosto	8.8	94	41	66	91	95.6	88.5	227.4	93.5	74.4	6.3	7	9.6	11.2	21	29.6	25.2	21.7	31.5	21.1
Septiembre	14.7	93.1	47.3	72.1	92.7	94.1	88.5	244.6	90.5	72.5	5.7	6.3	10.3	10.6	22	30	26	22	32	22
Octubre	7.5	92.7	44.8	66.9	90.8	93.5	70	252.6	85.3	73.3	8.2	7.6	11.4	12.5	21.4	29.4	25.4	21.5	31.5	21.1
Noviembre	1.8	92.4	38	56.1	86.4	93	93.1	276.5	77.5	73.1	7.	7.1	11	12.5	21.5	30.5	26	22	32.1	21.2
Diciembre	66.5	92	38.5	57.6	83.6	94	81.1	71.2	103.5	64.5	6.2	5.9	9.4	10.3	20.9	30.6	25.1	22.3	32.3	21.2
TOTAL	4101.8	94.8	48.4	74.5	93.1	96.4	137.5	207.1	108.7	114.3	5.1	6.5	8.9	7.5	21.5	29.4	24.8	22.2	31.5	21.3

Exhibit 3.e

Process Flow Chart: Cerro Blanco Plant



Raw material preparation. Limestone, clay, and sand are mixed in the desired proportions, homogenized, and fed into either of two rotating drum ball mills, where the mixture is simultaneously dried and pulverized. Hot kiln gases at 350°C-450°C provide heat for the drying process. Dust generated in the ball mills is collected in filters and returned to the process. The powdered feed is then fed to silos for blending and storage. Raw feed from the silos with a moisture content of 0.9 percent next enters the two clinker production lines. The process up to this point consumes mainly electrical energy for mechanical drives.

Clinker production. In this stage, raw feed is burned and calcined to produce clinker. Most of the thermal energy consumption in the plant takes place in clinker production, specifically in firing the kilns.

Raw feed first enters a four-stage cyclone preheater (three-stage on line 1), where in the top stage it comes in contact with kiln gases at 317°C moving in the opposite direction. The feed moves through the cyclones until it enters the rotary kiln. At that point, feed is mixing with kiln exit gases entering the preheater at 978°C. It then enters the upper or feed end of a rotary kiln, where it is conveyed by the slope and rotation (1.0-1.7 RPM) through a 1,266°C sintering zone to the firing or discharge end of the kiln. The clinker discharged from the kiln at 1,000°C is air-quenched to 200°C in a travelling grate cooler. A portion of the air leaving the cooler at 800°-1,000°C is mixed with air used for combustion of the kiln fuel. After cooling, the clinker is transported to silos. The subsequent stages of the process consume mainly electrical energy.

Mixing and grinding. In this stage, the lumps of clinker are mixed with gypsum and other additives, and are ground to a fine powder in a ball mill. As with raw material milling, the system comprises a closed circuit that employs an air separator to classify the ground material. Fine finished material is sent to storage, while course fractions are returned to the ball mill for further grinding.

Packaging and shipping. Cement from the silos is transported to hoppers for feeding to bagging machines that fill and seal the bags. Their capacity is 5,000 50-kg bags per hour. Alternatively, the cement moves through two bulk loaders with total capacity of 300 tons/hour. The bags or bulk cement are then gravity-fed to trucks waiting below at ground level.

Major Energy-Consuming Systems

Electrical equipment includes four ball mills (6,896 kVA), two DC kiln fans powered by thyristor banks (2,500 hp), six AC kiln and mill fans (1,722 kVA), and five crushers with their main conveyor (1,177 kVA). Specifications of the major motors, accounting for about 80 percent of electricity consumption, are shown in Exhibit 3.f. The plant's power factor is .87 and maximum demand is 19,440 kW (July 1984).

Thermal equipment consists mainly of the two kilns, which are fired by residual oil, and their fuel oil preheaters (thermal fluid type), which consume diesel oil. Diesel oil consumption is largely divided between the fuel oil preheaters

Exhibit 3.f

Major Electric Motors

4,000 volt motors -- 3-phase, 60-cycle AC

Quantity	Synchronous motors	HP	RPM
2	Raw mills Allis-Chalmers	3,500	200
2	Cement mills Allis-Chalmers	4,200	200
	Induction motors (Line 1)		
1	Blower no. 2 (mill)	350	720
1	Blower no. 3 (kiln/mill)	600	720
1	Blower no. 4 (kiln)	400	600
1	A/C separator	400	514
1	Air separator	400	514
1	Pump compressor	250	514
1	Pump compressor	250	600
1	Compressor (blending)	250	600
	Crushing		
1	Primary crush	500	505
1	Conveyor	400	1,780
1	Secondary crush	350	710
	Line 2		
1	Raw mill		
1	Separator	500	505
1	Blower no. 2 (mill)	700	885
1	Blower no. 3 (kiln/mill)	550	890
1	Blower no. 4 (kiln)	375	885
	Clinker separator	400	595

Exhibit 3.f (continued)

Major Electric Motors

480 volt motors -- 3-phase, 60-cycle AC

Quantity	Induction motors	HP	RPM
3	Tertiary crushers	200	500

Compound motors DC

	Line 1		
1	Preheater blower, 550 volt	1,250	1,200
1	Main kiln, 500 volt	250	1,150

	Line 2		
1	Preheater blower, 500 volt	1,250	1,150
1	Main kiln, 550 volt	400	1,200

(33 percent) and mining equipment (67 percent). Waste heat is used for preheating of combustion air, preheating of raw feed, and drying of raw materials.

A list of major equipment is presented in Exhibit 3.g.

Instrumentation

Both production lines are controlled from a central control room situated between the kilns. The older control station (Line 1) has several display panels with electromechanical gauges and recorders, while the newer station (Line 2) uses an electronic information and control system with CRT displays and computer graphics. Line 2 has an automatic control capability, guided by set points (process parameters) established by the operator. In practice, the operator adjusts fuel oil flow on the basis of pressure, temperature, amperage, and material flow rate data received, and the system adjusts other process controls automatically to optimum conditions. A similar system will be retrofitted to Line 1.

Pyrometers monitor temperatures inside the kiln as well as the kiln surface temperature. Other fixed instruments include gas analyzers (O_2 and CO), fuel flowmeters, RPM indicators (fans and kilns), weight indicators (bins), vibration indicators (fans), voltmeters, and bearing thermometers.

There is extensive metering of the in-plant electric power distribution system, beginning with metering of overall reactive and active power consumption, as well as recording of energy demand in 15-minute blocks. Meters are installed on the secondary side of all transformers and in all branch circuits. Of the 54 meters installed, only half are being read at any time. There are plans to install meters that will provide input directly into a computer-controlled monitoring system.

Maintenance Procedures

The maintenance organization, which is staffed by approximately 120 persons, is divided into three sections:

- Mechanical maintenance
- Electrical maintenance (including instruments)
- Preventive maintenance.

The preventive maintenance staff of six persons primarily administers the function through planning, work orders, and record keeping. The condition of the plant indicated a high level of maintenance: thermal insulation was intact and complete, valves were tight, equipment controls were in good condition, and overall housekeeping was very good.

Exhibit 3.g

Major Equipment

Description	Make	Type	Model	Capacity	Dimensions	Motor	Remarks
Mining							
2 drills	Atlas Copco	Hammer	ROC-301-04	14 m/hr			
2 drills	Worthington	Hammer	Wrangler II	20 m/hr			
2 compressors	Atlas Copco	Screw	PRH425 Dd	12 m^3/min		Diesel, 170 hp	7 bar
1 compressor	Atlas Copco	Screw	PTH5900 Dd	24.8 m^3/min		Diesel, 150 hp	10.5 bar
2 compressors	Worthington	Screw	850 SQT	24 m^3/min		Diesel, 250 hp	7 bar
2 tractors	IHC		TD-25C			310 hp, 2100 rpm	
1 tractor	Caterpillar		D8K			300 hp, 1330 rpm	
2 tractors	Caterpillar		D9L			450 hp, 1900 rpm	
2 front loaders	Caterpillar		988B	7 yd^3/5.35 m^3		378 hp, 2200 rpm	
2 front loaders	IHC		560	6.5 yd^3/5.0 m^3		380 hp, 2200 rpm	
2 front loaders	Michigan		275B	6.5 yd^3/5.0 m^3		342 hp, 2300 rpm	
2 front loaders	IHC		530	3 yd^3/2.3 m^3		158 hp, 2500 rpm	
4 trucks	Wabco		35C	14.6 m^3/35 t		420 hp, 2300 rpm	
4 trucks	IHC		330	14.6 m^3/35 t		420 hp, 2200 rpm	
Crushing							
1 primary crusher	Nordberg	Rotating	GY-543	1600 t/h	16'10" diam.	500 hp, 4160 v, 502 rpm	
1 secondary crusher	Symons	Standard head		540 t/h	7' diam.	350 hp, 4000 v, 710 rpm	
1 tertiary crusher	Symons	Short head		200 t/h	5'6" diam.	200 hp	
3 screens	Tyler		990	750 t/h	8' x 16'		
4 screens	Tyler		990	345 t/h	6' x 16'		
1 limestone prehomogenizer	MVT	Circular storage		76,000 t	106 m diam.		
1 clay crusher	Williams	Hammer		200 t/h		200 hp, 450 v	
1 clay prehomogenizer	Buehler-Miag	Transversal		60,000 t			
Raw milling							
Mill no. 1	Allis-Chalmers	Ball		120 t/h	4.7 diam. x 6.4 m	3500 hp, 4000 v, 200 rpm	
Silo no. 1 batch homogenizer				3500 t			
Silo no. 2 storage				3500 t			
Silo no. 3 batch homogenizer				4100 t			
Mill no. 2	F. L. Smidth	Ball	TSFP 1700 B	136.5 t/h	4.5 m diam. x 8.26 m	3500 hp, 4000 v, 514 rpm	
Homogenization silo	Claudius Peters			5000 t			

Exhibit 3.g (continued)

Major Equipment

Description	Make	Type	Model	Capacity	Dimensions	Motor	Remarks
Clinker production							
Preheater no. 1	Buehler-Miag	3-stage	B-41805				5 precal-cinators
Kiln no. 1	Allis-Chalmers	Rotating		1500 t/day	4.42 diam. x 62 m	259 hp, 500 v, 1150 rpm	
Clinker cooler no. 1	Allis-Chalmers	Fuller			24.38 m x 4 m	40 hp, 25 hp	
Preheater no. 2	F. L. Smidth	4-stage	1700863				4 precal-cinators
Kiln no. 2	F. L. Smidth	Rotating		1550 t/day	435 m x 65 m	400 hp, 1200 rpm	
Clinker cooler no. 2	F. L. Smidth	Fuller			18.3 m x 3.6 m	2 x 25 hp	
Cement milling							
Mill no. 1	Allis-Chalmers	Ball		80 t/h	3.9 m diam. x 12.8 m	4200 hp, 4000 v, 200 rpm	
Mill no. 2	Allis-Chalmers	Ball		95 t/h	3.9 m diam. x 13.7 m	4200 hp, 4000 v, 200 rpm	
Silo no. 1				8170 t			
Silo no. 2				9900 t			
Silo no. 3				8170 t			
Silo no. 4				8170 t			
Packaging							
2 baggers	Hayer & Boecker	Rotating auto.	6060-8RV	1500 bags/h			
1 bagger	Hayer & Boecker	Rotating auto.	6074-8RVK	2000 bags/h			
2 bulk loader	Hayer & Boecker	Movable loader	4655A	300 t/h			

Specific Energy Consumption

The specific energy consumption data in Exhibit 3.h provide an approximate index of energy efficiency and trends. Specific consumption of residual oil in Line 1 (997 kcal/kg) is in line with the international average of 1,010 kcal/kg of clinker. The specific consumption of the newer Line 2 (822 kcal/kg) is well below the average and is approaching the best international performance level (705 kcal/kg clinker). Specific consumption of electricity at 113 kWh/tonne cement is at the international average level of 114 kWh/tonne cement.

Exhibit 3.h

Specific Energy Consumption

	Clinker manufacture				Cement manufacture			
	Residual oil (kcal/kg)		Diesel oil (kcal/kg)	Electricity (kWh/t)	Residual oil (kcal/kg)		Diesel oil (kcal/kg)	Electricity (kWh/t)
	Line 1	Line 2			Line 1	Line 2		
1979	981	—	20					125.0
1980								
1981								
1982	978	862						118.0
January								
February								
March								
April								
May								
June								
July								
August								
September								
October								
November								
December								
1983	963	845						131.0
January	1,059	867						142.0
February	1,022	891						184.0
March	967	800						107.0
April	923	853						136.0
May	983	827						126.0
June	960	793						117.0
July	942	849						118.0
August	956	853						111.0
September	981	849						115.0
October	928	822						111.0
November	919	805						118.0
December	932	958						108.0
1984								
January	990	895						104.5
February	906	786						107.9
March	980	776						127.9
April	1,000	835						126.2
May	980	801						
June	1,054	874						
July	1,020	775		128				
August	1,042	836						
August 1984	997	822						113.3

Based on this preliminary audit, and considering projects already planned (Pages 3.1-3.2), it appears that the energy cost savings potential at the Cerro Blanco plant is relatively small. The plant is relatively new, well-maintained and clean, and uses the energy-efficient dry production process. In view of the above, a detailed energy audit is not warranted in this case; nevertheless, some improvements in electricity consumption and maximum demand appear to be possible.

Short-Term Measures

The following measures can be implemented in the short term at low cost:

- Survey lighting requirements plant-wide and adjust lighting levels to accepted standards
- Evaluate centralized automatic control of lighting and air conditioning systems plant-wide
- Insofar as possible, disconnect the primary side of transformers when the secondary side is not loaded
- Analyze the causes of the maximum demand (between 6:00 p.m. and 9:00 p.m.) and reschedule operations or shed loads to reduce it.

All of the above measures would reduce demand, which is a key factor in the tariff structure. For example, a 5-percent reduction in maximum demand would reduce electricity cost 2.7 percent, even assuming no reduction in consumption.

Longer-Term Measures

Longer-term measures involving significant capital expenditures should also be evaluated:

- Recuperation of the waste heat from kiln and cooler shells should be studied.
- Also, precrushing of clinker before it enters the cement mill should be considered, as crushing is less energy-intensive than grinding.

Although energy appeared to be well under control by plant staff, it is recommended that a series of additional steps be taken to ensure continuous and further achievements in energy efficiency, namely:

- Appoint an energy coordinator and establish a formal energy management program to raise awareness, set objectives, and develop and implement projects.

- Carry out the short-term measures listed in Chapter 4 to reduce electrical demand and consumption.

- Analyze the longer-term measures listed in Chapter 4 to determine technical and financial feasibility.

With the likelihood of increasing oil prices over the next few years, it will probably be wise to conduct a detailed instrumented audit of the plant as soon as some of the long-term measures exhibit some financial merits (probably by 1987).