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INDUSTRIAL ENERGY EFFICIENCY AUDIT REPORT

CIMPULUNG CEMENT PLANT
Cimpulung, Romania

JANUARY 1992

PREPARED BY: RESOURCE MANAGEMENT ASSOCIATES OF MADISON, INC.
Madison, WI

and

INSTAPART
Bucharest, Romania

U.S. EMERGENCY ENERGY PROGRAM FOR EASTERN AND CENTRAL EUROPE

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
BUREAU FOR EUROPE
WASHINGTON, D.C. 20523

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520 University Avenue
Suite 300
Madison, WI 53703
(608) 283-2880

and

INSTAPART
Sos. Catelu nr. 9
Bloc PM 62, Sc 1, Ap. 12, Et 2
Bucharest III
Romania
40-48-388388

U.S. EMERGENCY ENERGY PROGRAM FOR EASTERN AND CENTRAL EUROPE

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
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OFFICE OF DEVELOPMENT RESOURCES
ENERGY & INFRASTRUCTURE DIVISION
WASHINGTON, D.C. 20523

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i. Industrial Energy Efficiency Program

The countries of Eastern Europe face unprecedented changes both in their political and economic systems. To aid in the transition to market economies, the U.S. Agency for International Development (USAID) designed the Eastern Europe Emergency Energy Program. Resource Management Associates of Madison, Inc. (RMA) is the technical assistance contractor for the Industrial Energy Efficiency Component (IEEC) of the program in Romania.

The Industrial Energy Efficiency Component was designed to address the problems of industrial energy efficiency with a short-term program aimed at the immediate needs of industry. The program involves three main activities:

1. To identify and implement cost-effective low-cost/no-cost energy improvements, with an emphasis on oil savings.

2. To conduct energy audits and transfer energy auditing and management techniques, including financial and economic analysis.

3. To provide energy auditing and/or energy efficiency equipment to implement the program objectives, improve energy management, and identify additional energy efficiency opportunities.

The IEEC program deliverables consist of plant audit reports, a policy and institutional analysis report, an industry profile report, and the in-country audits, training, and equipment delivery and installations. The tasks are being carried out by a team of energy specialists and policy analysis experts in four different phases:

- Phase One: Screening - During this phase the plants to be audited will be identified, and a specific plan to implement the following phases developed and put in place.

- Phase Two: Industrial Plant Energy Audit/Training - A team of energy specialists will arrive in-country and perform a detailed energy audit at the eight selected industrial sites. They will identify short-term energy efficiency measures, develop recommendations to implement these measures, demonstrate and train plant personnel on auditing techniques, and demonstrate financial and economic methodologies for justifying energy improvement projects. Additional equipment will be ordered for Phase Three.

- Phase Three: Implementation - The recommendations identified in Phase Two will be implemented, evaluated, and modified as necessary. Additional training will be provided and the final energy efficiency equipment turned over to the host country.

- Phase Four: Analysis of Factors - This phase will analyze the factors that make up energy efficiency management and investment decision making. Recommendations for policy reform and options for enhanced energy management will be identified and a program for implementation suggested.

Energy monitoring and testing equipment will be turned over to the Romania industrial sector and the Government of Romania (GOR). The GOR will be provided with analysis and recommendations for further energy efficiency measures.

ii. Executive Summary

The energy audit was performed at Cimpulung Cement Plant. Participants from the plant included Mr. Jon Florea, Chief Energy Engineer, and Mr. E. Rusu, Chief Technical Engineer.

The audit team was very well received, and were provided with considerable information regarding plant operation. Many short and long-term energy conservation opportunities were identified during the energy audit. Discussions were held with plant personnel regarding the importance of reducing energy consumption and the effect consumption has on product cost. The methods used to justify different projects were discussed, and U.S. audit instruments were demonstrated.

The plant has five cement plants that operate with six kilns fired from either oil or natural gas. The 2,500 personnel at the plant are organized in three main divisions: Technical, Sales and Accounting. The personnel involved in energy projects are located in two sections. For electrical energy efficiency projects the key personnel are in the Energy/Measurement Section, while the personnel for the gas and oil consumption are in the Technical Section. The facility operates 24 hours/day, 365 days/year. The plant is presently at 60% capacity, primarily due to fuel shortages.

At the present production level the electrical consumption for the plant is about 20 MW, with a .93 power factor. The primary electric consumers are the asynchronous motors of 500 to 1,600 kW used in the cement mills and kilns. Most of the fuel is consumed in the kilns. When fired on gas the kilns consume 4,000 m^3/hr. When using oil they consume 3 metric tons/hr. The steam produced from three 10 metric ton boilers is used primarily to preheat fuel oil used in the kilns. These boilers have no automatic combustion controls and there is no condensate return.

The electric and gas intensity of the plant is relatively constant at different production levels. This indicates that there should be energy savings available at the higher production levels.

The audit of the plant revealed that the kiln efficiency measure was 72% when burning oil and 81% when burning gas. The measurements indicated high levels of incompletely burned gases, which in turn indicates a need for better air and fuel mixing. Kiln surface temperatures ranged from 160 °C to 730 °C. The range shows the large degree of difference between insulation levels at various points in the kiln and the need to repair certain areas. The efficiency of the boilers was measured at 82% with high excess air. If excess air could be controlled to 50% the efficiency would rise to 86%.

The main recommendations made for the plant included monitoring combustion of the kilns and boilers, close monitoring and decisive action on kiln surface temperatures, installing some level of condensate return, and monitoring the larger electrical motors to determine potential conservation measures. Long-term recommendations include installation of fixed automated boiler and kiln combustion controls and a complete condensate return system. The plant plans to establish the position of energy conservation engineer, with responsibility for coordinating the identification and justification of energy efficiency projects.

The implementation phase of the audit involved a return trip to the facility from August 5 to 9, 1991 to facilitate the installation and use of the equipment. Training on portable equipment was provided for the plant staff. The fixed energy efficiency equipment had not yet arrived at the time of the implementation visit, but extensive discussion took place on the proposed locations, installation procedures, and operation of the fixed meters. The draft audit report was reviewed with the plant staff, and a utilization plan was developed for the equipment.

1.0 Plant Description

1.1 General

The Cimpulung Cement Plant (CLC) is located approximately 240 kilometers northwest of Bucharest. Plant construction began in 1968 and finished in 1972-73. The dry process technology is Romanian, as is most of the equipment. Some equipment comes from the GDR, including filtration equipment, and other equipment is from CSFR. Approximately 2,500 people are employed at the plant. The plant is designed primarily to make cement, which accounts for 90% of total production. The remaining 10% of production is for other construction materials, including such products as specialty brick.

There are five cement mills with the following capacities:

Theoretical	80-100 metric tons/hr
Actual	60-75 metric tons/hr

Within the cement plant there are six kilns fired on fuel oil and natural gas. Gas is preferred, but due to poor availability of gas more fuel oil is being fired. The factory wants to convert to coal fuel, and is constructing a facility to process coal. The coal pulverizing plant remains to be built, but due to a lack of capital, there are no current plans to finish it soon. CLC is typical of ten other cement plants around the country. Six are of the same technology and age, while four (2 dry process and 2 wet process) are considerably older. All raw materials, including clay, limestone and pyrite, are mined within the country.

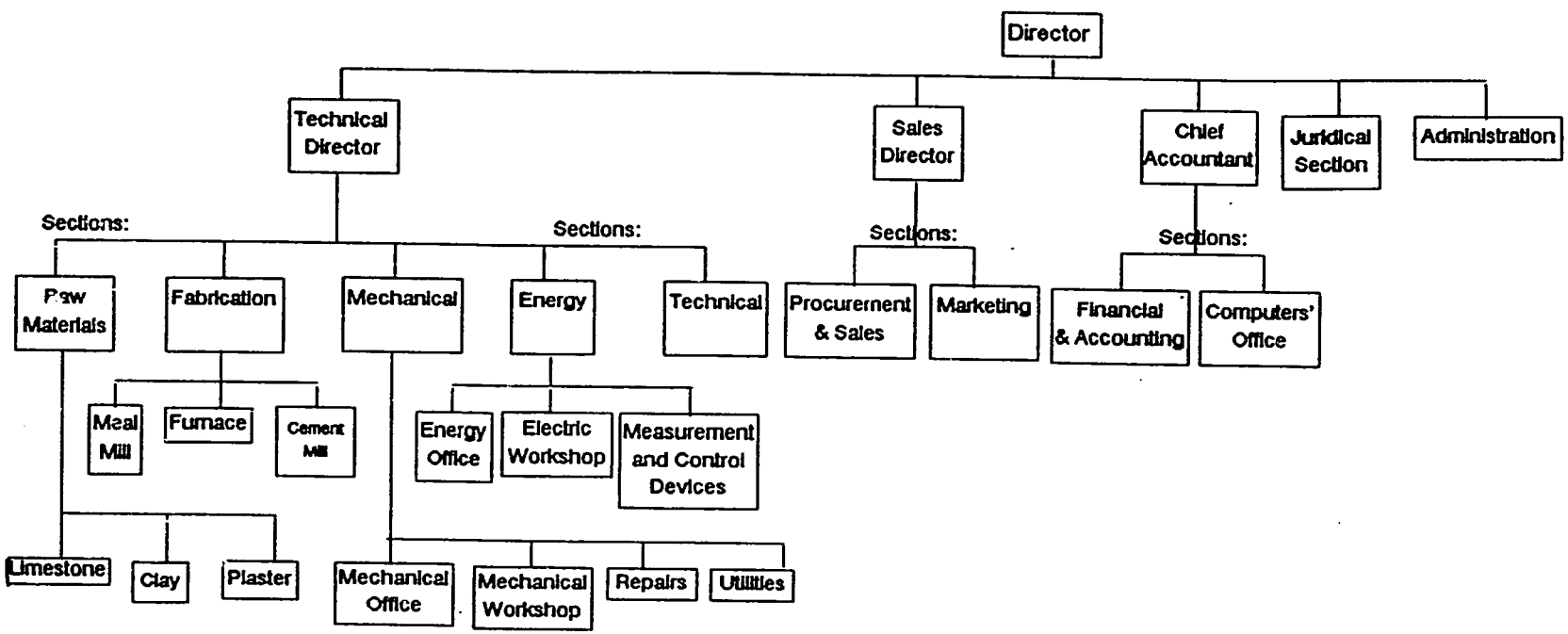
1.2 Organization

The key plant staff the audit team met with were Mr. Jon Florea, Chief Energy Engineer, and Mr. E. Rusu, Chief Technical Engineer. The organizational chart for the plant is illustrated in *Figure 1*. There are 76 engineers, 26 associate engineers, and 43 supervisors. The two sections most directly involved with energy conservation, the Mechanic Section and the Energy Section, both report to the technical director. Greater cooperation between these sections is needed to optimize energy conservation within the plant. A related problem is that the boiler house reports to the Mechanic Section rather than to the Energy Section. *Table 1* shows the breakdown of technical personnel at the plant.

Table 1. Technical Personnel

Specialty	Total	Electric Field	Mechanical Field	Technological Field	Other Specialties
Engineers	76	11	16	25	24
Assoc. Engineers	26	2	12	9	3
Supervisors	43	9	21	10	3

Figure 1. Organizational Chart



1.3 Operation

The facility is operated 24 hrs/day, 7 days per week, 52 weeks per year. Plant capacity is 1,700,000 metric tons/year. The plant is presently operating at 60% of capacity due to a lack of fuel and repeated breakdowns of the rotary kilns.

The equipment using the most energy in the plant is in the kiln operation. The operation of the kiln includes the main sections of the raw mill, the gas exhaust system, the suspension preheater, the rotary kiln, and the grate cooler. The raw mill dries and processes raw material, such as limestone, clay and material collected in the suspension preheater. A motor of 1,600 kW is used to turn the mill. The kiln's exhaust system is a complex network that includes the suspension preheater, cooling towers and an electrostatic precipitator (ESP) system. The main exhaust fan consumes 500 to 1,000 kW, the recirculation fan consumes about 600 kW, and the ESP fan consumes about 400 kW.

The suspension preheater is used to capture material expelled from the kiln in the exhaust gases. The inlet temperature of the gases to this system is about 800 °C while the outlet temperature is about 1,000 °C. The rotary kiln consumes the greatest quantity of fuel in the plant. At full capacity it can consume 4,000 m^3/hour of gas or 3 metric tons/hr of oil. Electricity is consumed mainly by a 250 kW motor that is used to rotate the kiln.

The grate cooler is the area where there may be the most opportunity for energy savings. The grate cooler is composed of a moving grate system that takes the hot "clinkers" from the kiln and cools these clinkers for further processing. The air used to cool the clinkers is the main source of combustion air to the kiln and, therefore, much of the heat is recovered. There are a number of motors for the grate cooler ranging in size from 50 to 200 kW with outlet dampers controlling the air flow. The grate speed is controlled on one kiln by a frequency converter.

There are six kilns fired on fuel oil and natural gas. Gas is preferred because it is less costly, but due to a lack of supply, more fuel oil is being fired. The management wants to convert the plant to coal fuel, but the project is currently on hold at 60% completion.

1.4 Electrical

The plant is supplied from RENEL through two 40 MW substations. Plant loads are as follows:

Full Production	35-38 MW
60% Production	20 MW
Power Factor	0.93 constant

Neutral power factor is 0.92, so the plant tries to keep just above this. No incentives exist from RENEL to raise the power factor or reduce the electrical consumption.

Electric rates are somewhat variable:

1.0 lei/kWh	off-peak	
2.6 lei/kWh	peak period	5 hr/day winter 1 hr/day summer

The plant has automatic electric rate meters which totalize the consumption during off-peak and on-peak periods. The utility also has a meter which does the same. The plant operating staff has an ongoing program to shift loads to off-peak periods.

The primary electricity using equipment is in the cement mill and kiln areas. Electric asynchronous motors in the 500 kW to 1,600 kW range make up the bulk of the load. Each power bus has power factor correction capacitor banks. The loads are constant, so automatic switching capacitors are not required. Most motors are 10 to 15 years old.

Electricity has been supplied in the past on an allotment basis. This continues to be the case at this time, but the quote is variable from month to month, based on availability. Thirty percent is paid in convertible currency. If allotments are exceeded the facility is charged a penalty fee (See Appendix C for the current government penalty structure). Electrical energy amounts to approximately 13.8% of the product cost. The electrical distribution system is shown in *Figure 2*. Daily electrical profile for a typical day is illustrated in *Figure 3*. The average electrical demand is 15.46 MW.

1.5 Thermal

Most of the thermal loads are in two kiln lines of three kilns each. Specific operations are as follows:

Four kilns can fire fuel oil or fuel gas;
Two kilns are fuel gas only; and
For 60% production, 3-4 kilns are operated.

When fired on gas, each kiln has the following consumption:

Capacity:	31 metric tons/hr of clinker
Fuel Gas:	3,800 - 4,000 m^3/hr
Power:	48-50 kWh/metric ton of clinker

When fired on fuel oil, each kiln has the following consumption:

Capacity:	30 metric tons/hr of clinker
Fuel Oil:	3 metric tons/hr
Power Consumption:	+ 10% over fuel gas firing

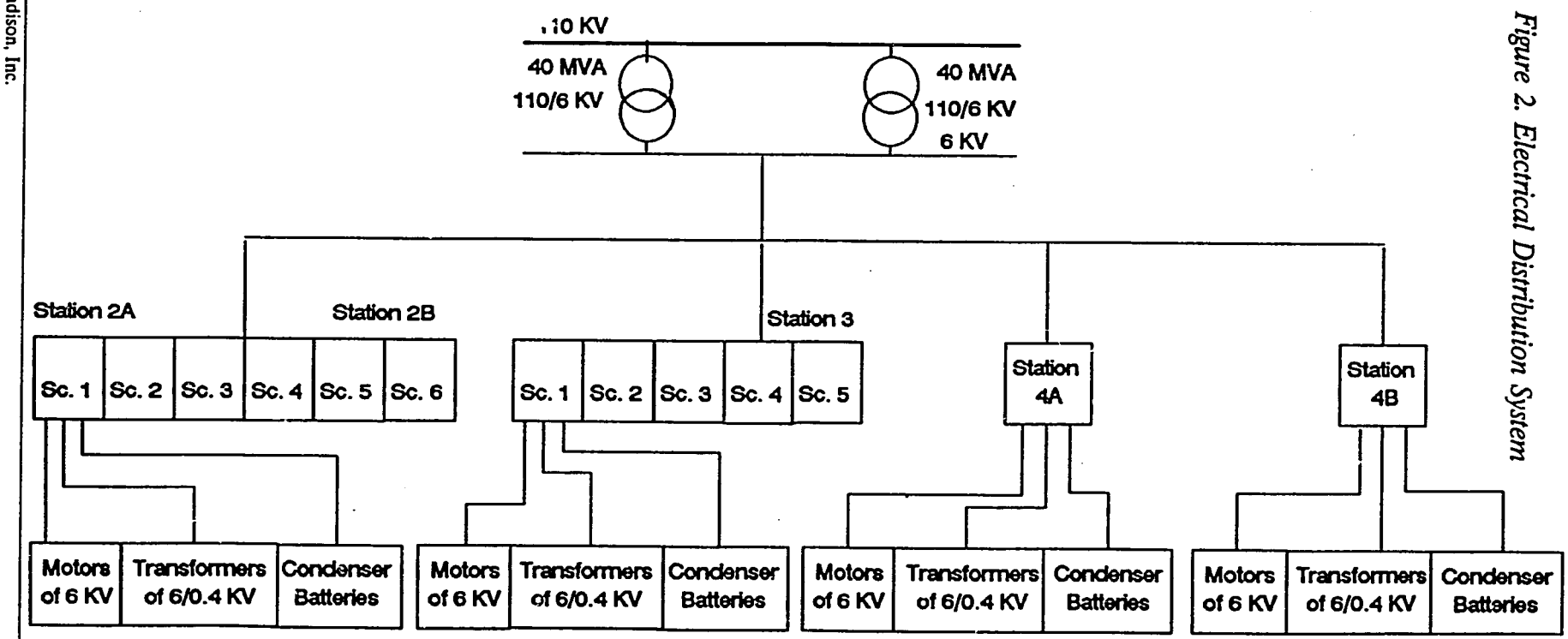
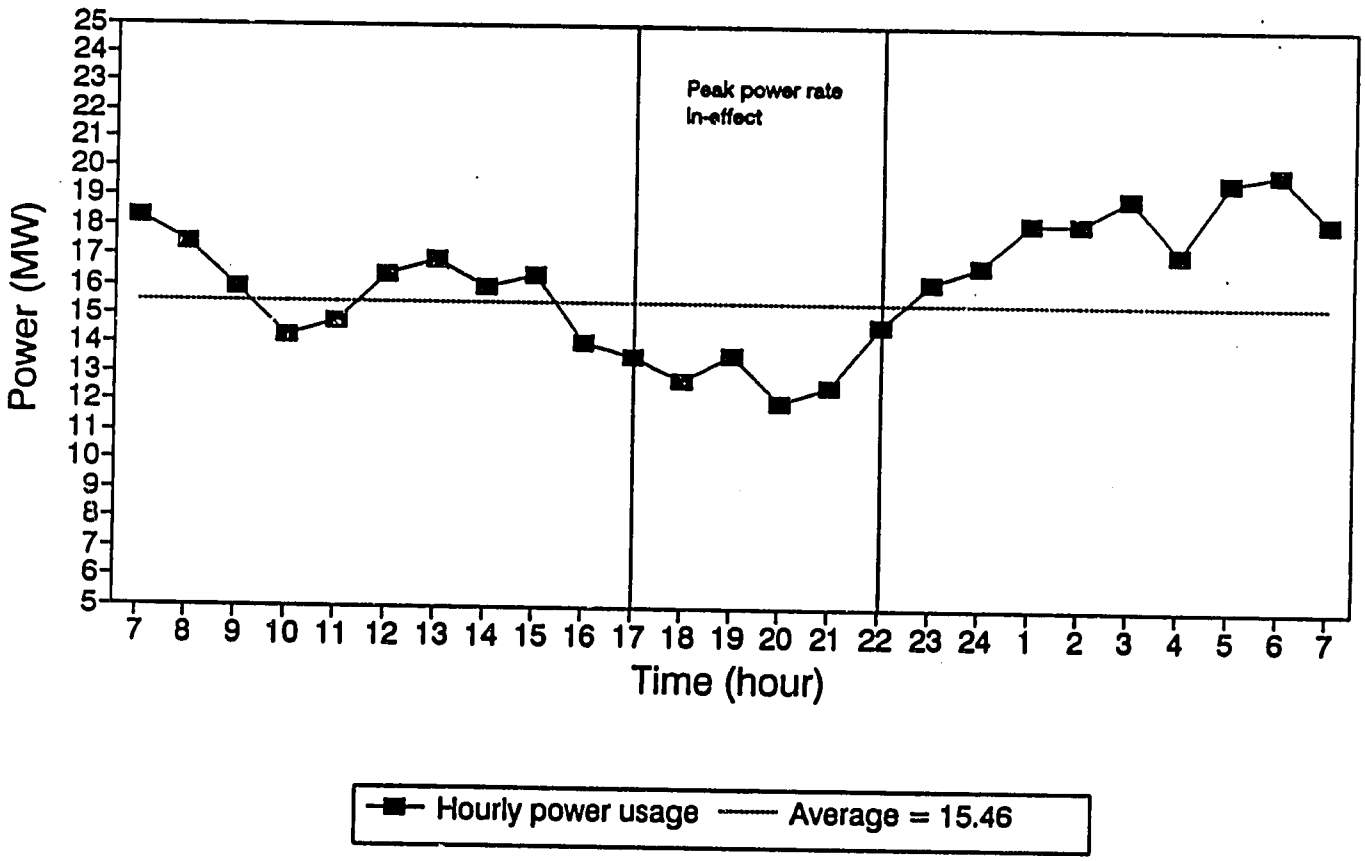


Figure 2. Electrical Distribution System

Figure 3. Daily Electrical Profile



The fuel oil is preheated by steam produced from three Romanian-manufactured boilers.

Number of Boilers	3
Pressure	8 bar saturated
Fuel	2 - fuel gas, 1 - fuel oil
Controls	Manual
Operation	2 on line, 1 spare
Distribution	90% load for fuel oil preheating
	10% for building space heating

Energy consumption increases by 10% when fuel oil is fired instead of gas, with a slight reduction in capacity. Plant staff were not sure of the exact numbers, which indicates that more attention should be given to energy consumption. Their approach is to fire whatever fuel is available. Natural gas, when available, comes through the national pipeline. Fuel oil is purchased and transported separately. Fuel costs are as follows:

Fuel Gas	2.8 lei/m^3
Fuel Oil	4,900 lei/metric ton

No condensate is recovered and most of the steam distribution lines have leaks. Most of the controls are manual. Some automation installed earlier no longer works due to the lack of spare parts. Combustion controls and fuel monitoring are non-existent. Steam is used primarily for fuel oil preheating.

1.6 History of Energy Efficiency Measures

A list of energy efficiency measures implemented by the plant is provided in Appendix A. It should be noted that all projects listed were primarily for the purpose of increasing production. Increased energy efficiency was a by-product.

The main projects that have been implemented in the last five years include the addition of the frequency converter for the grate cooler. The converter is used to vary the speed of the grate to maximize the recuperation of heat in the cooler. This project cost 6 million lei and is expected to have a six year payback. Another project involved the installation of 21 air powered blasters that reduce sediment in the gas exhaust system. The energy savings from this operation are expected to result in a three year payback. Other projects mainly intended to increase production, but which will eventually reduce energy intensity, include the use of variable revolution in the feeding of raw materials to the cement mill to improve accuracy and reduce waste, and the use of automatic controls to maintain proper gas temperatures to the electrostatic precipitator system.

1.7 Process Description

The Cimpulung Cement Plant utilizes the dry cement manufacturing process. Limestone, clay, pyrite, plaster and stone are the principal raw materials. The three main components, limestone, clay, and pyrite, are combined and crushed in a feed mixture. The product is then dried, preheated, and introduced into six clinkerization furnaces. The clinker product is then cooled and stored in silos. This clinker and additives (plaster, stone and slag) are crushed in the five cement plants and processed into raw cement for storage, bagging, and distribution. See Appendix B for a more complete description of the process operations. *Figure 4* illustrates the overall process.

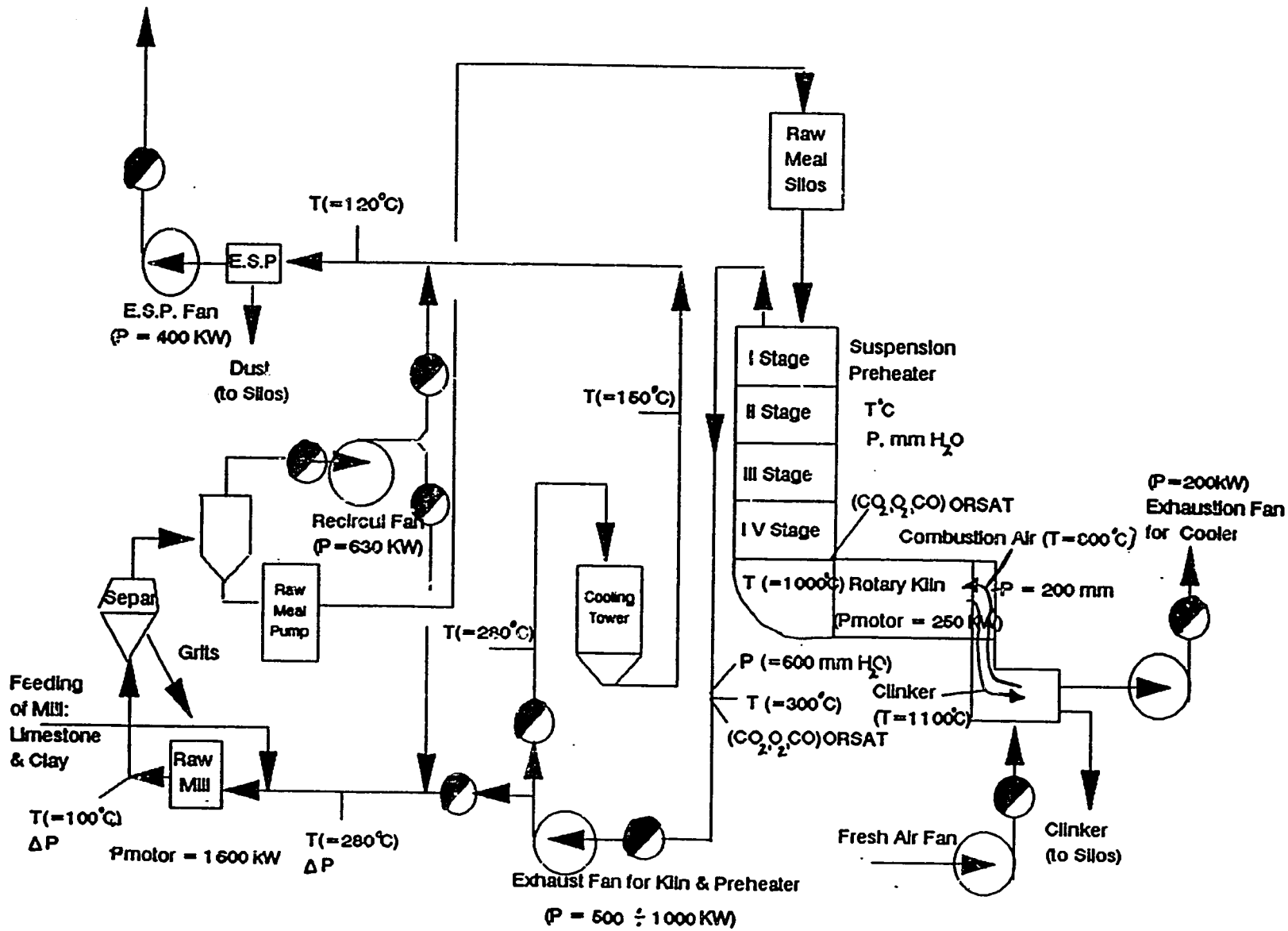


Figure 4. Process Description

2.0 Plant Energy Profile

Energy consumption for the plant may be categorized as follows:

- Electrical - used to power process equipment
- Steam - used to preheat the fuel oil
- Natural Gas - used to fire the kilns in the production process
- Fuel Oil - used to fire the kilns in the production process

2.1 Electrical

The monthly electrical consumption for 1989 is presented in *Table 2* and illustrated as a function of production in *Figure 5*. The consumption trend is towards increasing electrical consumption for increasing production, as expected. The electrical intensity as a function of production is illustrated in *Figure 6*. While there is a gradually decreasing trend of electrical intensity versus production, the decrease is slight and demonstrates little electrical efficiency for increasing production.

Average load in 24 hours:	15.46 MW
Annual consumption for all products (1989):	194,583 MWh
Annual consumption for cement only (1989):	159,078 MWh
Annual cost in lei:	233,499,600 lei
Power Factor:	0.94

2.2 Thermal

The monthly natural gas consumption for 1989 is presented in *Table 2*. Also presented are the first three months of 1990, including the switch to fuel oil. The consumption pattern is illustrated in *Figure 7*, and shows increasing natural gas consumption for increasing production. Energy intensity of natural gas versus production is illustrated in *Figure 8*. As with the electrical energy intensity, the variation with production is slight.

Table 2. Plant Energy Profile

1990 Energy Consumption and Intensity

Month	Production (thousand metric tons)	Electrical Energy			Natural Gas			Fuel Oil #6	
		Total Consumption (MWh)	Cement Consump. (MWh)	Intensity (kWh/ metric ton)	Total Consumption (thousand m3)	Cement Consump. (thousand m3)	Intensity (m3/ metric ton)	Cement Consump. (metric tons of oil)	Intensity (metric tons oil/ thou metric tons of product)
January	115.9	14,726.0	13,237.0	115.1	13,200.0	10,672.0	92.8		
February	109.0	14,018.0	12,655.0	116.1	13,500.0	10,257.0	94.1		
March	125.0	16,068.0	14,363.0	114.9	16,508.0	11,550.0	92.4		
April	127.0	16,695.0	14,567.0	114.7	16,100.0	11,646.0	91.7		
May	140.0	18,303.0	15,932.0	113.8	15,822.0	12,600.0	90.0		
June	123.0	18,759.0	14,256.0	115.9	15,100.0	11,525.0	93.7		
July	132.0	19,860.0	15,220.0	115.3	16,000.0	12,263.0	92.9		
August	110.0	16,562.0	12,782.0	116.2	15,274.0	10,516.0	95.6		
September	130.0	17,526.0	15,041.0	115.7	15,100.0	11,921.0	91.7		
October	100.0	17,173.0	12,060.0	120.7	14,200.0	10,410.0	104.1		
November	93.0	12,851.0	11,141.0	119.8	9,975.0	8,947.0	96.2		
December	60.0	12,041.0	7,824.0	130.4	10,424.0	6,624.0	110.4		
ANNUAL	1,344.0	194,583.0	159,078.0	118.3	171,203.0	128,931.0	95.9		

1991 Energy Consumption and Intensity

January	60.0	11,298.0	8,094.0	134.9	2,850.0	2,021.0	94.9	3,142.0	81.2
February	45.0	7,692.0	6,129.0	136.2	2,340.0	1,240.0	95.4	2,611.0	81.6
March	65.0	11,486.0	8,450.0	130.0	3,083.0	1,420.0	92.8	4,001.0	80.5

Figure 5. Electrical Consumption

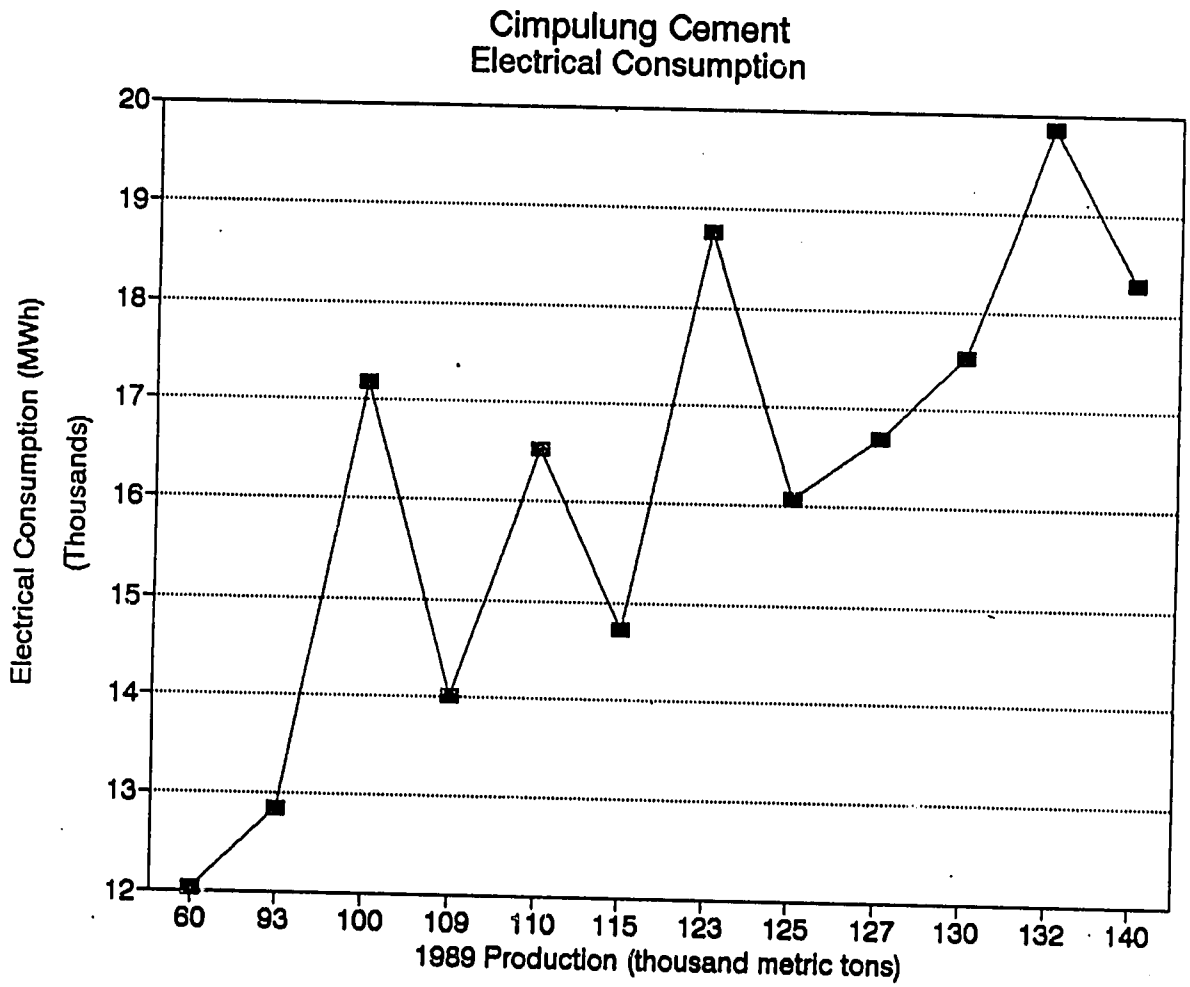


Figure 6. Electrical Intensity

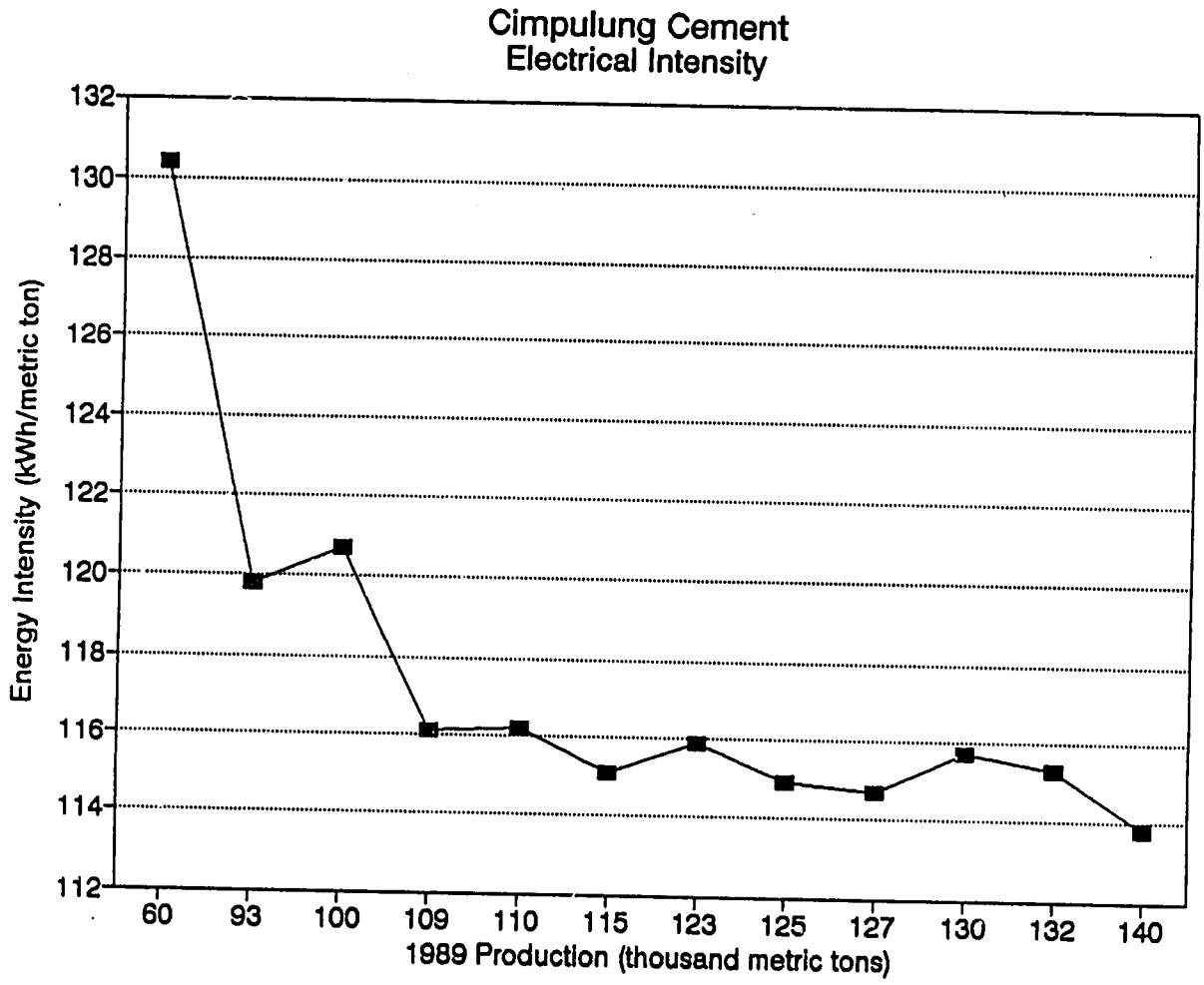


Figure 7. Natural Gas Consumption

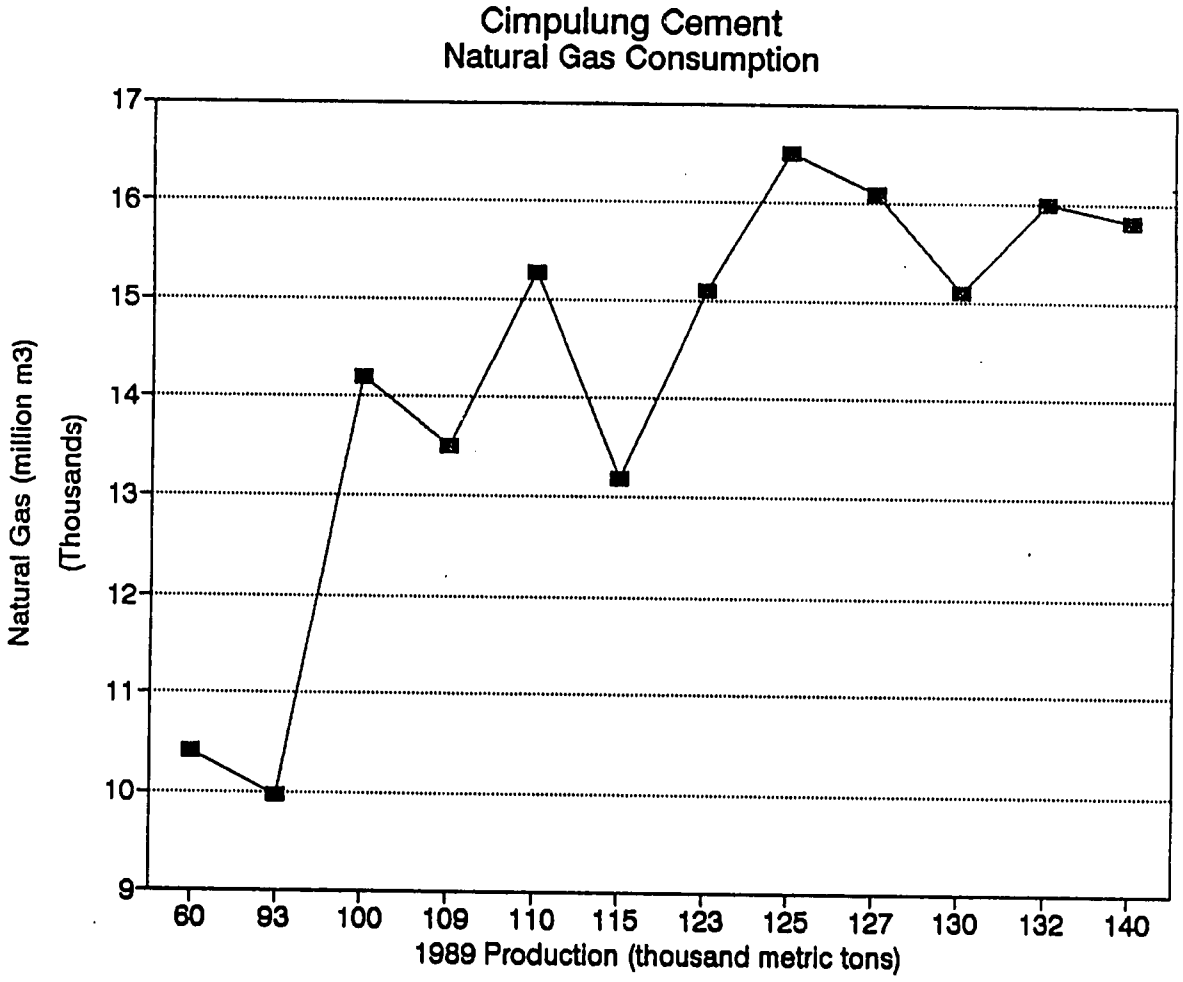
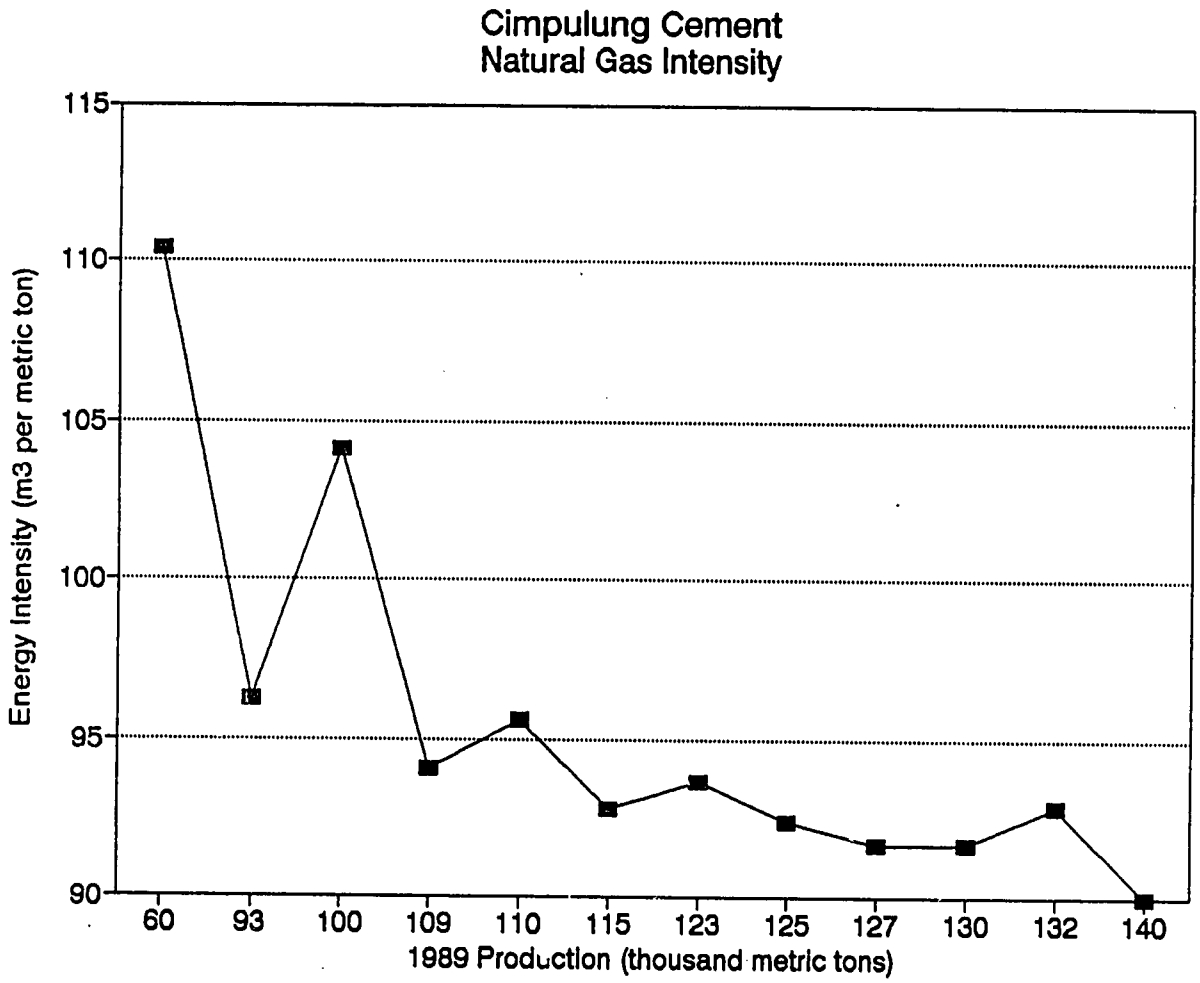


Figure 8. Natural Gas Intensity



3.0 Audit Description

After discussions with plant engineering personnel, Kiln #4, Kiln #5, and the steam boilers were identified as major energy users.

The following problems were identified:

- Lack of boiler combustion controls.
- Lack of kiln combustion controls.
- Lack of metering.
- Waste of condensate.
- Lack of boiler blowdown heat recovery.
- Steam leaks.
- No Energy Management Program.
- No Preventive Maintenance Program.
- Poor process automation.

3.1 Kiln Efficiency

Kiln combustion efficiency was tested with a combustion analyzer. The kilns are long cylindrical furnaces that are mounted horizontally at a slight incline and slowly rotate. The kilns are the principle energy consumer in the plant. They are used in the process of calcinating the raw materials, to promote an endothermic chemical reaction at high temperatures. Part of the process drives off water vapor and carbon dioxide. The combustion analyzer was used to measure the content of the stack gases. The average results of these measurements are shown in the following table for kilns #4 and #5.

Table 3. Combustion Analysis Results (Kiln Combustion)

Kiln	Fuel	Stack Temp (°C)	Oxygen (%)	Carbon Monoxide (ppm)	Efficiency (%)
4	Oil(#6)	145	3.3	473	72
5	Gas	145	4.5	935	81

The stack temperature used is a weighted average of the flue gas temperature before the cooling towers and after preheating in the suspension preheaters. The oxygen percentage readings used were those of gas samples taken closest to the exhaust of the kiln. The high carbon monoxide readings indicate that for both the oil and the gas that there is incomplete combustion. The high carbon monoxide levels leaving the kiln represent significant losses of unburned combustible gases. The data also indicates the need to introduce more air or oxygen to completely utilize the combustible gases.

An energy saving project which may solve this problem would be the installation of an oxygen enrichment system to increase efficiency. Oxygen enrichment can reduce fuel consumption by 15% and, even taking into account energy to produce additional oxygen, there can be significant energy savings.

Temperature measurements were taken with infrared thermometers inside the kiln and at the envelope level. The inside temperature was found to be between 1380-1580 °C. The recommended range is between 1480-1520 °C. At the envelope level the temperature range was between 160-730 °C. The temperature differences can be explained by the variable thickness of interior insulation. Prior to this kind of measurement the insulation thickness could be determined only when shut-down occurred for maintenance purposes.

The lower the temperature, the higher the deposition inside the kiln. This has an adverse effect on production and on energy consumption, which increases by 10-15% for 2-4 days until the problem is solved.

3.2 Boiler Combustion Efficiency

The combustion analyzer was used on the ten metric ton boiler that supplies steam primarily for oil and some other building heating requirements. The results of the stack gas sampling are shown in the following table.

Table 4. Combustion Analysis Results (Boiler Combustion)

Boiler	Fuel	Stack Temp (°C)	Oxygen (%)	Carbon Dioxide (%)	Excess Air (%)	Efficiency (%)
2	Oil(#6)	205	11.4	7.7	111	82
2	Oil(#6)	206	11.0	7.9	105	83

The efficiency of the combustion is low, with high excess air. By decreasing the excess air to 50%, the efficiency of the boiler would rise to 86%. Subsequent tests performed by the plant personnel with the same combustion analyzer on the other operating boiler showed even higher excess air. The initial excess air measured for boiler #1 averaged about 180%. After the boiler operator reduced the amount of air intake into the boiler the readings decreased dramatically to 90-120% excess air. This excess air could still be further reduced.

4.0 Summary of Results and Recommendations

The plant energy audit identified many areas of opportunity for the adoption of energy efficiency measures within the facility. This section provides a summary of these items and recommended actions.

A. Kilns and Boilers - Combustion Controls and Metering

All boilers and kilns operate manually, with no automated controls, limited metering, and no sampling of the combustion parameters. Excess air was found to be 180% in one instance. Boiler efficiency was raised during the audit from 75% to 82% with the help of the combustion analyzer. Kiln combustion efficiency was found to be 72% for kiln #4 and 81% for kiln #5. If efficiency is improved by only 1%, the following may be conserved:

Natural Gas	1,400,000 m^3/year
Oil #6	1,120 metric tons/year
Electricity	1700 MWh/year

B. Kiln Insulation Monitoring

By constant measuring of the envelope (surface) temperature, it is estimated that approximately 88,887 Gcal/year or 100,000 m^3/year of natural gas can be conserved. The constant monitoring will permit the staff to detect insulation faults much more quickly, so that prompt repairs can take place.

C. Condensate Recovery System

By installing a condensate return piping end pump, it is estimated that 1,053,566 m^3/year of natural gas could be conserved. The actual savings in lei will be higher due to the added cost of treating the make-up water.

4.1 Recommended Short-Term Measures

A. Metering and Combustion Testing for Boilers and Kilns

The following savings will occur if efficiency is increased by only 1%:

Natural Gas

Total Gas Savings	1,400,000 m^3/year
Total Energy Savings	11,200 Gcal/year
Total Cost Savings	3,920,000 lei/year ($112,000/year)

Oil #6

Total Oil Savings	1,120 metric tons/year
Total Energy Savings	10,700 Gcal/year
Total Cost Savings	4,592,000 lei/year ($131,200/year)

The equipment to be provided would include: a fuel oil meter at a cost of $5,000; a portable combustion analyzer at a cost of $5,300; a smaller hand-held combustion analyzer at a cost of $800; and a high temperature infrared temperature sensor at a cost of $2,400.

Estimated cost of improvement = $13,500
Payback period = 3 weeks

B. Timely Replacement of Kiln Lining

The current energy loss in this area is calculated at 21,600 m^3 of natural gas per kiln, or approximately 1,150 Gcal/year for six kilns. Assuming the six kilns are refurbished 25 times per year, saving perhaps 77% of the lost energy, the savings would be as follows:

Total Gas Savings	100,000 m^3/year
Total Energy Savings	887 Gcal/year
Total Cost Savings	310,000 lei/year ($8,870/year)

The equipment provided will consist of one low temperature (0 to 1000 °C) infrared temperature sensor, at a cost of $2,200.

Estimated cost of improvement = $2,200
Payback period = 3 months

C. Electrical Improvement

If the combustion efficiency is to be increased by 1% through the use of portable combustion analysis equipment, there will be a resulting decrease in the combustion air required. It is necessary to supply air to maintain a 10:1 ratio of air to natural gas for example, and 20-30% excess air is acceptable. However, one boiler was measured at 180% excess air.

Excess air can be reduced through the use of dampers, but this is a relatively inaccurate approach. A better way to proceed is to install variable speed drives on the large blower motors providing combustion air. An AC power analyzer could be used to monitor electrical energy used by these motors, so that an economic justification can be prepared for the variable speed drive.

The overall average plant electrical load is 15.46 MW, much of which is concentrated in very large motors of as much as 1,600 kW. Thus, in addition to analysis of the combustion blower motors, AC power analysis could be used throughout the plant to justify power factor correction and electrical efficiency improvements.

A sensitivity analysis shows that even a small efficiency improvement of 0.1% would result in reasonable payback for this equipment:

1989 Electrical consumption:	194,583 MWh
194,600 MWh x 0.1% =	194.6 MWh/yr
194.6 MWh x (1000 kWh/MWh) X 2 lei/kWh =	389,200 lei/yr

At the present exchange rate of 35 lei/$, cost savings equals $11,120/yr. The cost of the equipment, including the AC power analyzer at a cost of $5,700 and a laptop computer at a cost of $3,300, is estimated at $9,000. Therefore, payback with only 0.1% improvement would be 10 months.

4.2 Recommended Long-Term Measures

A. Installation of Fixed Automated Boiler and Kiln Combustion Controls

Cost in dollars	$250,000
Savings/year	$80,200
Payback period	3 years

B. Condensate Return System

Total Energy Savings (8,064 Gcal/0.82 efficiency)	9,834 Gcal
Total Gas Savings	1,104,943 m^3/year
Total Cost Savings	2,209,887 lei
Cost in lei	5,000,000 lei
Payback period	2.5 years

4.3 Equipment List

The following energy efficiency equipment is recommended:

1. Fuel Oil Meter:

Type:	1.5" Helix Meter
Flow Range:	0-5000 liters/hour
Temperature:	90-130 °C
Pressure:	25 to 60 bar
Pipe Size:	2" (50.8 mm) internal diameter
Oil Kinematic Viscosity:	2-5 E (0.000015 to 0.000038 m^2/s
Oil Sulfur Content:	2-4%, similar to #6

2. Portable Combustion Analyzer, including measurement of sulfur dioxide and oxides of nitrogen, a built-in printer, and capability to operate on 220 V, 50 Hz power.

3. Hand-held Combustion Analyzer, capable of measuring oxygen, carbon dioxide, and percent efficiency.

4. Infrared Heat Spy - High Temperature (to 3,000 °C)

5. Infrared Heat Spy - Low Temperature (to 1,000 °C)

6. AC Power Analyzer

7. Computer - portable PC, printer, software (lotus and energy economics package)

5.0 Plant Organization Description

The existing organizational chart for the plant is provided in *Figure 1* (page 6). As described previously, both the Mechanic Section and the Energy Section report directly to the Technical Director. Day to day maintenance of the facility is the responsibility of the Raw Materials Section and the Fabrication Section. Both of these divisions also report to the Technical Director. It was noted that while some of the energy waste at the facility is due to poor day to day maintenance (steam leaks, etc.), the Mechanic and Energy Sections are involved only in major overhauls at the facility.

The boiler house currently reports to the Mechanic Section. It was observed that another possible configuration would be to have the boiler house report directly to the Energy Section. It was also suggested that those sections responsible for maintenance report directly to the Energy Section or the Mechanic Section.

5.1 Future Organizational Changes

The facility management plans to designate an energy conservation engineer to identify energy conservation opportunities within the plant. This same person will provide a conceptual design, estimate cost and cost savings and perform an economic analysis of proposed opportunities. The design and installation of the project may be done by outside contractors. This individual, however, will be responsible for supervision and implementation of the project.

It is hoped that through implementation of an energy management program, energy consumption will be reduced by 20% over five years. Energy cost is currently at approximately 40% of the cost of the product.

6.0 Implementation Phase

The implementation phase of the audit involved a return trip to the facility from August 5 to August 9 of 1991. During this phase the main objective was to facilitate the installation and use of the equipment that was purchased for the facility, based on the previously discussed recommendations. The distribution of the equipment to the site was performed by the Romanian Ministry of Industry. A representative from the Ministry was also involved during this phase. The key elements of this phase were:

1. Distribution of portable measuring instrumentation.
2. Training of plant staff.
3. Installation of fixed energy efficiency equipment.
4. Review of draft audit report with plant staff.
5. Monitoring of equipment performance.
6. Discussion of past and future conservation activities.
7. Development of a specific plan for equipment utilization.

A draft of the audit report containing sections 1.0 through 5.0 was provided to the Ministry and plant staff for their review prior to the site visit.

6.1 Summary

All the portable equipment was received and distributed by the Ministry before the end of the implementation phase. The representative from the Ministry at the site was Mr. Nicolae Chivoiu. Also present during much of the site visit were Mr. Julian Toma and Mr. Gheorgha Popa from an agency called MRI in Pitesti. The primary plant contacts were Mr. Emil Rusu, Chief of Technology and Mr. Jon Florea, Chief of Energy. The General manager of the plant is Mr. Gheorghe Pepenel.

Training on the equipment was completed for the plant staff who would use the equipment. Demonstrations were conducted for the power analyzing equipment, including the "down loading" of the power data collected to the EPSON PC computer. Demonstration of the software on the computer included techniques in developing audit reports and project justification.

The hand-held combustion analyzer calibration and training were completed during sample tests of the steam boilers. The portable combustion analyzer (ENERAC) was used on the kilns using gas and oil for combustion and the appropriate staff were trained. A separate test was made on the kiln to determine whether the two types of combustion analyzers would read comparable values. From the tests taken the oxygen readings were within 1% of each other.

The high temperature infrared thermometer was used to measure the temperature inside the kiln and on the kiln body. During the training on this instrument a hot spot was measured on the kiln surface. This instrument can be used to quantify a hot spot to determine the optimal time to repair the kiln wall. A permanent oil flow meter was also scheduled to be installed at the facility, but had not arrived as of the site visit. A new private Romanian engineering company, INSTAPART, has the responsibility of ensuring proper installation and commissioning of the meter.

The draft audit report was reviewed with Mr. Florea and Mr. Rusu. The major inaccuracy they found concerned the average power consumption at the plant which was stated at 1.546 MW, but was actually 15.46 MW. Other than this error they could find no inaccuracies with the figures in the report and felt in general that the report usefully summarized their primary energy concerns. The plant management plans to take a number of energy efficiency improvement measures similar to those recommended in the audit report. The equipment implementation plan was developed by the staff, and outlined the methods and frequency with which the equipment will be used to reduce energy use.

6.2 In-Country Review of Draft Audit Report

Comments were solicited on the draft audit report. The management felt that the report was basically an accurate portrayal of the plant's energy problems. They found the most useful audit results to be the specific recommendations of equipment to meet their needs. New prices were given for fuel and electricity, as follows:

Electricity	• off-peak	2.25 lei/kWh
	• on-peak	6.00 lei/kWh
Gas		2.94 lei/m^3

The actions of the plant in response to the recommendations in the audit were discussed. Plant staff are eager to use the combustion analyzing equipment to increase their burning efficiency on both the kilns and the steam boilers. They demonstrated during the site visit how they can use the infrared temperature sensor to identify hot spots on the kiln surface and take corrective action. The use of the power analyzer will be constant and productive. They have already determined system improvements.

During the site visit the power analyzer was connected to a 1 MW fan used to provide combustion air to the kilns. They plan to evaluate the possibility of implementing variable speed drive system on the fans. They already have a variable speed drive system that controls the cooling grate speed, using a frequency converter from 5 to 200 Hz to regulate speed primarily based on the temperature of the air from the grate to the kiln.

6.3 Energy Efficiency Measures Adopted by the Facility

The projects already implemented by the facility in the last five years to improve energy efficiency include the use of the variable speed drive on the grate speed. This system was installed three years ago at the cost of 6 million lei and is estimated to have a six year payback. Others include the installation of 21 blasters to remove sediment in the gas exhaust system, and an automatic control loop for control of gas temperature to the electrostatic precipitators.

During the discussion of future energy efficiency projects, plant personnel brought out a list of projects for their "program of modernization". From this list that they had previously developed, the projects affecting energy efficiency were identified as follows:

- Variable speed drives for the kiln fan, which presently uses a reostat system, and for the exhaust fan for the clinker cooler, which presently uses inlet air dampers to regulate air flow
- Inlet dampers on grate cooler fans
- Improve sealings for ends of kilns, grate cooler and raw mills to reduce infiltration
- Retrofit insulation for ducts of air to raw mills (drying)
- Improve fuel oil burning in kiln
- Interlock feeding of material to raw/cement mill
- Install condensate return.

Plant staff are also interested in using fixed combustion analyzers at the end of the combustion chamber in each kiln, to measure oxygen and carbon monoxide levels. They feel fixed automated boiler combustion controls would not be appropriate due to the age of the boilers (20 years).

They also developed the following list of equipment for desired future projects:

- Sensor for vibration control of motors
- Frequency converter for fan control in cement mill
- Frequency converter for fan control in grate cooler
- Oscilloscope to install and repair frequency converter

- Air flow meter to optimize air compressor operation
- Equipment for dynamic equilibration of large fan rotors.

6.4 Management Results

Plant management has not changed the management structure since the first site visit. They are still considering designating an energy person to coordinate and identify energy efficiency projects. The management of energy projects is currently divided between two teams. The automation department (the Measurement of Control Devices Department) is in charge of surveying electrical energy equipment. The use of oil or gas is monitored by the technical department.

The role of the Ministry of Industry (MRI) in decisions on which projects to implement was also discussed. Apparently the plant is still heavily under the control of the state. The MRI controls the funding of projects that are related to increasing energy efficiency. The Ministry's budget is limited and the money needs to cover many facilities. The decision on projects to pursue seems to be based less on issues like payback than on production considerations.

6.5 Implementation Plan

1. Portable Combustion Analyzer

The analyzer will be used daily in the kiln as mentioned above and once every two days to monitor boiler combustion efficiency. The boiler excess air will be adjusted based on these readings.

2. Handheld Combustion Analyzer

The analyzer will be used daily in the kiln as mentioned above and once every two days to monitor boiler combustion efficiency. The boiler excess air will be adjusted based on these readings.

3. Infrared Temperature Sensor (High Temp)

This sensor will be used to measure the temperature of the clinker twice per week for each kiln. Initial use will be helpful in clarifying operational problems and optimizing the system. Also it will be used to identify problems with burning such as excess air, bad atomization and quality control of clinkerization.

4. Infrared Temperature Sensor (Low Temp)

Temperature will be monitored at locations three to four meters apart along the kiln surface. Hot spots will be noted and action will be taken appropriately. Identification of high heat losses will be addressed especially in the burning zone of the kiln.

5. Power Analyzer

The electric power consumption of each kiln line will be measured and compared to the other kilns to identify the most efficient kiln and efficiency problems on other kilns. The problems will then be investigated and corrected.

The power level will be monitored for a short time on new motors, to verify the quality of operation and balanced phases.

The power analyzer will also be used to develop proposals for new projects such as variable speed drives for fans, and to evaluate power factor correction requirements

The PC Computer will be used in tandem with the AC power analyzer, for performing analyses of the downloaded measurements.

6. Expected Energy Savings

The expected energy savings are based on earlier estimates of energy savings and the equipment utilization plan listed above. The combustion analyzer is expected to assist the staff in increasing the boiler and kiln efficiency by at least 1%, resulting in a savings of 1,400,000 m^3/yr of gas or 1,120 metric tons/yr of oil. The power analyzer, PC computer, and temperature sensors will be used on many projects and equipment type. Therefore, it is impossible to quantify the overall effect of their use on plant efficiency.

APPENDIX A
List of Energy Efficiency Measures

L I S T

with examples of technical improvements carried - out in order to reduce the power consumption

1. Effectuation of the driving device with variable revolution in continuous current, for the grids that cool the grate.

   Efficiency: 350,000 m^3/year
   980,00 lei/year

2. Driving of the raw materials volumetric dosing device for the cement mills, with variable revolution, in order to allow a proper utilization of the electronic elements.

   Efficiency: 3,000 MWh/year
   3840000 lei/year
   153,000$ / year

3. Erecting of the sediment removing plant, at the passing chambers towards the three clinker furnaces (Big - Blaster)

   Efficiency: 300,000 m^3/year
   840,000 lei/year

4. Effectuation of the automated control loop, for the temperature of the burnt gases that are introduced in the electrofilter.

   Efficiency: 1,000 MWh/year
   1280000 lei/year
   51,000 $ /year

5. Mechanization of the flap driving devices that are set on the burnt gases pipes by means of which they are transported to the meal mills, with remote control electromechanical elements.

   Efficiency: 200 MWh/year
   256,000 lei/year
   10,200 $/year

6. Mechanization of the flap driving devices for the dynamic separators of the fans of the cement mills, with remote control electromechanical elements:

   Efficiency: 400 MWh/year
   512,000 lei/year
   20,400 $/ year

7. Original constructive improvement of the grate coolers for the clinker furnaces with the view of recovering the clinker heat.

   Efficency: 420,000 m^3 of methane gas/yea
   1176000 lei/ year

APPENDIX B
Process Description

TRADE JOINT COMPANY "CIMUS" S.A.
CIMPULUNG ARGES

BRIEF DESCRIPTION OF THE CEMENT PRODUCING PLANT

With the view of cement obtaintion, raw materials like limestone, clay, pyrite, plaster stone and slag are used.

Limestone is extracted from the natural deposit, extant at 2.5 km distance from the plant, by throwing - out the rock from the mountain by means of the explosive material.

The "FKG" excavators (capacity of 4.6 m^3) load the "Belaz" dumping cars that transport the rock to the stone breaking and sorting plant and the waste dump (with pre - homogenization), that lay-out at 0.6 km from the deposit.

From here, by means of a rubber band relay, the material is extracted and transported to the feeding bunkers of the meal mills (extant at 1.9 km from the breaking and sorting plant and the waste dump).

Clay (diorite sand) is exploited from the natural deposit, extant at a distance of 2.2 km from the plant, by means of the "FKG" (of 4.6 m^3 capacity) and "F 302" excavators; after that, the "Belaz" dumping cars transport the material to the breaking and drying plant. From here it is sent, by means of a rubber band relay, to the feeding bunkers of the meal mills (that lay - out at 250 m distance from the breaking and drying plant).

Pyrite is brought by railway and is unloaded from the trucks in the dumping cars by means of a rolling bridge ; after that it is transported with a rubber band relay and introduced into the bunkers of the meal mills (that lay-out at 2oo m distance from the unloading station).

The three components (8o % limestone, 19.5 % clay and o.5 % pyrite) are volumetrically dosed and introduced in order to be crushed in six drying mills (with a length of 7.5 m and a diameter of 3.6 m) with a capacity of 7o t/h.

The obtained meal is introduced in the homogenisation silos and then in four depositing silos.

From here it is extracted by means of the "Schenk" gravimetric dosing devices and transported with the "Fuller" pumps towards the "Wedag" heat - exchanger in four steps.

The pre - heated meal is introduced into the six "CR" clinkerization furnaces, with a capacity of 8oo t/day(with a length of 64 m and a diameter of 4 m).

The obtained clinker is poured into the "Fuller-Constantin" modified grate cooler (yield 6o%).

From here, by means of a conveyer and a rubber band relay, it is transported towards five depositing silos ; each of them has a capacity of 7,5oo tons.

Plaster stone is exploited by taking the rock off the natural deposit(extant at 18 km distance from the plant) by means of the drilling machine, the "D 141" and " F 1251" excavators.

From here the plaster is transported with the dumping cars to the breaking plant (that lay-out at o.2 - o.7 km from the deposits) and with the cable railway to the four depositing silos (extant at o.4 km from the breaking plant). The material is then transported, by means of the dumping cars, to the cement mills (extant at 13.5 km from the depositing silos) and deposited in five bunkers.

Furnace granulated slag is brought by railway, unloaded by means of the rolling bridge and sent to the drying process or deposited in waste dumps.

The drying of the slag is carried-out in two rotative tubular dryers (with a length of 18 m, a diameter of 3 m and a capacity of 3o t/h) with baffles, By means of a rubber band relay, the material is then sent into five bunkers.

The clinker and additives crushing process is carried-out into

five plants composed of mill (with a length of 1o.5 m and a diameter of 4.2 m), two chambers with spherical elements, dynamic separator, electrofilter and interphasic transport equipments (elevator, pneumatic gutters) with an average capacity of 8o t/h.

The finished product (cement) is transported by means of two rubber band relais and pneumatic gutters into twelve depositing silos with a total capacity of 12o.ooo tons.

The cement delivery is carrying - out in bulk or in bags by railway or by road.

Power consumption

The cement factory was equiped with a methane gas burning plant for clinker obtaintion and with a crude oil burning plant that was put into service in 1991.

The initial methane gas burners used primary (cold) air and secondary (warm) air from the grate coolers.

Presenty, with the view of burning the clinker, 7o-8o% of the total fuel is represented by crude oil.

In order to dry the clay and the slag, methane gas is used; this represents 5-6 % of the total consumption.

The technological air preparation for turning crude oil into liquid state, for heating water and apartments, is carried-out by means of three "CR 9" boilers (among which two are in function), with a flow of 1o t of steam/h (at 8 barr). These can use crude oil or methane gas.

The average flows of the burners are:

- for clinker boiler : 3,8oo Nm^3/h, methane gas
  3,2oo kg/h crude oil
- "CR 9" steam boiler : 8oo Nm^3 of methane gas/h
  67o kg of crude oil/h

The electric power feeding of the combine works is carried-out by means of the National Power System, using a deep joint formed by two transport lines of 11o,ooo V, and two transformers of 4o MVA, 11o,ooo/6,ooo V each of them.

From the central system of bars of 6,ooo V, 18 substations are feeded, each of them having its own bars of 6,ooo V and belonging to a technological line or to some independent auxiliary sections.

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By means of these substations the consumers of a technological line, respective motors of 6,000 V, transformers of 6,000/400 V and condensers batteries, are used.

The range of the electric motors of 6,000 V is from 160 kW to 1,600 kW and of the motors of 380 V from 0.37 kW to 160 kW.

The power transfer cells and the consumers feeding cells are endowed with control devices (for current, active and reactive power).

1991, April, 5

FLOW SHEET OF CEMENT FABRICATION

SCHEMA DE PRINCIPIU A FABRICARII CIMENTULUI

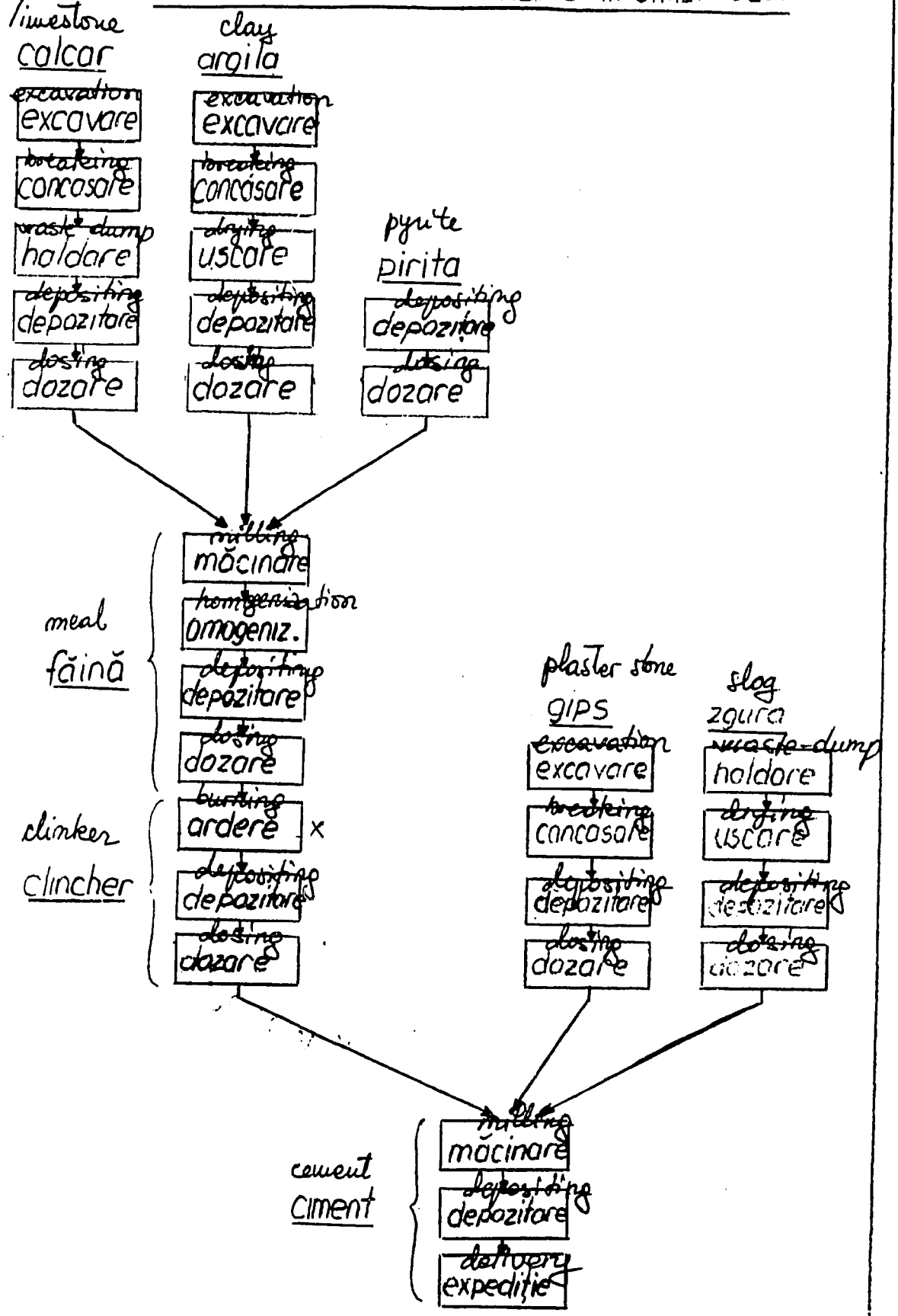

Fig 4

APPENDIX C
Energy Penalty Structure

GOVERNMENT OF ROMANIA

D E C R E E

regarding measures to be taken with the view of reasonable utilization of natural gases and thermo-electric power.

The Government of Romania decides:

Art.1-(1) The economic agents are forbidden to exceed the contracted quantities of natural gases and thermo-electric power.

(2) When the quantities are exceeded, penalties will be put into operation, according to the enclosure that makes integral part of this Decree.

(3) When due to producing possibilities the feeding of existing economic agents is no longer carried-out, the providing will be stopped with a previous notice of five days.

Art.2- In order to reduce the consumptions of natural gases and thermo-electric power in comparison with the contracted quantities, the suppliers will grant reductions to the economic agents; for each percentage of consumption reduction, a percentage of 1% of discount will be accorded.

Art.3-(1) The economic agents that have their own currency resources can import-in order to carry-out supplementary products for exportation in currency, or for delivery on the domestic market, in lei- by means of the suppliers, supplementary quantities of natural gases and electric power, in comparison with those stipulated in the contracts, concluded taking also into account the material balance.

(2) The invoiced costs for the economic agents that contract observing the conditions of paragraph (1) will comprise the costs in currency and the suppliers' transportation and distribution costs, calculated in lei.

Art. 4- The penalties that were raised by applying the provision of Art.1, paragraph(2), diminished with the discounts granted in accordance with Art.2, will be deposited in the budget of the State, in ordertto fill the budget of the Romanian Agency for Energy Conservation, that will be utilized exclusively for financiation of the projects approved by the Resources and Industry Ministry with

the view of power consumption reduction, substitution of hydrocarbons and extension of the utilization of inconvenient energy resources.

Prime-Minister,
Petre Roman
1991, January, 31

Bucharest
1991, January, 31

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ENCLOSURE

PENALTIES

for the quantities of natural gases and thermo-electric power supplementary consumed, in comparisàn with those consumed daily, monthly, and trimestrial, due to approved balances.

Supplementary consumptions, in the range:	Penalties
1oo-1o5%	1,5 times the approved prices
1o5-11o%	2 times the approved prices
11o-115%	2,5 times the approved prices
115-12o%	3 times the approved prices
more than 12o%	4 times the approved prices

APPENDIX D
Energy Costs and Price Structure

Costs

Electric Power	1280 lei/Mwh	$51/Mwh
Natural Gases	2,80 lei/mc	
Crude Oil	4000-4900 lei/tonne	$71,6/tonne
Termic Power	640 lei/Gcal	

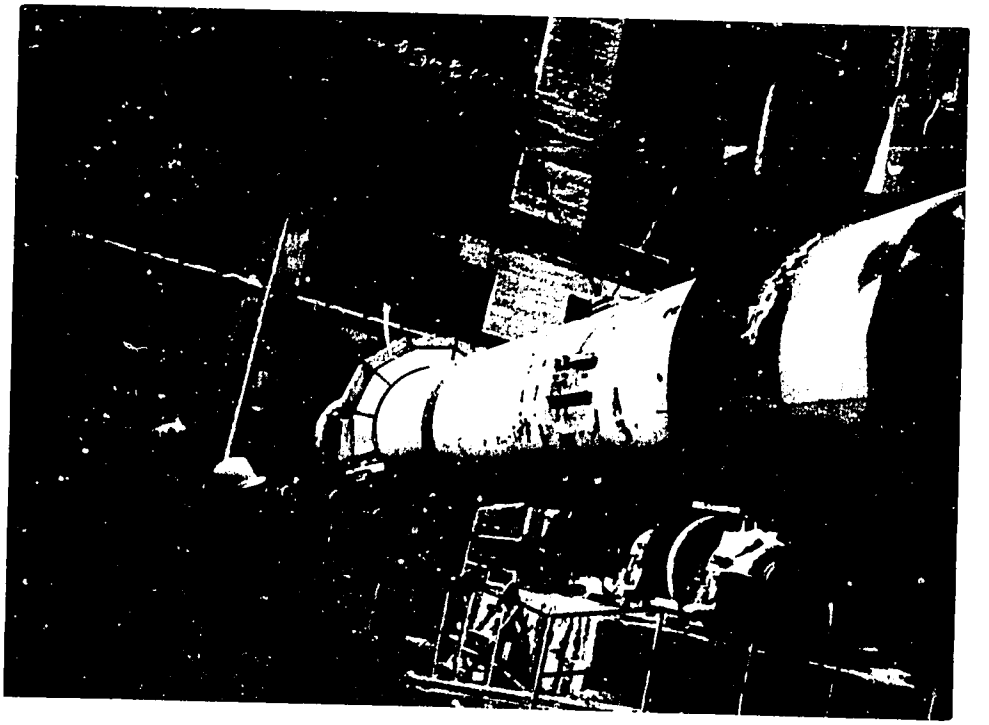
Price Structure for Cement

Electric Power	13,8%
Fuel	25,7%
Raw Materials	45,0%
Salaries	14,4%
Other Expenses	1,1%

APPENDIX E
Photographs

1. Plant technical staff use the hand-held Bacharach combustion analyzer to measure boiler efficiency.

2. Using the ENERAC combustion analyzer, the plant staff measure the combustion efficiency of a kiln.



3. Mr. Rusu and technical staff measure kiln surface temperature with an Infrared Heat Spy.

4. Training session for computer and Dranetz Power Analyzer with the Automation Section. Attendees include Mr. Rusu, Mr. Florea, Mr. Toma, Mr. Chivoiu and Mr. Nicol.

APPENDIX F
List of Abbreviations

AC	= alternating current
amps	= amperes
atm	= atmosphere = 14.696 pounds per square inch
bar	= 100,000 pascals = 14.504 pounds per square inch
BTU	= British thermal unit
cfm	= cubic feet per minute
cm	= centimeter = 0.3937 inches
cm^2	= square centimeter = 0.155 square inches
CO	= carbon monoxide
CO_2	= carbon dioxide
DC	= direct current
°C	= degree Celsius T[°C] = 5/9*(T[°F] + 32)
°F	= degree Fahrenheit
°R	= degrees Rankine T[°R] = T[°F] + 460
eff	= efficiency
ex air	= excess air
Gcal	= gigacalorie = 1 billion calories = 3.968 million BTU
GJ	= gigajoules = 1 billion joules
gph	= U.S. gallons per hour
gpm	= U.S. gallons per minute
GWh	= gigawatt hours = 1 billion watt hours
H_2	= hydrogen
H_2O	= water
H_2SO_4	= sulfuric acid
hectare	= 10,000 square meters = 2.471 acres
hectoliter	= 100 liters = 26.42 U.S. gallons
Hg	= mercury
hr	= hour
Hz	= hertz = cycles per second
J	= joules
K	= Kalvin
kcal	= kilocalories = 1 thousand calories = 3.968 BTU
Kcs	= 29.77/$1 US
kg	= kilogram = 2.2046 pounds
Kgcc	= 7,000 kcal = 27,776 BTU
kJ	= kilojoules = 1 thousand joules = 0.947813 BTU
km	= kilometer = 0.621 miles
kN	= kilonewton = 1 thousand newtons
kPa	= kilo pascals = 1 thousand pascals = 0.14504 pounds per square inch
kV	= kilovolts = 1 thousand volts
kVA	= kilovolt-amperes
kVAr	= kilovars = 1 thousand volt-amperes (reactive)
kW	= kilowatt = 1 thousand watts
kWh	= kilowatt hour = 1 thousand watt hours
lbs	= pounds
liter	= 0.2642 U.S. gallons = 0.03531 cubic feet

m	= meter = 39.37 inches
m^2	= square meter = 10.76 square feet
m^3	= cubic meter = 35.31 cubic feet
mA	= milliampere = 0.001 amperes
MCal	= megacalorie = 1 million calories
metric ton	= 1 thousand kilograms = 1.1023 U.S. tons
mg	= milligrams
min	= minute
MJ	= megajoules
mm	= millimeter = 0.03937 inches
MPa	= 1 million pascals = 145.04 pounds per square inch
MVA	= megavolt-amperes
MW	= megawatt = 1 million watts
MWh	= megawatt hours = 1 million watt hours
NG	= natural gas
nm	= nanometer
Nm^3	= cubic meters at standard conditions of temperature and pressure (20°C and 1 atmosphere)
NO_X	= nitrogen oxide
O_2	= oxygen
P	= pressure
PC	= personal computer
PF	= power factor
ppm	= parts per million
psi	= pounds per square inch
psig	= pounds per square inch (gauge)
R	= thermal resistance
s	= second
SO_2	= sulfur dioxide
sq ft	= square feet
Tcal	= teracalorie = 1 trillion calories = 3.968 billion BTU
T	= temperature
V	= volts
VArs	= volt-amps (reactive)
VSD	= variable speed drive
W	= watts
yr	= year