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ENERGY EFFICIENCY AUDIT REPORT
BORIS KIDRIC PORCELAIN & CERAMICS FACTORY
TITOV VELES, MACEDONIA, YUGOSLAVIA

MARCH 1992

PREPARED BY: RCG/HAGLER, BAILLY, INC.
Arlington, VA

and

TEKON Tehno-Konsalting
Belgrade, Yugoslavia

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

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
BUREAU FOR EUROPE
WASHINGTON, D.C. 20253

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ENERGY & INFRASTRUCTURE DIVISION
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DISCLAIMER

QUALITY ASSURANCE

The contents of this report include recommendations based on data provided by the client plant, measurements made on site, calculations, and engineering judgment. The conclusions reached were based on a limited engagement of only about one week's duration in the plant, and not an exhaustive engineering analysis. RCG/Hagler, Bailly, Inc. certifies that this report conforms to the level of best commercial practice for industrial energy audits of similar level of effort, as conducted in the United States. This report has been prepared under the guidance of a registered Professional Engineer, licensed to practice in the United States.

PRELIMINARY ENERGY AUDIT
BORIS KIDRIC PORCELAIN & CERAMICS

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DRAFT
PRELIMINARY ENERGY AUDIT
BORIS KIDRIC PORCELAIN & CERAMICS
TITOV VELES, MACEDONIA, YUGOSLAVIA

BY
RCG/HAGLER, BAILLY, INC. AND TEKON

I. EXECUTIVE SUMMARY

A team of engineers from RCG/Hagler, Bailly, Inc. and TEKON, carried out site activities at Boris Kidric Porcelain and Ceramics from March 18-22, 1991 to work together with Boris Kidric staff to identify and implement improvements to energy efficiency.

Based on consumption in 1990 and energy prices prevailing at the time of the visit, total energy costs for 1991 at Boris Kidric are estimated as Dn 100 million ($7 million at Dn 14=$1.00), with the primary energy forms being LPG (15,000 tons per year, Dn 75 million per year, $5.4 million) and electricity, (3.6 MW average peak demand, 20,300 MWh/yr, Dn 26 million per year, $1.8 million).

RCG/Hagler, Bailly estimates the potential for energy efficiency improvement at Boris Kidric as 10-15% without process changes. During the survey, the RCG/Hagler, Bailly team identified energy efficiency projects, which represent a cost savings of Dn 6.2 million per year, or 6.2 % of 1991 energy costs, at a total cost of Dn 3.4 million, (a financial payback of 7 months):

A.1 Energy Management Information and Control System
expected cost: Dn 356,000; net savings: Dn 2,830,000
A.2 Electric Motor Survey Team
expected cost: Dn 112,000; net savings: Dn 1,500,000
B.1 Electric Load Management System
expected cost: Dn 580,000; net savings: Dn 1,043,000
C.1 Power Factor Correction
expected cost: Dn 2,240,000; net savings: Dn 865,000

RCG/Hagler, Bailly recommends the following procurement budget for Boris Kidric, subject to final approval by USAID:

A.1 Energy Management Information and Control System: $4,000
A.2 Electric Motor Efficiency Team: $8,000
B.1 Electric Load Management System: $20,000

Boris Kidric agreed to pay for installation and other costs necessary to implement the projects and make full use of the equipment supplied by USAID.

II. INTRODUCTION

Boris Kidric Porcelain and Ceramics (Boris Kidric Fabrika za Porcelan i Keramicki Plocki) is located in Titov Veles, Macedonia, Yugoslavia. The company manufactures three main products: ceramic tiles used by the building construction industry to finish (1) floors and (2) walls; and (3) porcelain ware for household use.

Energy represents about 12-15% of manufacturing cost. Gas is the major energy cost; all gas consumed at Boris Kidric is LPG (propane and butane) because there is as yet no natural gas pipeline installed in this region of Macedonia. The LPG is produced at the Skopje refinery.

The major energy consuming systems are:

1. clay drying - gas-fired spray dryers which have some heat recovery from tile kilns

2. raw material preparation crushing, grinding, mixing - electric mills

3. material firing - gas-fired kilns, separate kilns for tiles and porcelain, several types of kilns of different ages and designs (the new tile kilns are much more efficient)

4. glazing preparation - oil-fired furnaces make glaze from sand

It is expected that by June 30, 1991, partial privatization of Boris Kidric will be in place, through an initial offering of a minority of shares (about 30%) to Boris Kidric employees. The remaining ownership is also expected to be privatized, but at a later date.

A team of senior engineers from RCG/Hagler, Bailly, Inc. and TEKON, carried out site activities at Boris Kidric Porcelain and Ceramics from March 18-22, 1991 to work together with Boris Kidric staff to identify improvements to energy efficiency. The project manager for the effort was Mr. Trajkov Trajce, Dipl. Ing., Manager of Investment in the Boris Kidric Development Department. The RCG/Hagler, Bailly team consisted of:

David Keith, RCG/Hagler, Bailly, Project Director
Mark Oven, RCG/Hagler, Bailly, Manager for Yugoslavia
Eduardo Maal, RCG/Hagler, Bailly, Energy Audit Team Leader
Ljubomir Radenkovic, TEKON, Director

At the request of the management of Boris Kidric, the audit focused on electrical energy, since plans are underway to reduce fuel consumption through conversion to new kilns. This conversion is expected to take place as part of the privatization of the factory. The factory already has some new kilns installed, which are far more efficient than the older ones.

The RCG/Hagler, Bailly team presented its recommendations to Mr. Bogdan Daev, Deputy General Director, Mr. Andreja Stojanov, Director for Development, and Mr. Trajkov Trajce, at the final review meeting March 22, 1991, before leaving Boris Kidric.

The RCG/Hagler, Bailly team observed that the standard of management and engineering expertise already in place at Boris Kidric is quite high. Technical staff is very knowledgeable about energy conservation in general, especially in relation to their process. The RCG/Hagler, Bailly team expects that this staff, with a few additional instruments, tools, and equipment, will be fully capable of making significant improvements to energy efficiency.

The RCG/Hagler, Bailly team would like to express their sincere appreciation for the extraordinary assistance and warm hospitality offered by the staff of Boris Kidric. It is only because of their openness and cooperation that this effort was possible. The RCG/Hagler, Bailly team is glad to have had the opportunity to become friends with the staff of Boris Kidric, and hopes to return their hospitality at some time in the future, whenever Boris Kidric staff visit the United States.

III. ENERGY CONSUMPTION ANALYSIS

A graphical presentation prepared by RCG/Hagler, Bailly of basic data received from Boris Kidric on energy consumption, production, specific energy consumption, and other key parameters is attached as Appendix 1.

These graphs are provided for use by Boris Kidric in identifying variations in energy efficiency. The analysis is a tool to point the way for more detailed investigations. These detailed investigations are beyond the scope of the current study, but several points are evident from the analysis. The main points arising from the analysis which were used to develop specific recommendations are as follows:

1. Specific energy consumption (gas usage per ton or electric energy consumption per ton of tiles or porcelain) is highly variable, as indicated in the scatter diagrams. This could be made more consistent, at a level lower than the present average, through improved to energy management and control of process operations.

2. The trend in specific energy consumption from month-to-month seems to have been deteriorating in 1990 for porcelain, whereas tiles held relatively steady. It should be noted that porcelain production was down significantly in 1990.

3. Boris Kidric has begun managing peak electrical demand (MW), and through the use of manual control systems has achieved good results (a reduction of about 500 kW, more than 10%). Further improvements are possible, but will require automated systems.

4. Power factor (cos phi) is lower than 0.95, so penalty charges are being paid. This is an area where improvements are possible.

IV. ELECTRICAL ENERGY COST ANALYSIS

Boris Kidric has begun efforts to improve fuel energy utilization through process improvements, such as installing new kilns of more modern design, including integrated heat recovery for spray drying. Their major area of concern is now electricity costs, therefore the energy audit focused on electrical energy.

1. Electricity tariff

As of February 1991, the following electricity tariff was in effect for Boris Kidric, (converted based on Dn 14 = $1.00, the rate of exchange at the time):

- Demand charge: Dn 282.12 per kW per month ($20.15)
- Energy charge:
  - On-peak (day) Dn 0.83 per kWh ($0.059)
  - Off-peak (night) Dn 0.43 per kWh ($0.031)
- Power factor penalty (for kVAR in excess of 0.33 x kWh):
  - On-peak (day) Dn 0.21 per kVARh ($0.015)
  - Off-peak (night) Dn 0.10 per kVARh ($0.007)

2. 1990 annual electricity consumption and expected 1991 costs

1. Peak demand (avg): 3627 kW, Dn 12.28 million, ($877,000)
2. Energy:
   - Porcelain:
     - On-peak (day): 4871 MWh, Dn 4.04 million, ($289,000)
     - Off-peak (night): 5435 MWh, Dn 2.34 million ($167,000)
   - Tiles:
     - On-peak (day): 4792 MWh, Dn 3.98 million, ($284,000)
     - Off-peak (night): 5215 MWh, Dn 2.24 million, ($160,000)
3. Power factor penalty:
   - Porcelain reactive energy:
     - On-peak (day): 3508 MVARh (PF = 0.81, 1900 MVARh excess) = Dn 399,000, ($28,000)
     - Off-peak (night): 3733 MVARh (PF = 0.82, 1939 MVARh excess) = Dn 194,000, ($14,000)
   - Tiles reactive energy:
     - On-peak (day): 3068 MVARh (PF = 0.84, 1487 MVARh excess) = Dn 312,000, ($22,000)
     - Off-peak (night): 3674 MVARh (PF = 0.82, 1953 MVARh excess) = Dn 195,000, ($14,000)
   - Total power factor penalty: Dn 1.10 million ($78,000)

Total electric cost: Dn 25.98 million ($1.856 million)

V. RECOMMENDATIONS FOR ENERGY EFFICIENCY IMPROVEMENT

RCG/Hagler, Bailly's recommendations for energy management and efficiency improvement have been grouped in three categories:

A. General and Energy Management - These projects are opportunities which are recommended for immediate action, and require little or no expenditure. These projects affect management systems and techniques, rather than process equipment. These projects are the primary focus of the USAID Emergency Energy Program for Yugoslavia.

B. Low-cost, Short-term Improvements - These projects are low-cost improvements to process plant and equipment which are recommended for implementation in the short-term (in 1991). Because of the low cost and quick payback (less than one year), these projects could be implemented from the company's annual maintenance budget. Some of these projects may be of interest to the USAID Emergency Energy Program for Yugoslavia.

C. Capital Improvements - These projects are longer term projects, requiring investment of more than $100,000. Such projects would require careful study, beyond the scope of this preliminary energy audit. These projects are also beyond the scope of funding under the USAID Emergency Energy Program for Yugoslavia.

A. GENERAL AND ENERGY MANAGEMENT

Boris Kidric Action A.1 -
Introduce an energy management information and control system

1. Process Area

Management

2. Statement of Recommendation

Plant management needs to be able to obtain the information needed quickly enough to exercise the control required to improve efficiency in the use of energy and other valuable inputs. There are several steps required to achieve closed loop control for efficiency.

Step 1 - The daily report (tiles) should be modified to include energy consumption (LPG and electric) and a calculation of the ratio of energy consumption to metric tons of production. Boris Kidric top management agreed to add this information to the daily report as soon as possible.

Step 2- A management information system (M.I.S.) should be installed on Boris Kidric existing PC computer to provide the information necessary for energy management. This system must have software designed to calculate the necessary performance ratios and to present information to management in an easily-understandable form.

Step 3 - Management must use the information to make short-term management decisions which lead to control actions (changes) which affect plant operations. A plant-wide management control system should be developed on a daily basis.

Step 4 - Realistic energy management targets should be set, based on improvements in performance ratios. Specific projects, operational changes, and maintenance procedures should be carried out in order to achieve these targets (such as those suggested elsewhere in this report), and success of these actions should be measured and documented by the M.I.C.S.

3. Description/Rationale

3.1 Existing Conditions

The system of management information and control in place at Boris Kidric is typical of most factories in Yugoslavia. Production is based on plans, and management exercises control over the process to see that the plan is carried out. These plans set performance targets, which are based on input and output quantities.

A vast amount of data is collected by hand every day, in the form of logs and other records from many different sources. In the case of tiles, the data are used to assemble daily reports. The main purpose of these daily reports is to monitor production quantity and also quality. At present, no information regarding energy consumption is included in the daily reports. In the case of porcelain, there is such a wide variety of products that daily reports are not indicative. Therefore only weekly progress reports are prepared which compare progress against monthly production targets

3.2 Findings

Energy usage should be well correlated with production, as indicated by the results of a regression analysis. In such a regression analysis, RCG/Hagler, Bailly, Inc. analyzes the correlation between energy consumption and the physical production processes which constitute energy demand. In Boris Kidric, two types of energy are used, fuel energy consumption in the form of propane/butane gas (liquified petroleum gas - LPG), and electricity. The amount of energy consumed in any given period (dependent variable) should be correlated to the production achieved during the same period (the independent variables).

Four separate regression analyses were carried out for Boris Kidric on the tiles and porcelain production. The independent variables selected for Boris Kidric were monthly production (tons) of porcelain and tiles. The dependent variables were LPG consumption and electricity consumption (kWh). These analyses lead to the development of a factory energy performance linear equation, of the form:

$$y = ax + b,$$

where y = dependent variable (energy consumption)
x = independent variable (production)
a = slope, "x coefficient" (variable energy per ton)
b = intercept, "constant" (fixed energy usage per day or month)

RCG/Hagler, Bailly analyzed monthly data during a three-year sample period (1988-1990). Compared to our experience in carrying out similar analyses in other plants in other countries, the indicator of correlation, r squared, at 0.5 is lower than expected (except in the case of porcelain electric energy, 0.7). This analysis indicates that (1) energy consumption varies excessively for a given level of production, and (2) energy consumption at Boris Kidric more closely approximates a fixed cost than a variable cost.

In the short-run, such as on a batch, shift, or daily basis, energy consumption in the plant seems to operate as an "open loop" control system. Although data regarding energy consumption may be collected, it is not organized, analyzed and presented to management on a daily basis. For example, performance ratios such as energy per unit of production are not developed on a daily basis, although they could be calculated from the available meters. Because management does not have a good picture of how well the process is performing, in terms of energy efficiency, on a daily basis, management cannot exert short-run control actions which would improve efficiency. By the time management receives the monthly report, it is too late to exercise the control function. Thus the plant seems to run open-loop against a reference value, the production target.

The RCG/Hagler, Bailly team believes that the lack of a closed-loop plant energy management system accounts for the increased variability in energy consumption and the high constant energy consumption observed in the regression analysis.

Boris Kidric - LPG analysis
Regression based on 36 months data 1988-1990

1. Predicting Tiles LPG from tiles production

Regression Output:

Constant	8.52	thousand m3 per month
Std Err of Y Est	22.2	
R Squared	0.52	
No. of Observations	36	
Degrees of Freedom	34	
X Coefficient(s)	0.044	thousand m3 per ton
Std Err of Coef.	0.007	
"t" statistic	6.100	

2. Predicting Porcelain LPG from porcelain production

Regression Output:

Constant	52.7	thousand m3 per month
Std Err of Y Est	11.9	
R Squared	0.52	
No. of Observations	36	
Degrees of Freedom	34	
X Coefficient(s)	0.093	thousand m3 per ton
Std Err of Coef.	0.015	
"t" statistic	6.100	

Boris Kidric - Electrical analysis
Regression based on 36 months data 1988-1990

3. Predicting Tiles MWh from tiles production

Regression Output:

Constant		196.2 MWh per month
Std Err of Y Est		97.4
R Squared		0.54
No. of Observations		36
Degrees of Freedom		34
X Coefficient(s)	0.200 MWh per ton	
Std Err of Coef.	0.032	
"t" statistic	6.329	

4. Predicting Porcelain MWh from porcelain production

Regression Output:

Constant		326.3 MWh per month
Std Err of Y Est		76.5
R Squared		0.73
No. of Observations		36
Degrees of Freedom		34
X Coefficient(s)	0.935 MWh per ton	
Std Err of Coef.	0.098	
"t" statistic	9.536	

4. Benefits

4.1 Energy savings

The RCG/Hagler, Bailly team estimates that conversion to the closed loop system, together with specific management actions to control operational efficiency, can achieve energy savings in the amount of 10-15% of annual energy consumption, based on experiences of similar companies in the U.S. and Europe which have highly variable specific energy consumption before implementing such systems. However, to be conservative the RCG/Hagler, Bailly team assumes a savings of just 3% in calculating the benefits of the system. Thus the expected value of the energy savings is:

Gas - management control
    1990 LPG consumption 15,000,000 kg:
        at cost Dn 5/kg, Dn 75 million per year
    annual benefit estimate (3%) =
        Dn 2.2 million per yr, $160,000

Electric - management control
    expected 1991 energy costs: Dn 25.98 million, $1.86 million
    annual benefit estimate (3%) =
        Dn 780,000 per yr, $55,000

4.2 Other benefits

Additional savings, such as reduced use of raw material and reduced generation of scrap are possible but are beyond the scope of this report and are therefore not estimated.

5. Implementation cost

Equipment required:
    Personal computer (IBM compatible):
        (to be proposed for procurement under USAID program)
        (1) 286, VGA, 2 MB RAM, 20 MB disk
        (1) 24-pin dot matrix wide carriage printer
        (1) spreadsheet software (Lotus 1-2-3)
        total estimated cost $4,000

    Spreadsheet software development:
        local contract - Dn 150,000 (by Boris Kidric)

Staff training:
local contract - Dn 150,000 (by Boris Kidric)

Total development cost (Dn 14 = $1.00) - Dn 356,000

Annual incremental costs:
equipment and maintenance - Dn 150,000 (by Boris Kidric)

6. Financial analysis

Payback period (including investments by both USAID and Boris Kidric) = capital cost/net annual cost savings

Dn 356,000/(Dn 2,980,000 - Dn 150,000) = 0.1 year

7. Implementation schedule

Task 1 - Boris Kidric adds measure of specific energy consumption to the daily report to management.
Milestone: May 10, 1991

Task 2 - Boris Kidric assigns responsibility for tracking specific energy consumption, for reporting trends, and making recommendations for improvement.
Milestone: May 10, 1991

Task 3 - RCG/Hagler, Bailly prepares specification for computer equipment and submits for approval by USAID.
Milestone: June 21, 1991

Task 4 - USAID provides final approval for procurement.
Milestone: June 31, 1991

Task 5 - RCG/Hagler, Bailly issues purchase order for equipment.
Milestone: July 2, 1991

Task 6 - Equipment delivered to Boris Kidric.
Milestone: August 2, 1991

Task 7 - Boris Kidric completes development of operating procedure for use of equipment. Boris Kidric staff complete training course in Lotus 1-2-3 by their local contractor.
Milestone: August 16, 1991

Task 8 - Equipment installed in plant, and software in place by Boris Kidric or their local contractor.

Milestone: August 16, 1991

Task 9 - Equipment fully operational and in use, monitoring begins by Boris Kidric.
Milestone: September 1, 1991

8. Technical risk

The project equipment is well proven and will not become an integral part of the process, so there is no technical risk. There is a risk that the energy savings achieved will be less than expected, but there is an equal chance that greater savings will be achieved.

9. Back-up data and calculation

Please refer to the graphical analysis of energy consumption and efficiency included as Appendix 1.

10. Specification of equipment

Personal computer (IBM compatible):
(to be proposed for procurement under USAID program)
(1) 286, VGA, 2 MB RAM, 20 MB disk
(1) 24-pin dot matrix wide carriage printer
(1) spreadsheet software (Lotus 1-2-3)
total estimated cost $4,000

Spreadsheet software:
(to be developed by Boris Kidric or local consultants)
database of daily data
graphical analysis of trends
scatter diagrams of energy vs. production
daily report form
monthly report form
annual report form

A. GENERAL AND ENERGY MANAGEMENT

Boris Kidric Action A.2 -
Activate electric motor efficiency team to reduce losses

1. Process Area

Management

2. Statement of Recommendation

RCG/Hagler, Bailly recommends that Boris Kidric form an Electric Motor Efficiency Team. Personnel for this team should be drawn from Boris Kidric staff, as this exercise should become a continuous part of plant operations and maintenance. The Electric Motor Efficiency Team would be responsible to survey motor load and efficiency, check and clean motors, replace underloaded motors, rewind or replace motors with excessive reactance, and develop a plan for introduction of high efficiency motors.

3. Description/Rationale

3.1 Detailed Description

The Electric Motor Efficiency Team should have the following specific tasks:

- Based on nameplate and available meters, make a complete inventory of all motors over 5 kW, which identifies the motor number, rating (kW), location, age, voltage, rpm, running amperes, expected annual energy consumption, description of use.

- Obtain curves of efficiency vs. percentage load and power factor vs. percentage load from Boris Kidric's major suppliers of motors families of motors now installed in the plant. (Typical curves are included in RCG/Hagler, Bailly's report for reference).

- Develop specifications for the procurement of new motors for the plant, for new applications. Obtain manufacturer's data on price, efficiency and power factor (cos phi) for alternative lines. In the U.S., manufacturers offer two types of electric motors - standard motors and high efficiency motors which reduce energy consumption by 3-10% for the same application.

The increase in efficiency is greatest for smaller sizes (under 50 kW), since large motors are relatively efficient. The high efficiency motor costs about 50% more than the standard motor, but in applications with high duty factor (over 4,000 hours per year, like Boris Kidric), this incremental cost can be recovered in one year or less. RCG/Hagler, Bailly expects that the results of this analysis will result in the development of a new specification, for high efficiency motors.

- After carrying out the analysis and developing the new high efficiency specification for new motors, consider the possible replacement of existing motors with high efficiency motors on a phased basis. One way to implement this policy would be to buy a quantity of high efficiency motors which would be used to replace burned-out motors, instead of rewinding them. Often, rewound motors have lower efficiency than new motors, as the magnets can suffer reduced flux if they are overheated in the process. Efficiency loss can also result because rewinding is usually done to lower quality standards than new manufacturing, so increased friction can result from slight misalignment. Finally, if wire of smaller diameter or higher resistivity is used in the rewind job, resistive losses will increase. It is the RCG/Hagler, Bailly team's experience that a rewound motor has an efficiency 1-5% less than a new motor, and rewinding costs 50% or more of the cost of a new motor.

- Using portable volt-ammeter, power factor meter, carry out an electric motor load survey. The load (kW, kVAR, cos phi), voltage on each phase, and efficiency of all motors over about 10 kW should be checked using a systematic procedure.

- Using a strip-chart demand recorder, carry out power demand survey (kW, kVAR, metered demand kW, and kWh/shift) for load centers over 100 kW. Based on this data, develop a power demand balance for the plant, under various operating conditions.

- Based on the results of the power demand survey, work together with process personnel to investigate ways to reschedule operations to reduce peak demand and to shift consumption from peak to off-peak hours.

- If motors with excessive reactance are identified, they should be taken out of service for rewinding or replacement, since kVAR charges paid by Boris Kidric are substantial.

- Institute a monthly policy of motor maintenance. Check that bearings are getting proper lubrication. Electrical connections should be checked and tightened if necessary. The housing and ventilation air intake on all motors should be cleaned to improve cooling and efficiency. Compressed air should be used to blow out dust and dirt from internal parts of the motor (air should be dry and less than 4 bar pressure to avoid damaging insulation). The motor and its drive system drive should be checked for proper alignment, proper belt tension, and proper lubrication. Insulation should be tested with a megohmeter, and a log should be kept of these readings so that comparisons can be made from month-to-month. Check for excessive vibration.

- As underloaded motors are identified by the survey, they should be changed for motors appropriately sized for the job. The inventory (developed above) should serve as the basis for moving motors from one location to another within the plant to match sizes to loads. If properly sized motors are available from spares or stocks, replacements of a given kW rating should prioritized on the basis of the possible efficiency improvement (degree of underloading and operating hours per year).

- If phase-to-phase voltage imbalance is found (over 2%), then adjustments should be made to correct the problem. For every 2% variation in phase-to-phase voltage, a motor loses about 1% in efficiency. For the 0.4 kV system, the phase voltages should be equal within ± 5 volts, otherwise efficiency is reduced. Voltage imbalance can be caused by loose or corroded connections at bus bars, starter terminals, fuses, or the motor itself. If the problem is caused by single-phase loads which are attached one of the phases, these loads should be more equally distributed among the phases, or else the transformer should be retapped.

3.2 Existing Conditions

Boris Kidric has hundreds of electric motors installed in the plant, for material processing (grinding, mixing), pumping (water and process flows), ventilation (fans), and material handling. These motors are not necessarily sized according to the capacity needed to do the job. There are also many motors operating in extremely dusty environments, such as raw material preparation.

3.3 Findings:

Demand survey, electrical energy balance

On March 20, 1991, the RCG/Hagler, Bailly team carried out a spot-check assessment of power demand on the Boris Kidric electrical system at Transformer Station "A". This day was generally representative of the typical factory operating condition. This station feeds the major electrical energy use in the plant, raw material grinding and preparation.

Primary consumption:

Incoming lines at 10.5 kV =
Power factor (cos phi) measured as 0.86 on Transformer I, (assumed the same on rest of circuits, which are not metered)

Circuit	Amps	kVA	P.F.	kW
Transformer I, plant A	98	1,782	0.86	1,533
Transformer II, plant A	8	145		125
Transformer III, plant A	8.5	155		133
Feeder to plant B	39	709		610
	153.5	2,792		2,401

A detailed analysis of energy demand can be carried out by Boris Kidric staff. The results of this analysis should be useful in identifying electric energy costs.

Motor efficiency:

The RCG/Hagler, Bailly team conducted spot checks of three motors, CEBEC #3-5, which are grinding mills for raw material preparation. Of these, all were 75 kW motors, which were found to be oversized (given the load which varies from 17 to 42 kW). Based on interviews with key plant electrical staff, the RCG/Hagler, Bailly team expects that other such opportunities exist in the plant.

Spot checks by the RCG/Hagler, Bailly team of one primary circuit (Aa) and three raw material mill motors (CEBEC 3-5) revealed excessive reactive power on one of the three motors and on the raw mill Aa circuit.

The RCG/Hagler, Bailly team conducted a power demand survey of the Plant "A" load using a strip-chart recording kW, kVAR meter.

Three motors (CEBEC #3-5) were analyzed using a true RMS digital multimeter, a power factor meter and a strobe tachometer. The load on mill circuit Aa was measured continuously for 24 hours from March 21-22, 1991 and the load was found to be highly variable, 50 kW, but varying from 30-60 kW in response to the sinusoidal load. The reactive power was constant at about 90 kVAR, the average power factor (cos phi) was 0.5.

In the raw material preparation shop for floor tiles, three identical Siemens ILA4-280B3 75 kW (100 horsepower) motors, driving grinding mills (ball mills), were tested. The mechanical load (quantity of batch mix and balls) on all three motors was identical at the time. The motor full load characteristics are 142 A, PF=0.86, 1480 rpm.

Speed readings were made using a strobe tachometer, but these were not accurate because it was only possible to observe speed after the clutch and gearbox, through which additional slip could have occurred. Therefore it was not possible to make an accurate estimate of the motor efficiency. The motor load varies continuously with the rotation of the mill drum. The following readings were obtained:

Description	Current (amps)			Power factor (cos phi)		
	Min	Avg	Max	Min	Avg	Max
CEBEC #3	48	69	88	0.5	0.6	0.7
CEBEC #4	49	63	87	0.5	0.6	0.7
CEBEC #5	104	113	136	0.25	0.37	0.5

Calculations made by the RCG/Hagler, Bailly team together with Boris Kidric electrical engineers revealed that all three motors are drawing the same real (active) power - 16 kW (min), 27 kW (avg), 42 kW (max). However, the reactive power on CEBEC #5 is 69 kVAR, compared to only 37 kVAR on the others.

3.2 Findings

The RCG/Hagler, Bailly team concludes that the motor for CEBEC #5 has a high reactance, indicative of internal damage to stator or rotor windings, blockage of air gaps with dust, or breakdown of insulation. During the course of the audit, the RCG/Hagler, Bailly team worked together with Boris Kidric electrical engineers to demonstrate the situation and to discuss rewinding the motor. This was agreed by Boris Kidric.

The 32 kVAR excessive reactive power at CEBEC #5 represents a cost of 6.7 Dinars per hour on-peak and 3.2 Dinar per hour off-peak, or 118 Dinars per day. At 300 days per year, this represents an excessive cost of 35,000 Dinars per year ($2,500 per year).

4. Benefits

4.1 Energy savings

The RCG/Hagler, Bailly team estimates that the potential savings of this program is 1.5% of peak demand and electric energy and 20% of excess kVAR cost, in the first year. Over time, as motors are replaced and maintenance is improved, the ultimate possible savings are about 5% of electric energy consumption. The cost savings for the first year is estimated as follows:

1. Peak demand: 54 kW, Dn 182,000, $13,000
2. Energy:
   - Porcelain:
     - On-peak (day): 73 MWh, Dn 60,000, $4,000
     - Off-peak (night): 82 MWh, Dn 35,000, $2,000
   - Tiles:
     - On-peak (day): 72 MWh, Dn 60,000, $4,000
     - Off-peak (night): 78 MWh, Dn 34,000, $2,000
3. Power factor penalty:
   - Total power factor penalty: Dn 220,000, $16,000

Total year 1 electric cost savings: Dn 591,000, $42,000

By the second year, savings of Dn 1,500,000 should be achievable.

4.2 Other benefits

The maintenance program will increase motor life, thereby reducing replacement and rewinding costs over the long run. The maintenance and monitoring program will also reduce the frequency of shutdowns in production operations because of motor failures, thereby having a productivity benefit. These benefits are not estimated in this report.

5. Implementation cost

Equipment required:

Electric motor survey instruments:

(1) Power demand analyzer (Esterline Angus Miniservo)
(1) Digital strobe tachometer
(1) Digital multimeter/megohmeter with current clamp
(1) Power factor meter
total estimated cost $8,000 (USAID)

Incidental equipment and repairs budget Dn 15,000 per year
Total cost (Dn 14 = $1.00) - Dn 112,000 plus ongoing labor

and maintenance cost of Dn 15,000 per year

6. Financial analysis:

Payback period (including investments by both USAID and Boris Kidric) = capital cost/net annual cost savings
Dn 112,000/(Dn 1,500,000 - Dn 15,000) = 0.1 year

7. Implementation schedule

Task 1 - Boris Kidric forms Electric Motor Efficiency Team (E.M.E.T.)
Milestone: June 10, 1991

Task 2 - RCG/Hagler, Bailly prepares specification for monitoring equipment and submits for approval by USAID.
Milestone: June 21, 1991

Task 3 - USAID provides final approval for procurement.
Milestone: June 31, 1991

Task 4 - RCG/Hagler, Bailly issues purchase order for equipment.
Milestone: July 2, 1991

Task 5 - Equipment delivered to Boris Kidric.
Milestone: August 2, 1991

Task 6 - Boris Kidric E.M.E.T. completes inventory of installed motors, using nameplate data and existing instrumentation. E.M.E.T. receives data from motor manufacturers on efficiency and power factor vs. load in Yugoslavia. RCG/Hagler, Bailly provides similar data from manufacturers in U.S. E.M.E.T. begins evaluation of motor specification by investigating cost/benefit of high efficiency motors.
Milestone: August 2, 1991

Task 7 - Boris Kidric E.M.E.T. completes development of operating procedure for use of equipment, including design of motor survey. E.M.E.T. begins survey.
Milestone: August 16, 1991

Task 8 - Boris Kidric E.M.E.T. completes survey and prepares report on results.
Milestone: October 16, 1991

8. Technical risk

None.

9. Back-up data and calculation

10. Specification of equipment

(1) Power demand analyzer (Esterline Angus Miniservo III S22904-1-50 or equivalent):

Strip chart type - 3-pen (display any three of kW, kVAR, power factor, integrated demand over 15-minute electric utility window sliding scale)

LCD display of kVA or power factor

counter-type display of cumulative kWh

50 Hz, 220 V

(3) clamp-on current transformers, 1000 amperes

spare pens and charts for 1-year expected operation

(1) Digital tachometer (Transcat 7258FST-W or equivalent)

strobe-type, 0-15,000 rpm

digital display to 0.1 rpm

accuracy ± 2 rpm

50 Hz, 220 V

(1) Digital multimeter (ITT or equivalent)

measure amps, volts, ohms, and power factor
voltage probes suitable for 1000 volts
clamp-on current probe - 1000 amps, 2 inch diameter
rugged industrial case

B. LOW-COST, SHORT-TERM IMPROVEMENTS

Boris Kidric Action B.1 - Install Electric Load Management System

1. Process Area

Electrical system

2. Statement of Recommendation

RCG/Hagler, Bailly recommends that Boris Kidric install an electric load management system (LMS). This system should be a basic controller, capable of controlling a minimum of 24 points.

The LMS should carry out two functions:

- Limit peak demand (kW)
- Shift interruptible loads to off-peak hours

3. Description/Rationale

3.1 Existing Conditions

Boris Kidric purchases electricity under a time-of-day tariff and pays nearly 50% of electricity cost for peak demand (kW). There are many opportunities in the factory to reschedule activities in order to shift electricity usage to off-peak hours.

3.2 Findings:

The RCG/Hagler, Bailly team analyzed Boris Kidric electric energy consumption records for the period 1988-90. From this analysis, it appears that electricity usage is not being optimized according to the time-of-day. Boris Kidric electrical engineers confirmed this.

4. Benefits

4.1 Energy savings

Based on their experience with similar systems in the U.S., the RCG/Hagler, Bailly team estimates that the potential savings of the EMS is 8% of the electric peak demand, and that 2% of on-peak (day time) energy consumption can be shifted to off-peak hours (night time).

Reduced peak demand: 290 kW, Dn 981,000 per year, $70,000

Shift peak energy to off-peak (saving 0.4 Dn/kWh shifted):
Porcelain: 97 MWh/yr, Dn 39,000 per year, $3,000
Tiles: 96 MWh/yr, Dn 38,000 per year, $3,000

Total savings: Dn 1,058,000 per year, $76,000

4.2 Other benefits

None.

5. Implementation cost

Equipment required:
Electric load management system:
(1) 24 point, PLC-type LMS
estimated cost $20,000 (USAID)

Installation cost: Dn 300,000

Incidental equipment and repairs budget Dn 15,000 per year

Total cost (Dn 14 = $1.00): Dn 580,000 plus ongoing maintenance cost of Dn 15,000 per year

6. Financial analysis

Payback period (including investments by both USAID and Boris Kidric) = capital cost/net annual cost savings

Dn 580,000/(Dn 1,058,000 - Dn 15,000) = 0.6 year

7. Implementation schedule

Task 1 - RCG/Hagler, Bailly prepares specification for load control equipment and submits for approval by USAID.
Milestone: June 28, 1991

Task 2 - USAID provides final approval for procurement.
Milestone: July 10, 1991

Task 3 - RCG/Hagler, Bailly issues purchase order for equipment.
Milestone: July 12, 1991

Task 4 - Equipment delivered to Boris Kidric.
Milestone: September 12, 1991

Task 5 - Boris Kidric completes development priorities for grinding, crushing, and mixing operations and load-shedding procedure.
Milestone: September 12, 1991

Task 6 - Boris Kidric completes installation work of system interconnection.
Milestone: September 19, 1991

Task 7 - Boris Kidric completes all installation and check-out. Equipment placed into operation, load shedding procedure adopted
Milestone: October 16, 1991

8. Technical risk

Disrupting process operations has limited risk, but is not judged to be serious because raw material in crushing, grinding, and mixing operations will not solidify. All sheddable loads will be such low priority and therefore interruptible.

9. Back-up data and calculation

To be provided after final equipment selection.

10. Specification of equipment

Functions: Start/Stop based on:
- time of day
- peak demand
- delay of ~20 minutes (adjustable)

Control points: 24 channels
- 8 to 10 motor groups (4 to 6 motors of 10-30 hp each)
- 12 to 16 individual motors (30 to 160 hp each)
- motor voltage is 380 V, 50 Hz

Power input: 220 V; 50 Hz

Type of relay: contact (simple relay)

Equipment: Programmable control panel
Wiring/cable connections for controlled loads
Peak demand readout at panel

C. CAPITAL IMPROVEMENTS

Boris Kidric Action C.1 - Electric Power Factor Correction

Existing Conditions:

Boris Kidric purchases electricity under a time-of-day tariff with a power factor (cosine phi) penalty and pays about Dn 1.1 million per year for excessive reactive power factor. Boris Kidric has some power factor correction capacitors installed already, but they are insufficient.

Findings:

The RCG/Hagler, Bailly team analyzed Boris Kidric electric energy consumption records for the period 1988-90. From this analysis, it is apparent that the average power factor is about 0.81, or about 10 MVAR.

Recommendation:

Power factor will be improved somewhat (to about 0.85) by the Electric Motor Efficiency Team, as they replace underloaded motors and rewind motors with excessive reactance. RCG/Hagler, Bailly recommends that Boris Kidric further improve power factor to 0.95 by installing additional power factor correction capacitors.

Expected Results:

Through this program, Boris Kidric can achieve a plant power factor of 0.95, and hence avoid power factor penalties (for excess kVAR). Of the improvement, 20% is expected to come from the motor team and its survey and the remainder (80%) from the installation of additional capacitors. Reduction in reactive energy by capacitors:

Dn 880,000 per year, $63,000

Cost Estimate:

Power factor correction capacitor system: 8,000 kVAR at $30/kVAR: Dn 3,000,000
Incidental equipment and repairs budget Dn 15,000 per year

Financial analysis:

Payback period = capital cost/net annual cost savings
Dn 3,000,000/(Dn 880,000 - Dn 15,000) = 3.5 year

C. CAPITAL IMPROVEMENTS

Boris Kidric Action C.2 - Continue long-term strategy toward process improvements

Boris Kidric has already installed some new kilns which have a specific energy consumption approximately 30% less than their old kilns. These kilns also improve productivity and product quality. Continued process improvement is the key not only to improved energy efficiency but also profitability, and in fact the company's ability to perform in a market-oriented economy.

RCG/Hagler, Bailly recommends that Boris Kidric develop a long-term strategy and business plan for the company. This strategy would include two basic elements:

1. Development of a statement of corporate objectives. This would define the company's future product lines and markets. It would be based on an analysis of the profitability and competitiveness of Boris Kidric's current products and the potential market for other similar porcelain and ceramic products. It would define the niche in which Boris Kidric as a business enterprise will operate through the year 2000. This will represent the basis for corporate strategy.

2. Based on the corporate strategy, Boris Kidric should develop specific business plans for the main functional areas of the company. Each business plan should cover the primary inputs required to execute the corporate strategy. The main functional areas are:

- Marketing - development of a marketing plan and improvements to the marketing department. This will include a system of pricing products, and a decision system for entering and leaving markets.

- Production - identification of the process improvements required to manufacture the products required by the market at a cost which will enable the company to make a profit. This will include a plan for investments quality control, packaging, production capacity expansion, energy efficiency, and environmental control. It will also include development of a plan for improved labor productivity.

- Finance - development of a plan to finance the operations of the company, through sales of products and injection of debt and equity capital.

- Management - improvements to the organizational and management system to maximize profit margins and return on shareholders' equity.

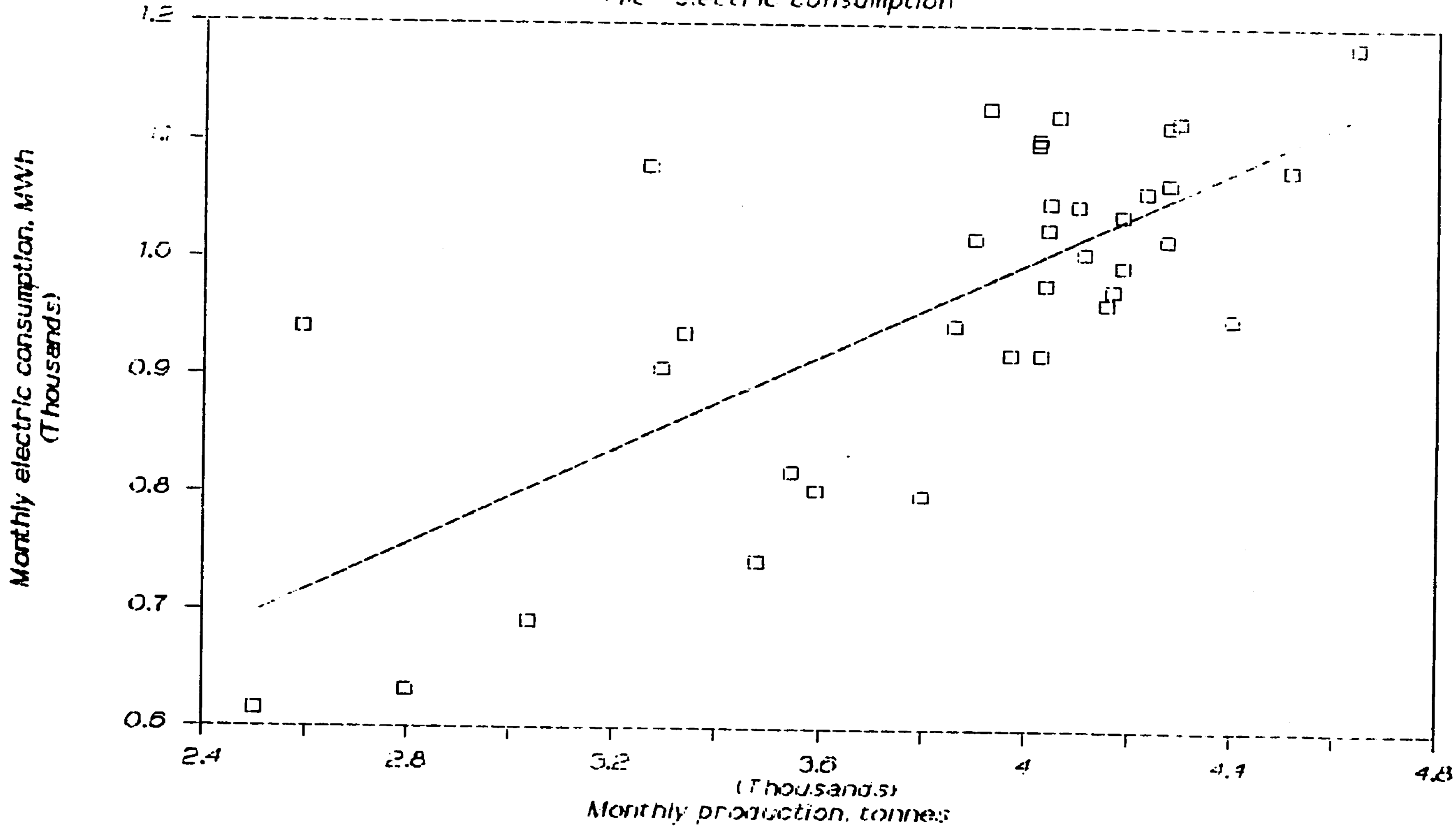
- Research and development - improvements to the company's R&D department to develop new products and to reduce production costs of existing products.

APPENDIX 1
GRAPHICAL PRESENTATION OF HISTORICAL ENERGY CONSUMPTION AND EFFICIENCY DATA

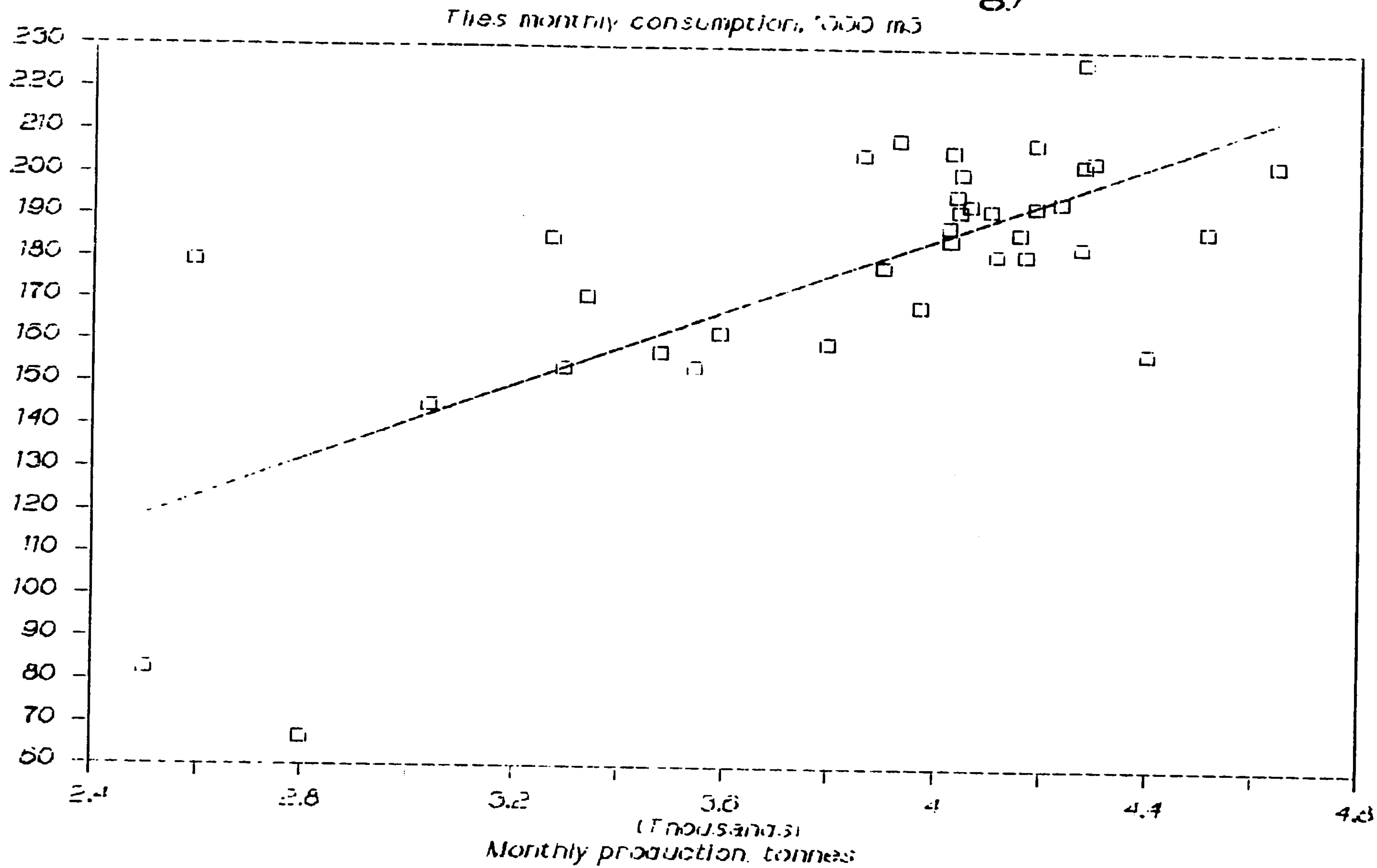
BORIS KIDRIC PORCELAIN & CERAMICS

Boris Kidric - Electric Energy

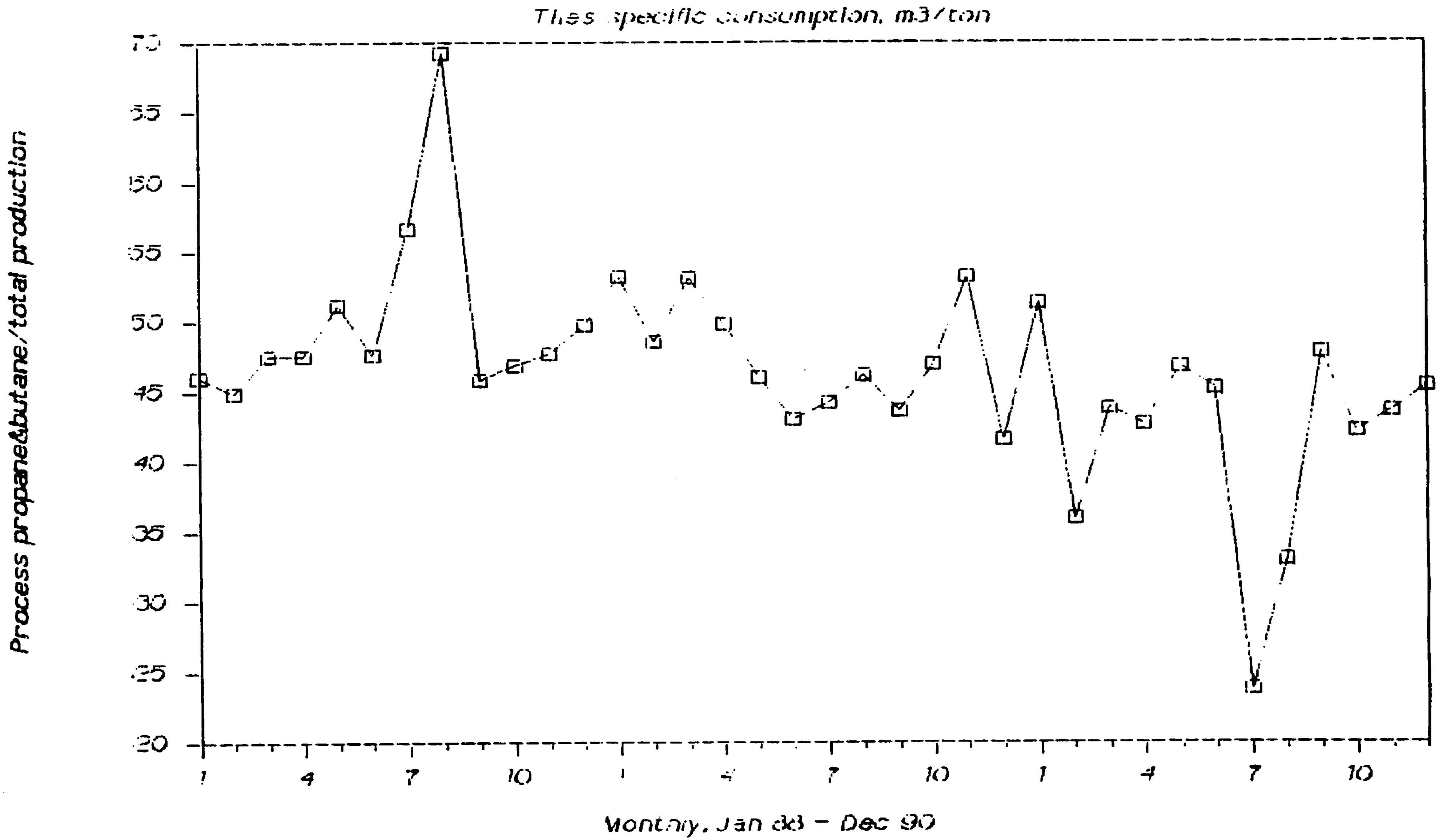
The electric consumption



Boris Kidric - LPG Energy

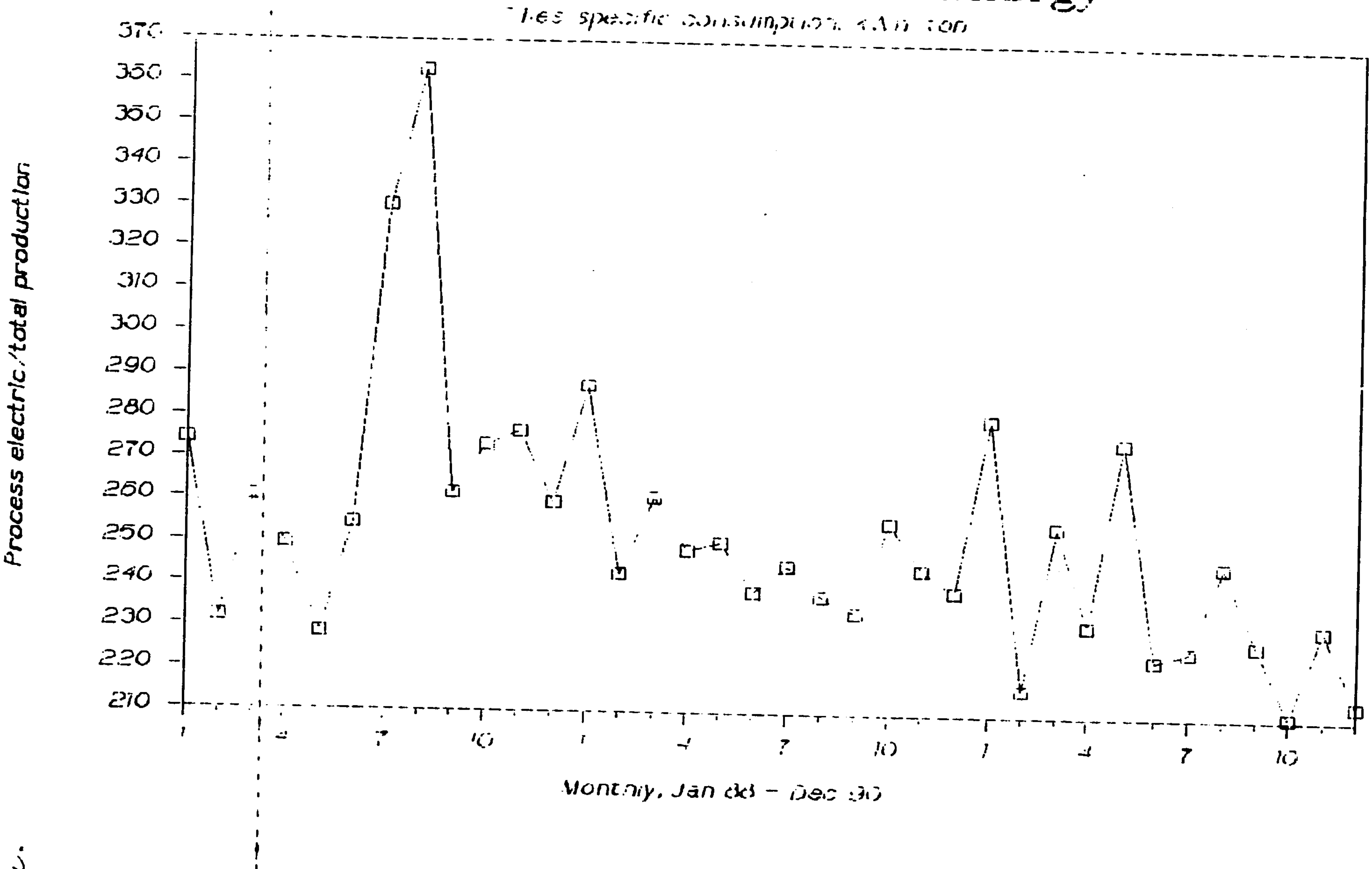


Boris Kidric - LPG Energy



22

Boris Kidric - Electric Energy



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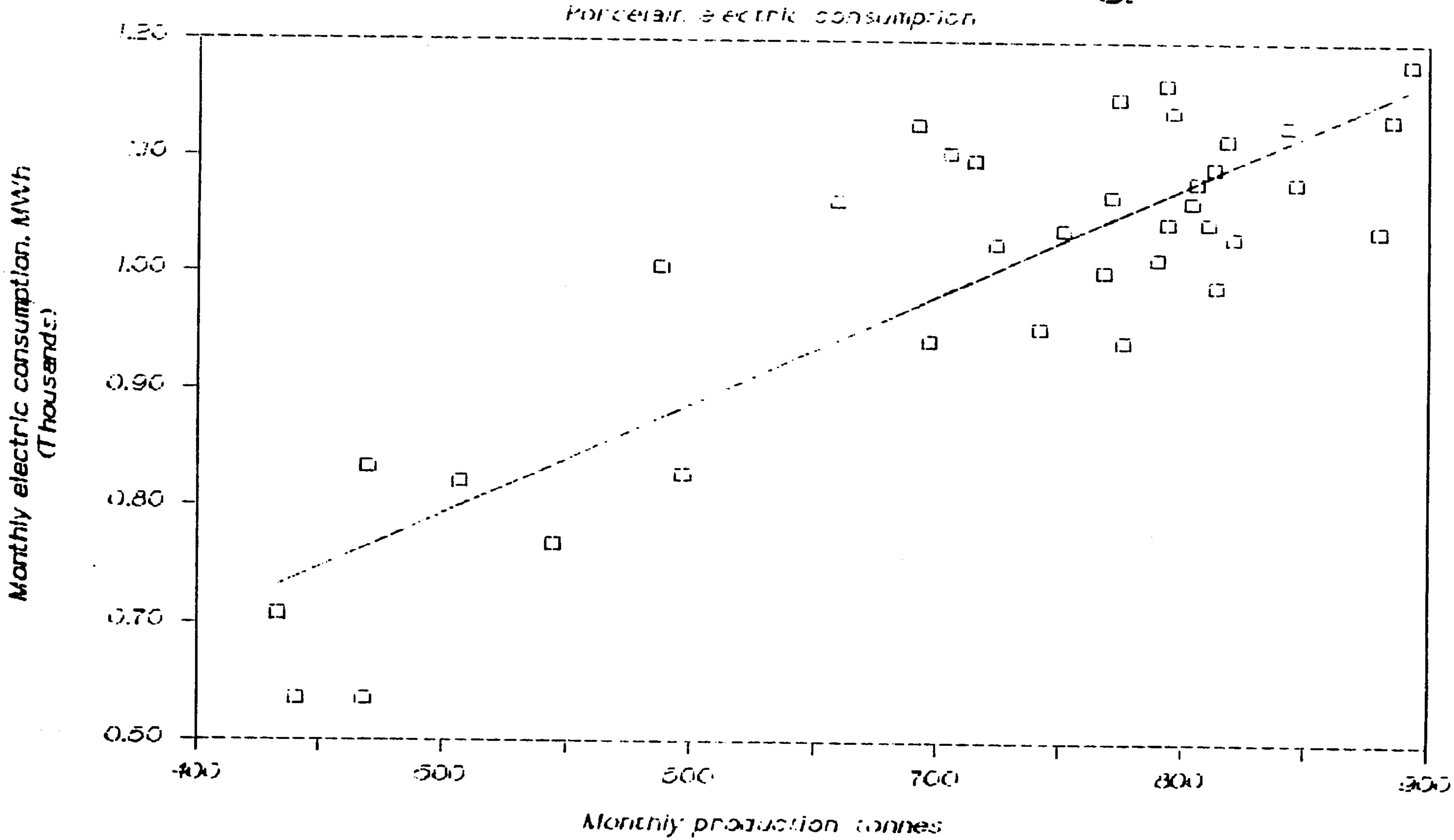

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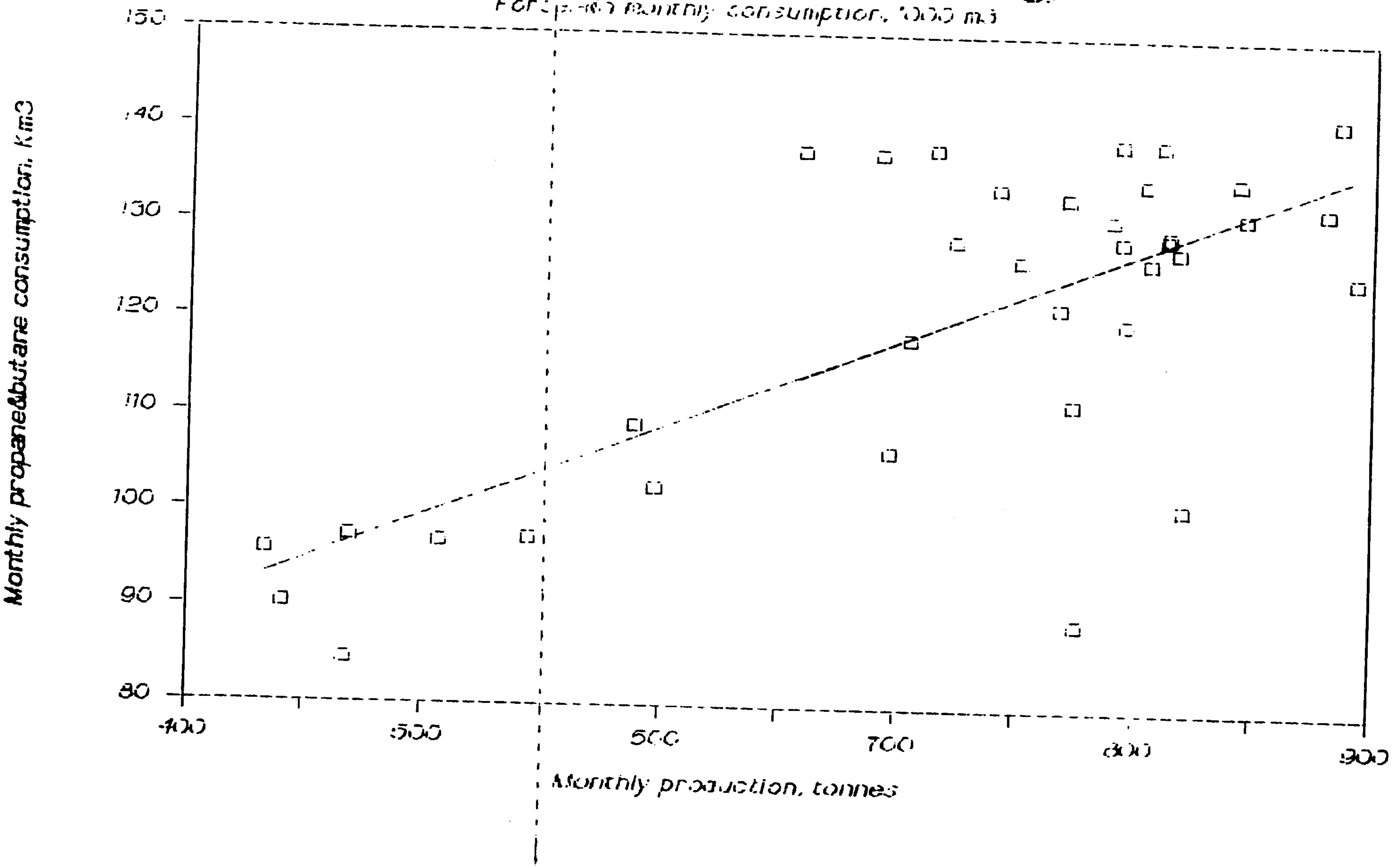

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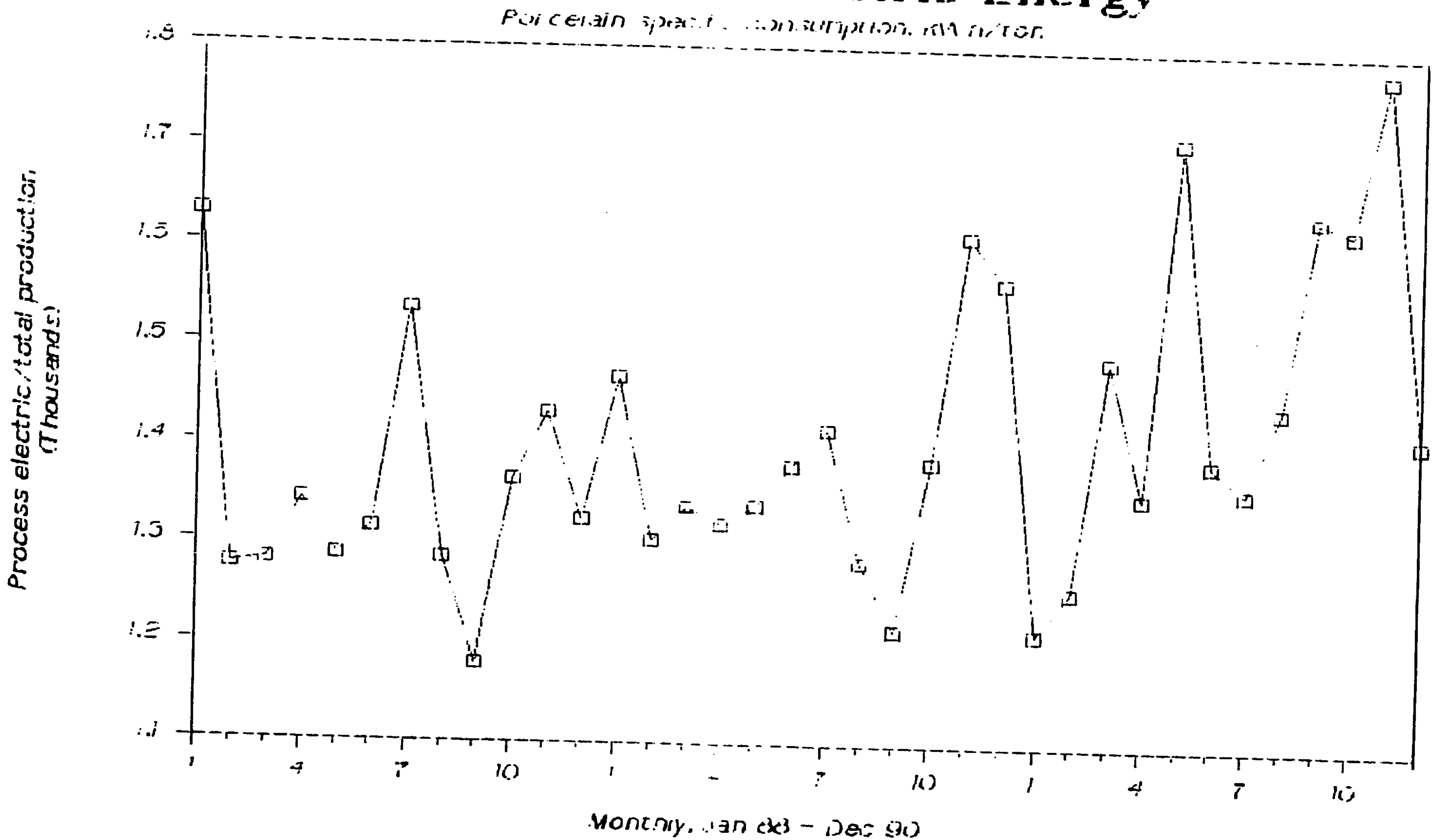
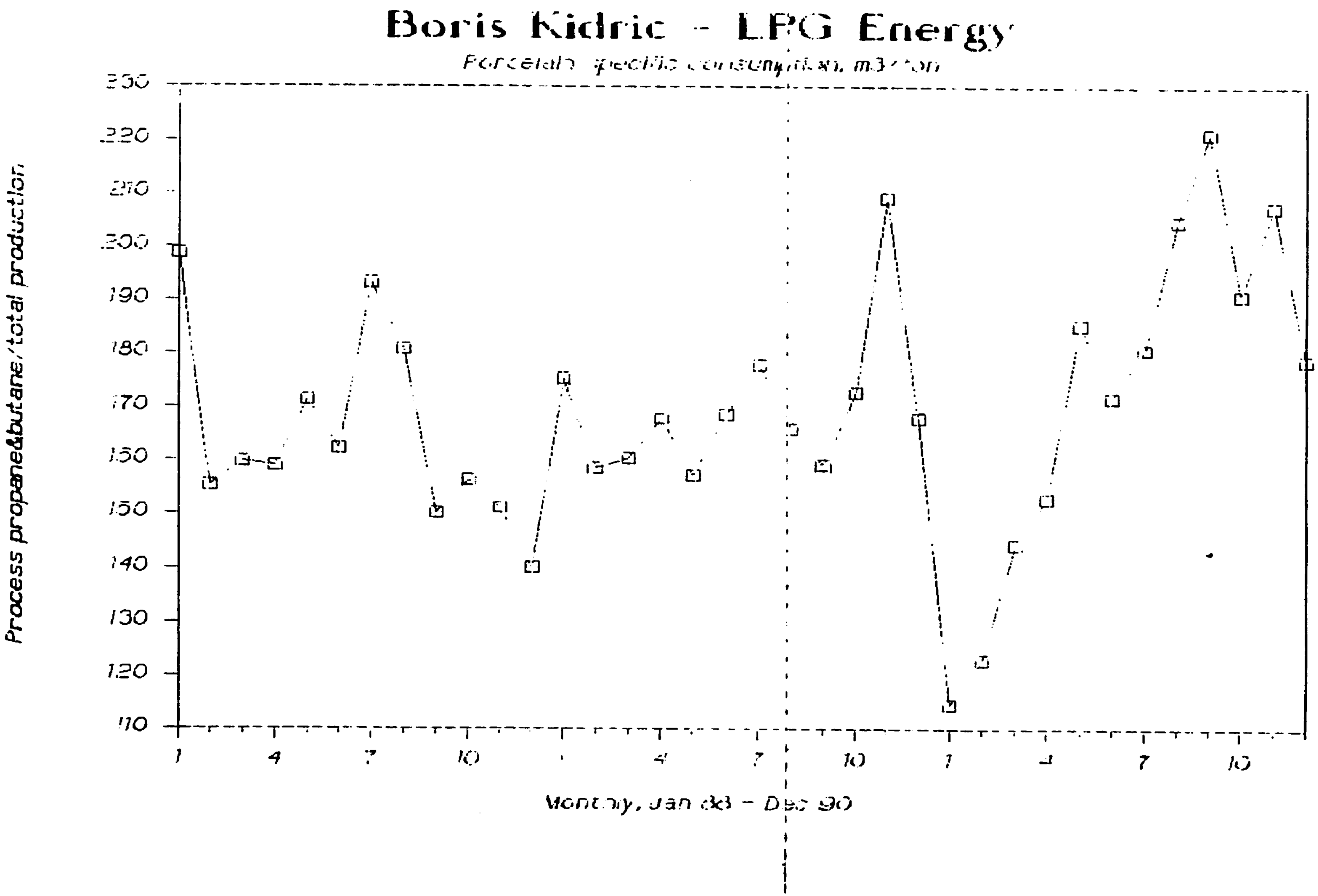
Boris Kidric - Electric Energy

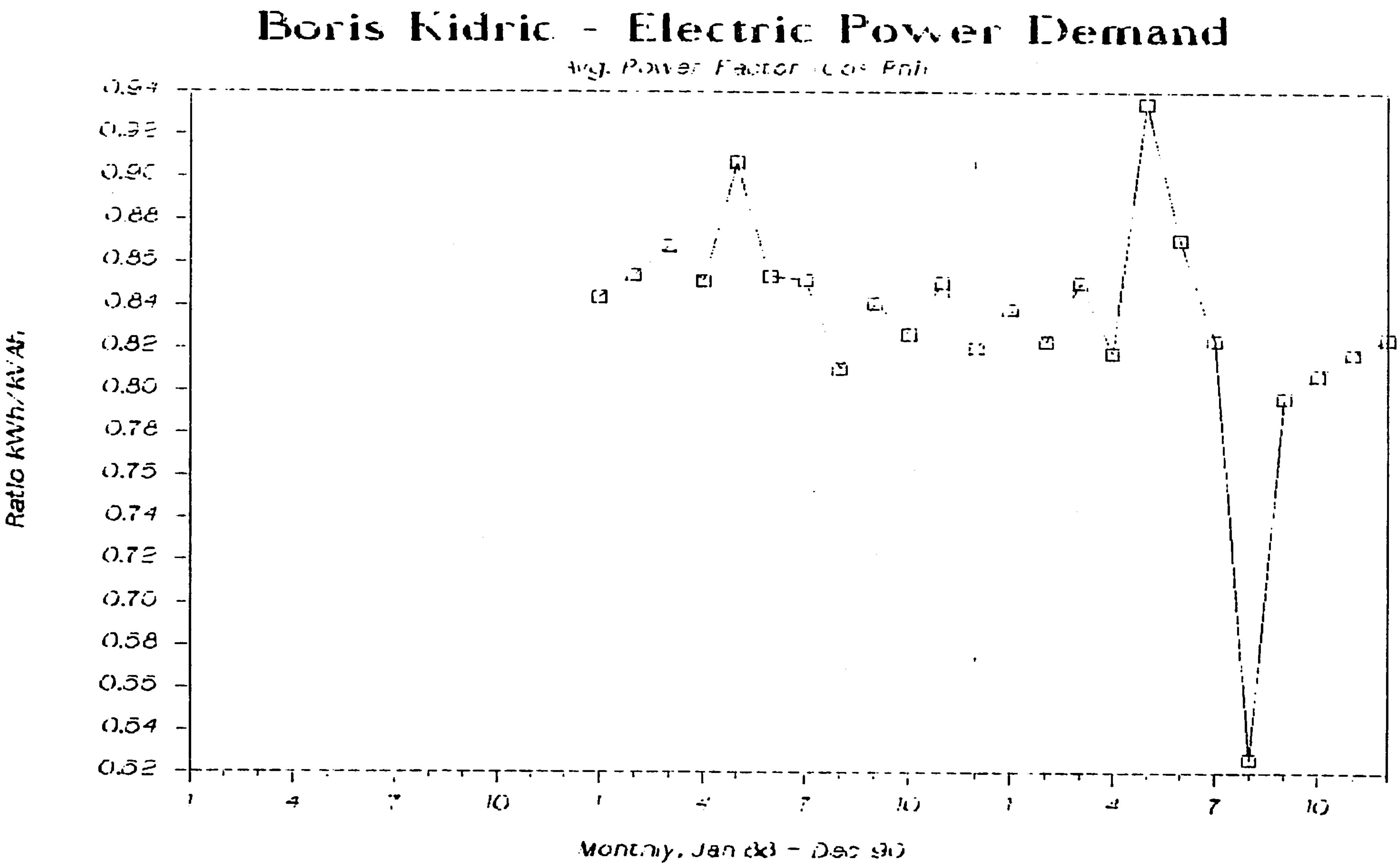


36.



Boris Kidric - LPG Energy
Porcelain specific consumption, m3/ton
Process propane&butane/total production
Monthly, Jan 88 - Dec 90

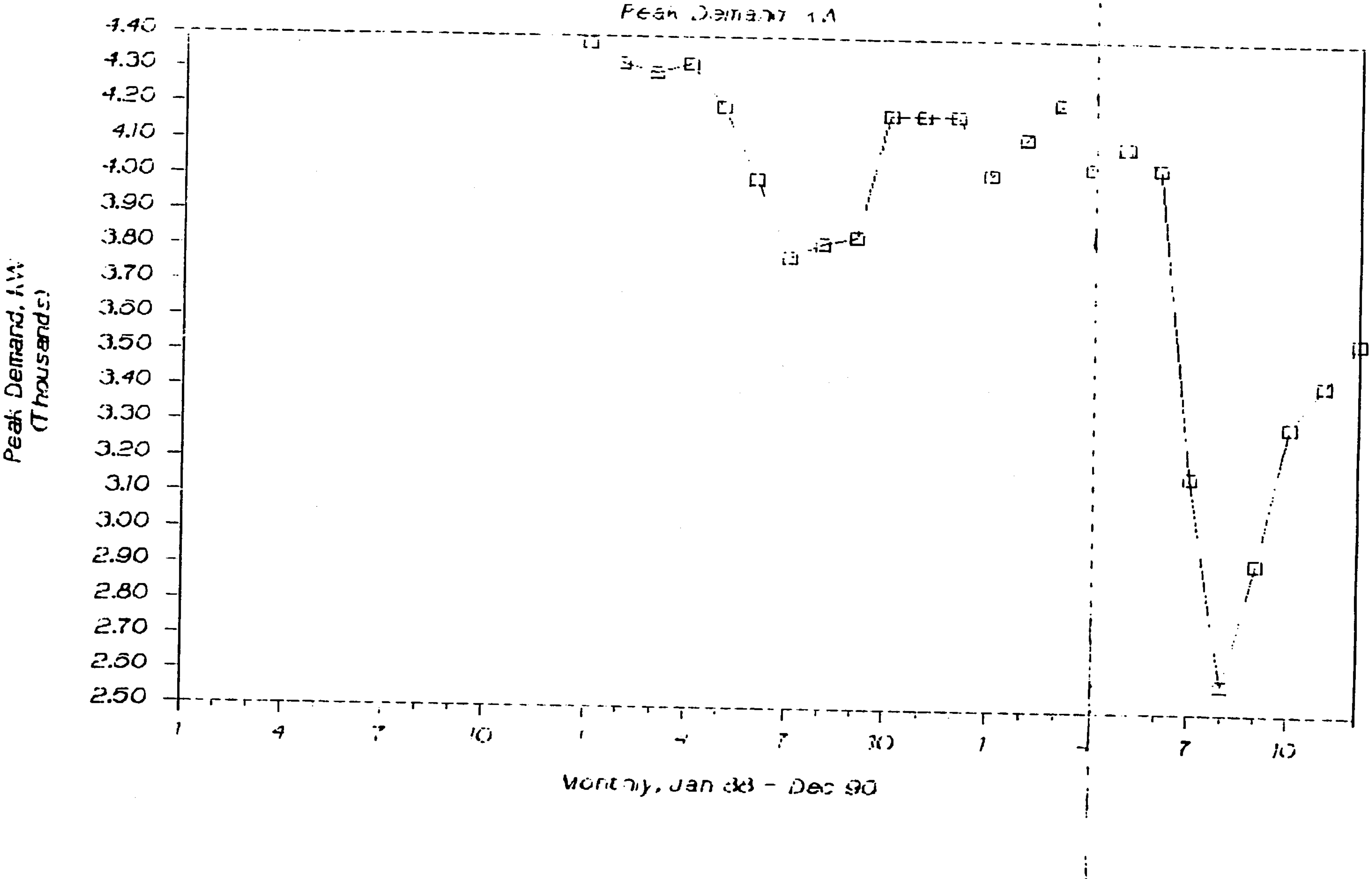
37

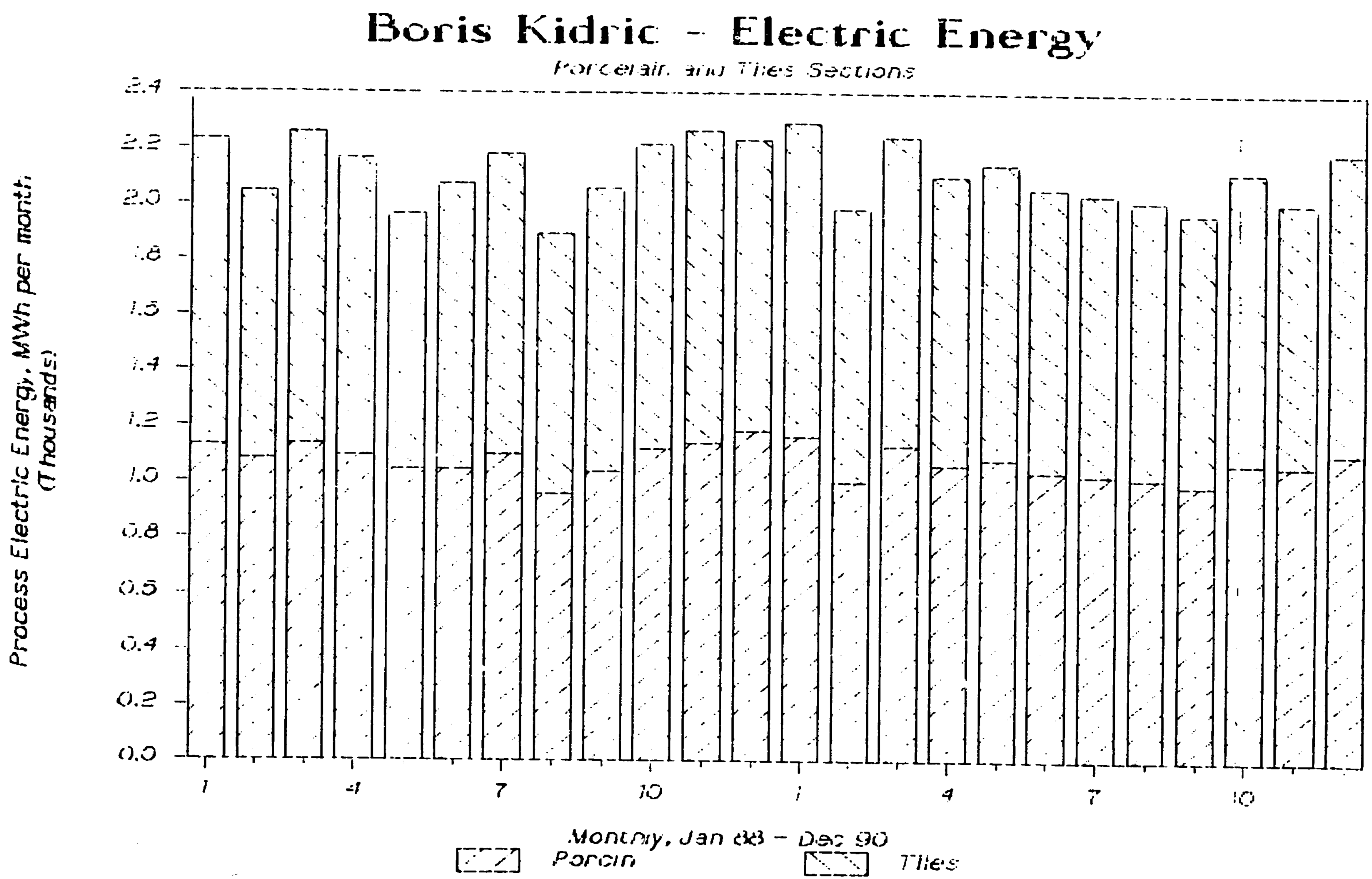


Boris Kidric - Electric Power Demand
Avg. Power Factor (Cos Phi)
Ratio kWh/kVAh
0.94
0.92
0.90
0.88
0.86
0.84
0.82
0.80
0.78
0.76
0.74
0.72
0.70
0.68
0.66
0.64
0.62
1
4
7
10
1
4
7
10
1
4
7
10
Monthly, Jan 88 - Dec 90

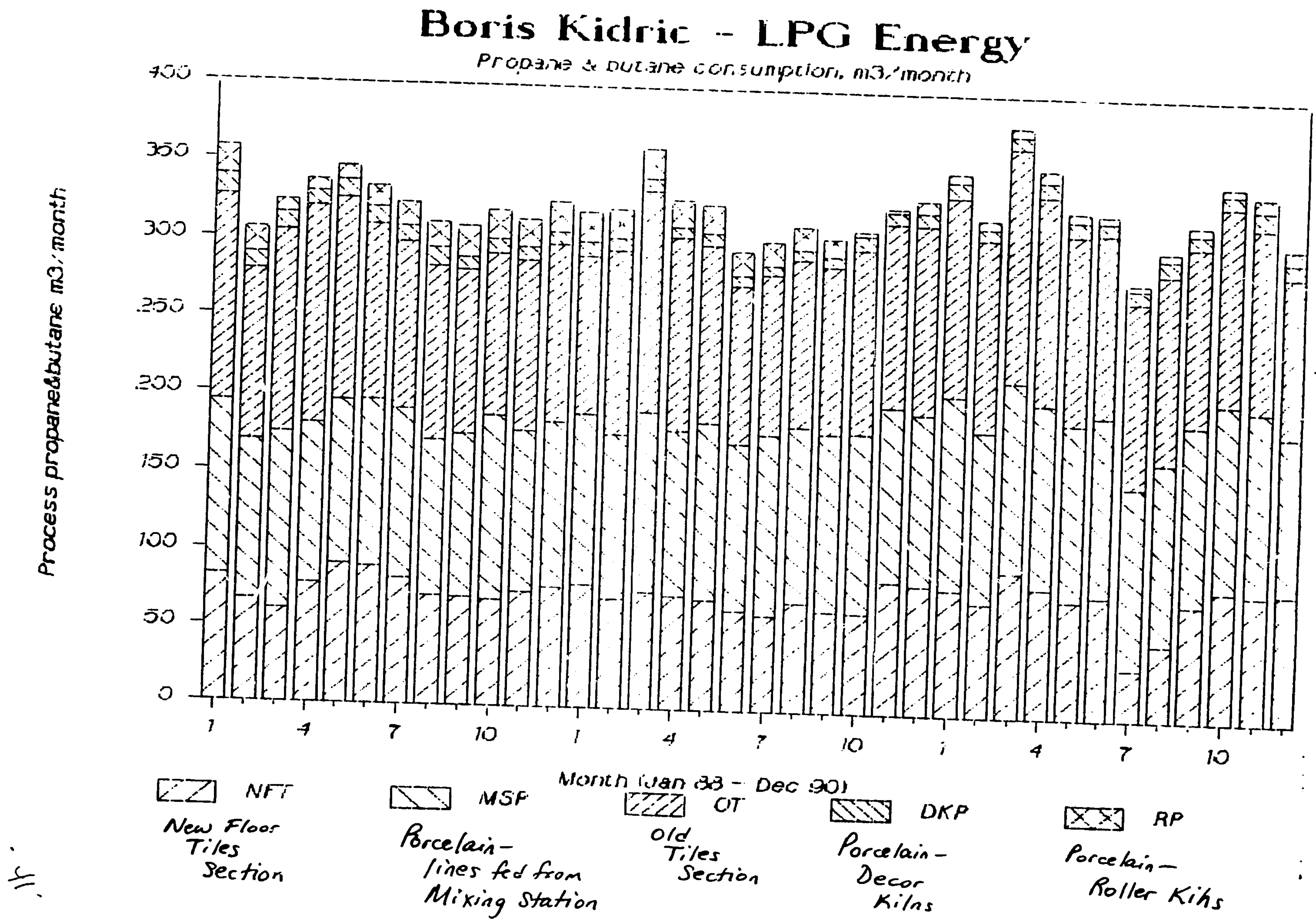
38.

Boris Kidric - Electric Power Demand

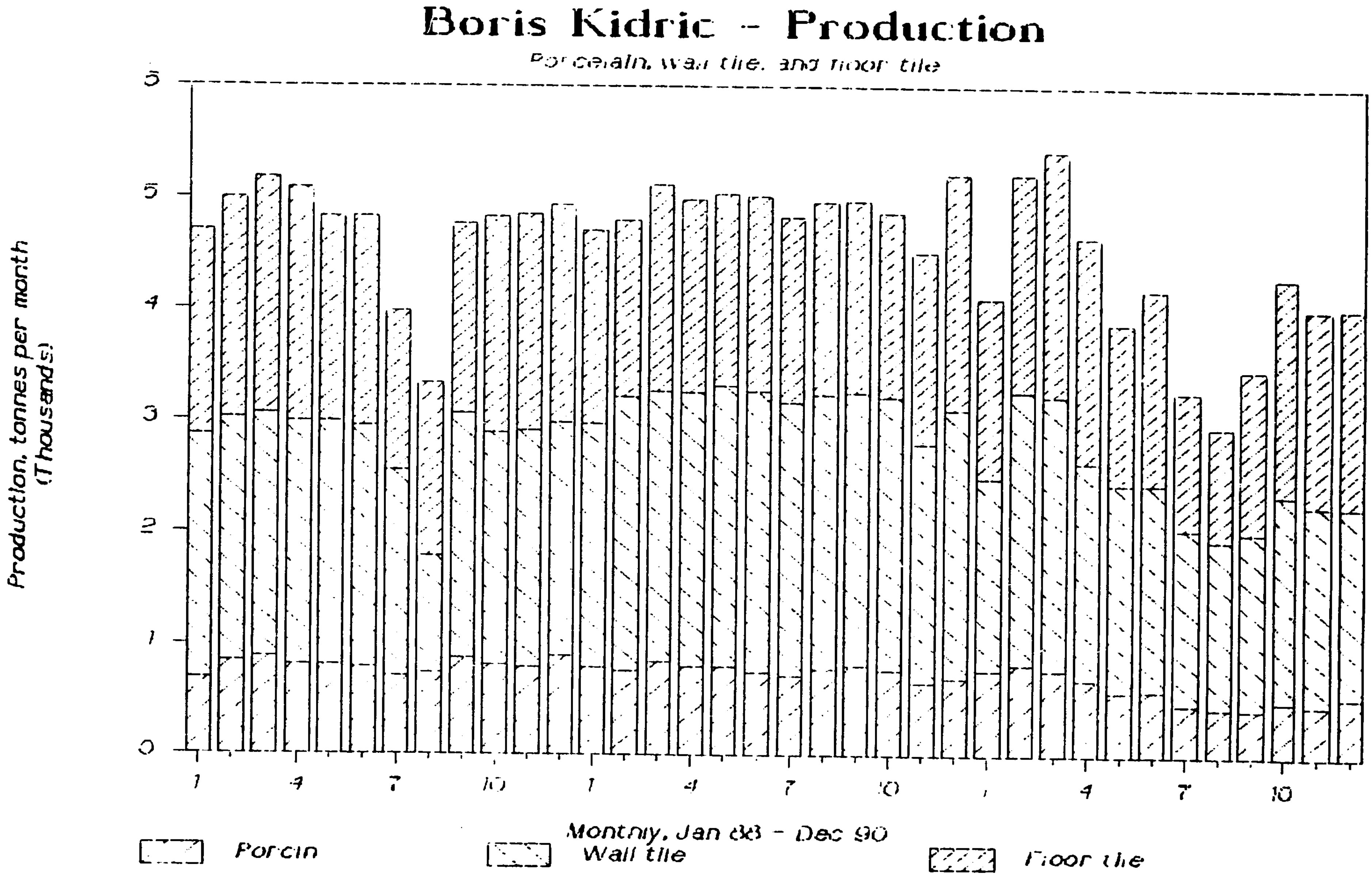




Boris Kidric - Electric Energy
Porcelain and Tiles Sections
Process Electric Energy, MWh per month
(Thousands)
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
1
4
7
10
1
4
7
10
Monthly, Jan 88 - Dec 90
Porcin
Tiles



Boris Kidric - LPG Energy
Propane & butane consumption, m3/month
Process propane&butane m3/month
400
350
300
250
200
150
100
50
0
1
4
7
10
1
4
7
10
1
4
7
10
Month (Jan 88 - Dec 90)
NFT
New Floor Tiles Section
MSF
Porcelain - lines fed from Mixing Station
OT
Old Tiles Section
DKP
Porcelain - Decor Kilns
RP
Porcelain - Roller Kilns


Boris Kidric - Production
Porcelain, wall tile, and floor tile
Production, tonnes per month
(Thousands)
0
1
2
3
4
5
1
4
7
10
Monthly, Jan 88 - Dec 90
Porcin
Wall tile
Floor tile