PN-ABL-020
76695

ENERGY EFFICIENCY AUDIT REPORT
CELPAK PRIJEDOR PULP & PAPER PLANT
PRIJEDOR, BOSNIA, 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

ENERGY EFFICIENCY AUDIT REPORT
CELPAK PRIJEDOR PULP & PAPER PLANT
PRIJEDOR, BOSNIA, YUGOSLAVIA

MARCH 1992

PREPARED BY: RCG/HAGLER, BAILLY, INC.
1530 Wilson Boulevard
Suite 900
Arlington, VA 22209
(703) 351-0300

and

TEKON TEHNO-KONSALTING
Lenjinov Bulevar 123
Belgrade, Yugoslavia
(3811) 145-367

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

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
BUREAU FOR EUROPE
OFFICE OF DEVELOPMENT RESOURCES
ENERGY & INFRASTRUCTURE DIVISION
WASHINGTON, D.C. 20253

USAID Contract EUR-0015-C-00-1007-00

DISCLAIMER

The contents of this report are offered as guidance. RCG/Hagler, Bailly, Inc., TEKON Tehno-Konsalting, and the United States Agency for International Development, and all technical sources referenced in this report do not (a) make any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe upon privately owned rights; (b) assume any liabilities with respect to the use of, or for damages resulting from, any information, apparatus, method or process disclosed in this report. This report does not reflect official views or policies of the above named institutions. Mention of trade names or commercial products does not constitute endorsement or recommendation for exclusive use.

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
DP CELPAK - PRIJEDOR
PULP & PAPER PLANT

CONTENTS

DRAFT
PRELIMINARY ENERGY AUDIT
DP CELPAK FABRIKA CELULOZE I PAPIRA - PRIJEDOR
PRIJEDOR, BOSNIA, YUGOSLAVIA

BY

RCG/HAGLER, BAILLY, INC. AND TEKON (TEHNO-KONSALTING)

I. EXECUTIVE SUMMARY

A team of engineers from RCG/Hagler, Bailly, Inc. and TEKON, carried out site activities at DP CELPAK - Prijedor pulp and paper plant from March 25-29, 1991 to work together with KAT 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 CELPAK are estimated as $9 million[1], as follows:

mazout (heavy fuel oil): 36,000 tons per year, $4.7 million
purchased electric power 7 MW peak demand, $1.8 million
purchased electric energy 34,000 MWh/yr, $1.7 million.
power factor penalties: 50,000 MVARh/yr, $0.8 million

RCG/Hagler, Bailly estimates the potential for energy efficiency improvement at CELPAK as 20-30% without process changes. During the survey, the RCG/Hagler, Bailly team identified short-term, low-cost energy efficiency projects, which, if implemented, will achieve an energy cost savings of $2 million per year, or 22% of expected 1991 energy costs, at a total implementation cost of $813,000 (a financial payback to CELPAK of 5 months):

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

B.1: Boiler low excess air burners ($90,000)

CELPAK agreed to pay for installation and other costs necessary to install the burners and make full use of the equipment supplied by USAID.

---

[1] Energy costs are quoted in US dollars in this report because of the severe devaluations of the Yugoslav Dinar in early 1991. Yugoslavia is adjusting energy prices so that they remain relatively constant in US dollars.

DP CELPAK - PRIJEDOR

Summary of energy efficiency projects

	Oil	Electric			Cost
	ton/yr	MW	MWh/yr	MVARh/yr	MUS$/yr
BASE CASE	36,000	7.0	34,000	50,000	$9.000

RECOMMENDATIONS AND ESTIMATED SAVINGS:

	Oil	Electric			Benefit
	ton/yr	MW	MWh/yr	MVARh/yr	MUS$/yr
A. General & Energy Management					
A.1 Energy management	700		1,000		$0.136
A.2 Efficiency teams	1,800	0.35	1,700	5,000	$0.475
B. Short-term, Low-cost Efficiency Improvements					
B.1 Boiler #1 burners	1,623	0.01	80		$0.217
B.2 Boiler #2 burners	812	0.01	40		$0.108
B.3 Combustion O2 & CO	168				$0.022
B.4 Condensate return	1,500				$0.195
B.5 Elect demand control		1.00			$0.260
B.6 Cos Phi correction				40,000	$0.600
TOTAL SAVINGS	6,603	1.37	2,820	45,000	$2.013
Percent of base case	18%	19%	8%	90%	22%

II. INTRODUCTION

2.1 Plant Description and Energy Consumption

The Celpak Pulp and Paper Company is located in the town of Prijedor on the Sana River in the Republic of Bosnia. The plant was constructed in the late 1940's and achieved startup in 1950. It produces a wide range of paper products plus some ancillary chemicals as byproducts. The plant cogenerates slightly more than half of its own electricity and sells steam to a neighboring company and to the town of Prijedor for town heating. About 2700 workers are employed at the plant. Energy costs represent about 20% of CELPAK's direct manufacturing cost.

Celpak's present production capacities are:

48,000	tons/year of celulose (pulp) for its own use
65,000	tons/year of paper
15,000	tons of value-added paper products converted from its own raw paper stock
20,000	tons/year of chemical products
12,000	tons/year of wood waste brickettes for cooking

The pulp plant was started up in 1950 but has undergone two reconstructions to increase capacity--one in 1955 and one in 1977. The majority of the current equipment is about 20 years old. The current system has no method for recovery of the black liquor and poses both energy efficiency and environmental problems for the plant. Approximately 150,000 tons of organic matter per year are discharged into the Sana river. Celpak currently has made application to the World Bank for $30 Million to fund a project to install a black liquor boiler which would supplant approximately 40% of their mazout consumption and eliminate the discharge of the liquor into the river.

The paper plant includes four paper machines, including two Yankee type and two Fourdiniere types. The latter were installed in 1960, and in 1983 one of them was rebuilt to increase its capacity and add computer control. The Yankee machines were installed in 1970 and have had no major maintenance done since installation.

The power plant includes two boilers and two steam turbine-generator sets. The boilers are identical an have capacities of 75 tons/hour each of steam at 40 bar, 440 degrees C. There is a 12 MW back-pressure turbine and a 5 MW combined condensing/extraction turbine. The 12 MW is the primary one, and provides electric power and steam at 7 bar for process heat, sale to a neighboring company and for town district heating.

The average steam production in the plant is about 70 tons/hour, and the power house consumes about 36,000 tons of mazout per year. Average electric consumption is about 73 million kWh per year, of which about 39 million kWh are generated on-site.

Celpak has completed two studies of projects for reducing energy costs related to the power plant. One is the installation of a condensate return system for plant heating and some process heating systems. Currently only about 30% of the condensate from these consumers is returned. The second project is a peak demand shaving project which would reduce electric demand charges for purchased power. Both projects are currently stalled for lack of funds.

The December 1990 official price of mazout delivered to CELPAK was Dn 3,675 per tonne ($262 per ton, based on Dn14 = $1.00 in March 1991). Fuel imported by other Yugoslavian industrial companies cost $130/tonne in April. The higher, Government-controlled local price still reflected the Gulf conflict oil prices. The price of $130 is used throughout this report.

Electricity tariffs paid by CELPAK were as shown below in March 1991. Because of fluctuation of the Dinar, US dollar equivalent prices are used throughout this report.

	Dn	$ (eq.)
Demand per kW per month	Dn303	$21.64
Energy per kWh (active)		
on-peak (day)	Dn0.84	$0.060
off-peak (night)	Dn0.42	$0.030
Reactive per kVARh		
on-peak (day)	Dn0.28	$0.020
off-peak (night)	Dn0.14	$0.010

At these prices, annual energy costs at CELPAK are estimated as $9 million, distributed follows:

mazout (heavy fuel oil): 36,000 tons per year, $4.7 million
purchased electric power: 7 MW peak demand, $1.8 million
purchased electric energy: 34,000 MWh/yr, $1.7 million
power factor penalties: 50,000 MVARh/yr, $0.8 million

2.1 Energy Audit Activities

A team of senior engineers from RCG/Hagler, Bailly, Inc. and TEKON, carried out site activities at CELPAK from March 25-29, 1991 to work together with KAT staff to identify improvements to energy efficiency. The project manager for the effort was Mr. BANOVIC Dusan, Dipl. Ing., Deputy General Director, assisted by Mr. KADIC Jovan, Director of Investment and Development, and Mr. DJURIC Miroslav, Head of Development Division, and Mr. VUCETA Novo, Staff Mechanical Engineer. The RCG/Hagler, Bailly team consisted of:

David KEITH, RCG/Hagler, Bailly, Project Director
Eduardo MAAL, RCG/Hagler, Bailly, Audit Team Manager
Dr. Larry BANTA, consultant to RCG/Hagler, Bailly, on leave from Mechanical Engineering Dept., University of West Virginia
LAZAREVIC Dusan, TEKON, Project Manager

Based on initial screening with RCG/Hagler, Bailly's portable energy audit instruments, the audit team focused their efforts in the short time available on combustion systems in the power station.

A primary focus of the audit was an attempt to achieve immediate energy savings through improvements in combustion efficiency. For this purpose, RCG/Hagler, Bailly's digital combustion analyzer (which measures O_2, CO, CO_2, unburned hydrocarbon combustibles (HC)) was used, together with a laptop personal computer, using software developed by RCG/Hagler, Bailly which calculates combustion efficiency from these measurements, on the basis of the chemical equations of combustion (molal basis). Adjustments were made to combustion air/fuel ratios, but unfortunately the burners installed would not allow improvements - CELPAK was already operating the equipment at minimum air/fuel ratio.

By the end of the week, the RCG/Hagler, Bailly team had carried out tests of boiler efficiency, had instrumented electric motors for power factor tests and demand analysis, analyzed various projects already begun by CELPAK, and collected, organized and analyzed energy consumption and production data.

The RCG/Hagler, Bailly team presented its recommendations to Mr. DRAGOMIR Kaurin, General Director, at the final review meeting March 29, 1991, before leaving CELPAK. RCG/Hagler, Bailly recommended, and CELPAK agreed, that new low-excess air burners for the boilers should be procured under the USAID emergency energy program, so that CELPAK will be able to achieve maximum energy cost savings from the limited funds available under the program.

The RCG/Hagler, Bailly team observed that the standard of management and engineering expertise already in place at CELPAK is very good. Technical staff is 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 CELPAK. 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 CELPAK, and hopes to return their hospitality at some time in the future, whenever CELPAK staff visit the United States.

III. ENERGY CONSUMPTION ANALYSIS

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

These graphs are provided for use by CELPAK 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:

> CELPAK has begun programs to reduce peak demand for purchased electricity, which have reduced the peak from 7.68 MW in 1989 to 7.05 in 1990, a reduction of more than 8%.
>
> Power factor (cos phi) for purchased electricity is very low, consistently less than 0.7.
>
> Specific electrical energy consumption for paper (kWh/ton) was more variable in 1990 than in previous years, and was about 5% higher. Specific electrical energy consumption for celulose was about the same as previous years.
>
> Specific steam energy consumption for paper and pulp (GJ/ton) was more variable in 1990 than in previous years, and was about 5% higher.
>
> Steam consumption is not well correlated to production. For example, at a production rate of 4,500 tons paper per month, monthly steam consumption (paper plus celulose) varied from 100-120 TJ.
>
> Electrical consumption is not well correlated with production. For example, at a production rate of 4,500 tons paper per month, monthly electrical consumption (paper plant) varied from 3,300 to 4,000 MWh.
>
> Boilerhouse specific fuel consumption (ratio of fuel to steam delivered at 7 bar) varies significantly with load. At low loads, such as in the summer months, efficiency is about 15% lower than in winter months, indicating the difficulty CELPAK has in controlling the boilers.

IV. PREVIOUS ACTIVITIES FOR ENERGY EFFICIENCY IMPROVEMENT

As noted in the introduction, CELPAK had made several studies of energy conservation projects in the past. The largest of these projects is the installation of a black liquor boiler to supplant some of the plant's residual oil consumption and to eliminate a major water pollution problem. This project is of obvious merit, of great importance and should be pursued. CELPAK estimates the project cost at $30 million, which is clearly outside the scope of this project. CELPAK is pursuing funding through the World Bank. Once implemented, this project will enable about 65 ton/hr of steam to be generated from waste. RCG/Hagler, Bailly estimates the annual potential fuel oil savings from this project as at least 20,000 tons/yr (55% of present consumption), for an annual cost saving of $2.6 million. Additional financial benefits will accrue from reductions in penalties for enviromental compliance.

Less costly and also of great importance is a project to return steam condensate to the boiler from many plant processes and from plant heating. RCG/Hagler, Bailly wishes to encourage further pursuit of this project as one with great potential for energy conservation at moderate cost. Perhaps some of the funds saved via the implementation of the measures recommended in this report could be set aside to fund the condensate return line construction project. We estimate the annual potential fuel oil savings from condensate return as 5%, for an annual cost saving of $195,000.

Finally, CELPAK has commissioned a study of electric demand shaving using computerized load-shedding. The study was performed by Josef Steffan Institute and seems to have been carefully done. The immediate effect of this project would be to reduce the unit price of electricity by reducing the monthly demand charge. Plant personnel estimate the cost to complete this project at $50,000 to $60,000. This project seems to present a good economic opportunity, and although it is outside the venue of the USAID program the RCG/Hagler, Bailly team encourages CELPAK to continue its pursuit. We estimate the potential reduction in peak demand for purchased electricity as 1 MW, for an annual cost savings of $132,000. Additional savings from shifting load from on-peak to off-peak hours are possible.

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

MANAGEMENT

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

Existing conditions

The system of management information and control in place at CELPAK 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.

CELPAK currently monitors most of the important energy consumption and conversion parameters vital to the efficient operation of the plant. Mazout consumption, steam production, electrical energy production, and the consumption of electrical energy and steam by various sub-areas of the plant are currently recorded on a monthly basis. Likewise, production figures for various portions of the plant, and in some cases for individual machines are currently collected and reported on a monthly basis.

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 CELPAK, two types of energy are used, fuel energy consumption in the form of mazout (heavy fuel oil), 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 CELPAK. The independent variable selected for CELPAK was monthly production (tons) of paper, the largest and main product (pulp is used to produce paper). The dependent variables were steam consumption, fuel oil consumption, and electricity consumption (kWh). These analyses lead to the development of factory energy performance linear equations, 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)

CELPAK fuel oil energy:
y = daily fuel oil consumption
y = 5.9 tons per day fixed consumption (losses)
+ 0.57 tons per ton paper
+ 2.30 tons per heating degree-day[2]

CELPAK electric energy:
y = daily electricity consumption
y = 26 MWh per day fixed consumption (losses)
+ 0.98 MWh per ton paper

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, is better than most plants surveyed in Yugoslavia, but still needs improvement, at least in the case of electricity. This analysis indicates that (1) energy consumption varies for a given level of production, and (2) energy consumption at CELPAK 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 could be reduced by analysis of performance ratios such as energy per unit of production. This would give a good picture of how well the process is performing, in terms of energy efficiency, on a daily basis, so management can exert short-run control actions which would improve efficiency.

---

[2] Since much of the steam generated by CELPAK is used for heating purposes, a measure of ambient temperature is needed. Heating degree-days are a method of estimating the demand for heat, calculated based on a reference temperature of 20C. If the average temperature for the day is 10C, the heating demand for that day is 10 degree-days.

CELPAK - steam and fuel oil analysis
Regression based on 36 months data 1988-1990

1. Predicting process steam from paper production

Regression Results:

Constant		0.30314 TJ per month
Std Err of Y Est		7.68
R Squared		0.85
No. of Observations		36
Degrees of Freedom		34
X Coefficient(s)	0.02528 TJ per ton	
Std Err of Coef.	0.00181	
t test	13.99	

2. Predicting fuel from steam production

Regression Results:

Constant		811 ton per month
Std Err of Y Est		202
R Squared		0.92
No. of Observations		36
Degrees of Freedom		34
X Coefficient(s)	15.13 ton/TJ	
Std Err of Coef.	0.75	
t test	20.27	

3. Predicting fuel oil from paper production & ambient temperature

Regression Output:

Constant		177.42 tons per month
Std Err of Y Est		223.71
R Squared		0.909
No. of Observations		36
Degrees of Freedom		33
X Coefficient(s)	0.56995 tons per ton +	2.30191 tons per degree day
Std Err of Coef.	0.05576	0.21287
t test	9.47	10.81

CELPAK - Electrical analysis
Regression based on 36 months data 1988-1990

4. Predicting paper plant kWh from paper production

Regression Results:

Constant		467 MWh per month
Std Err of Y Est		310
R Squared		0.725
No. of Observations		36
Degrees of Freedom		34
X Coefficient(s)	0.69 MWh per ton	
Std Err of Coef.	0.07	
t test	9.47	

5. Predicting total process (pulp & paper) electricity from paper production

Regression Results:

Constant		783 MWh per month
Std Err of Y Est		436
R Squared		0.73
No. of Observations		36
Degrees of Freedom		34
X Coefficient(s)	0.98 MWh per ton	
Std Err of Coef.	0.10	
t test	9.53	

Recommendation

The RCG/Hagler, Bailly team recommends that collection and analysis of energy consumption data be done on at least a daily basis, and preferably on a shift by shift basis. Shift supervisors from each of the major energy producing and consuming areas of the plant should report specific energy consumption figures (i.e. tons of paper per ton of steam or tons of steam per ton of mazout). These data should be compared as to day-to-day performance, and the results of operating or equipment changes should be documented and fed back to operating personnel.

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 should be modified to include energy consumption (steam, fuel and electric) and a calculation of the ratio of energy consumption to metric tons of production.

Step 2- A management information and control system (M.I.C.S.) should be installed on a personal 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 and success of these actions should be measured and documented by the M.I.C.S.

Daily tracking of energy efficiency is the first and most crucial step in establishing an effective energy management program. Without proper monitoring of consumption, it is impossible to prioritize potential energy conservation projects or to measure their effectiveness once they are implemented. Daily tracking provides immediate feedback for the evaluation of changes in operating practices or warning of equipment degradation or failure. Since the control of some of the major energy consuming equipment such as the boilers is done on a largely manual basis, it is important to provide timely feedback to operators as a means of helping them to control the equipment most efficiently. Boiler operating efficiency is not currently measured, so operators have no basis for improving their performance from an efficiency standpoint.

Secondly, a detailed monitoring program can provide warnings as to the degradation or failure of important equipment. For example, a sudden jump in the specific steam consumption for one of the paper machines might signal a failed steam trap. If the consumption data are averaged over an entire month, the failure would be more difficult to spot and a great deal of energy could be wasted before corrective action was taken.

Finally, a thorough energy monitoring program will increase the awareness of both supervisory and operating personnel to the importance of energy conservation, resulting in cooperation and perhaps contribution of ideas to assist the program. Workers at all levels must be enlisted as partners for energy conservation programs to work effectively.

Expected results

The precise savings that can be achieved by establishing such a program are impossible to estimate accurately, but experience has shown that from one percent to ten percent reduction of energy costs have been attributed by other plants to their monitoring programs. This is based on experiences of similar companies in the U.S. and Europe which have highly variable specific energy consumption before implementing such systems.

The investment required to implement the program is minimal. CELPAK already has installed sufficient instrumentation to begin. Over time, additional equipment could be purchased for submetering of steam and electricity consumption by various equipment, financed from the savings generated by conservation projects.

Based on the observed variability in the regression analysis for CELPAK, the RCG/Haglcr, Bailly team estimates a savings of 2% for fuel oil and 3% for electricity in calculating the benefits of the system. The expected value of the energy savings is $136,000 per year:

Fuel and steam - management control
1990 fuel oil consumption 36,000 tons, at cost $130/ton

annual benefit estimate (2%) = 700 tons
$91,000 per year

Electric - management control
1990 energy consumption 34,000 MWh, at avg cost $45/MWh

annual benefit estimate (3%) = 1,000 MWh
$45,000 per year

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.

Equipment required:
Personal computer (IBM compatible):
(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 - $10,000

Staff training:
local contract - $10,000

Total development cost = $24,000

Annual incremental costs:
additional metering equipment and maintenance - $50,000

Financial analysis

The payback period for the project is less than four months:

Payback = capital cost/net annual cost savings

$24,000/($136,000 - $50,000) = 0.28 year

A. GENERAL AND ENERGY MANAGEMENT

ENERGY & UTILITIES
CELPAK Action A.2 -
Put energy efficiency teams in action to reduce energy losses

Existing conditions:

Energy requirements at CELPAK are growing year-by-year for a given level of production. This is indicative of a deteriorating situation which could benefit from increased maintenance.

During the audit, the RCG/Hagler, Bailly team observed steam leaks with substantial energy cost in the plant.

Recommended action:

RCG/Hagler, Bailly recommends that CELPAK form "Energy Efficiency Teams" for steam, electric motors, and compressed air. Personnel for this team should be drawn from CELPAK staff, and this exercise should become a continuous part of plant operations and maintenance.

The Steam Efficiency Team would be responsible for the identification and repair of leaks in steam systems, and to inspect and repair thermal insulation. The Electric Motor Efficiency Team would be responsible to survey electric 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. The Compressed Air Efficiency Team would be responsible to evaluate efficiency of compressed air systems, and to seek out and repair leaks in compressed air lines.

The Steam Efficiency Team should have the following tasks:

- Develop an inventory of the uses of steam in the plant.
- Carry out a survey of the condition of steam pipe insulation in the plant, using thermocouples and other temperature indicators.
- Check the operation of all steam traps in the plant on

a monthly basis, using the "glove test" or other simple methods. Repair or replace leaking traps as found.

Carry out a survey of steam leaks on a monthly basis. For each leak found, calculate the cost of the leak (using Georgia Tech's Steam Leak chart on the following page[3]) and estimate the cost to repair the leak. If the payback period is less than 1 year, recommend the repair of the leak. Develop a log to keep track of the growth of leaks from month-to-month. Develop a monthly plan for repairs.

---

[3] The chart is printed in English units. The cost of steam at CELPAK is $8.50 per tonne, which is approximately $3.50 per 1,000 pounds. The chart shows that a steam leak with a visible plume of 1 meter (3 feet) would cost CELPAK almost $1,000 per year in wasted energy.

IEES Energy Tips

Energy management suggestions from the Industrial Energy Extension Service
a joint service of the Georgia Office of Energy Resources and Georgia Tech's Engineering Experiment Station.

ENERGY TIP NO. 2

ELIMINATE STEAM LEAKS

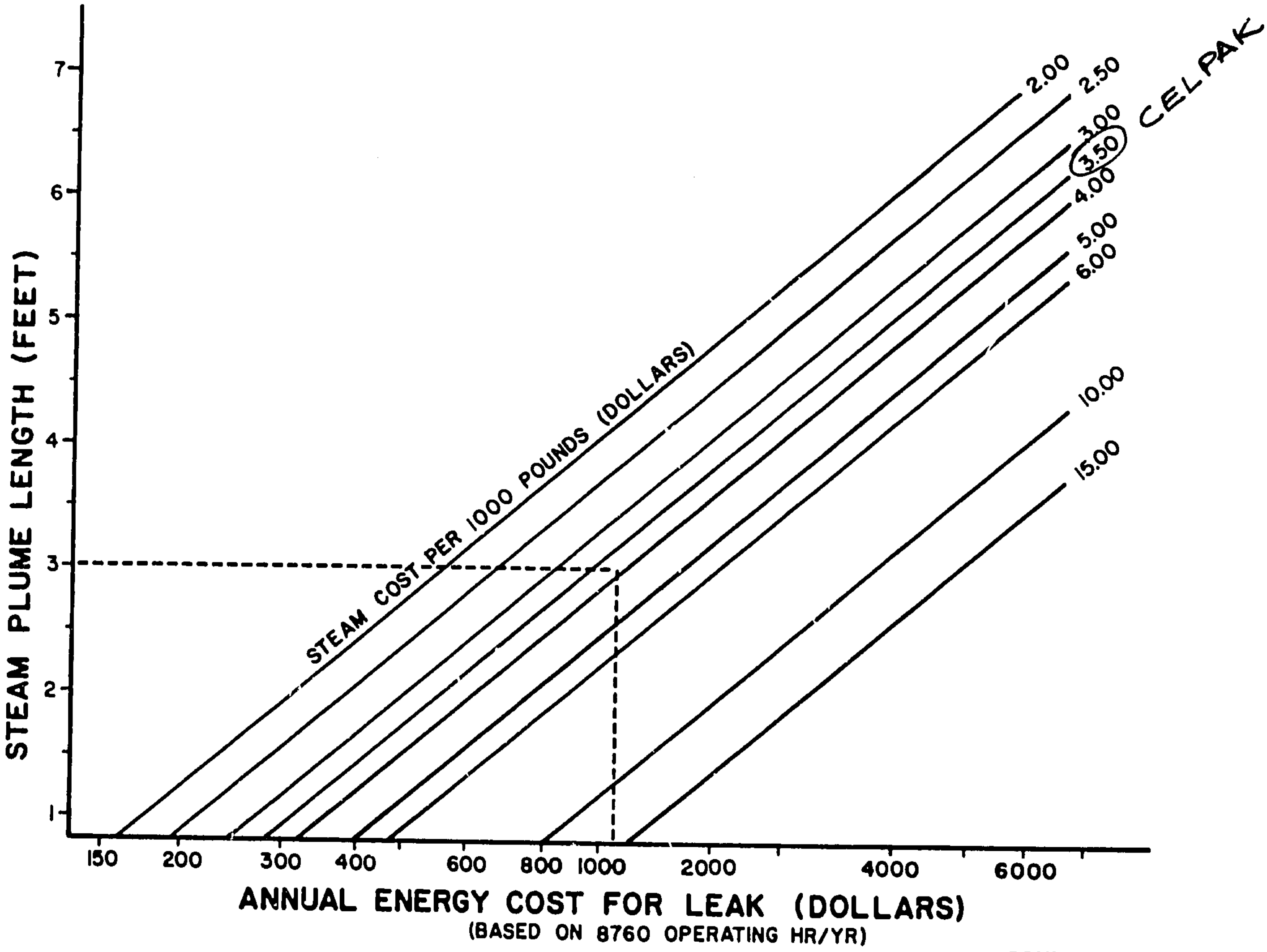
A conspicuous waste of energy are the numerous steam leaks at pipe joints, valves, unions, etc. Until the cost of energy skyrocketed, it was generally thought that small leaks should be tolerated and that fixing them was not worth the time or cost.

The graph below is a rough approximation of what a steam leak costs in terms of annual fuel expense. To use the graph, determine the leak's "Blow Length" by measuring the length of the steam plume or the approximate distance at which water condenses out of the stream onto your hand (usually beyond the visible plume). Enter the graph with the blow length and move across to the corresponding cost of steam line determined by using the "Steam Cost" chart, Energy Tip No. 1. Read the annual energy cost at the bottom of the graph.

EXAMPLE

A survey of a plant's steam distribution system reveals a steam leak at an equipment connection flange. The plume length of the leak is approximated at 3 ft. What is the energy cost of not fixing the leak?

Using the graph and a steam cost of $4.00/1000 lbs determined from Energy Tip No. 1, the annual cost is $1200.



SOURCE: GA TECH EES

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 10 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 CELPAK's major suppliers of motors families of motors now installed in the plant.
- 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 CELPAK), 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.
- 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.
- An inventory of on-peak (day) and off-peak (night) uses of electricity should be made. Based on this inventory, priorities should be established, and candidates should be identified for shifting non-critical activities from on-peak to off-peak. These shifts will achieve financial benefits, because the cost of electricity during off-peak hours is only one-half that during on-peak.

The Compressed Air Efficiency Team should have the following tasks:

- Based on design data, make an inventory of all uses of compressed air
- On a monthly basis, carry out an analysis of air compressor efficiency and record in logbook. If less than design, investigate the causes.
- Carry out a survey of the plant every month to identify compressed air leaks, and record them in a log book. Measure the flow of leaks using a velometer and prepare a report, with the monthly cost of each leak clearly indicated. Develop a plan for leak repair, based on priority.

<u>Expected results:</u>

The RCG/Hagler, Bailly team estimates that the potential savings of an improved maintenance program based on these procedures is

5% of peak purchased electrical demand, 5% of the plant's purchased electric energy consumption, 10% of reactive energy purchased, and 5% of steam energy consumption. The benefits of these savings are $475,000 per year, estimated as follows:

Electric power:
5% x 7 MW = 350 kW
350 kW x $21.64/kW/mo x 12 mo/yr = $90,000/yr

Electric energy:
5% x 34 million kWh/yr = 1,700,000 kWh/yr
1,700,000 kWh/yr x $0.045/kWh = $77,000/yr

Electric reactive energy:
10% x 50 million kVARh/yr = 5,000,000 kVARh/yr
5,000,000 kVARh/yr x $0.015/kVARh = $75,000/yr

Thermal (mazout for steam):
5% x 36,000 tons/yr = 1,800 tons/yr
1,800 tons/yr x $130/ton = $233,000/yr

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.

Equipment required:
(1) Digital strobe tachometer
(1) Digital multimeter/megohmeter with current clamp and Power factor meter
(1) Velometer
(1) Digital thermocouple indicator and probes
(1) Infrared thermal imager
total estimated cost $25,000

RCG/Hagler, Bailly estimates that CELPAK should budget $100,000 per year for additional incidental equipment and repairs (additional maintenance), such as steam traps, insulation, motors, and the like.

Financial analysis:

Based on a cost of $25,000 and a net savings of $300,000 per year, the project payback period is one month.

B. LOW-COST, SHORT-TERM IMPROVEMENTS

BOILERS

CELPAK Action B.1 -

Improve combustion efficiency of main boiler - install new burners designed to properly atomize fuel for combustion at low excess air

Existing Conditions:

CELPAK currently uses 8 very simple burners in each boiler which include no steam or forced air atomization. Fuel mechanically atomized by a spinner in the burner tip, and is sprayed into the combustion chamber in droplets which appeared to be as much as 3 mm in diameter. The RCG/Hagler, Bailly team made measurements of boiler combustion efficiency and found the one operating boiler to be running at approximately 150% excess air. The team worked together with CELPAK personnel to adjust firing conditions in an attempt to lower the excess air level, but discovered that any significant reductions in air flow resulted in unacceptable CO and smoke levels. It was concluded that the poor atomization of the fuel by the existing burners was the source of the problem.

Recommended Actions:

Mechanical atomization is no longer judged sufficient for burning mazout at modern energy prices. The cost of the high excess air is simply too much to bear. Modern methods use steam or compressed air to achieve smaller particle size, allowing the fuel to be completely burned in the furnace with a much smaller quantity of air.

RCG/Hagler, Bailly recommends that CELPAK replace the existing burners on ONE BOILER with more modern ones which use steam or compressed air to atomize the mazout into very fine droplets which can be more easily burned. RCG/Hagler, Bailly intends to recommend that this project be partially underwritten by USAID as part of the 1991 Emergency Energy Program for Yugoslavia. We will recommend that the US government purchase the burners for one of the boilers. In return, CELPAK would pay for the installation the burners, including any required steam or compressed air lines for fuel atomization. We also recommend several additional repairs and changes in operating procedure.

The damper for the induced draft fan on one of the boilers was damaged and could not be properly closed. As a consequence, boiler operators were regulating combustion chamber pressure by increasing forced draft airflow above normal levels. This practice results in excessive fan power consumption and excessive boiler stack losses at medium to low firing rates. We recommend that the damper mechanism be repaired immediately to rectify this situation and to allow proper control of the boiler.

The boiler control procedure is currently primarily manual and seems to be unique to each operator. Burner firing rate is controlled by the pressure of the mazout delivered to the burner. Mazout pressure is automatically controlled by the boiler pressure, presumably in the steam drum. Combustion air flow is controlled by the operator more or less manually. The operator selects a forced draft fan damper position corresponding to the boiler load as displayed on the control room strip chart recorder. The correlation between boiler load and forced draft damper seems to be a function of operator experience and was different between the first and second shift operators on the days the RCG/Hagler, Bailly team spent in the boiler house. The final operator-controlled parameter is induced draft fan damper setting. Normally, the operator sets the damper to maintain a constant slightly negative combustion chamber pressure.

Following repair of the induced draft fan damper and installation of the new burners, we recommend that boiler control practices be modified as follows. Fuel flow should still be based on boiler pressure as is done now. The method of regulating fuel flow through the new burners may be slightly different than the current method. At the least, the burner flow rate as a function of oil pressure will probably be different from the old burners and will require some calibration. Rather than basing forced draft airflow on boiler load, we recommend that the combustion air be regulated to give the minimum excess combustion air that can be achieved without excess smoke production. We estimate that excess air levels of 30% should be possible, without oxygen trim control.

The best measure of excess air is a combustion analyzer that can measure oxygen and carbon monoxide or carbon dioxide levels in the boiler stack gas. After installation of the burners, we recommend that CELPAK purchase appropriate instrumentation to rehabilitate their existing oxygen sensors (see Action B.3). Boiler operators must be retrained to use the new instrumentation as their basis for adjusting forced draft fan damper position. Induced draft fan damper position should be controlled as in the past, to maintain combustion chamber pressure as specified by the boiler manufacturer.

Expected Results:

CELPAK currently uses about 36,000 tons of mazout per year, virtually all of which is burned in the boilers. We estimate that 2/3 of this fuel is used in the main boiler which is operated year-round (2,000 tons mazout per month) and 1/3 is used in the other boiler, which is operated only during the heating season. We anticipate that with modern burners and careful operation of the boiler, excess combustion air levels can be reduced to around 30%, resulting in an increase in combustion efficiency of more than 6%. For the main boiler, this will result in fuel savings of approximately 1,600 tons of mazout per year. At a projected price of $130 per ton, annual fuel oil savings will be $211,000. Detailed combustion efficiency analysis is provided for the "before" and "after" conditions on the following two pages. A summary is given below.

CELPAK - BOILER COMBUSTION EFFICIENCY

	Measurements				Calculation	Estimates	
	O2 %	CO ppm	HC %	Temp C	Combstn on LHV,%	Mazout tonne/yr	Cost K$/yr
Boiler #1							
before	13.0	3	0.00	170	85.5	24,000	3,120
after	5.0	3	0.00	180	91.7	22,377	2,909
savings						1,623	211

In addition to the fuel oil savings, some electrical savings will result from the reduction in air flow required to the boilers. This is estimated as 10 kW, 80,000 kWh per year, for annual savings of about $6,000.

10 kW x $21.64/kW/mo x 12 mo/yr = $3,000/yr
80,000 kWh/yr x $0.045/kWh = $3,600/yr

We estimate the cost of the burners to be $90,000. In addition, CELPAK will incur some cost to install the burners and instruments, install air or steam lines for atomization, to calibrate the oil pressure regulator with the new burners and to repair the induced draft fan damper. We estimate these costs will be approximately $10,000.

Financial analysis:

At a cost of $100,000 with benefits of $217,000 per year, the payback period for this project will be less than six months.

CELPAK Prijedor – Boiler #1
Combustion Calculations – Molal Basis

Date of test: 28 Mar 91
Time of test: 1100

RCG/Hagler, Bailly, Inc.
Steam rat . 38 ton/hr

Fuel, O2, and Air per Unit of Fuel | **Flue Gas Composition, Moles per Fuel Unit**

Line	Fuel Constit	Per Fuel Unit, lb	Mol. Wt Divisor	MolesFuel Constit	O2 Multiplr	O2 Moles TheoReqd	CO2 + SO	O2	N2	H2O	CO
1	C to CO2	86.20	12.00	7.18	1.00	7.18	7.18				
2	C to CO	0.00	12.00	0.00	0.50	0.00					0.00
3	CO to CO2	0.00	28.00	0.00	0.50	0.00	0.00				
4	C unburnd	0.00	12.00	0.00	0.00	0.00					
5	H2	10.00	2.00	5.00	0.50	2.50				5.00	
6	S	2.30	32.00	0.07	1.00	0.07	0.07				
7	O2 deduct	-0.50	32.00	-0.02	1.00	-0.02					
8	N2	0.10	28.00	0.00		0.00			0.00		
9	CO2		44.00	0.00		0.00	0.00				
10	H2O	0.74	18.00	0.04		0.00				0.04	
11	Ash	0.12		0.00		0.00					
12	Sum	99.96		12.28		9.74					
	Total air = 250.0% (from stack test)										
13	O2 (theo) reqd = O2, line 12					9.74					
14	O2 (excess) = (Total air -1) * line 12					14.61					
15	O2 (total) supplied = lines 13+14					24.35		14.61			
	Total Air (TA) = line 15/line 13					250.0%					
16	N2 supplied = 3.76*O2,line 15					91.55			91.55		
17	Air (dry) supplied = O2+N2					115.90					
18	H2O in air = moles dry air *A/(B-A)					2.46				2.46	
19	Air (wet) supplied = lines 17+18					118.36					
20	Flue gas constituents = lines 1 to 18, total						7.25	14.61	91.55	7.50	0.00

21 Note: for air at 80F and 60%RH, A/(B-A)=0.0212 is used as a standard

LINE	MAZOUT				
a	Fuel analysis as fired (AF), % by wt or vol				
	C=	86.2%	CO=	0.0%	
	H2=	10.0%			
	S=	2.3%			
b	O2=	0.5%			
	N2=	0.1%			
	H2O=	0.7%			
	Ash=	0.1%			
	TOTAL=	99.96%			
	Flue gas analysis by test				
	CO2=	6.0%			
c	CO=	3 PPM, =	0.000%		
	O2=	13.0%	CMBSTBL	0.00%	
d	Total air (TA), based on above O2 test				
	TA=	250%			
e	Lines f,g,h for gaseous fuels only				
f	Wt, fuel unit + sum (moles each * mol wt), lb				
g	Mol wt of fuel + line f / 100				
h	Density of fuel = line g/394 (lb/cuft)				
i	Higher heat value, fuel		10146	, Btu/lb =	18300
j	%C in refuse				
k	Combustibles unburned, % of fuel				0.00%
l	Stack temp, degrees C			a	170
m	Ambient temp, dry bulb, degrees C				15

	Wet Flue Gas	Dry Flue Gas
Total Moles	120.91344	113.41828

DETERMINATION OF FLUE GAS AND COMBUSTIBLE LOSSES IN BTU PER FUEL UNIT (AS FIRED)

Conversion to metric units

Line		CO2 + SO	O2	N2	H2O	CO	Btu Total	kcal total	kJoules total
22	Fuel unit 100.00 lb Flue gas constituents:								
23	MCp, Molal specific heat, mean, t2 to t1	9.91	8.17	7.20	7.07	7.10			
24	In dry flue gas, moles each, line 20*MCp*(t2-t1)	20057	33296	183965					
25	In H2O in moles H2O, line 18*MCp*(t2-t1)					0.71	237339	59609	250393
26	In sens heat, H2O in fuel, moles, lines (5+10)*MCp*(t2-t1)				4845		4845	1221	5111
27	In latent heat, H2O in fuel, moles, lines (5+10)*1040*18				9940		9940	2505	10487
28	Total in wet flue gas				94370		94370	23781	99560
29	Due to unburned combustibles, line k*14,100 Btu/lb						346494	87317	365551
30	Due to unburned CO in flue gas; moles C to CO*12*9755 Btu/lb						0	0	0
31	Total flue gas losses + unburned combustible = lines 28+29+30						42	11	44
32	Higher heat value (HHV) of fuel unit= 100 * line I for solid & liquid fuels						346536	87327	365596
	= 394 * line I * 100 for gaseous fuels						1830000	461160	1930650
33	Stack and combustible loss, % of heat input, 100*line 31/line 32						18.9%	18.9%	18.9%
34	Combustion efficiency, HHV, % of heat input 100-line 33						81.1%	81.1%	81.1%
35	Combustion efficiency, LHV basis (line 27 subtracted from heat value and losses)						85.5%	85.5%	85.5%

CELPAK Prijedor – Boiler #1
Combustion Calculations – Molal Basis

Date of test: INSTALL NEW BURNERS
Time of test:
Steam rate:

RCG/Hagler, Bailly, Inc.

	Fuel, O2, and Air per Unit of Fuel						Flue Gas Composition, Moles per Fuel Unit				
Line	Fuel Constit	Per Fuel Unit, lb	Mol. Wt Divisor	MolesFuel Constit	O2 Multiplr	O2 Moles TheoReqd	CO2 + SO	O2	N2	H2O	CO
1	C to CO2	86.20	12.00	7.18	1.00	7.18	7.18				
2	C to CO	0.00	12.00	0.00	0.50	0.00					0.00
3	CO to CO2	0.00	28.00	0.00	0.50	0.00	0.00				
4	C unburnd	0.00	12.00	0.00	0.00	0.00					
5	H2	10.00	2.00	5.00	0.50	2.50				5.00	
6	S	2.30	32.00	0.07	1.00	0.07	0.07				
7	O2 deduct	–0.50	32.00	–0.02	1.00	–0.02					
8	N2	0.10	28.00	0.00		0.00			0.00		
9	CO2		44.00	0.00		0.00	0.00				
10	H2O	0.74	18.00	0.04		0.00				0.04	
11	Ash	0.12		0.00		0.00					
12	Sum	99.96		12.28		9.74					
	Total air =		130.0%	(from stack test)							
13	O2 (theo) reqd = O2, line 12					9.74					
14	O2 (excess) = (Total air –1) * line 12					2.92					
15	O2 (total) supplied = lines 13+14					12.66		2.92			
	Total Air (TA) = line 15/line 13					130.0%					
16	N2 supplied = 3.76*O2,line 15					47.61			47.61		
17	Air (dry) supplied = O2+N2					60.27					
18	H2O in air = moles dry air *A/(B–A)					1.28				1.28	
19	Air (wet) supplied = lines 17+18					61.55					
20	Flue gas constituents = lines 1 to 18, total						7.28	2.92	47.61	6.32	0.00

21 Note: for air at 80F and 80%RH, A/(B–A)=0.0212 is used as a standard

LINE		MAZOUT		
a	Fuel analysis as fired (AF), % by wt or vol			
	C=	86.2%	CO=	0.0%
	H2=	10.0%		
	S=	2.3%		
b	O2=	0.5%		
	N2=	0.1%		
	H2O=	0.7%		
	Ash=	0.1%		
	TOTAL=	99.96%		
	Flue gas analysis by test			
	CO2=	12.0%		
c	CO=	3	PPM, =	0.000%
	O2=	5.0%	CMBSTBL	0.00%
d	Total air (TA), based on above O2 test			
	TA=	130%		
e	Lines f,g,h for gaseous fuels only			
f	Wt, fuel unit + sum (moles each * mol wt), lb			
g	Mol wt of fuel + line f / 100			
h	Density of fuel = line g/394 (lb/cuft)			
i	Higher heat value, fuel	10146	, Btu/lb =	18300
j	%C in refuse			
k	Combustibles unburned, % of fuel			0.00%
l	Stack temp, degrees C		a	180
m	Ambient temp, dry bulb, degrees C			15

	Wet Flue Gas	Dry Flue Gas
Total Moles	64.106064	57.787272

DETERMINATION OF FLUE GAS AND COMBUSTIBLE LOSSES IN BTU PER FUEL UNIT (AS FIRED)

Conversion to metric units

		CO2 + SO	O2	N2	H2O	CO	Btu Total	kcal total	kJoules total
22	Fuel unit 100.00 lb Flue gas constituents:								
23	MCp, Molal specific heat, mean, t2 to t1	9.94	8.18	7.21	7.07	7.11			
24	In dry flue gas, moles each, line 20*MCp*(t2–t1)	21427	7097	102002		0.38	130526	32893	137705
25	In H2O in air, moles H2O, line 18*MCp*(t2–t1)				2683		2683	676	2831
26	In sens heat, H2O in fuel, moles, lines (5+10)*MCp*(t2–t1)				10587		10587	2668	11169
27	In latent heat, H2O in fuel, moles, lines (5+10)*1040*18				94370		94370	23781	99560
28	Total in wet flue gas						238166	60018	251265
29	Due to unburned combustibles, line k*14,100 Btu/lb						0	0	0
30	Due to unburned CO in flue gas; moles C to CO*12*9755 Btu/lb						21	5	22
31	Total flue gas losses + unburned combustible = lines 28+29+30						238187	60023	251288
32	Higher heat value (HHV) of fuel unit= 100 * line i for solid & liquid fuels = 394 * line i * 100 for gaseous fuels						1830000	461160	1930650
33	Stack and combustible loss, % of heat input, 100*line 31/line 32						13.0%	13.0%	13.0%
34	Combustion efficiency, HHV, % of heat input 100–line 33						87.0%	87.0%	87.0%
35	Combustion efficiency, LHV basis (line 27 subtracted from heat value and losses)						91.7%	91.7%	91.7%

Schedule:

Task 1 - RCG/Hagler, Bailly prepares specification for burners and submits for approval by USAID.
Milestone: June 21, 1991

Task 2 - USAID provides final approval for procurement.
Milestone: June 31, 1991

Task 3 - RCG/Hagler, Bailly issues purchase order for burners.
Milestone: July 2, 1991

Task 4 - Burners delivered to CELPAK.
Milestone: September 13, 1991

Task 5 - Burner manufacturer's representative arrives for one week installation assistance.
Milestone: September 23, 1991

Task 6 - Burners installed and operational, and CELPAK completes development of operating procedure.
Milestone: September 27, 1991

Task 7 - Equipment fully operational and in use.
Milestone: October 11, 1991

B. LOW-COST, SHORT-TERM IMPROVEMENTS

BOILERS

CELPAK Action B.2 -

Improve combustion efficiency of second boiler - install new burners designed to properly atomize fuel for combustion at low excess air

Existing conditions:

The second boiler was shut down at the time of the audit, so no measurements could be made. It is assumed to be in a similar condition to boiler #1.

Recommended Actions:

After retrofitting the main boiler with new burners (Action B.1), RCG/Hagler, Bailly recommends that CELPAK carry out the same improvements for the second boiler.

Expected Results:

CELPAK currently uses about 36,000 tons of mazout per year, virtually all of which is burned in the boilers. We estimate that 2/3 of this fuel is used in the boiler which is operated year-round (2,000 tons mazout per month) and 1/3 is used in the second boiler, which is operated only during the heating season. We anticipate that with modern burners and careful operation of the boiler, excess combustion air levels can be reduced to around 30%, resulting in an increase in combustion efficiency of more than 6%.

For the second boiler, this will result in fuel savings of approximately 800 tons of mazout per year. At a projected price of $130 per ton, annual savings will be $105,000.

CELPAK - BOILER COMBUSTION EFFICIENCY

	Assumptions				Calculation	Estimates	
	O2 %	CO ppm	HC %	Temp C	Combstn on LHV,%	Mazout tonne/yr	Cost K$/yr
Boiler #2							
before	13.0	3	0.00	170	85.5	12,000	1,560
after	5.0	3	0.00	180	91.7	11,188	1,455
savings						812	105

In addition to the fuel oil savings, some electrical savings will result from the reduction in air flow required to the boilers. This is estimated as 10 kW, 40,000 kWh per year, for annual savings of about $3,000.

10 kW x $21.64/kW/mo x 6 mo/yr = $1,500/yr
40,000 kWh/yr x $0.045/kWh = $1,800/yr

We estimate the cost of the burners to be $90,000. In addition, CELPAK will incur some cost to install the burners and instruments, install air or steam lines for atomization, to calibrate the oil pressure regulator with the new burners and to repair the induced draft fan damper. We estimate these costs will be approximately $10,000.

Financial analysis:

At a cost of $100,000 with benefits of $108,000 per year, the payback period for this project will be less than one year.

B. LOW-COST, SHORT-TERM IMPROVEMENTS

BOILERHOUSE
CELPAK Action B.3 -
Improve combustion efficiency - install fixed instrumentation to measure CO and O_2 content of the boiler stack gases. Revise operating procedures.

Existing Conditions:

The control of the air to fuel ratio in the boilers is presently done based on operators' experience for a given load. The operator sets the fuel oil pressure to the burners and the damper on the forced draft fan according to his experience. Visible smoke from the stack is used as an indicator.

As noted in Action B.1, an oxygen sensor was once installed in a bypass line on the CELPAK boiler.

Recommended Actions:

RCG/Hagler, Bailly recommends that equipment for monitoring O_2 and CO content of the stack gases be procured and installed by CELPAK after installation of the new burners.

After installation, CELPAK should revise the boiler operating procedures to control combustion air to the burners based on the O_2 and CO content of the stack gases. Primary and secondary air should be regulated to give the minimum amount of excess air to the burner which is required for complete combustion of the fuel.

Expected Results

The equipment described above is expected to improve boiler efficiency by 0.5%, over and above the improvements gained by installing the new burners.

The annual savings are approximately:

0.5% x 33,566 tons/year = 168 tons/yr
168 tons/yr x US $130/ton = $22,000 per year

The cost of implementing this recommendation would be approximately $12,000 for each boiler, calculated as follows:

Instrumentation	
Oxygen and CO Analyzer	$8,000
(Ametek Thermox WDG-HPIIC, or equivalent)	
Calibration gas and spare cells	$2,000
Instrument Cable	$ 400
60 meters 6pr Shielded twisted pair @ $7/m	
Installation and Calibration	$500
20 man-hours @ $25/hr	
Experimentation for Operating Curves	$1,000
40 man-hours @ $25/hr	
Total	$11,900

Financial analysis:

Based on a total installed cost of $24,000 (for two boilers) and a savings of $22,000 per year, the payback period is just over one year.

B. LOW-COST, SHORT-TERM IMPROVEMENTS

STEAM SYSTEM
CELPAK Action B.4 - Return additional condensate to the boilerhouse

Existing Conditions:

CELPAK has identified the need to return additional condensate to the boilerhouse and is seeking funding to implement the project.

Recommended action:

RCG/Hagler, Bailly recommends that CELPAK fund this project from next year's maintenance budget.

Expected results:

By recovering the heat available in condensate, we estimate the annual potential fuel oil savings as 5%.

5% x 30,000 tons/yr = 1,500 tons/yr
1,500 tons/yr x $130/ton = $195,000/yr

The estimated cost of the project is $200,000.

Financial analysis:

The project payback period is estimated as one year.

B. LOW-COST, SHORT-TERM IMPROVEMENTS

ELECTRICAL SYSTEM
CELPAK Action B.5 -
Install electrical energy management system

Existing Conditions:

CELPAK has begun a program to manage peak electrical demand, which is a major part of electrical energy cost. Some reduction has been made using manual systems, however further improvements will require automatic equipment.

CELPAK has commissioned a study of electric demand shaving using computerized load-shedding. The study was performed by Josef Stefan Institute and seems to have been carefully done. CELPAK has procured a computer for use in the project and has sent the computer to Josef Stefan for programming.

Recommended Action:

RCG/Hagler, Bailly recommends that funds be found for this project from next year's maintenance budget so that it can be carried out to completion.

Expected Results:

The immediate effect of this project would be to reduce the unit price of electricity by reducing the monthly demand charge. We estimate the potential reduction in peak demand for purchased electricity as 1 MW, for an annual cost savings of $260,000.

1 MW x $21,640/MW/month x 12 mo/yr = $260,000

Additional savings from shifting energy consumption from peak to off-peak hours are likely to result.

Plant personnel estimate the cost to complete this project at $50,000 to $60,000. Based on our experience with similar projects, the RCG/Hagler, Bailly team estimates that the cost may be as much as double the expected cost, $130,000.

Financial Analysis:

Even based on the most pessimistic assumptions, this project would provide a payback period of six months or less.

B. LOW-COST, SHORT-TERM IMPROVEMENTS

ELECTRICAL SYSTEM
CELPAK Action B.6 - Install power factor correction capacitor system

Existing Conditions:

CELPAK purchases electricity under a time-of-day tariff with both active (kWh) and reactive (kVARh) components. CELPAK pays a severe penalty for low power factor (cosine phi), about $800,000 per year.
The RCG/Hagler, Bailly team analyzed CELPAK electric energy consumption records for the period 1988-90. From this analysis, it is apparent that the average power factor is about 0.6, or about 9.3 MVAR (see Appendix 1).

Recommendation:

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

Expected Results:

Through this program, CELPAK can achieve a plant power factor of 0.95, and hence avoid power factor penalties (for excess kVAR). Of the improvement, part is expected to come from the motor team (see Action A.2) and its survey and the remainder from the installation of an estimated 6,000 kVAR of capacitors. Reduction in reactive energy by capacitors will save $600,000 per year:

20,000 kVARh/yr (peak) x $0.020/kVARh = $400,000
20,000 kVARh/yr (off-peak) x $0.010/kVARh = $200,000

The estimated cost of the power factor correction capacitor system:

6,000 kVAR x $30/kVAR = $210,000

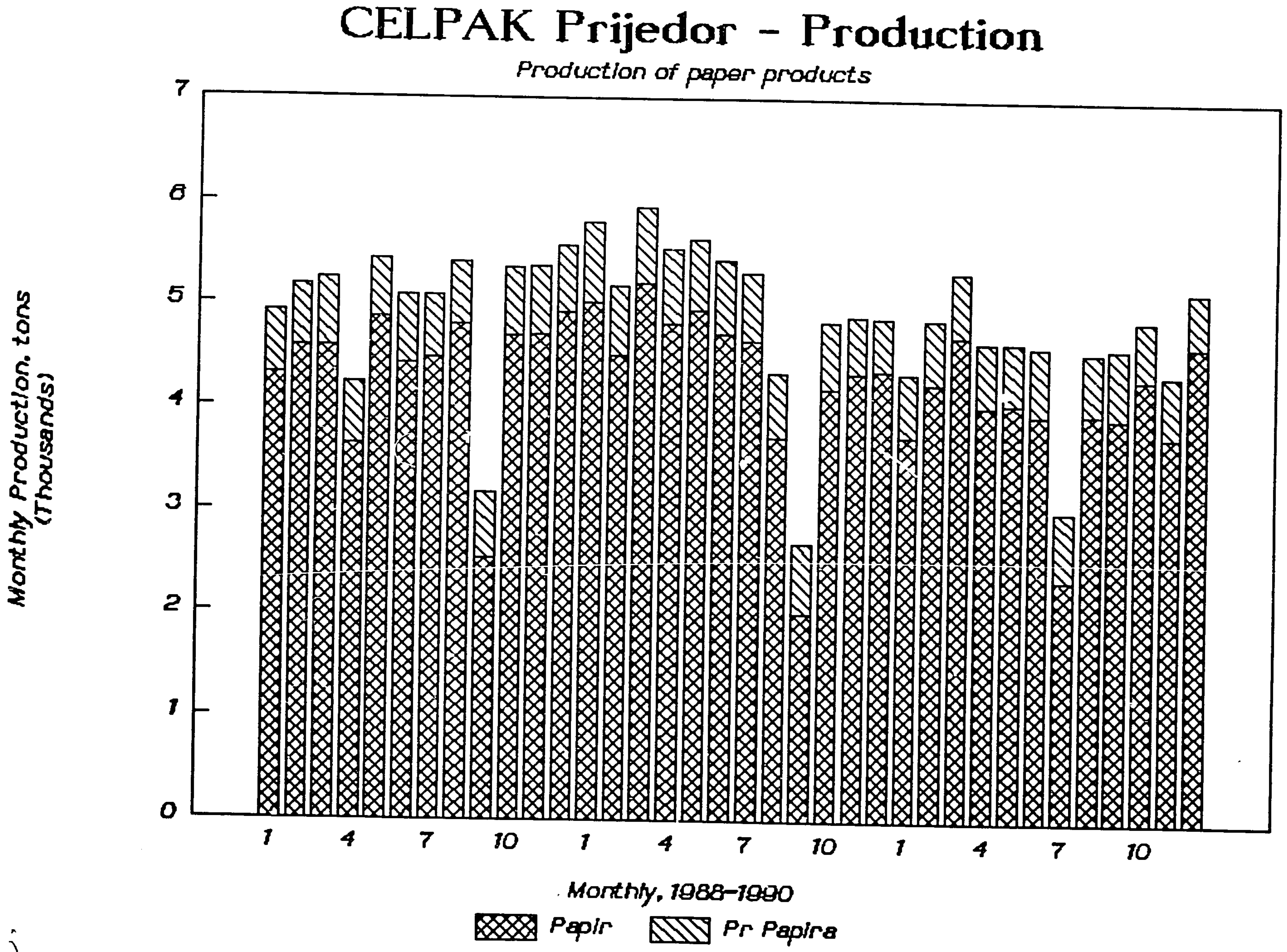
Financial analysis:

The payback period for the projects is less than five months:
$210,000/($400,000/yr + $200,000/yr) = 0.35 years

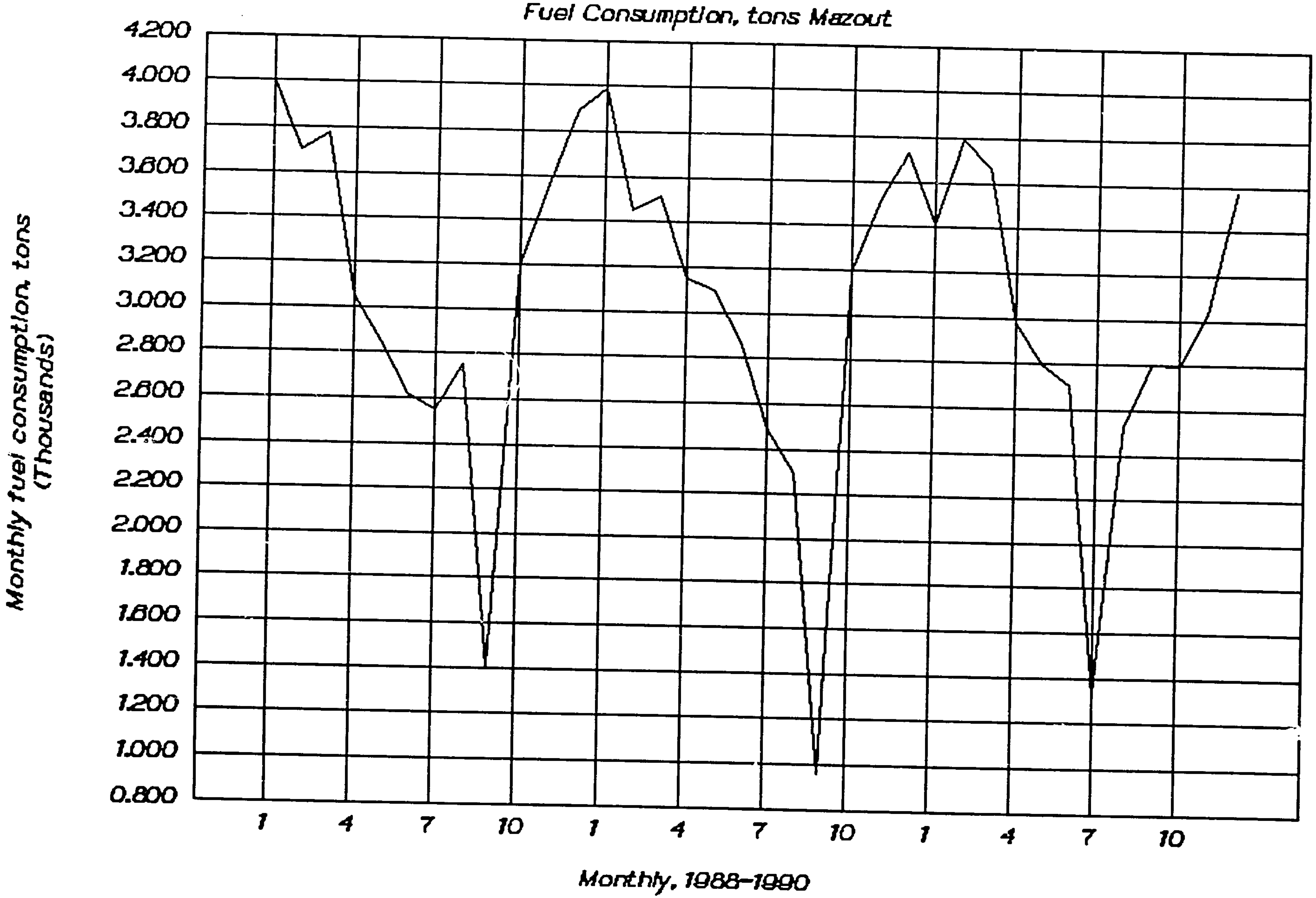
APPENDIX 1
GRAPHICAL PRESENTATION OF HISTORICAL ENERGY CONSUMPTION AND EFFICIENCY DATA

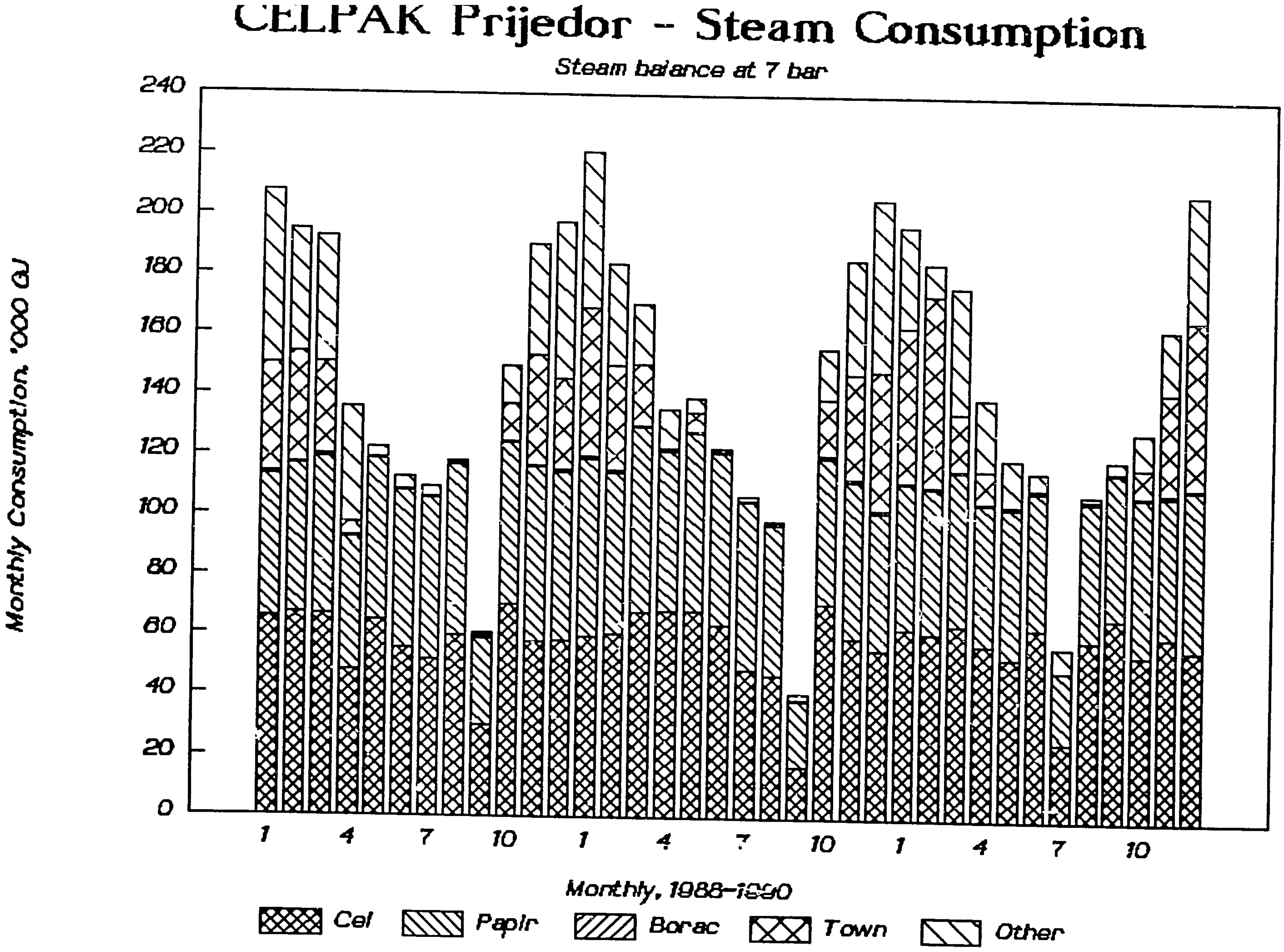
MONTHLY DATA

DP CELPAK - PRIJEDOR
PULP & PAPER PLANT


CELPAK Prijedor - Production
Production of paper products
Monthly Production, tons (Thousands)
0
1
2
3
4
5
6
7
1
4
7
10
1
4
7
10
1
4
7
10
Monthly, 1988-1990
▩ Papir
▧ Pr Papira

CELPAK Prijedor - Heavy Fuel Oil

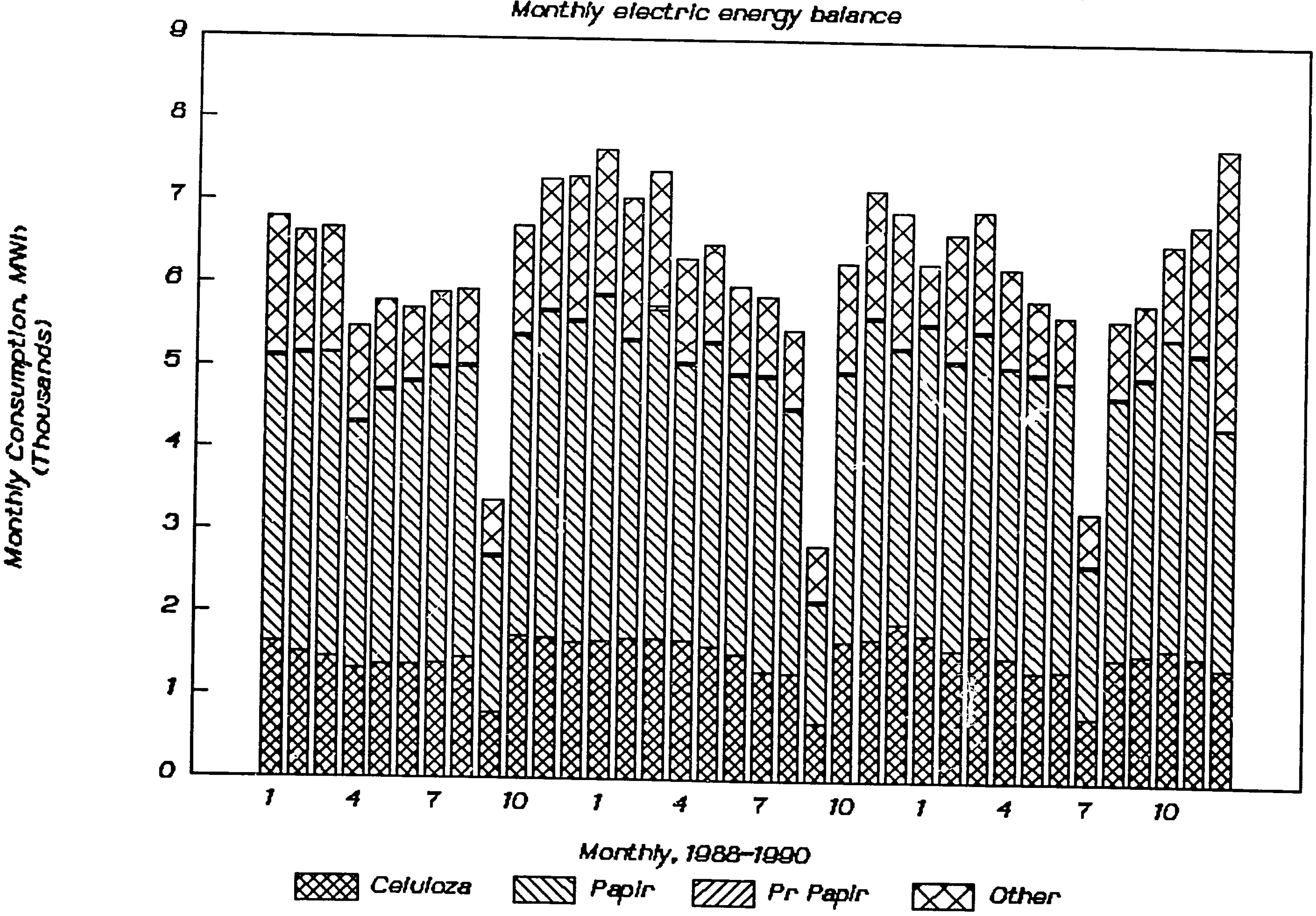




CELPAK Prijedor - Steam Consumption

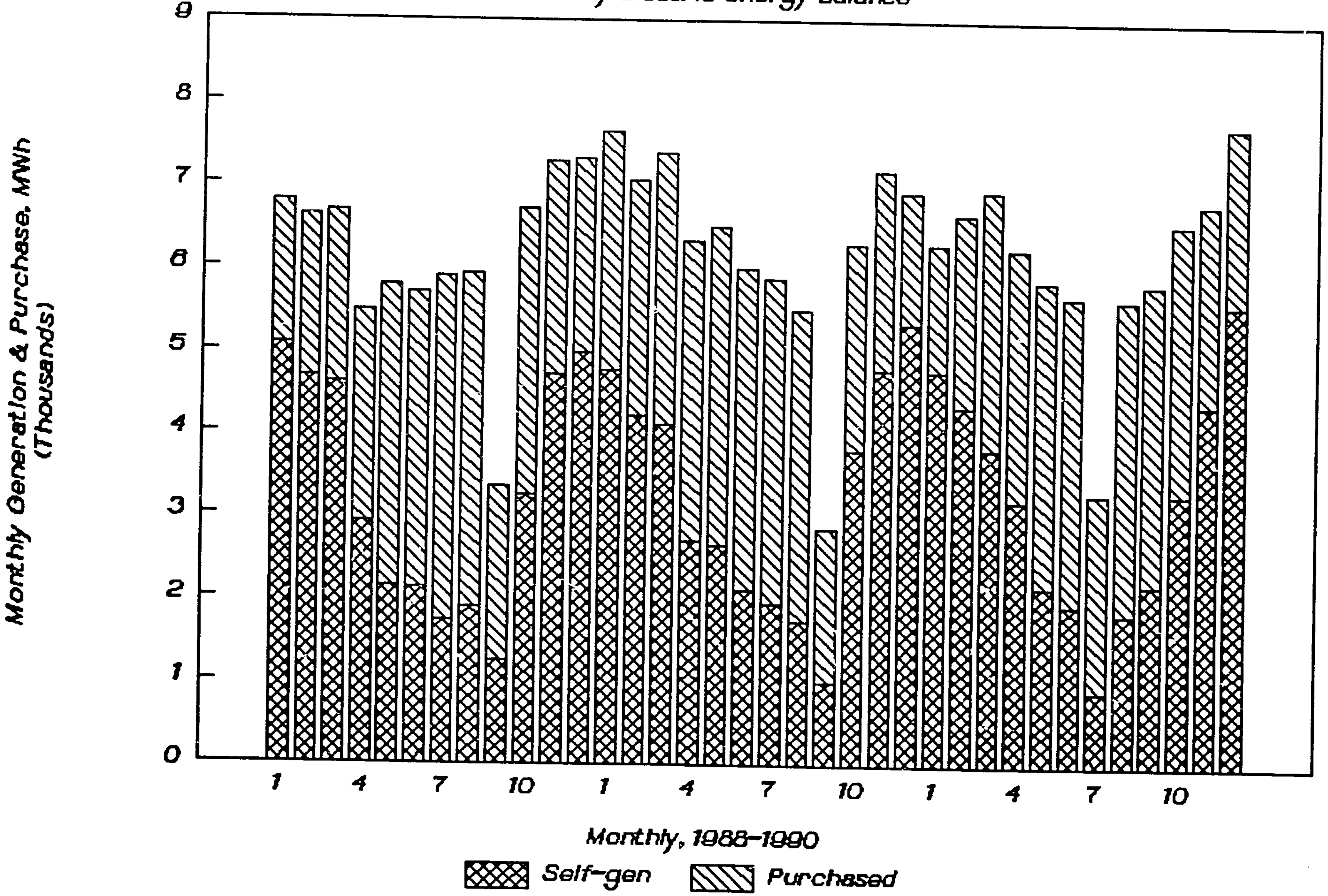
Steam balance at 7 bar

CELPAK Prijedor - Electric Consumption



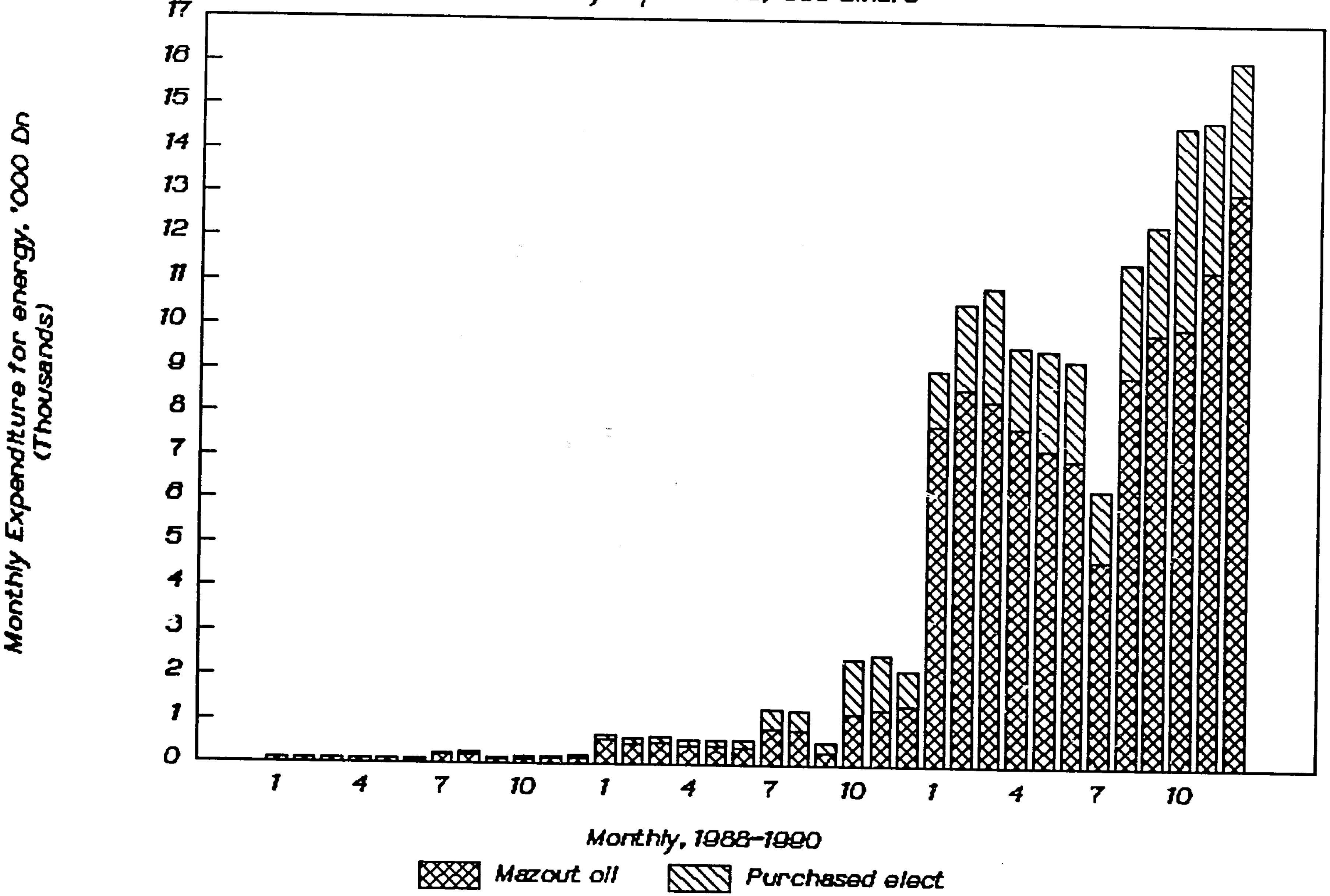
CELPAK Prijedor - Electricity Supply

Monthly electric energy balance



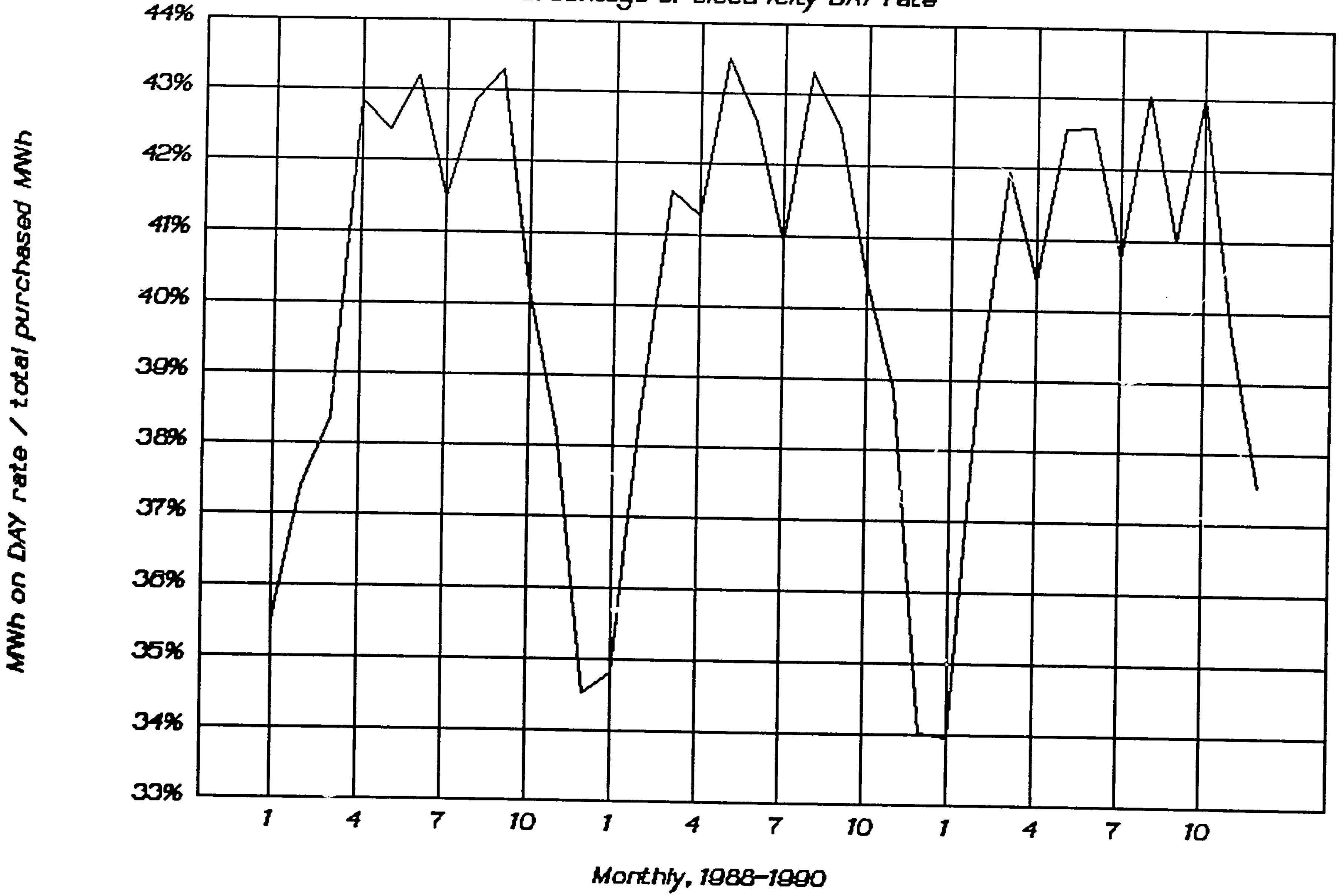
CELPAK Prijedor - Energy Cost

Monthly expenditure, '000 Dinars

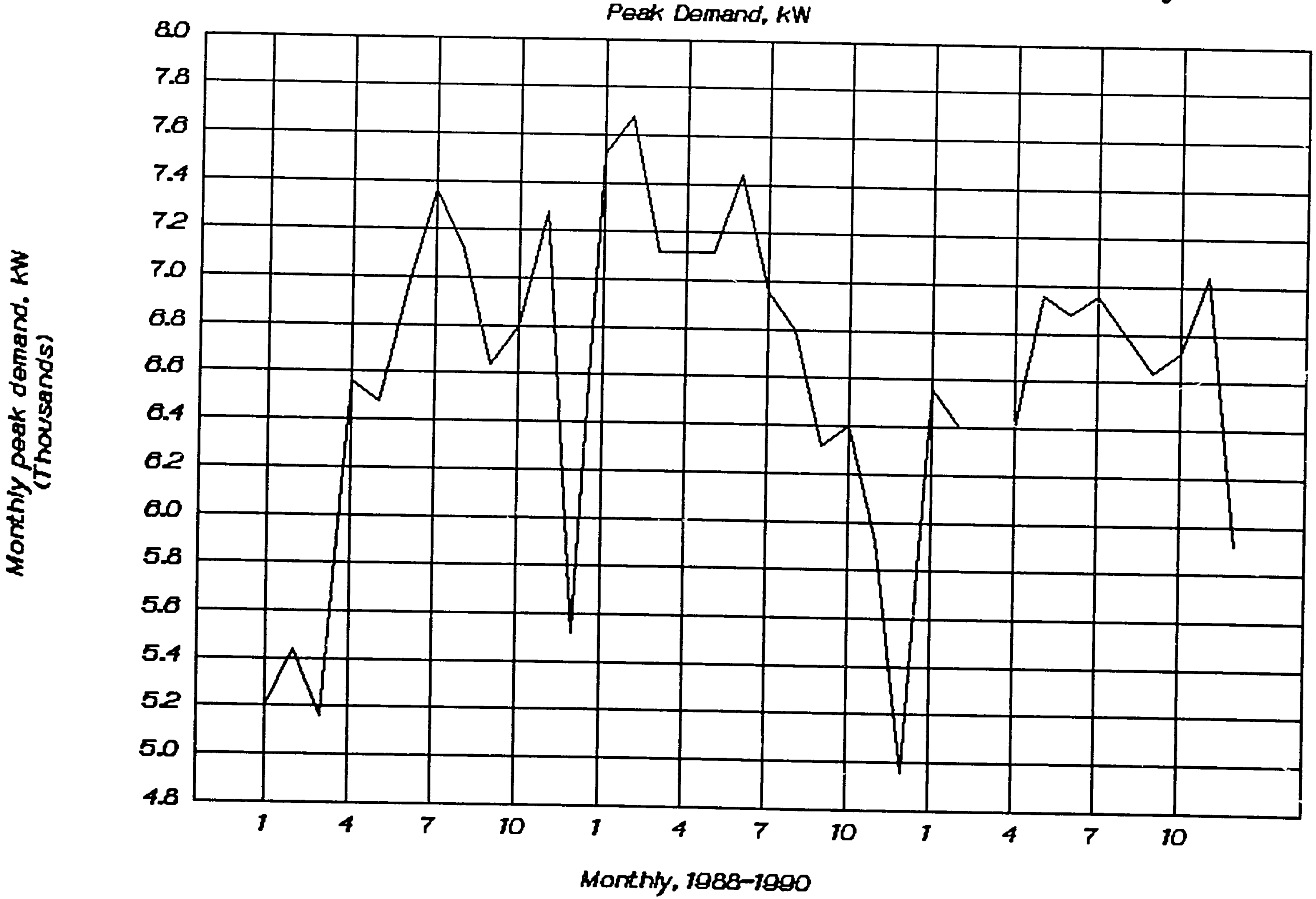


CELPAK Prijedor - Purchased Electricity

Percentage of electricity DAY rate

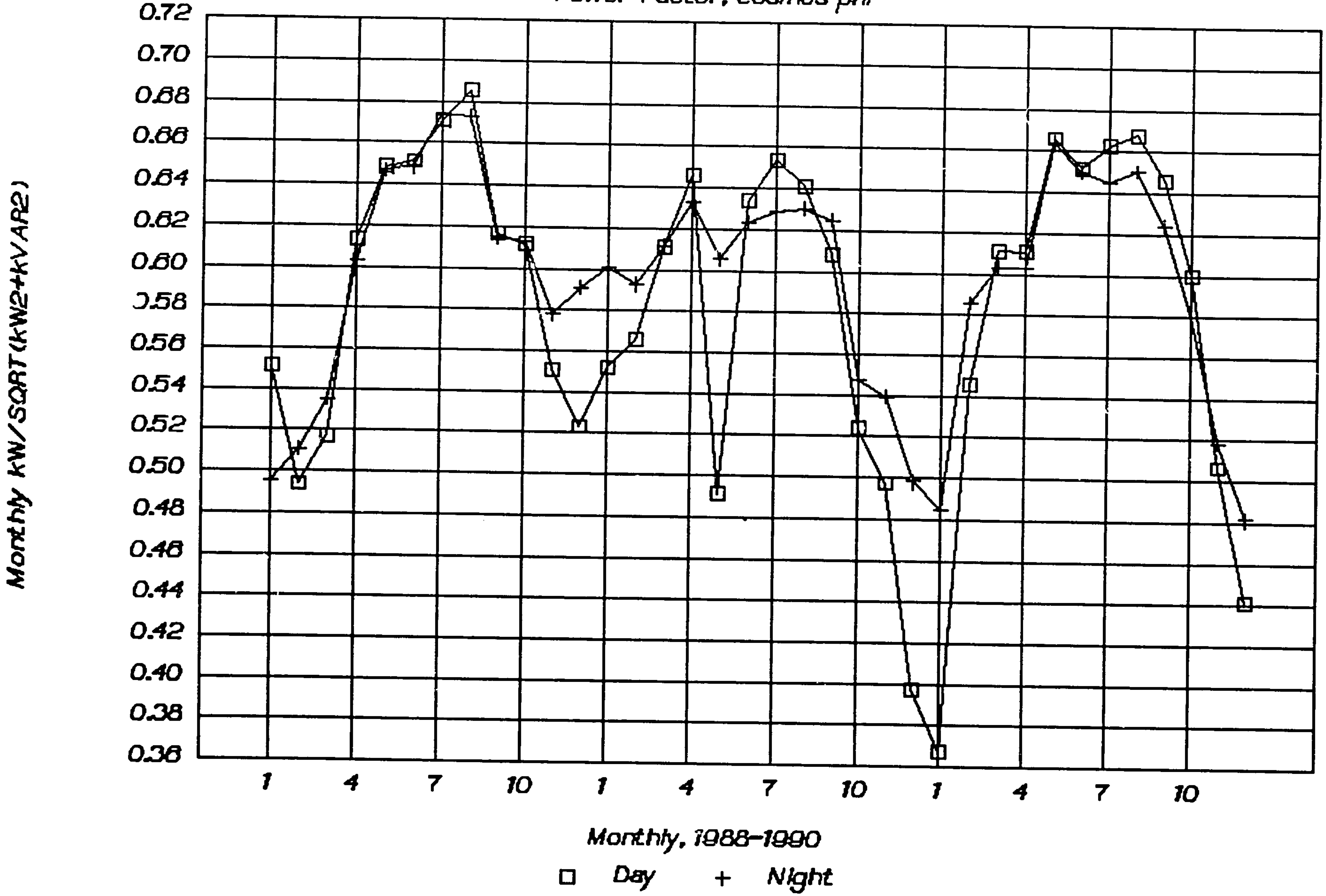


CELPAK Prijedor - Purchased Electricity

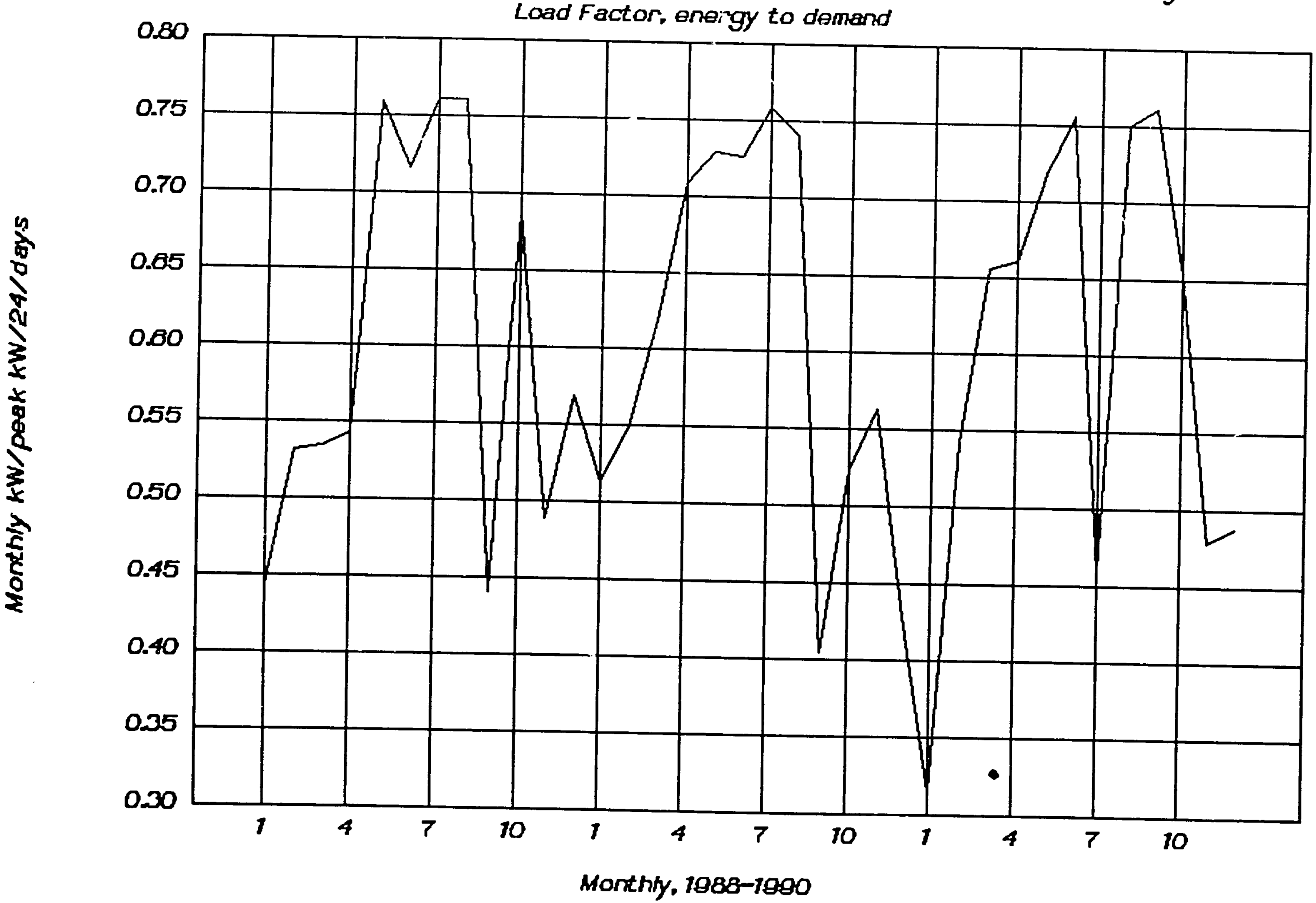


CELPAK Prijedor - Purchased Electricity

Power Factor, cosinus phi

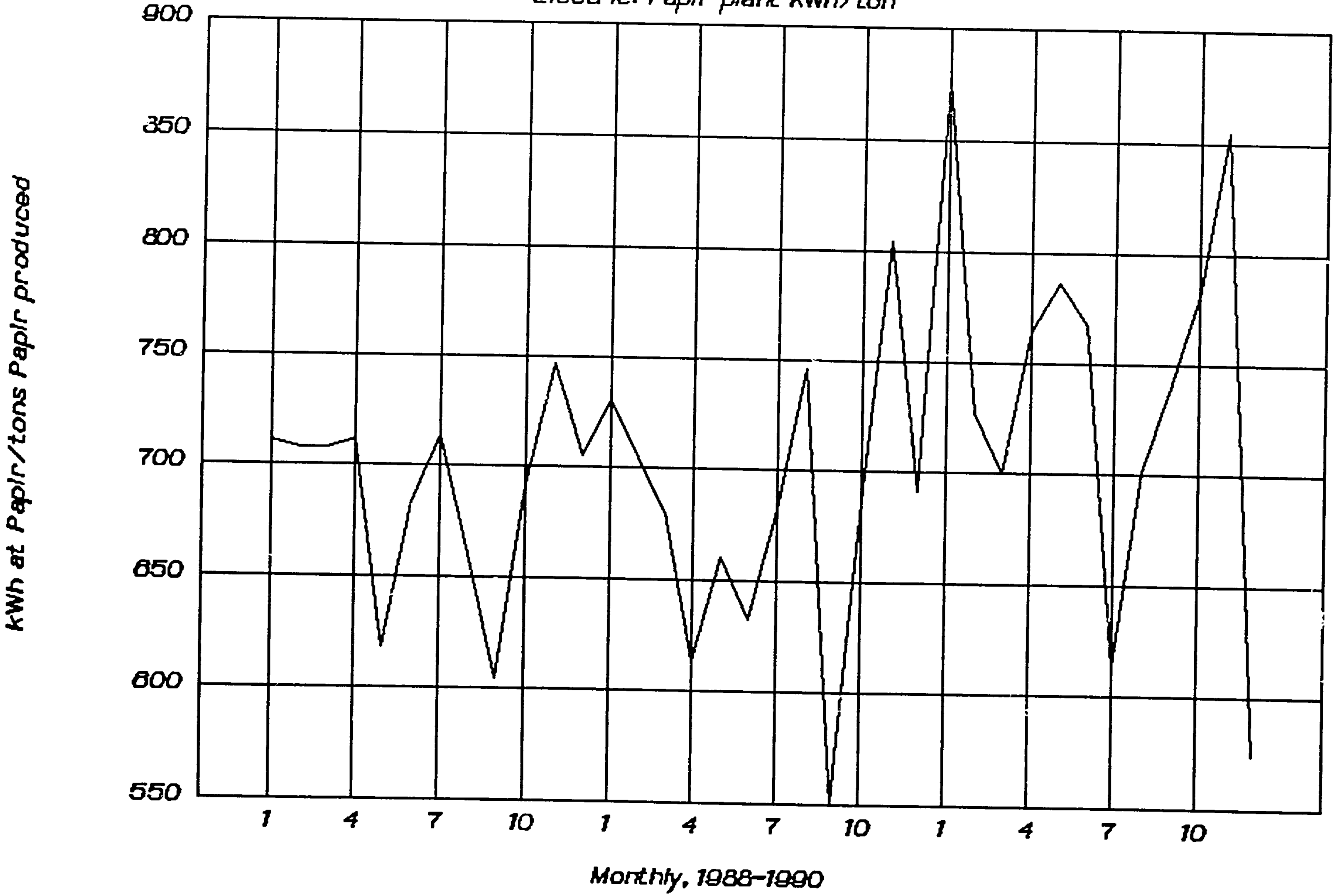


CELPAK Prijedor - Purchased Electricity



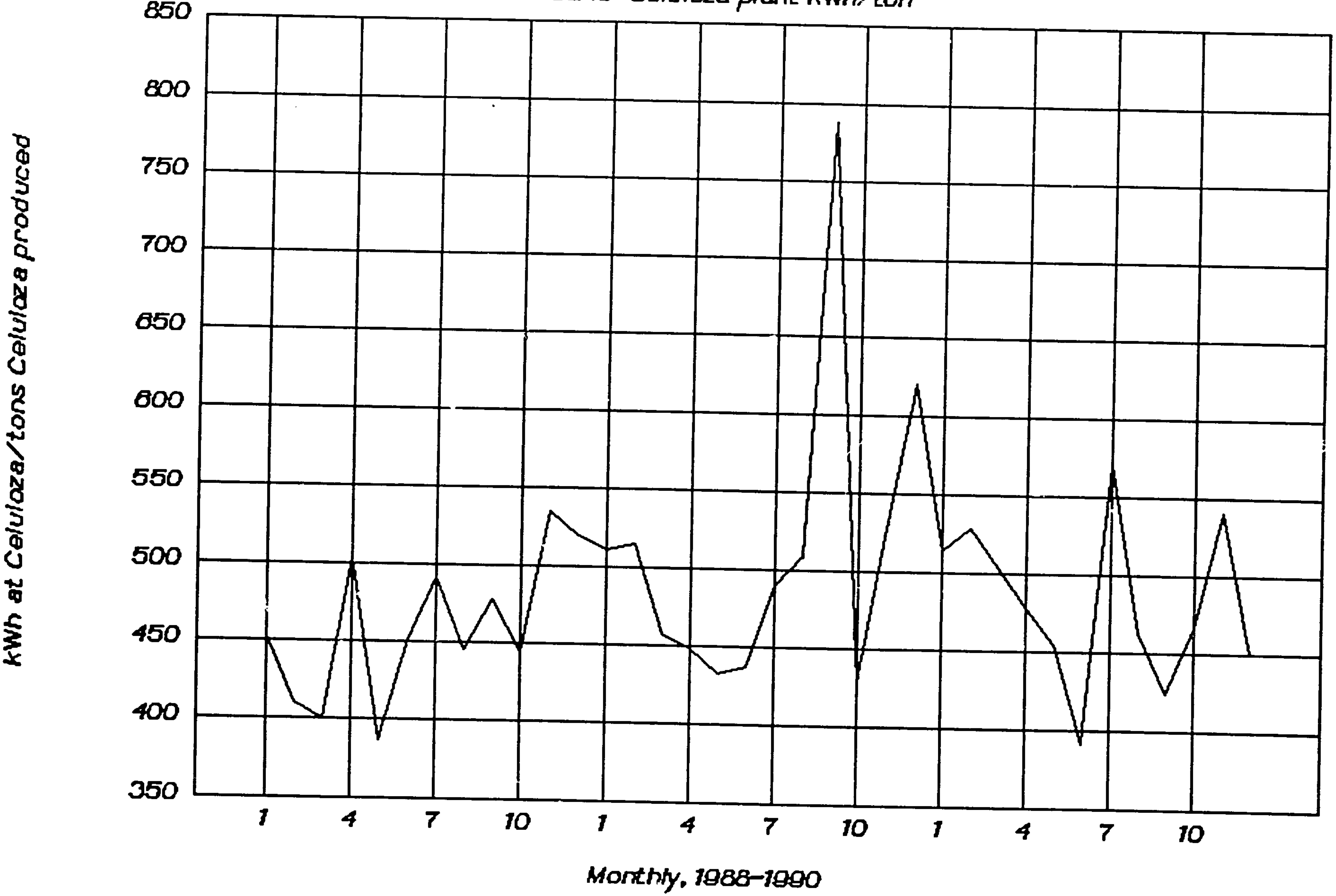
CELPAK Prijedor - Specific Energy Cons.

Electric: Papir plant kWh/ton



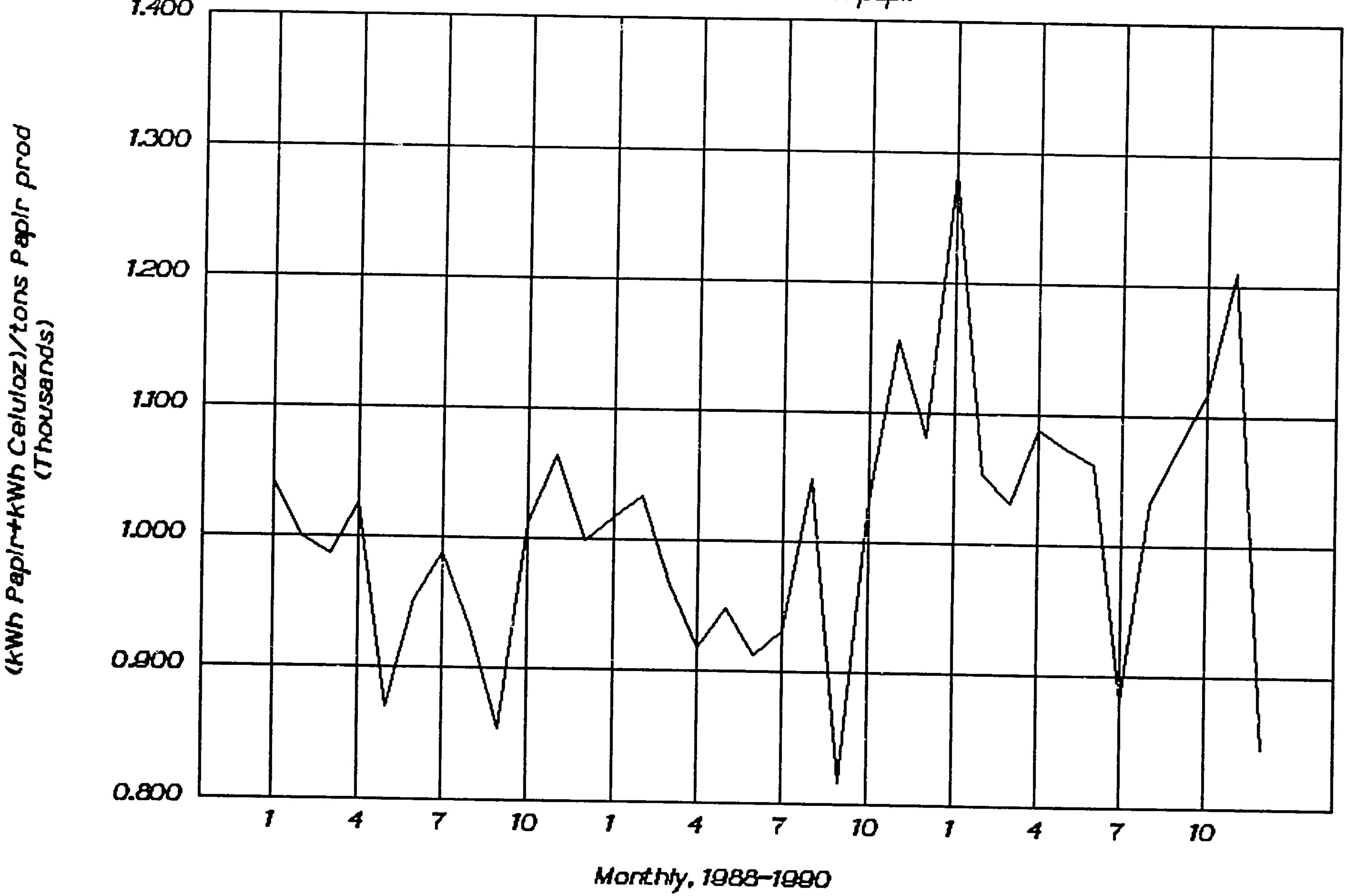
CELPAK Prijedor - Specific Energy Cons.

Electric: Celuloza plant kWh/ton

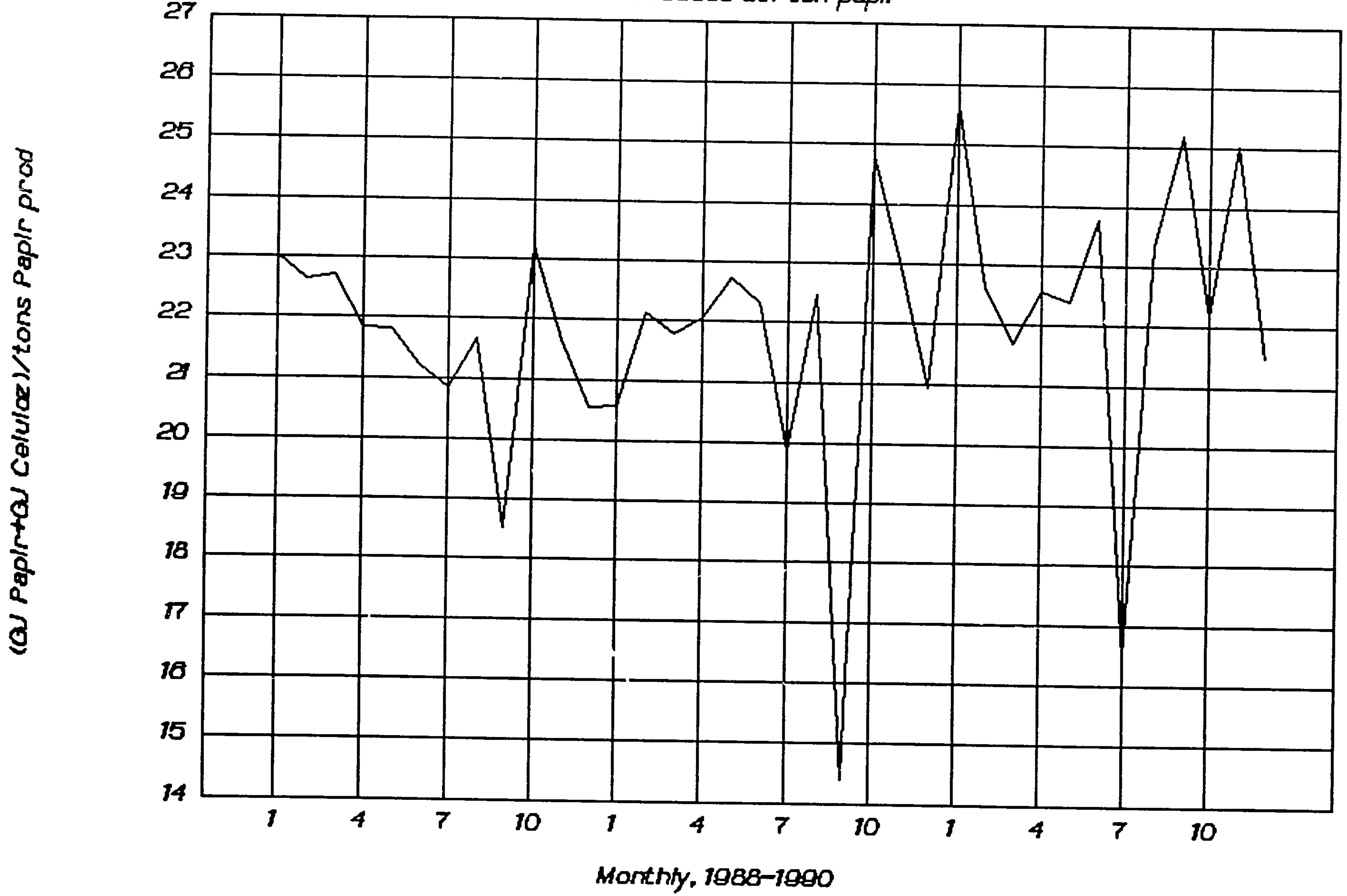


CELPAK Prijedor - Specific Energy Cons.

Electric: Process kWh/ton papir



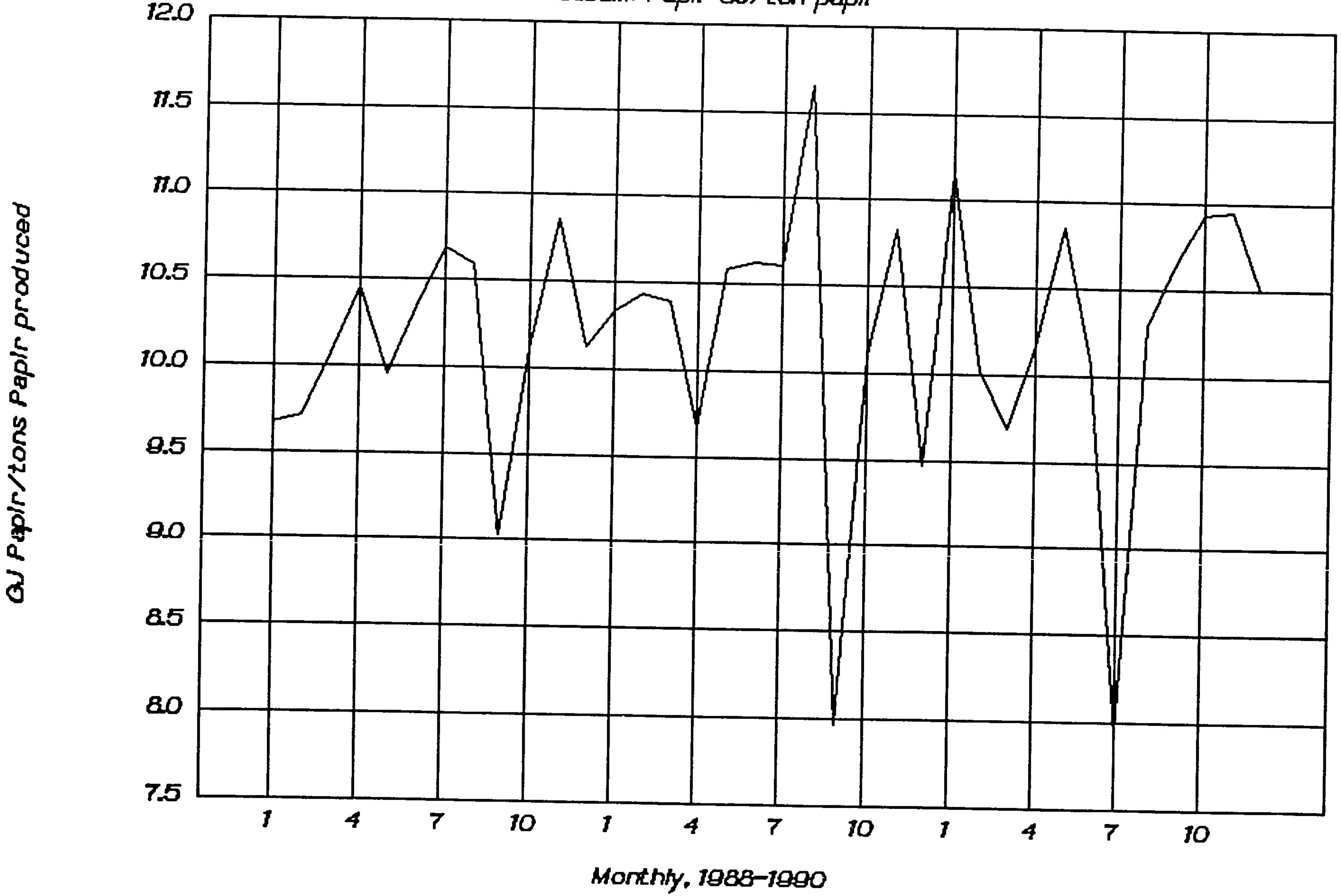
CELPAK Prijedor - Specific Energy Cons.



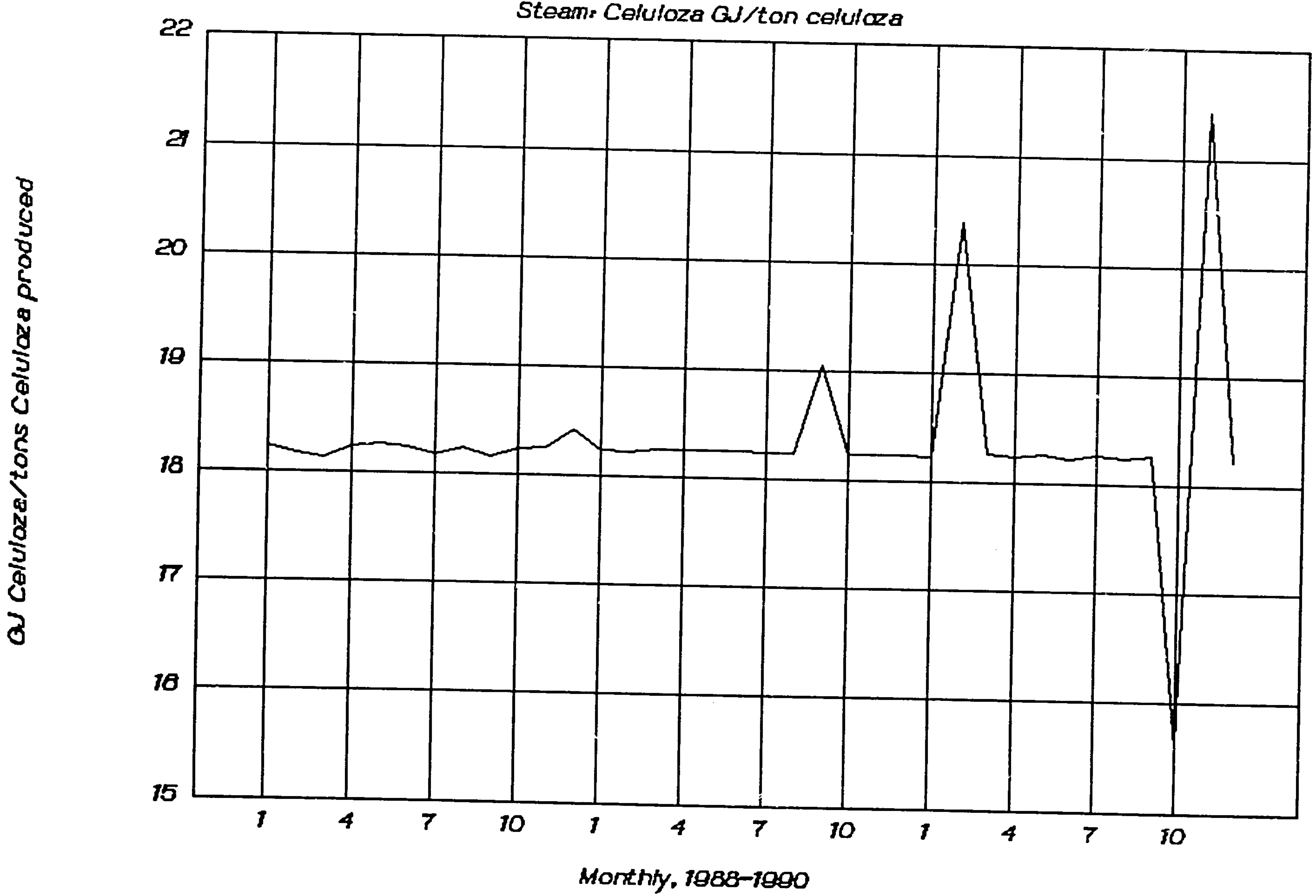
Steam: Process GJ/ton papir

CELPAK Prijedor - Specific Energy Cons.

Steam: Papir GJ/ton papir

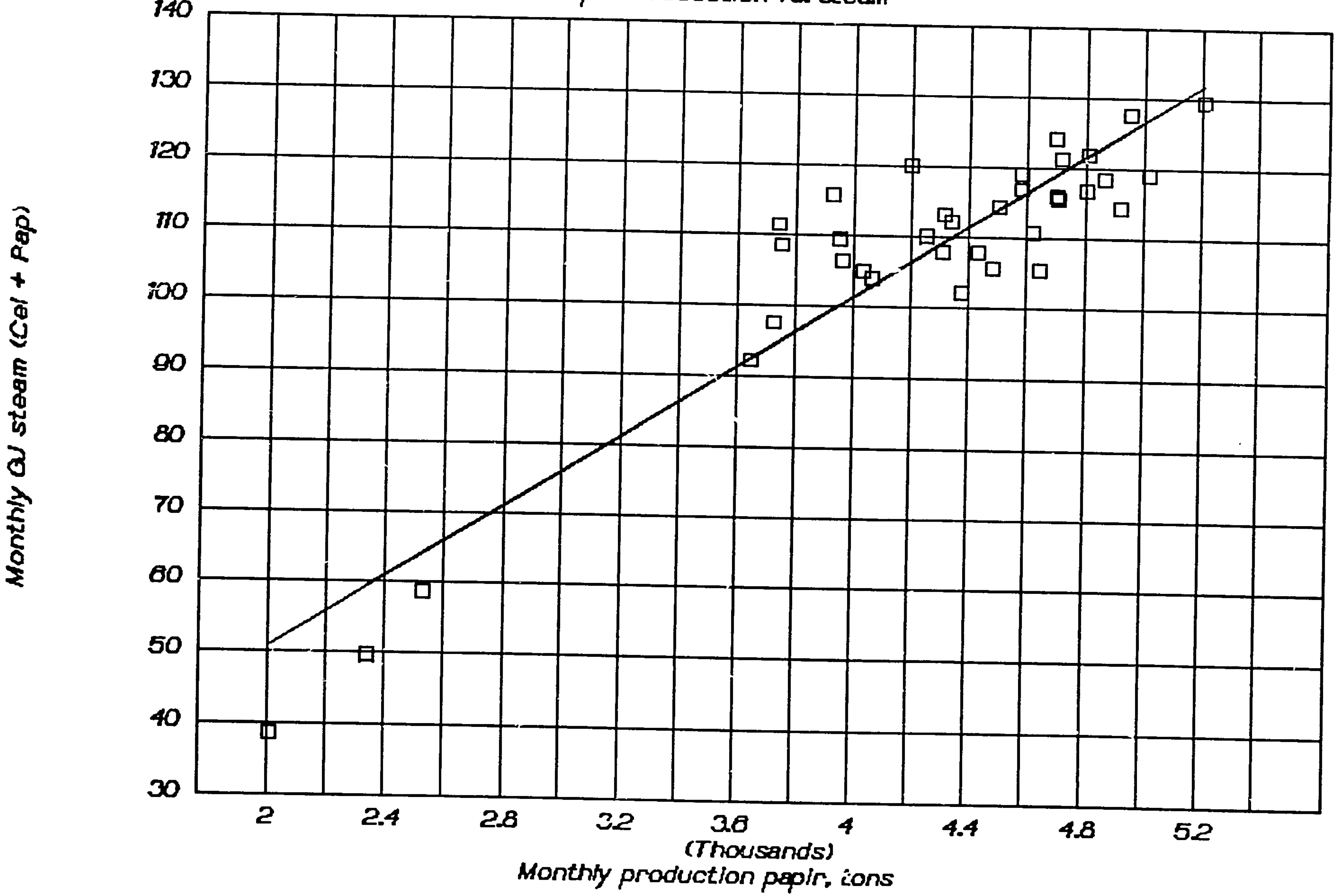


CELPAK Prijedor - Specific Energy Cons.

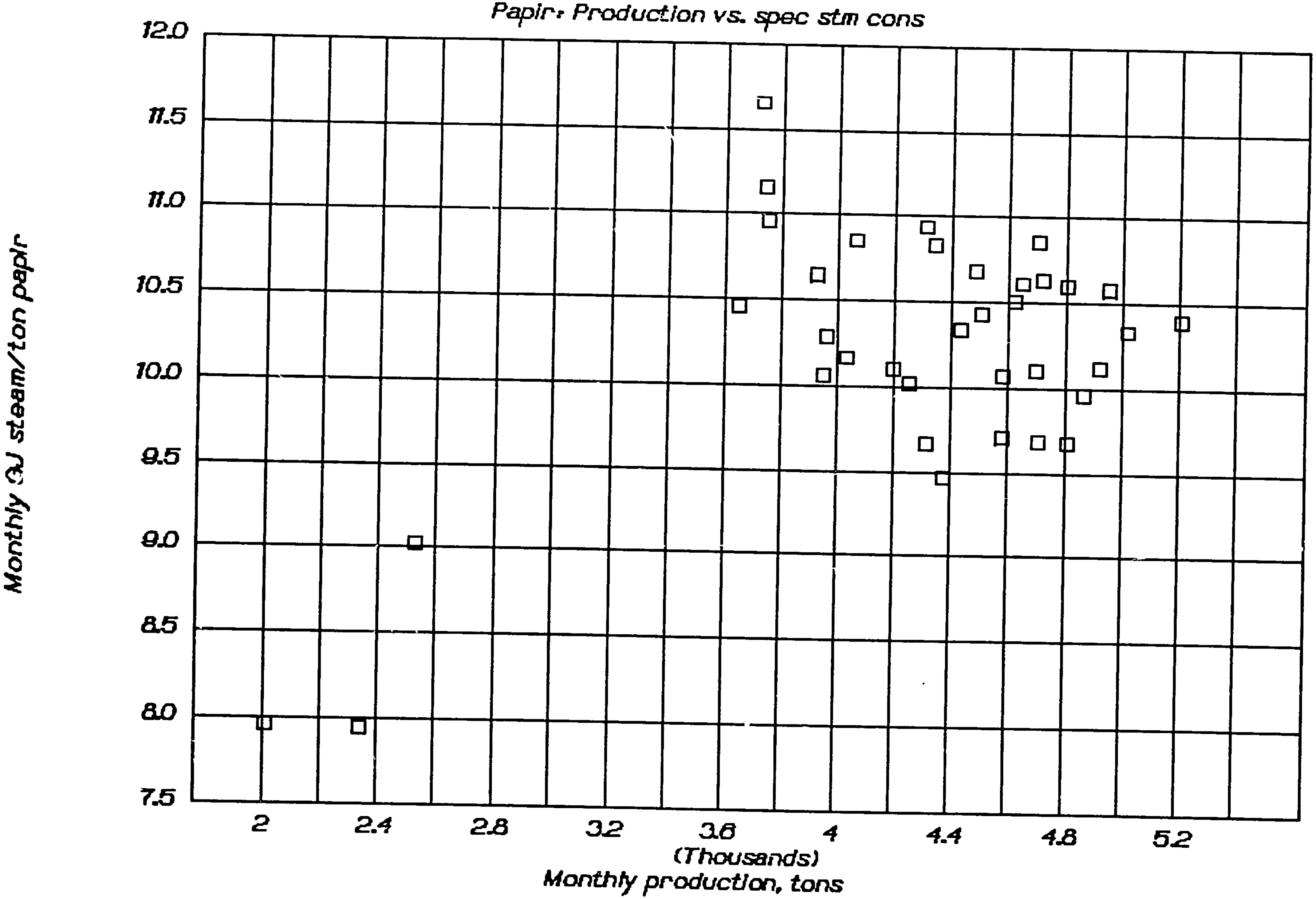


CELPAK Prijedor - Energy to Production

Papir: Production vs. steam

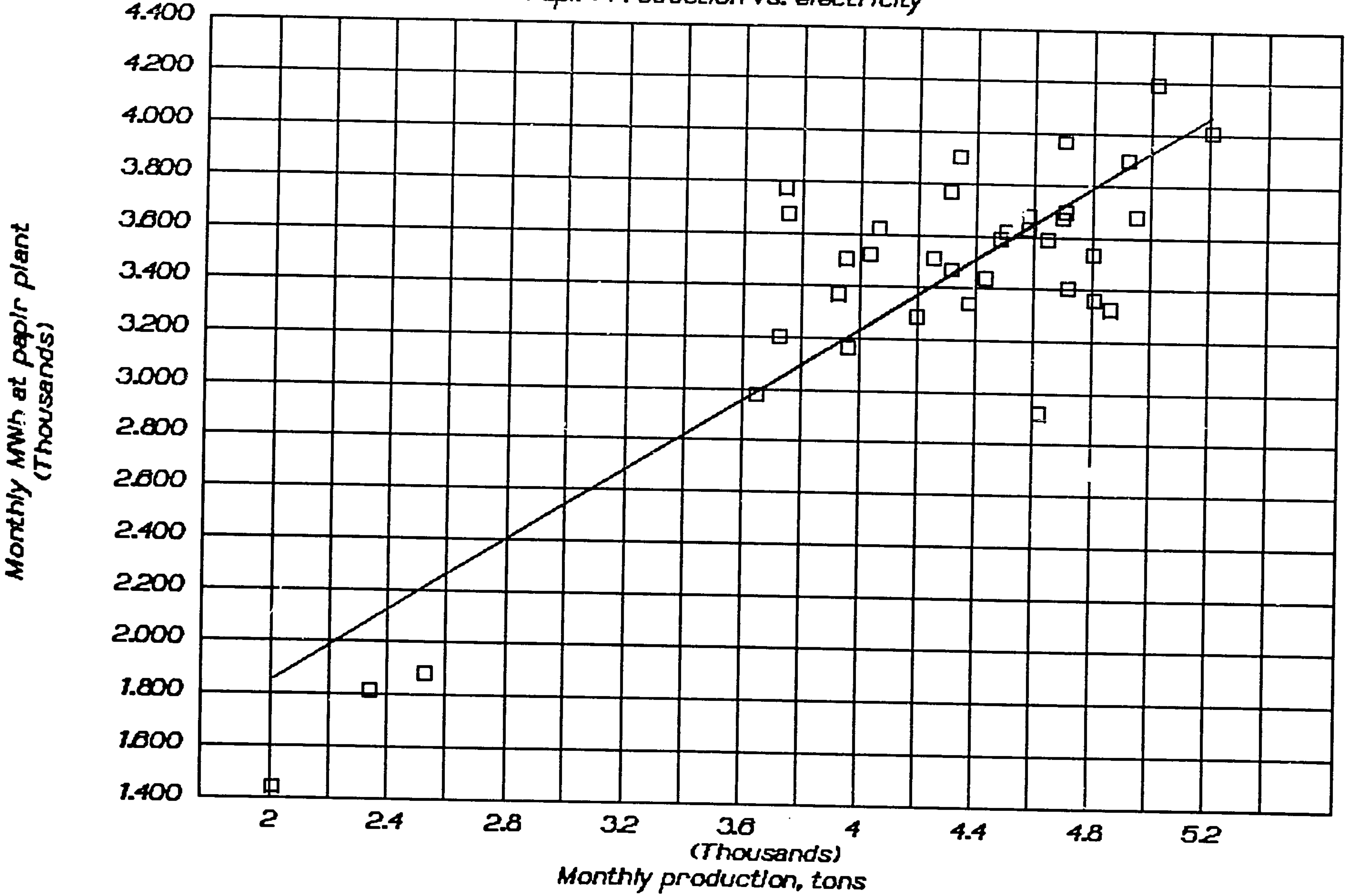


CELPAK Prijedor - Energy to Production

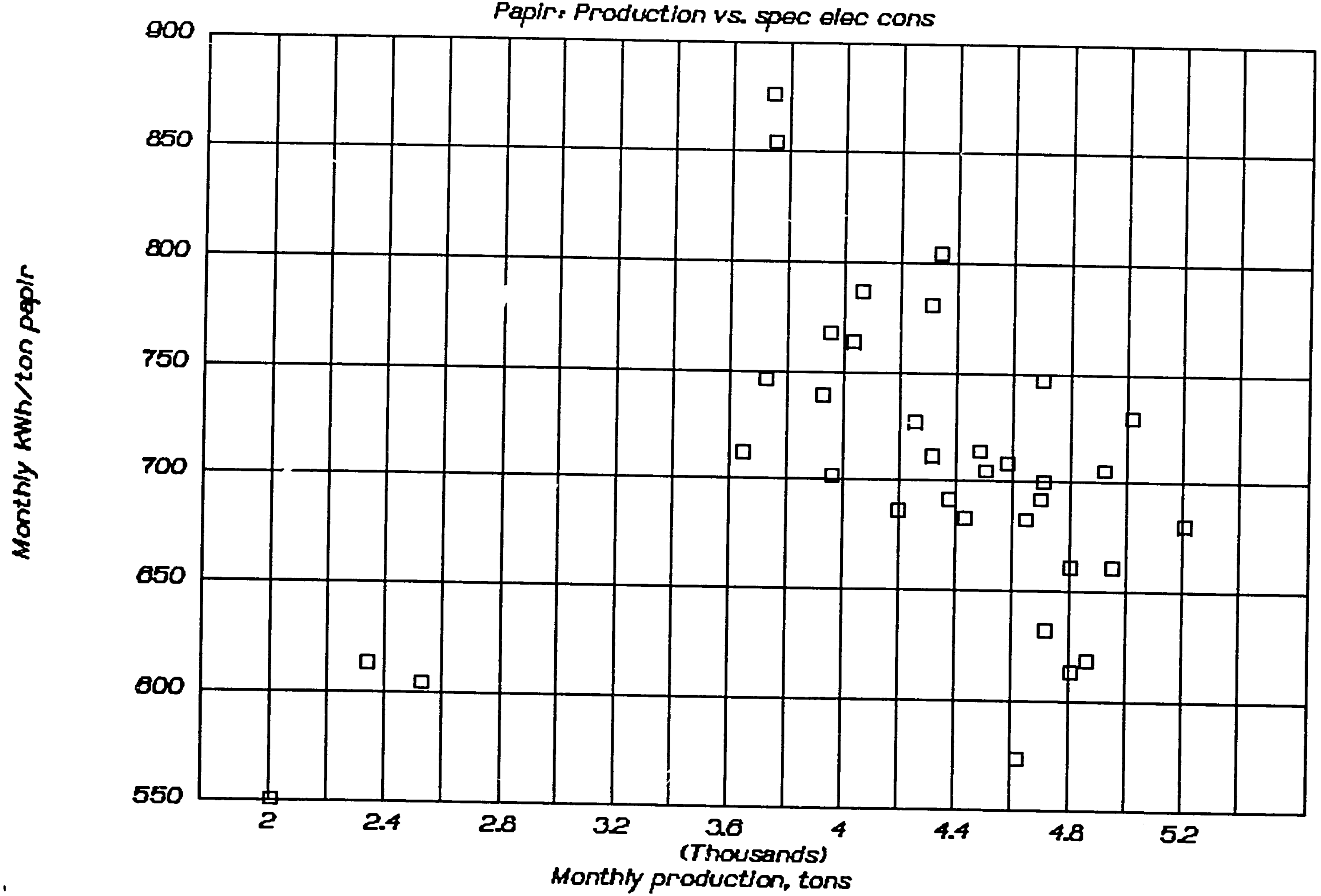


CELPAK Prijedor - Energy to Production

Papir: Production vs. electricity

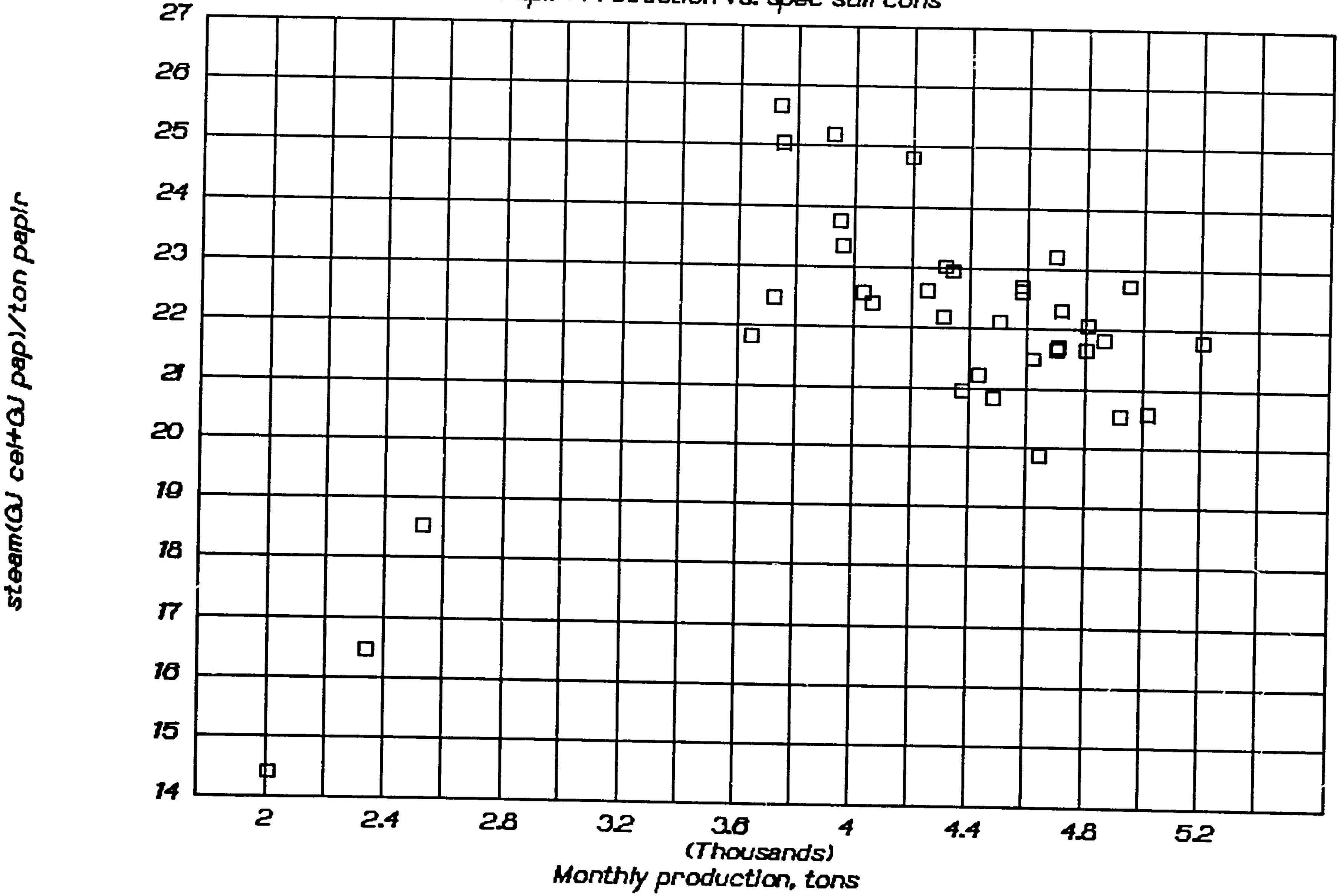


CELPAK Prijedor - Energy to Production



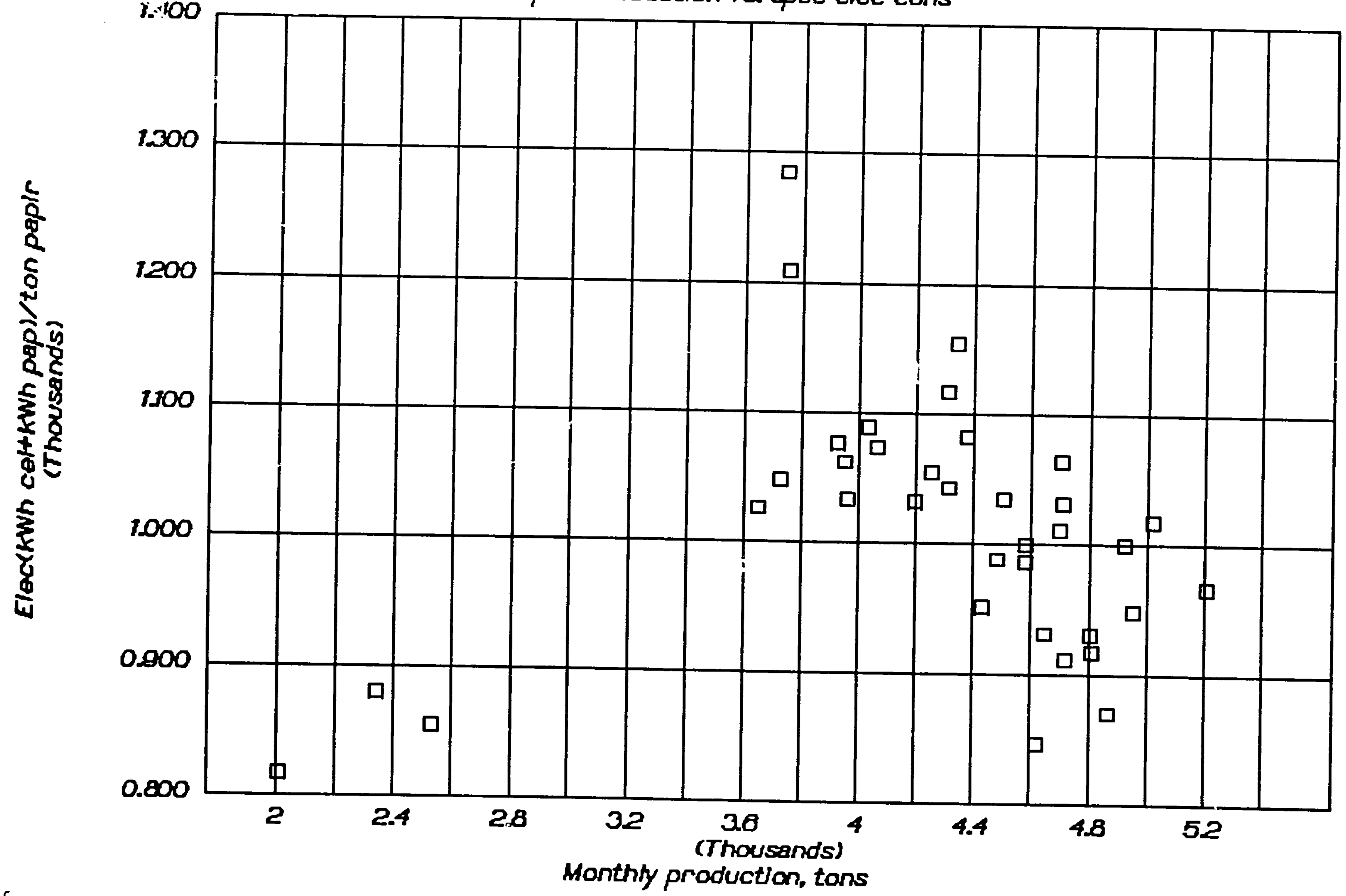
CELPAK Prijedor - Energy to Production

Papir: Production vs. spec stm cons



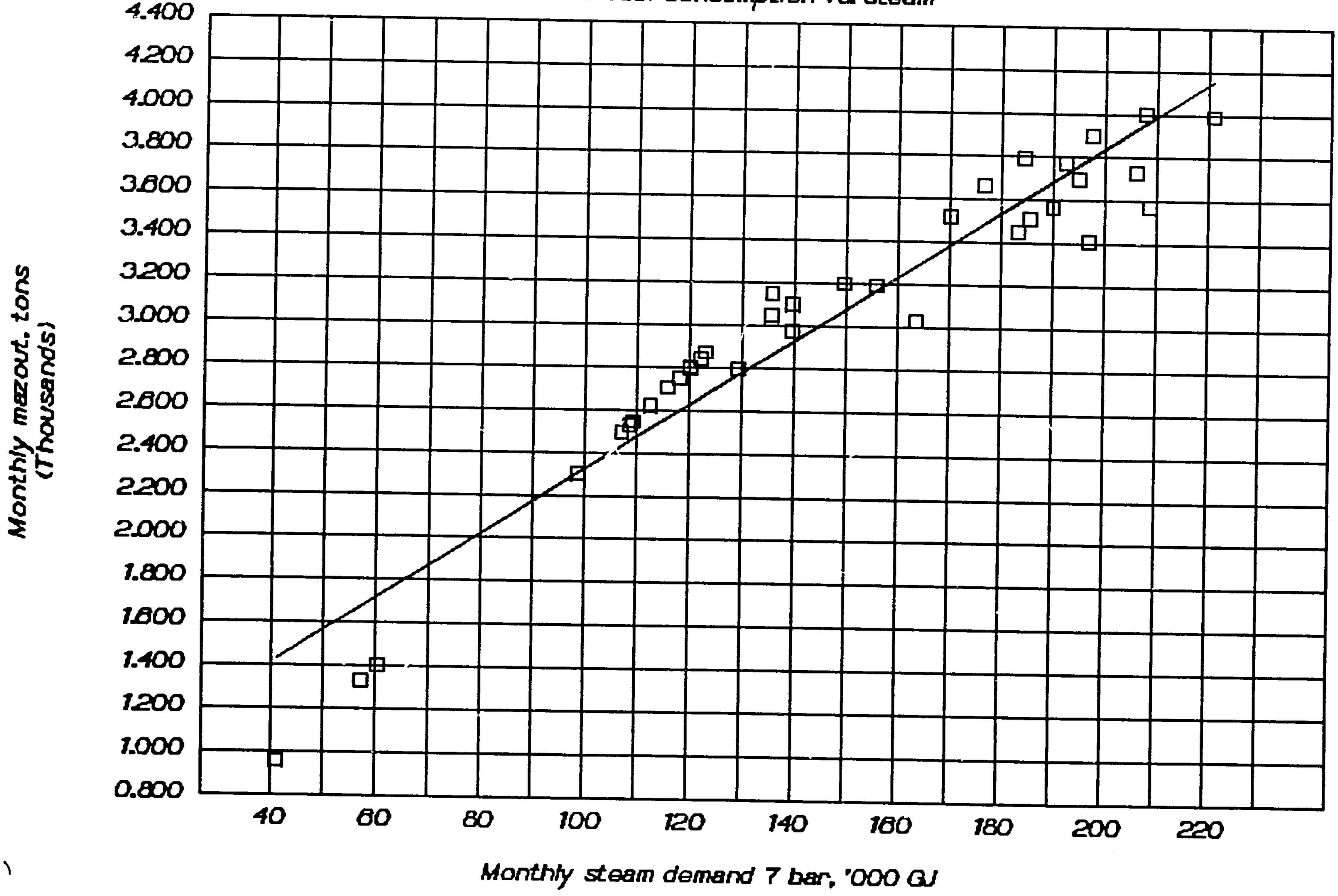
CELPAK Prijedor - Energy to Production

Papir: Production vs. spec elec cons



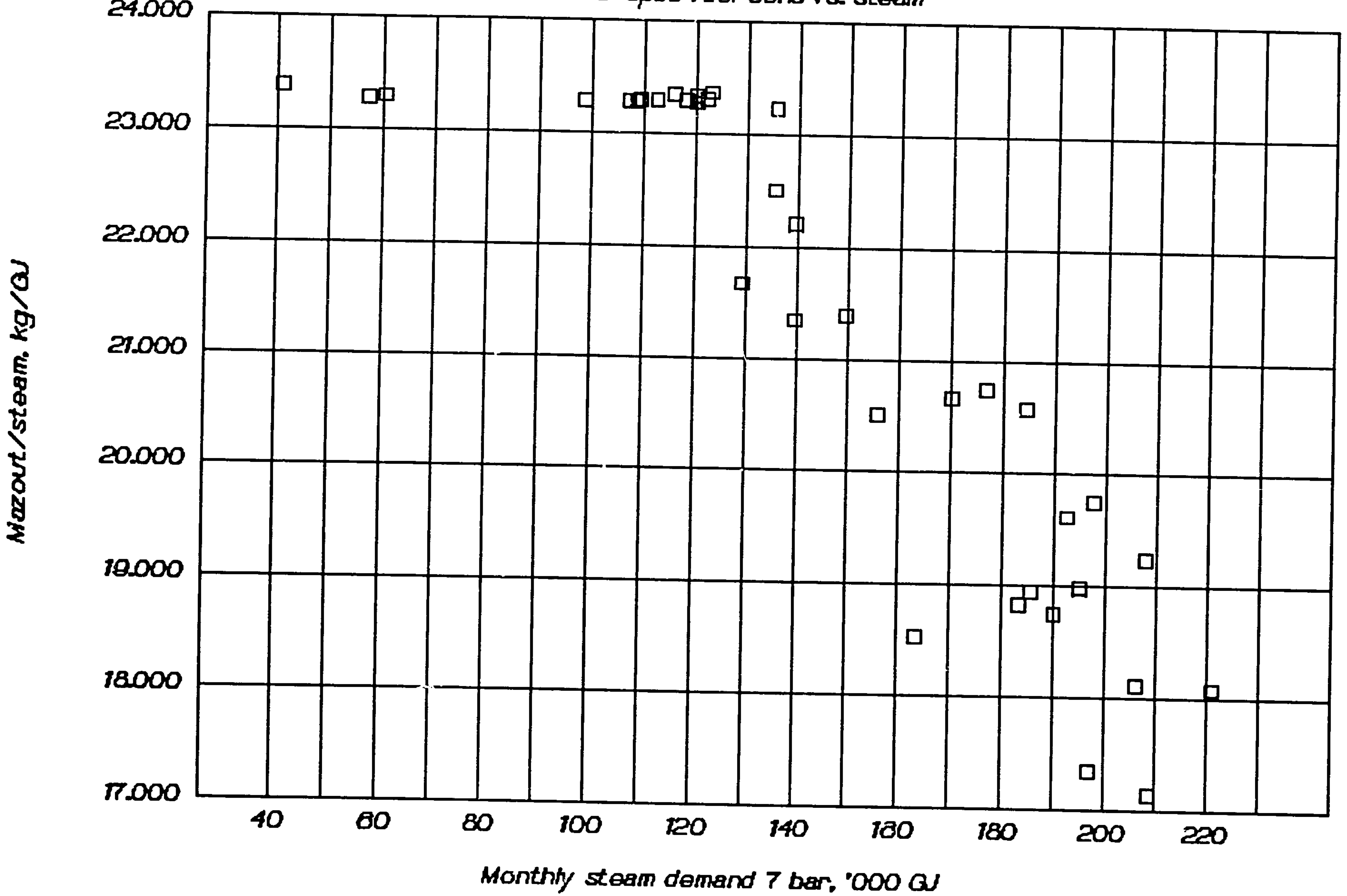
CELPAK Prijedor - Fuel to Steam

Boilers: fuel consumption vs. steam



CELPAK Prijedor - Fuel to Steam

Boilers: spec fuel cons vs. steam



CELPAK Prijedor - Heavy Fuel Oil

Boilers: Specific Fuel Consumption