PN-ABM-236
79204

ENERGY EFFICIENCY AUDIT REPORT
SAULKALNE BUILDING MATERIALS PLANT
SAULKALNE, RIGA REGION, LATVIA

JULY 1992

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

B.V. EKODOMA, LTD.
1 Kalka Str., RTU
226355 Riga Latvia
(70132) 40 95 53

and

RIGA TECHNICAL UNIVERSITY
1 Kronvalda Blvd.
226827 Riga Latvia
(70132) 32 32 52

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

TABLE OF CONTENTS

ACKNOWLEDGMENTS

I. EXECUTIVE SUMMARY 1

II. INTRODUCTION 5

2.1 Plant Description 5
2.2 Energy Audit Activities 6

III. ENERGY CONSUMPTION ANALYSIS 9

IV. ENERGY PROCUREMENT AND COST ANALYSIS 15

V. RECOMMENDATIONS FOR ENERGY EFFICIENCY IMPROVEMENT 18

A.1 Establish a market-based plant production and energy management system 19
A.2 Put energy efficiency teams in action to reduce energy losses 23
A.3 Optimize grinding - increase product particle size 28
A.4 Reorganize enterprise to put control for raw material supply under SAULKALNE authority 31

B.1 Install separator on building lime grinding shop to convert to closed circuit 33
B.2 Repair infiltration air leaks in kilns 34
B.3 Instrument kiln and modify operating practices 37

C.1 Convert kilns to burn natural gas 41
C.2 Study feasibility of modernizing process equipment 43

APPENDICES

ACKNOWLEDGEMENTS

USAID, B.V. Ekodoma, Ltd. and RCG/Hagler, Bailly, Inc. gratefully acknowledge the assistance and cooperation shown by USAID/Riga and Riga Technical University (RTU). We also gratefully acknowledge the personalized assistance and cooperation of the following Saulkalne individuals:

Mr. V. Parevskis	Director
Mr. A. Sergejevs	Chief Engineer

The RCG/Hagler, Bailly audit team of engineers consisted of:

Mr. David Keith	Principal Engineer/Project Director RCG/Hagler, Bailly, Inc.
Dr. Larry Banta	Senior Engineer/Consultant on leave from West Virginia Univ.
Dr. Dagnija Blumberga	President and Project Manager B.V. Ekodoma
Dr. Ivars Veidenbergs	Senior Engineer B.V. Ekodoma
Dr. Janis Bazhbauers	Project Advisor Riga Technical University

FINAL ENERGY AUDIT
CELNIECIBAS MATERIALU RAZOSANAS AKCIONARA BIEDRIBA "SAULKALNE"
SAULKALNE BUILDING MATERIALS PLANT
SAULKALNE, RIGA REGION, LATVIA

BY
RCG/HAGLER, BAILLY, INC.
B.V. EKODOMA
RIGA TECHNICAL UNIVERSITY

JULY 1992

I. EXECUTIVE SUMMARY

A team of engineers from RCG/Hagler, Bailly, Inc., Riga Technical Institute, and the company B. V. Ekodoma, Ltd. carried out in-plant diagnostic activities on-site at **CELNIECIBAS MATERIALU RAZOSANAS AKCIONARA BIEDRIBA "SAULKALNE"** (SAULKALNE Building Materials Plant) from January 13-15, 1992. Their objective was to work together with SAULKALNE staff to identify and implement improvements to energy efficiency.

Based on energy consumption in 1991 and European market energy prices prevailing at the time of the visit[1], the total economic cost to the economy of Latvia for the energy plan for 1992 at SAULKALNE is estimated as $1.4 million. The actual cost may be less, if Latvia succeeds in obtaining fuels and electricity at prices lower that the European market. The primary energy forms used at SAULKALNE are anthracite coal and electricity, and the total economic energy costs for 1992 at SAULKALNE are estimated as follows:

anthracite coal:
20,000 tons per year, or 480 TJ/yr[2]
(35,000 tons oil equivalent per year)
at an economic value of $840,000

---

[1] Energy prices in Latvia at the time of the visit were increasing rapidly, but were still far below European prices, reflecting a transition from the historical energy price subsidies provided in the Soviet Union.

[2] 1 TJ = 1 X 10^{12} joules, 480 TJ = 120 Tcal

purchased electric power:
3.5 MW peak demand,
at an economic value of $210,000
purchased electric energy:
6,500 MWh/yr,
at an economic value of $325,000.

RCG/Hagler, Bailly estimates the short-term potential for energy efficiency improvement at SAULKALNE as 25-40% of anthracite and 20-30% of electric energy, without process changes. During the survey, the RCG/Hagler, Bailly team worked together with SAULKALNE staff to identify short-term, low-cost energy efficiency projects, which, if implemented, will achieve economic benefits of $259,000 per year, or 19% of 1992 economic energy costs.

In addition, RCG/Hagler, Bailly also evaluated an organizational efficiency project, related to raw material supply, which would provide additional net economic benefits of $64,000 per year.

The recommendations and expected results are summarized in Exhibit 1.

RCG/Hagler, Bailly recommends that SAULKALNE receive a package of equipment from USAID. The procurement list and budget for SAULKALNE, as given preliminary approval by USAID, is summarized in Exhibit 2.

EXHIBIT 1
SAULKALNE Building Materials Plant

Summary of energy efficiency projects

	Coal ton/yr	Electric MWh/yr	MW	Cost US$/yr
BASE CASE	20,000	6,500	3.5	$1,375,000

RECOMMENDATIONS AND ESTIMATED ECONOMIC SAVINGS:

	Coal ton/yr	Electric MWh/yr	KW	Net benefits US$/yr
A. General & Energy Management				
A.1 Energy management	1,000	130		$43,000
A.2 Electric efficiency team		130	70	10,000
A.3 Product fineness		600	150	39,000
A.4 Raw material supply		130		64,000
B. Short-term, Low-cost Efficiency Improvements				
B.1 Install separator		100		5,000
B.2 Repair kiln leaks	2,000	160	40	86,000
B.3 Instrument kilns	2,000			76,000
TOTAL SAVINGS[3]	5,000	1,120	260	$259,000
Percent of base case	25%	17%	7%	19%

[3] Not including project A.4, which relates mainly to quality and organizational efficiency

EXHIBIT 2
AID EMERGENCY ENERGY PROGRAM FOR EASTERN EUROPE
LATVIA INDUSTRIAL ENERGY EFFICIENCY

PRELIMINARY PLANS FOR PROCUREMENT

SAULKALNE Building Materials Plant

	Estimated Procurement Budget
Energy/production management computers	4,000
Kiln combustion temperature indicators	20,000
Combustion gas analyzers (CO, O2)	5,000
Electric survey meter (with power factor)	1,000
Infrared thermometer	1,000
Laboratory equipment for coal testing/quality control	3,000
TOTAL	34,000

II. INTRODUCTION

2.1 Plant Description

The SAULKALNE Building Materials Plant is located on an ancient, rich dolomite deposit on the Daugava River about 15 km southeast of Riga, Latvia. The plant is about 35 years old, and produces burnt lime for building products such as plaster and mortar (50,000 tons per year capacity), burnt lime for agricultural use (150,000 tons per year capacity), and crushed dolomite for highway construction as a byproduct. The plant purchases the raw material (dolomite) from a quarry near Ogre some 19 km away. SAULKALNE's original quarry was flooded by a hydroelectric scheme. The primary fuel for lime burning is anthracite coal (25,000 tons per year capacity), imported from Ukraine and Russia.

Energy represented over 31% of production costs at SAULKALNE for 1991. The main items of the budget were:

25%	salaries and wages
20%	depreciation and amortization
20%	fuel - mainly anthracite coal for lime burning
17%	transportation cost for raw material
12%	electricity for crushing, grinding, compressed air, material handling
7%	other costs

All of SAULKALNE's production is sold in Latvia for the local market. The price of lime was controlled in 1991 by the Government of Latvia, at about 140 Rubles/ton for building lime and 60 Rubles/ton for agricultural lime. In 1991, SAULKALNE lost about 1 million Rubles, which was treated by the Government of Latvia as a subsidy to the agriculture and construction industries. In 1992, SAULKALNE will be able to operate in the new regime of free prices, which was established December 15, 1991. In 1992 SAULKALNE has its first chance to earn a profit.

In the technological process, the dolomite is first crushed and screened to obtain the proper size, and then conveyed to a large storage silo from which it is fed to one of two process lines - building lime or agricultural lime.

The lines are similar in that each has two vertical kilns, built in the 1950s. Vertical lime kilns are today regarded as an obsolete technology because of the difficulty in controlling the quality and energy consumption of the product. The dolomite is mixed with anthracite coal in a 1:10 ratio by weight, and fed by skip hoist to the top of the kilns. Two building lime

kilns use 40-120 mm diameter dolomite and produce approximately 75 tons/day each of lime. The two agricultural lime kilns use larger pieces of dolomite (>100 mm diameter) and produce approximately 150 tons/day of lime each.

Smaller dolomite pieces (<40 mm diameter) are not suitable for use in the kilns, but represent a substantial fraction of the primary crusher yield (about half). Some of these pieces are used as additives in agricultural lime, but most are sold as road building material, at a financial loss (the price SAULKALNE is able to obtain is less than the transportation cost of the dolomite to SAULKALNE).

After burning in the kilns, the lime is fed through a secondary crusher and conveyed to ball grinding mills (3 for building lime, 1 for agricultural lime) which grind the product to <1 mm sieve size. The finished product is stored in silos and then shipped from SAULKALNE in bulk by rail car or bagged for shipping by truck.

Anthracite coal for the plant is purchased from Ukraine and Russia (Danyetsk, Rostov, Kaliningrad) and obtaining the proper specification coal has been a serious problem for the plant. The kilns are constructed based on the use of anthracite coal with 7-8% ash content and 25-40 mm diameter size. SAULKALNE has been unable to obtain adequate supplies of this specification coal, and has been forced to use coal of much smaller size and higher ash content. This has led to problems in obtaining proper operating conditions in the kilns, resulting in reduced product quality.

The Soviet standard for building lime is 60% CaO+MgO, however SAULKALNE is now only able to achieve 42%, on average. The problem is not with the dolomite, which is low silicate and low iron and has a theoretical yield (activity) of 70-80%, but rather with the quality of coal supplied. In the absence of a market for coal, SAULKALNE has been in the unfortunate position of accepting whatever coal it can get. The coal in use at the time of the audit (January 1992) was of 37% ash content and 10-15 mm diameter size. The small particles pass through too quickly, so coal combustion is incomplete and lime burning is also incomplete.

2.2 Energy Audit Activities

A team of senior engineers from RCG/Hagler, Bailly, Inc., B.V. Ekodoma, and Riga Technical University visited SAULKALNE Building Materials Plant from January 13-15, 1992 to work together with SAULKALNE staff to identify improvements to energy efficiency. The key personnel from SAULKALNE were Mr. V. Parevskis, Director and Mr. A. Sergejevs, Chief Engineer. The RCG/Hagler, Bailly engineering team consisted of:

Mr. David Keith, P.E., RCG/Hagler, Bailly, Project Director
Dr. Larry Banta, P.E., RCG/Hagler, Bailly, Senior Engineer,
on leave from West Virginia University
Dr. Dagnija Blumberga, B.V. Ekodoma, Project Manager
Dr. Ivars Veidenbergs, B.V. Ekodoma, Senior Engineer
Dr. Janis Bazhbauers, Riga Technical University, Project Advisor

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 management information systems, improvements to the lime kiln efficiency, measurement of various electrical parameters, analysis of production and energy consumption, and the development of energy efficiency project opportunities.

A primary focus of the audit was an attempt to achieve immediate energy savings through improvements in combustion efficiency in the kilns. For this purpose, RCG/Hagler, Bailly's digital combustion analyzer (which measures O_2, CO, CO_2, unburned hydrocarbon combustibles (HC)) was used. Extremely high levels of O_2 and CO were observed in the flue gases, indicating both incomplete combustion of the coal and high air infiltration into the exhaust gas system. Some experiments were undertaken to attempt to increase the combustion air flow through the kiln, and inspection of the exhaust gas system was carried out to locate air infiltration points. Several large leaks were found, however due to technical problems at the plant, production was shut down before additional experimentation could be performed.

The RCG/Hagler, Bailly team also reviewed the major electric energy using equipment (grinding), analyzed various quality control testing measures currently used by the company, surveyed laboratory equipment used for these tests, demonstrated the use of various energy measurement and analysis equipment to plant personnel, and collected energy consumption and production data.

The RCG/Hagler, Bailly team presented its recommendations to the plant management and technical personnel at the final review meeting January 15, 1992 before leaving SAULKALNE Building Materials Plant. RCG/Hagler, Bailly recommended that SAULKALNE set up a computerized energy management program as a first step in controlling energy consumption and costs. Several other energy conservation projects were suggested, including repair of the scales and other production monitoring equipment, increased efforts to negotiate contracts for the proper specification coal for the kilns, and repair of air infiltration leaks in the kiln exhaust systems. In addition, RCG/Hagler, Bailly promised to analyze data taken at the plant and to review equipment requests proposed by plant personnel to determine the best ways to invest the USAID assistance money.

Following that analysis, a list of equipment and projects has been identified as is presented in the executive summary section of this report. The analyses leading to these recommendations are presented in this report.

The standard of management and engineering expertise already in place at SAULKALNE is very good. Technical staff is very knowledgeable about their process. The RCG/Hagler, Bailly team expects that this staff, with a market-driven focus, and a few additional instruments, tools, and equipment, will be fully capable of making significant improvements to energy efficiency. The staff of SAULKALNE have already begun adapting to market conditions.

The RCG/Hagler, Bailly team would like to express their sincere appreciation for the assistance and warm hospitality offered by the staff of the SAULKALNE Building Materials Plant. 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 SAULKALNE, and hopes to return their hospitality at some time in the future, whenever SAULKALNE staff visit the United States.

The trends at SAULKALNE are toward higher energy intensity (reduced efficiency), as follows:

	1989	1991
Anthracite coal, ton/ton		
Average	0.114	0.145
Range	0.103-0.124	0.139-0.158
Electric, kWh/kg		
Average	41.5	46.9
Range	34-55	31-100
		39-53[4]

Monthly energy/production relationships were analyzed for 1989-1991. Using monthly (lumped parameter) data, there should be a good correlation between energy and production. This analysis can be used to indicate the fixed energy consumption (constant amount per month) and the variable energy consumption (additional amount which is related to production). High fixed energy consumption indicates high energy losses in the plant.

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 SAULKALNE, two types of energy are used, fuel energy consumption in the form of anthracite coal, 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).

[4] Ignoring the very high and very low values of September and October 1991

Several separate regression analyses were carried out for SAULKALNE. The independent variable selected for SAULKALNE was total monthly production (tons) of lime, with separate analyses for agricultural and building lime. The dependent variables were coal consumption and electricity consumption (kWh). These analyses led to the development of factory energy performance model linear equations, of the following 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 consumption per day or month)

SAULKALNE (Building Materials)
MONTHLY PERFORMANCE DATA
JANUARY 1989 - DECEMBER 1991

ENERGY CONSUMPTION REGRESSION ANALYSIS
EMPIRICAL PRODUCTION ENERGY MODEL EQUATIONS

1. BUILDING LIME -
RELATIONSHIP BETWEEN ANTHRACITE COAL CONSUMPTION AND PRODUCTION

Average production = 3,611 tons lime/month
Average energy consumption = 607 tons coal/month
Fixed energy consumption = 67 tons/month
(Fixed consumption represents 11% of total)
Variable energy consumption = 0.149 ton coal/ton lime
(in addition to fixed consumption)

Other details of Regression Output:
R Squared 0.789
(good prediction)
t test 11.26
(good correlation between energy and production)

2. BUILDING LIME -
RELATIONSHIP BETWEEN ELECTRICITY CONSUMPTION AND PRODUCTION

Average production = 3,611 tons lime/month
Average energy consumption = 227,417 kWh/month
Fixed energy consumption = 52,950 kWh/month
(Fixed consumption represents 23% of total)
Variable energy consumption = 48.3 kWh/ton
(in addition to fixed consumption)

Other details of Regression Output:
R Squared 0.540
(fair prediction)
t test 6.32
(fair correlation between energy and production)

SAULKALNE (Building Materials)
MONTHLY PERFORMANCE DATA
JANUARY 1989 - DECEMBER 1991

ENERGY CONSUMPTION REGRESSION ANALYSIS
EMPIRICAL PRODUCTION ENERGY MODEL EQUATIONS

3. AGRICULTURAL LIME -
RELATIONSHIP BETWEEN ANTHRACITE COAL CONSUMPTION AND PRODUCTION

Average production = 10,233 tons lime/month
Average energy consumption = 1,091 tons coal/month
Fixed energy consumption = 256 tons/month
(Fixed consumption represents 23% of total)
Variable energy consumption = 0.082 ton coal/ton lime
(in addition to fixed consumption)

Other details of Regression Output:
R Squared 0.725
(good prediction)
t test 9.46
(good correlation between energy and production)

4. AGRICULTURAL LIME -
RELATIONSHIP BETWEEN ELECTRICITY CONSUMPTION AND PRODUCTION

Average production = 10,233 tons lime/month
Average energy consumption = 368,694 kWh/month
Fixed energy consumption = 110,768 kWh/month
(Fixed consumption represents 30% of total)
Variable energy consumption = 25.2 kWh/ton
(in addition to fixed consumption)

Other details of Regression Output:
R Squared 0.574
(fair prediction)
t test 6.76
(fair correlation between energy and production)

Daily data were analyzed for 91 days, from April 1, 1991 to June 30, 1991 to develop energy/production relationships for the plant. Upon analyzing this data, the RCG/Hagler, Bailly team observed that accurate figures for daily production are not available. Records are kept based on production estimates. This is one source of the erratic specific energy consumption figures, or of part of the specific energy consumption increases, if production is being overestimated.

IV. ENERGY PROCUREMENT AND COST ANALYSIS

SAULKALNE purchases coal from various suppliers, and electricity from Latvenergo, and pays in Rubles. SAULKALNE in recent times has been forced to accept coal of inferior quality

During our inspection, we discovered that Saulkalne has severe problems in production quality and quantity, and also low energy efficiency. These problems stem from the inability of Saulkalne to obtain anthracite coal of the correct specifications. The kilns at Saulkalne are designed to burn anthracite coal of 60-70 mm diameter (AK) and ash content of less than 8%. At the time of our inspection, however, Saulkalne was using AC coal (diameter 10-15 mm) and ash content of 37%. For most of 1991, Saulkalne was using AM coal (diameter 25-40 mm) and ash content of 20-40%. The residence time of the smaller coal is shorter, and complete combustion is not possible (we estimate that 20% of the carbon in the coal is unburned). The poor combustion results in incomplete calcination of the raw material (dolomite), resulting in product which is below the Soviet standard.

Energy prices applicable at SAULKALNE

The cost of energy at SAULKALNE, in Rubles, is still very low, compared to European prices. During the time of the audit, the Ruble suffered a severe and rapid devaluation. Energy prices, in Rubles, also increased rapidly during the period. Prices in Rubles as of November 1991, and a rate of exchange of 100 Rubles = US$1.00, are used below.

1. Financial energy prices are Latvian energy prices, as paid by SAULKALNE. As of December 1991, these were as follows:

	Rubles	US$ equivalent
Coal, per ton	300	$3.00
Electricity, per kWh[5]	0.074	$0.00074

2. Economic energy prices are European market energy prices, not including local taxes. These market prices represent the equivalent cost to the economy of Latvia in the near future. As Latvia integrates with the rest of Europe, there will be a trend to increase prices until they reach these levels. As of November 1991, European market prices averaged:

[5] Including base subscription demand charges.

	US$ equivalent
Coal, per ton	$42.00
Electricity, per kWh	$ 0.05
Peak demand, per kW per month	$ 5.00

As indicated above, 1991 financial prices in Latvia are only a small fraction of economic prices. In the case of coal, the economic value of the gas in the European market is 14 times the price paid by SAULKALNE. For electricity, the economic value is about 67 times the financial price.

Expected 1992 energy costs at SAULKALNE

1. Financial energy costs

Given the uncertainty in the energy sector in Latvia and Russia, it is impossible to predict the trend or average 1992 Latvian energy prices. For convenience, RCG/Hagler, Bailly estimates that the average 1992 prices in Latvia might be:

	Rubles
Coal, per ton	1,000
Electricity, per kWh	1.00

Based on these prices and 1992 planned consumption, financial energy costs are estimated as follows:

	Purchases	Cost, Rubles
Coal, tons	20,000	20,000,000
Electricity, MWh	31,000	31,000,000
Total energy cost		51,000,000

2. Economic energy costs

Using European market prices, we can calculate the economic value of the energy consumption at SAULKALNE as follows:

	Purchases	Value, US$
Coal, tons	20,000	$840,000
Electricity, MWh	6,500	325,000

Peak demand, kW	3,500	210,000
Total energy value		$1,375,000

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 Latvia.

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 1992). 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 Latvia.

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 Latvia.

A. GENERAL AND ENERGY MANAGEMENT

MANAGEMENT
SAULKALNE Action A.1

Establish a market-based plant production and energy management system.

Existing Conditions

The SAULKALNE plant has few means to monitor and manage energy consumption and efficiency. Tests of incoming anthracite quality are made and records are kept of coal/dolomite ratios used in the kilns, however there is no way to analyze or correlate these data with operating conditions and product quality. Power factor correction capacitors are installed at the plant substations but power and energy usage by various areas of the plant are not submetered. Most importantly, key production monitoring parameters are not measured.

At the time of our visit, most of the plant's equipment for monitoring raw material input and production output was inoperative. This includes truck scales for weighing purchased dolomite and weigh-counting devices for measuring finished product output from the processes. Production volume was being estimated by operating personnel for reporting purposes. Also, while some testing of dolomite, anthracite and finished product is currently being done, the laboratory equipment available for these tasks is inconvenient to use and of questionable accuracy.

Findings

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 kilns is done on a manual basis, it is important to provide timely feedback to operators as a means of helping them to control the equipment most efficiently. Kiln operating efficiency is not currently measured, so operators have no basis for improving their performance from an efficiency standpoint. If the consumption data are averaged over an entire month, trends are more difficult to spot and feedback comes too late to be of value.

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, most importantly, contribution of ideas to assist the program. Workers at

all levels must be enlisted as partners for energy conservation programs to work effectively.

Energy usage should be well correlated with production, as indicated by the results of a regression analysis. 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).

Recommendation

RCG/Hagler, Bailly recommends that a comprehensive production and energy management system be established at SAULKALNE. This will require the repair and installation of key pieces of equipment.

> The truck scales for weighing incoming dolomite and the scales and counting devices for measuring the actual output of each production line should be repaired and used to keep accurate records of the plant performance.
>
> If accurate systems do not now exist for measuring product shipments, they should be repaired and placed back in service.

In addition, some upgrade of the plant's laboratory equipment is needed to better monitor the quality of incoming raw materials and of the end product. This is particularly important from an energy conservation standpoint, since the proper fuel/dolomite mix depends on both the composition of the dolomite and on the quality of the anthracite. The consistency of the incoming dolomite is unknown, but that of the anthracite is extremely variable. Plant personnel indicated that the quality of the coal is usually lower than what is indicated by the shipper's testing data.

We recommend that coal quality analyses be performed not only on incoming rail car loads, but on the coal being fed from the storage hoppers into the kilns. Fuel quality should be assessed at least daily and preferably on a shift by shift basis to track the moisture, ash content and specific energy content of the fuel. These measurements should be correlated to records of dolomite quality, kiln operating conditions and product quality to help determine the best operating regimes for the different kilns. Electric energy consumption by the fans, ball mills and compressors should be similarly recorded and correlated with operating conditions. Grinding mills should be equipped with individual kWh meters, financed from energy cost savings realized from this and other conservation projects identified in this report.

The RCG/Hagler, Bailly team recommends that shift supervisors from each of the major

energy producing and consuming areas of the plant should collect the pertinent data and report specific energy consumption figures (i.e. tons of lime per ton of anthracite or tons of lime per MWh). 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. At first, only overall measurements will be possible because metering equipment is not available for individual areas of the plant. Nevertheless, some comparisons can be made for analysis.

Plant management needs to be able to obtain the needed information 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 (anthracite and electric) and a calculation of the ratio of energy consumption to metric tons of production for building lime and agricultural lime.

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.

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 5-10 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. Given the current lack of adequate tools for monitoring plant efficiency, we expect that a figure even higher is possible for the SAULKALNE plant. If we choose a conservative figure of 5% savings for coal and 2% for

electricity, the projected annual savings is $48,000.

5% x 20,000 tons coal/yr = 1,000 tons/yr

1,000 tons coal/yr x $42/ton = $42,000/yr

2% x 6,500,000 kWh/yr = 130,000 kWh/yr

130,000 kWh/yr x $0.05/kWh = $6,000/yr

RCG/Hagler, Bailly will recommend that USAID purchase some of the equipment necessary to implement these recommendations, such as computers and laboratory equipment. SAULKALNE will repair production scales and counters, and undertake local software development. The following equipment will be required:

Production scales	$5,000
Laboratory equipment - coal testing	$3,000
Personal computers (IBM compatible):	
(2) 286, VGA, 2 MB RAM, 40 MB disk	
(2) dot matrix wide carriage printer	
(2) spreadsheet software (Lotus 1-2-3)	
total estimated cost	$5,000
Spreadsheet software development:	
local contract	$1,000
Staff training:	
local contract	$1,000
	======
Total development cost	$15,000

Annual incremental costs:
additional metering equipment and maintenance - $5,000

Financial analysis

SAULKALNE will be responsible for installation and maintenance of the equipment plus the local contracts for software and staff training. These costs can probably be paid in Rubles. The payback period for the project is:

Payback = capital cost/net annual cost savings
($15,000)/($48,000 - $5,000/yr) = 0.35 yr

A. GENERAL AND ENERGY MANAGEMENT

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

Existing conditions:

The physical facilities at SAULKALNE are old and in many cases need repair. Of course, as in any plant in the lime industry, conditions are very dusty, contributing to poor equipment performance. Energy requirements are highly variable, and were reported by plant personnel to be growing for a given level of production. This is indicative of a deteriorating situation which could benefit from increased maintenance. For example, although some of the large motors in the plant are synchronous types, a significant amount of power factor correction is still required. This is indicative that many smaller motors are running in an underloaded condition or that phase to phase voltage imbalances exist at the motors. Both of these conditions can cause low power factor and reduced efficiency.

Recommended action:

RCG/Hagler, Bailly recommends that SAULKALNE form "Energy Efficiency Teams" for electric motors. Personnel for this team should be drawn from SAULKALNE staff, and this exercise should become a continuous part of plant operations and maintenance. 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 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 SAULKALNE's major suppliers of motors for the types 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) this incremental cost can be recovered in one year or less. For some applications at SAULKALNE such as conveyor motors or ventilation equipment the purchase of such motors may be justified. 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 stator laminations can suffer reduced flux if they are overheated in the rewinding 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 at least 50% 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 380V 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 to 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 much less than during on-peak.

Expected results:

The RCG/Hagler, Bailly team estimates that the potential savings of an improved maintenance program based on these procedures is 2% of peak purchased electrical demand, and 2% of the plant's purchased electric energy consumption. The benefits of these savings are $10,000 per year, estimated as follows:

Electric power:
2% x 3.5 MW = 70 kW
70 kW x $5/kW-month x 12 month/yr = $4,000/yr

Electric energy:
2% x 6,500,000 kWh/yr = 130,000 kWh/yr
130,000 kWh/yr x $0.05/kWh = $6,000/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 multimeter with current clamp and power factor (cos phi) meter, plus lineman's gloves
(1) Digital strobotach (optional)

total estimated cost $1,500

Financial analysis:
Based on a cost of $1,500 and a savings of about $10,000 per year, the project payback period is less than two months.

$1500/$10000/yr = 0.15 yr

RCG/Hagler, Bailly estimates that SAULKALNE should designate part of the annual electrical energy budget per year for additional equipment and repairs (additional maintenance), such as motors, additional metering equipment and the like. For example, most of the savings generated by the Electric Motor Efficiency Team could be reinvested in metering equipment and new motors to support their activities. Projects should be prioritized based on payback period as is done in this report.

A. GENERAL AND ENERGY MANAGEMENT

PRODUCT GRINDING
SAULKALNE Action A.3 -
Optimize grinding - increase product particle size

Existing conditions:

Particle fineness for finished lime from both the agricultural lime and building lime production lines are much finer than required by the Latvian specification, or by the "best quality" spec of the USSR.

	Latvia spec	USSR "best"	USSR "first"	Typical SAULKALNE
Agricultural lime				
3 mm screen	0%	0%	0%	0%
1 mm screen	2%	1%	1.5%	0.8%
0.25 mm screen	20%	15%	20%	14%
Building lime				
No. 02 screen	1.5%			0.8%
No. 008 screen	15%			10%

Exceeding the fineness specification requires excessive electrical energy consumption in grinding. The attached figure indicates the relationship between particle size (as measured by the Blaine index in specific surface area, cm^2/g).

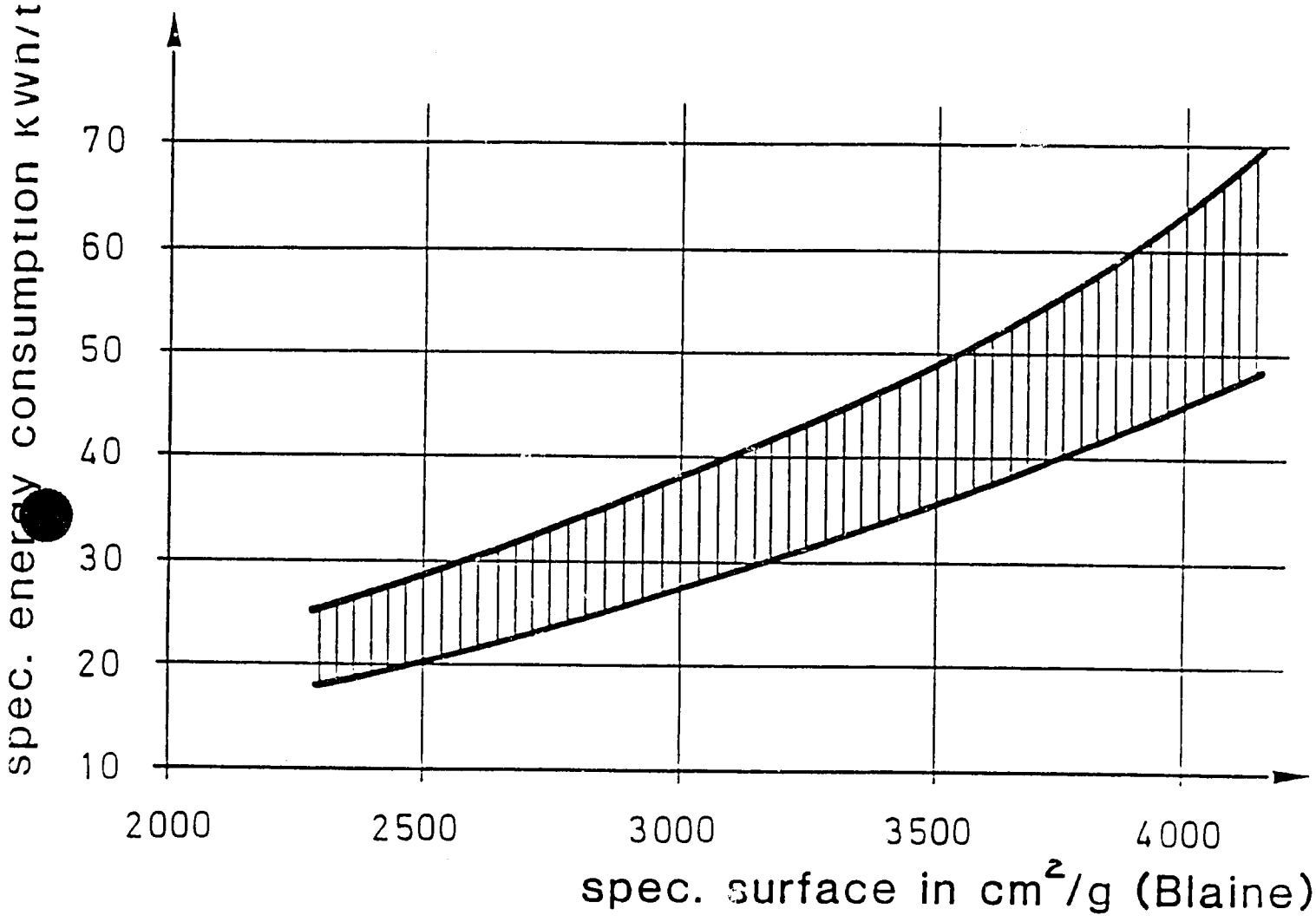
The ball mill charge (agricultural lime) is 6.5 tons. The ball size is 50% 125 mm, 30% 90 mm, and 20% 70 mm. The three building lime mills use small cylinders instead of balls, with a charge of 2 tons each.

Grinding energy consumption is estimated as almost 45% of total electric energy, or 3,000,000 kWh per year.

Figur 1
(cha: 1.1)

Optimisation Grinding Systems

Judgement of Specific Energy Consumption



open circuit → mill and feeders

closed circuit → mill
separator
bucket elevator
feeder

TS/VA

Recommended action:

The RCG/Hagler, Bailly team recommends that SAULKALNE check the state of wear on the mill diaphragms and mill liners on all grinding mills. If maintenance is required to repair the internal parts, it should be carried out.

The shell liners must assure an efficient lifting effect of the ball/cylinder charge. The lifting effect must be sufficient for high enough impact to reduce the size of larger particles, must be continuous so that all parts of the lining lift balls uniformly.

The diaphragm has the shortest lifetime of any part of the mill. The mill diaphragm should be inspected at regular intervals to clean and re-adjust the slots. Typical problems include breakage of slot liners, clogging of slots by broken balls or lumps of material, and too high (or too low) retention time of the material in the grinding compartment because of inadequate design of the slots.

Following these maintenance actions, SAULKALNE should carry out a program to optimize the charge of balls and cylinders (diameter of balls/cylinders and total weight of balls/cylinders) and the diaphragm slot size.

Expected results:

Based on the data provided by SAULKALNE, RCG/Hagler, Bailly estimates that specific energy consumption for grinding could be reduced by 20% through an optimization which leads to delivering finished product at the fineness indicated in the Latvia specification. Peak power for grinding can be reduced by 10%, if reducing the weight of the ball charge is part of the optimization. The expected savings is $39,000 per year, as follows:

Electric power:
10% x 3.5 MW x 0.45 = 150 kW
150 kW x $5/kW-month x 12 month/yr = $9,000/yr

Electric energy:
20% x 3,000,000 kWh/yr = 600,000 kWh/yr
600,000 kWh/yr x $0.05/kWh = $30,000/yr

The cost of the optimization is judged to be minimal. It could be that no equipment is required. If additional balls or adjustable diaphragms are needed, the cost should be $5,000

or less.

Financial analysis:

Based on a cost of $5,000 and annual benefits of $39,000, the payback period for the project is 0.13 years.

A. GENERAL AND ENERGY MANAGEMENT

RAW MATERIAL SUPPLY
SAULKALNE Action A.4 -
Reorganize enterprise to put control for raw material supply under SAULKALNE authority

Existing conditions:

Dolomite is transported from the quarry near Ogre to the SAULKALNE plant by truck over a distance of 19 km. The transportation is handled by a different company (not SAULKALNE).
Transportation costs represent a very significant part of SAULKALNE's operating cost. Furthermore, the handling of the raw material in transit has adverse effects on quality, as there is little consideration to rough handling. This handling causes the particles to break into smaller pieces, which are not suitable for the kiln and must be sold (at a loss) for road building. At present, full half of the raw material delivered to SAULKALNE is unusable.

The current division of labor between the mining and transportation operations and SAULKALNE is not conducive to high quality. The negative effects of poor raw material quality are suffered by SAULKALNE alone, which is not able to reflect this impact on its raw material suppliers.

Recommended action:

RCG/Hagler, Bailly recommends that the system be reorganized and integrated so that SAULKALNE has better control of its own raw material supply. This includes the following aspects:

- quarry planning - determining which sections of the quarry to mine and developing a schedule for mining
- quarry extraction - the mining operation and preliminary sizing
- transport loading - to eliminate fine particles at the quarry. If possible, a second road-building material supply could be established at the quarry. It may be possible to sell such material from there at a profit.

- transportation - delivery of raw material to SAULKALNE.

Implementation of this recommendation should be possible as a simple transfer of state property, and should not require significant investment. Over the long run, however, SAULKALNE would have to maintain and replace the necessary vehicles.

Transportation costs in 1991 were 1 million Rubles. However, in economic terms the cost is much higher, and costs will escalate rapidly as the price of diesel fuel is a driving factor. Transportation costs in 1991 were 85% of coal costs, Based on this, and considering local costs in transportation, RCG/Hagler, Bailly estimates the economic cost of transportation as 70% of the economic cost of coal.

Expected results:

RCG/Hagler, Bailly expects that reorganization can reduce transportation costs by at least 10% and increase the share of usable raw material from the present level of 50% to at least 60%. We expect this action can reduce specific electric energy consumption by about 2%, through reduced material handling and crushing. We estimate the economic transfer cost for used vehicles from the transportation company as zero. The financial cost of these vehicles might be about $50,000.

Transportation economic cost:
70% x $840,000/yr = $588,000 per year

Transportation cost reduction:
10% x $588,000/yr = $58,000 per year

Electric energy savings:
2% x 6,500,000 kWh/yr = 130,000 kWh/year
130,000 kWh/yr x $0.05/kWh = $6,000 per year

Financial analysis:

The economic benefit would be immediate, since there is no net investment (vehicles simply transferred to SAULKALNE). On a financial basis, the payback is less than 0.8 year, based on a cost of $50,000 and benefit of $64,000 per year.

B. LOW-COST, SHORT-TERM IMPROVEMENTS

PRODUCT GRINDING
SAULKALNE Action B.1 -
Install separator on building lime grinding shop to convert to closed circuit

Existing conditions:

The separator for the building lime production was damaged and taken out of service. These mills, designed to run in closed circuit configuration, are thus open circuit, with much higher energy consumption per ton of product.

SAULKALNE procured a new separator in late 1991 for 10,000 Rubles. At the time of the audit, it had not yet been installed.

Recommended action:

RCG/Hagler, Bailly recommended that SAULKALNE install the new separator as soon as possible. SAULKALNE agreed.

Expected results:

Based on the figure for grinding energy consumption (see Action A.3 above, which indicates energy consumption for closed circuit and open circuit systems), RCG/Hagler, Bailly estimates that installation of the separator and conversion to closed circuit will reduce grinding energy consumption by a further 10% (considering that Action A.3 is also taken). The estimated energy consumption for building material grinding is 1 million kWh/yr.

Electric energy:

10% x 1,000,000 kWh/yr = 100,000 kWh/yr
100,000 kWh/yr x $0.05/kWh = $5,000/yr

Financial analysis:

Based on a total project economic cost of $1,000 for the new separator and installation, the payback period is two months.

B. LOW-COST, SHORT-TERM IMPROVEMENTS

PYROPROCESSING
SAULKALNE Action B.2 -
Repair infiltration air leaks in kilns.

Existing Conditions

All of the lime kilns have significant air leaks near the exhaust gas outlets of the kilns. While it is recognized that sealing around the raw material inlet ports is difficult, there were also substantial leaks resulting from corrosion of the kiln skin around the stack outlet and near the top of the kiln. These leaks result in the infiltration of large amounts of cold air into the stack, which causes several problems. First, the induced draft fan is unable to pull sufficient air through the kiln to properly burn the anthracite charge in the kiln. Measurements of the exhaust gases showed oxygen content in the range of 18% and CO content in excess of 4000 parts per million (ppm). The exact amount of CO could not be determined, since our instruments only measure to 4000 ppm.

This high level of CO indicates that the coal charge is only being partially burned, and a great amount of fuel is being wasted up the stack. CO is also a dangerous pollutant, both explosive and poisonous. The high O_2 content shows that much of the exhaust gases are being pulled through the infiltration holes, since the air passing through the kiln should have zero oxygen content due to incomplete combustion of the anthracite. Secondly, the cold air drawn into the stack cools the stack gases below the dew point resulting in the formation of acid in the exhaust stack and ductwork. A steady stream of acidic water was observed running from the stack of the #1 building lime kiln. This acid causes corrosion of the ductwork, fan and exhaust stack, accelerating the deterioration of the kilns. Finally, the leaks cause the induced draft fan to pump more air and cooler air than is necessary, wasting electrical energy.

Recommended Action:

RCG/Hagler, Bailly recommended, and SAULKALNE agreed, that work begin immediately to track down and repair all air infiltration leaks in the kilns. Most of this work can be done using locally available materials and plant labor, and can be paid for in local currency. Much of the work can be done without requiring that production be halted, since some of the worst leaks are accessible from the outside of the kilns. Effective patches can be made by welding steel plate over the holes. RCG/Hagler, Bailly will recommend that USAID purchase combustion analysis instruments to aid SAULKALNE in diagnosis and monitoring

of the stack gases. Equipment required for this project will be:

Combustion Analysis Instruments:	
(2) CO meter with range 0-20,000 ppm	$2,000
(2) Fyrite combustion kit	600
(1) Electronic combustion analyzer	3,000
Infrared pyrometer	1,000
Total cost	$6,600

Expected Results:

As the leaks are sealed, the fan should be able to pull more air through the charge in the kiln resulting in more complete combustion of the anthracite. Temperatures both in the kiln and in the stack should increase resulting in better calcination and decreased acid production in the stack. Due to the inadequate size and poor quality of the coal presently used, it is unlikely that optimum burning conditions can be obtained by this measure alone, but substantial improvements in kiln operation are guaranteed. At present, approximately 87% of the stack gases are infiltration air--almost no combustion air is being drawn through the kiln. Much of the heating value of the fuel may be presently lost, partly as unburned carbon in the finished product and partly as CO in the stack. The low fuel utilization accounts for the very low calcination rate of the product--only about 60% of the dolomite is burned.

Given the measurements we were able to make, it is impossible to predict accurately the improvement in process efficiency that could be achieved by this measure. If we choose a conservative estimate that 10% of the fuel is currently lost either as unburned coal or as CO in the stack gases, then reducing infiltration air can have one of two effects. Either the amount of coal required to produce a ton of lime can be reduced, or better quality lime can be produced using the same amount of fuel. Either way, the specific energy consumption per ton of good quality lime would decrease. The savings would amount to 2,000 tons per year of anthracite. The value of these savings is $84,000/yr:

$$2{,}000 \text{ tons anthracite/yr} \times \$42/\text{ton} = \$84{,}000/\text{yr}$$

In addition to the fuel savings, we estimate that significant reductions in fan power will be realized along with improvement in the product quality. We estimate fan power reductions at a minimum of 10 kW per fan or 40 kW for the plant. Over a 4,000 hour operating year, the cost savings amount to $10,000/yr:

Energy savings:

40 kW x 4,000 hr/yr = 160,000 kWh/yr
160,000 kWh/yr x $0.05/kWh = $8,000/yr

Demand savings:
40 kW x $5/kW-month x 12 month/yr = $2,400/yr

Additional savings will result from improved product quality.

Financial Analysis

USAID purchased instruments will cost approximately $6,600. SAULKALNE will be expected to pay for the repair and maintenance of the kilns themselves. Many of the infiltration leaks can be repaired quite simply by welding steel sheet over the holes. Repairs of the raw materials loading mechanisms will be more difficult, requiring shutdown of the kiln. The job does not require any unusual materials or skills not available locally. Repairs should not cost more than US$2,000 per kiln ($8,000 total), payable in local currency. Because the kilns are old, an ongoing program of leak detection and repair must be implemented. This program will cost not more than $2,000 per kiln per year to operate. These costs are balanced against an annual savings of $94,000 in fuel and electricity costs.

The payback period is the capital investment divided by the net savings per year:

capital cost/(fuel savings - maintenance cost)

$14,600/($94,000/yr - $8,000/yr) = 0.17 yr

B. LOW-COST, SHORT-TERM IMPROVEMENTS

PYROPROCESSING
SAULKALNE Action B.3 -
Instrument kiln and modify operating practices.

Existing Conditions:

At present, the only operable instrumentation in any of the kilns is a draft gage on the exhaust stack. Originally there were other instruments, but they have all been inoperative for many years. The operator must gage the temperature in the burning zone by eye and attempt to control the kiln to achieve good quality product. He controls three parameters: the coal to dolomite mixture, the induced draft fan damper, and the lime grate travel (product removal rate). The interactions among these three variables and the ramifications to kiln efficiency and product quality are complex. For example, the calcining rate of the lime is extremely sensitive to the temperature in the burning zone. Robert Boynton's authoritative text on lime calcination says·

> "An increase in temperature exerts a much greater influence on the dissociation rate than ... [residence time]. Mather discovered that an increase in temperature of only 20 degrees C exerted as much influence on the calcination as extending the burning time from 2 to 10 hours...The optimum temperature for maximum calcination...varies with different stone and can only be determined...by experimentation. [6]

Boynton also notes that temperature cannot be raised indiscriminately, since too high temperatures cause "hard" burning and decrease the quality of the lime. While an experienced operator may be able to do a very good job at estimating the burning zone temperature by eye, it is impossible for anyone to be able to estimate the temperature to within 20 degrees C without instrumentation.

Recommended Action:

RCG/Hagler Bailly recommends that experiments be carried out to determine the temperature

[6] Boynton, Robert S., Chemistry and Technology of Lime and Limestone, 2nd Edition, John Wiley & Sons, New York, 1980, pp 168-173.

profiles presently existing in each kiln. Further experiments should then be performed to determine the effect of an increase in the burning zone temperature. We believe that repair of the air leaks mentioned in measure B.1 will partially accomplish this task automatically, however SAULKALNE will need to instrument the kilns with temperature measurement instruments to properly control the calcining process and maintain the precise temperatures needed to optimize the kiln operation. RCG/Hagler, Bailly will recommend that USAID purchase instrumentation for SAULKALNE to properly monitor kiln temperatures. The following equipment will be required:

4 Fixed infrared (IR) pyrometers with remote digital readout, for continuous monitoring of temperature in burning zone	$15,000
2 2-pen strip chart recorders	3,000
2 thermocouple sets	2,000
Total	$20,000

The fixed instruments should be installed so that they "look" into a sealed pipe, which will serve as a blackbody. This pipe should be welded shut at one end, with the closed end inserted approximately 0.5 - 1.0 meter into the kiln (burning zone), angled down slightly. The sensor for the IR pyrometer should be installed at the cool end, focused on the welded end. The welded end will approach the temperature of the burning zone. The welded pipe should be inspected every month, and replaced as necessary. Because of the high temperature in the burning zone, the pipe will not last very long. It is important to replace it to protect the delicate IR meter, which cannot withstand high temperatures.

Temperature measurements can be made through the existing inspection ports, using portable instruments. A length of pipe may be pushed into the port as a guide and as protection for the thermocouple probe. The probe can then be inserted through the pipe to make the measurement. Air leakage through the port should be eliminated by stuffing insulation around the openings during the measurements. Temperatures at several places in the kiln be monitored, not just in the burning zone. This is because the quality of both the dolomite and the coal will vary and the optimum temperature profiles in the kiln may change depending on the temperature and wetness of the raw feed, the quality and size of the anthracite and the amount of draft that can be generated by the induced draft fan. The agricultural lime kilns already have several inspection ports at different levels in the kiln. It may be necessary to create more openings in the building lime kilns where temperature measurements can be taken. Initial experimentation can be done using the existing setup.

Once the kiln is instrumented, experiments will also be necessary to determine better ways to control the kiln operation. Currently, three parameters are under operator control: coal to

dolomite ratio, induced draft fan damper setting and lime removal rate. According to the operator, the coal to dolomite ratio is set by blending the two on a theoretical energy/mass ratio. The fan damper and lime removal rate are adjusted to keep the burning zone at the correct height in the kiln. We make the following observations:

1. The time constants in the kiln are very long, and any adjustments to the operating parameters will take a long time to become apparent in the temperature profile readings. Adjustments to the combustion air draft will not change operating temperatures for many minutes--perhaps an hour or more. Changes to the fuel/stone ratio may not affect the operation for several hours. It is therefore necessary to attempt to operate the kilns in a constant flow, constant combustion condition as much as possible. Changes to the grate movement should be made only very rarely, and changes to the other parameters should be made in very small steps, watching the temperature profile readings over periods of several hours to determine their effects. Because the coal is undersized and tends to fall down through the layers of stone, it is likely that the maximum temperature burning zone is located lower in the kiln than would be the case with size AM or AK anthracite, and incomplete burning of dolomite is the result. With proper instrumentation the kiln should be controllable using a lower section as the burning zone.

2. In any combustion process, the temperature in the firebox is determined by the rate at which fuel is burned. In the lime kiln, combustion of the fuel occurs long after the coal is dumped into the kiln. As with coal or wood furnaces, the rate of burning must be controlled by the combustion air draft. Assuming that the infiltration air leaks are fixed, the induced draft fan damper will thus become the primary short-term control of burning zone temperature. The draft control should be set to completely burn the anthracite so that little or no CO is present in the stack gases (US Environmental Protection Agency requires that CO emissions from industrial stacks be less than 400 ppm), and so as little O_2 as possible is present. Small increases or decreases in the air flow about this basic operating point can then be used to regulate the temperature in the burning zone. If the correct temperature cannot be obtained with small adjustments to the kiln draft, the ratio of fuel to stone should then be adjusted slightly. The fuel/stone ratio will take a long time to have an effect, however.

3. It is necessary not only that the dolomite be heated to a specific temperature, but that it be held at that temperature for an extended period of time--from 2-7 hours, depending on the temperature and size of stone. The quantity of fuel mixed with the dolomite and the rate of travel through the kiln will be the major factors in determining the amount of time the stone is held at the calcining temperature. The

rate of travel of the stone through the kiln is governed by the grate movement setting at the bottom of the kiln. Production rates should be set to give sufficient residence time to produce the desired quality, i.e. lime which is completely calcined.

Expected Results:

By operating the kilns at steady state conditions, it will be possible not only to improve product quality but energy efficiency as well. No process operates at maximum efficiency under transient conditions, especially one with as much thermal inertia as a lime kiln. We anticipate that by modification of the kiln control practices, the annual energy consumption of the kilns could be reduced by approximately 10%. This would amount to a savings of

$$10\% \times 20{,}000 \text{ tons coal/yr} = 2{,}000 \text{ tons/yr}$$
$$2{,}000 \text{ tons/yr} \times \$42/\text{ton} = \$84{,}000/\text{yr}$$

Financial Analysis

The cost of the sensors and readouts for four kilns will be approximately $20,000 plus some local expense for installation and experimentation. We estimate local costs at approximately $2,000 for each kiln, or $8,000 total. SAULKALNE should also budget about $2,000 per year per kiln for spare parts and replacement of damaged probes. Given these estimates, the payback period for the project is:

$$(\$20{,}000 + \$8{,}000)/(\$84{,}000/\text{yr} - \$8{,}000/\text{yr}) = 0.37 \text{ year}$$

C. CAPITAL INVESTMENT PROJECTS

FUEL SUBSTITUTION
SAULKALNE Action C.1 -
Convert kilns to burn natural gas.

Existing Conditions

As noted earlier, the kilns presently burn anthracite which is mixed with the dolomite and charged into the kiln. The anthracite is of variable quality, and the kiln operation is difficult to control using this fuel. A natural gas pipeline is located near to the SAULKALNE plant, and they have considered the possibility of changing fuels to allow them to burn natural gas.

Recommended Actions

If the natural gas supply is available, RCG Hagler, Bailly believes the switch to natural gas firing of the kilns might be a good project. Natural gas may be more expensive than coal (on a delivered kcal basis), but it is much easier to control, more consistent in quality, cleaner and cheaper to handle and will produce a better quality product than the coal. Significant energy savings may result from a fuel switch. Robert Boynton surveyed U.S. lime companies that had changed vertical kilns from coal to natural gas combustion. These companies reported:

1. Increased capacity from 15% to 100%
2. 15%-20% increase in thermal efficiency
3. Better combustion control
4. Improved lime quality[7]

In addition, some expensive modification of the kilns would be necessary. Given that the structural integrity of the kilns is deteriorating, this project would have to be given much more careful analysis than can be performed based on the limited information available to the RCG/Hagler, Bailly team.

[7] Boynton, p. 282.

Expected Results

Given the difficulties SAULKALNE is experiencing with fuel quality and kiln control, we expect that the company could expect benefits at least as great as those recorded by U.S. companies--probably greater.

At world lime prices, the value of the increased production would be about $5 million per year.

C. CAPITAL INVESTMENT PROJECTS

PROCESS TECHNOLOGY
SAULKALNE Action C.2 -
Study feasibility of modernizing process equipment

Existing Conditions

As noted earlier, the kilns are more than 30 years old and are of the obsolete vertical design. The design of the plant contributes significantly to its lack of flexibility - it is not capable of producing acceptable quality lime when burning anthracite and dolomite of varying quality.

Recommended Actions

An engineering and economic feasibility study of process modernization should be carried out. This study should determine the costs and benefits of the project. Because the Government of Latvia cannot be expected to make large investments in the industrial sector in the near-term, this study should be made as part of a privatization plan for the plant.

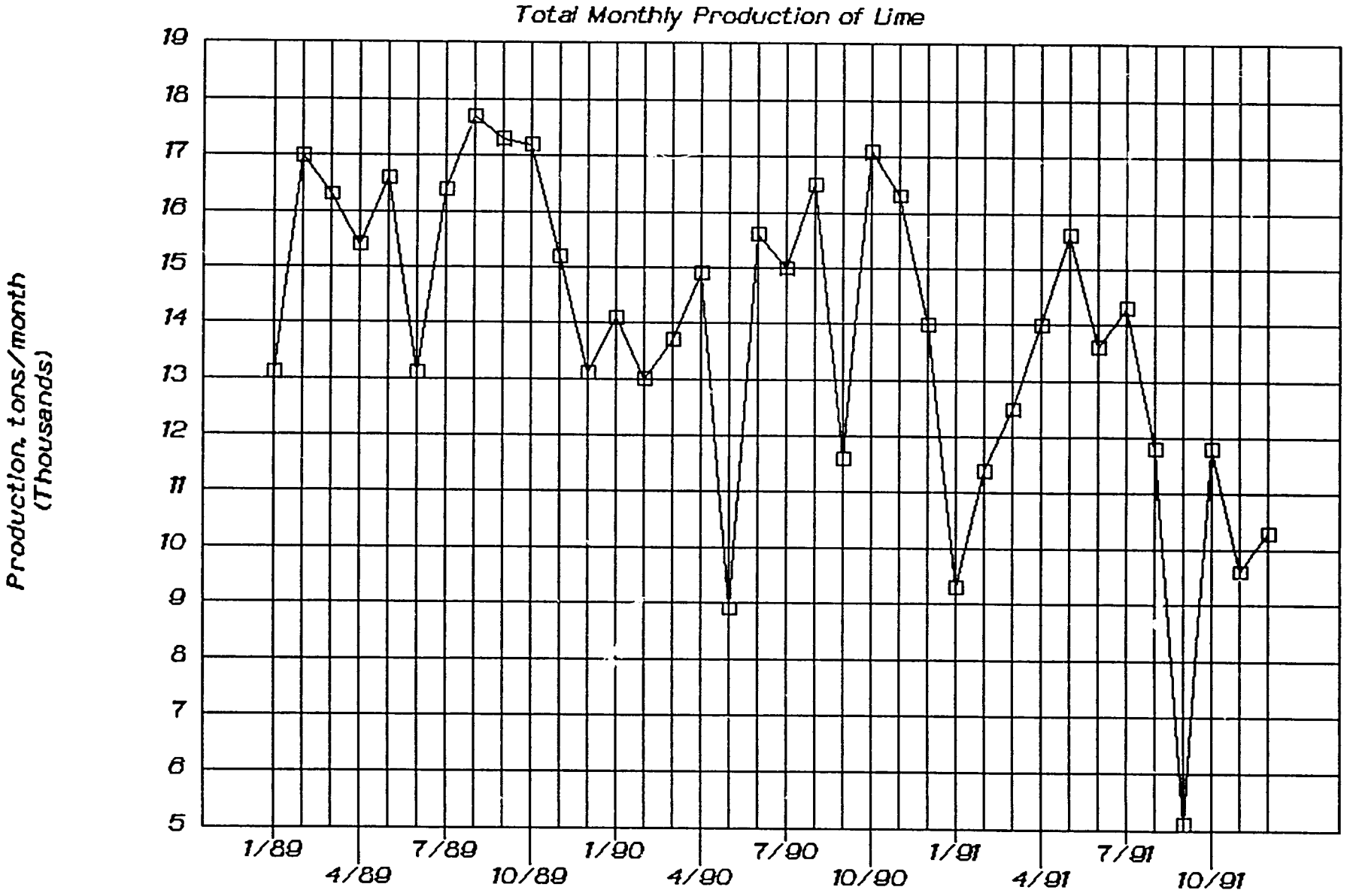
APPENDICES

SPREADSHEET AND GRAPHICAL PRESENTATION OF ENERGY DATA
SAULKALNE BUILDING MATERIALS PLANT

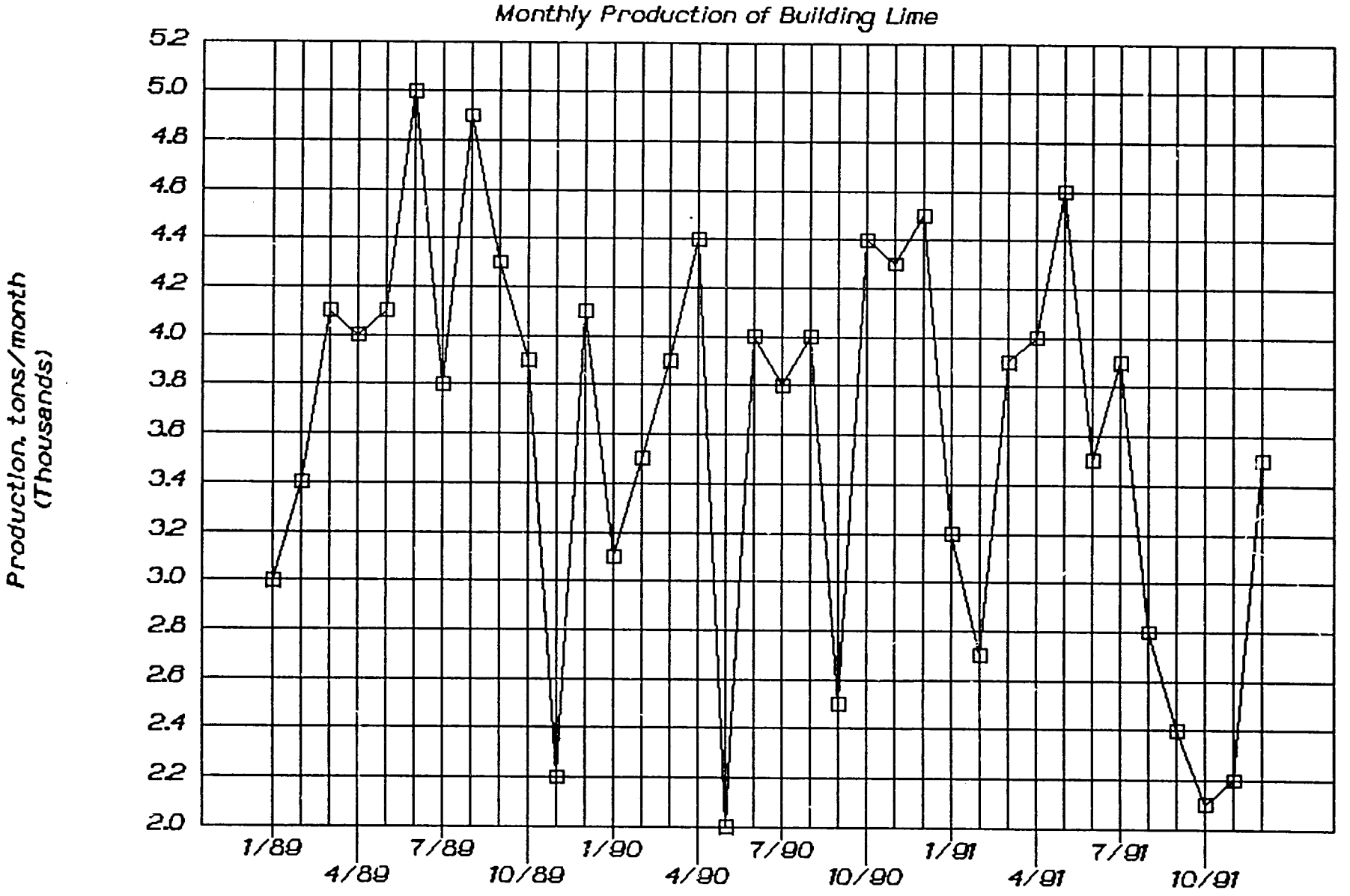
SAULKALNE – MONTHLY DATA

			BUILDING LIME			AGRICULTURAL LIME			TOTAL PRODUCTION & ENERG		
			Productn tons	Anthracite tons	Electricity kWh	Productn tons	Anthracite tons	Electricity kWh	Productn tons	Anthracite tons	Electricity kWh
1989	1	1/89	3,000	480	230,000	10,100	1,049	493,000	13,100	1,529	723,000
	2		3,400	612	164,000	13,600	1,491	418,000	17,000	2,103	582,000
	3		4,100	652	261,000	12,200	1,269	494,000	16,300	1,921	755,000
	4	4/89	4,000	634	230,000	11,400	1,086	438,000	15,400	1,720	668,000
	5		4,100	629	260,000	12,500	1,187	419,000	16,600	1,816	679,000
	6		5,000	788	310,000	8,100	772	315,000	13,100	1,560	625,000
	7	7/89	3,800	561	214,000	12,600	1,135	416,000	16,400	1,696	630,000
	8		4,900	733	280,000	12,800	1,183	367,000	17,700	1,916	647,000
	9		4,300	664	245,000	13,000	1,236	458,000	17,300	1,900	703,000
	10	10/89	3,900	625	215,000	13,300	1,357	469,000	17,200	1,982	684,000
	11		2,200	348	112,000	13,000	1,326	439,000	15,200	1,674	551,000
	12		4,100	654	254,000	9,000	919	319,000	13,100	1,573	573,000
1990	1	1/90	3,100	495	199,000	11,000	1,142	442,000	14,100	1,637	641,000
	2		3,500	500	195,000	9,500	921	332,000	13,000	1,421	527,000
	3		3,900	629	235,000	9,800	1,034	372,000	13,700	1,663	607,000
	4	4/90	4,400	693	268,000	10,500	998	314,000	14,900	1,691	582,000
	5		2,000	315	114,000	6,900	650	240,000	8,900	965	354,000
	6		4,000	629	260,000	11,600	1,097	246,000	15,600	1,726	506,000
	7	7/90	3,800	582	287,000	11,200	1,068	358,000	15,000	1,650	645,000
	8		4,000	623	191,000	12,500	1,188	466,000	16,500	1,811	657,000
	9		2,500	326	141,000	9,100	859	380,000	11,600	1,185	521,000
	10	10/90	4,400	705	257,000	12,700	1,295	445,000	17,100	2,000	702,000
	11		4,300	691	262,000	12,000	1,224	450,000	16,300	1,915	712,000
	12		4,500	786	280,000	9,500	1,056	367,000	14,000	1,842	647,000
1991	1	1/91	3,200	608	208,000	6,100	775	273,000	9,300	1,383	481,000
	2		2,700	521	203,000	8,700	1,108	359,000	11,400	1,629	562,000
	3		3,900	749	252,000	8,600	1,086	313,000	12,500	1,835	565,000
	4	4/91	4,000	791	275,000	10,000	1,270	367,000	14,000	2,061	642,000
	5		4,600	880	295,000	11,000	1,386	315,000	15,600	2,266	610,000
	6		3,500	679	222,000	10,100	1,266	391,000	13,600	1,945	613,000
	7	7/91	3,900	758	227,000	10,400	1,310	438,000	14,300	2,068	665,000
	8		2,800	531	186,000	9,000	1,134	340,000	11,800	1,665	526,000
	9		2,400	463	323,000	2,700	343	185,000	5,100	806	508,000
	10	10/91	2,100	405	108,000	9,700	1,237	264,000	11,800	1,642	372,000
	11		2,200	428	187,000	7,400	940	328,000	9,600	1,368	515,000
	12		3,500	680	237,000	6,800	862	243,000	10,300	1,542	480,000
TOTALS											
1989			46,800	7,380	2,775,000	141,600	14,010	5,045,000	188,400	21,390	7,820,000
1990			44,400	6,974	2,689,000	126,300	12,532	4,412,000	170,700	19,506	7,101,000
1991			38,800	7,493	2,723,000	100,500	12,717	3,816,000	139,300	20,210	6,539,000

SAULKALNE LIMEBURNING - PRODUCTION

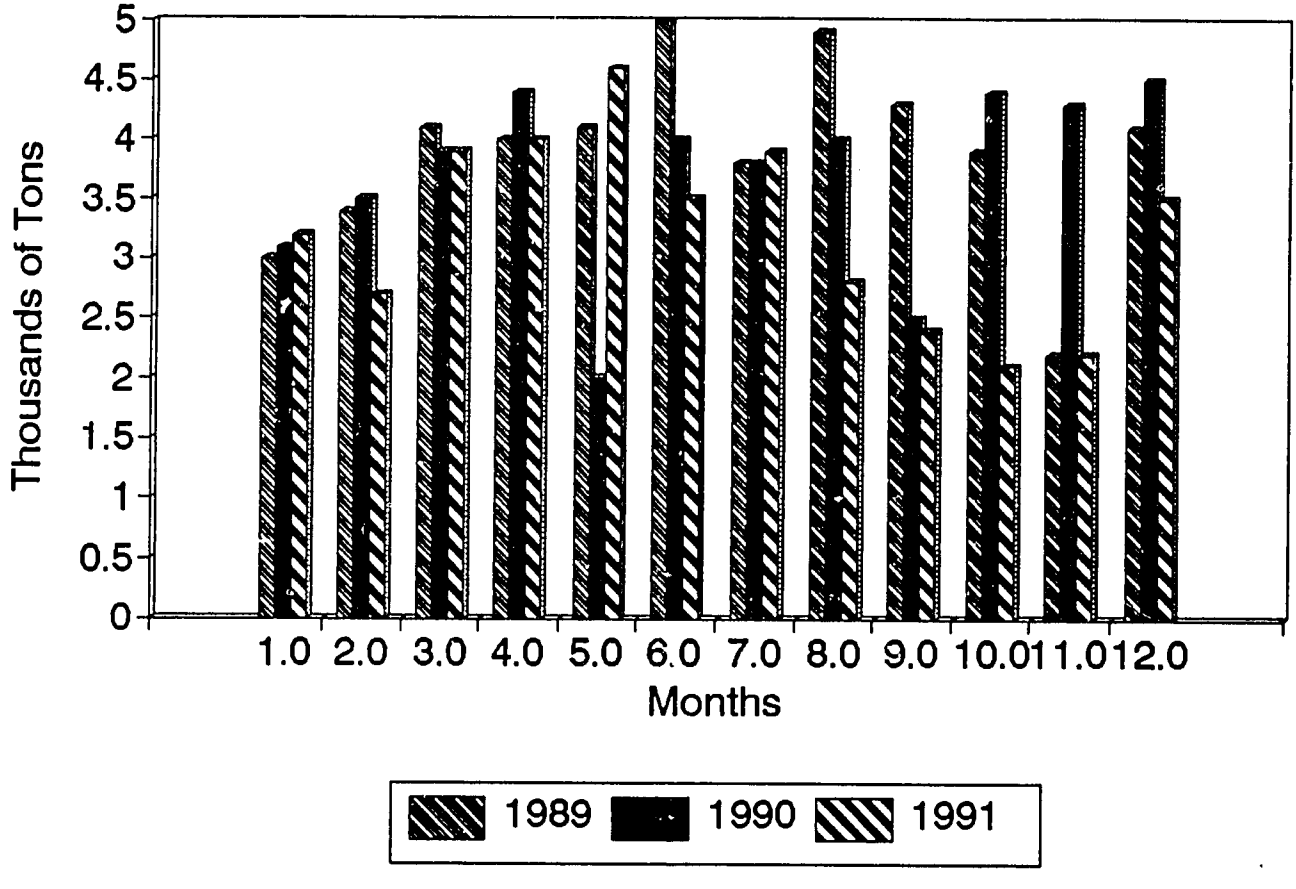


SAULKALNE LIMEBURNING - PRODUCTION

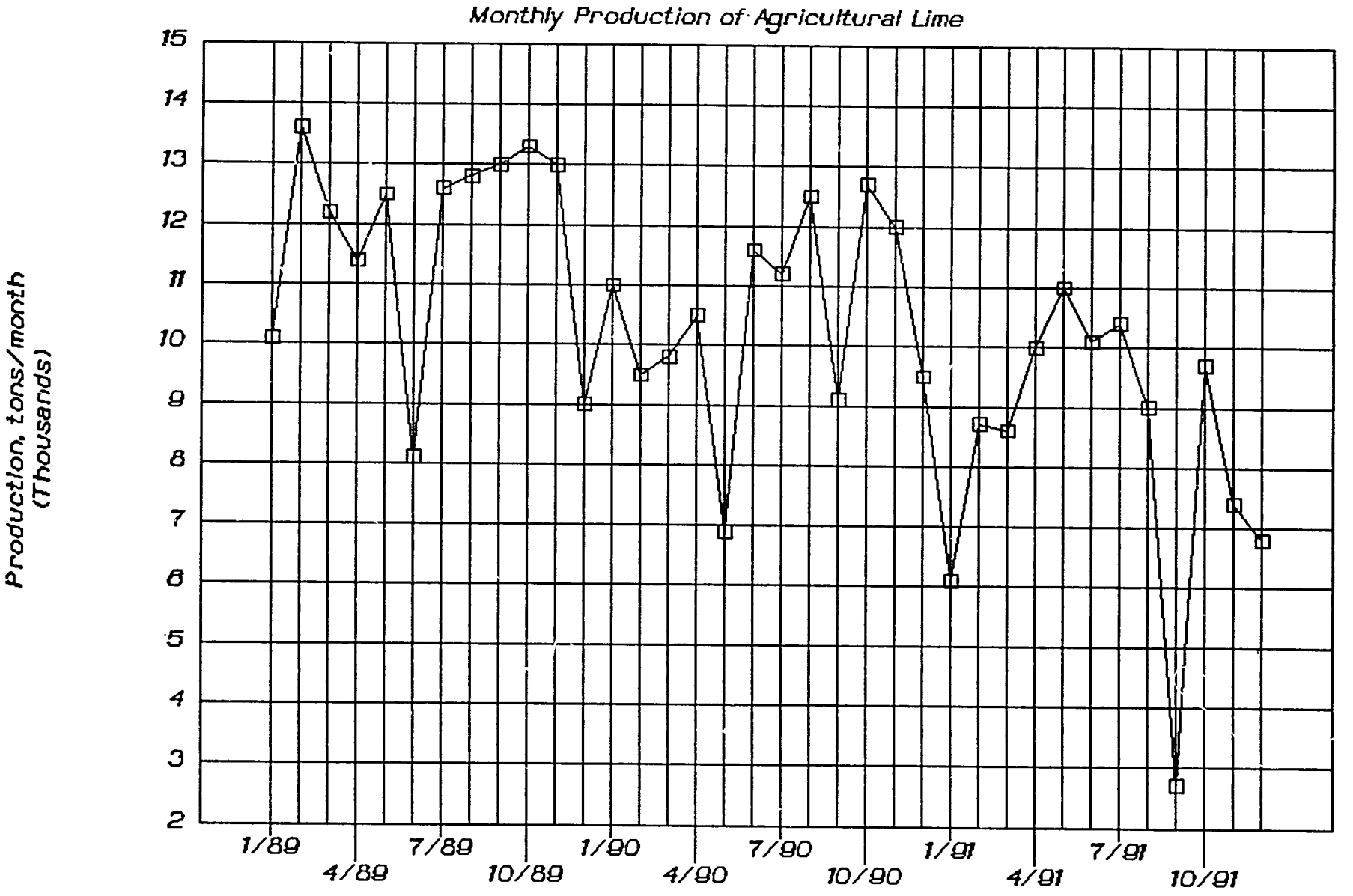


Saulkalne Building Materials Plant

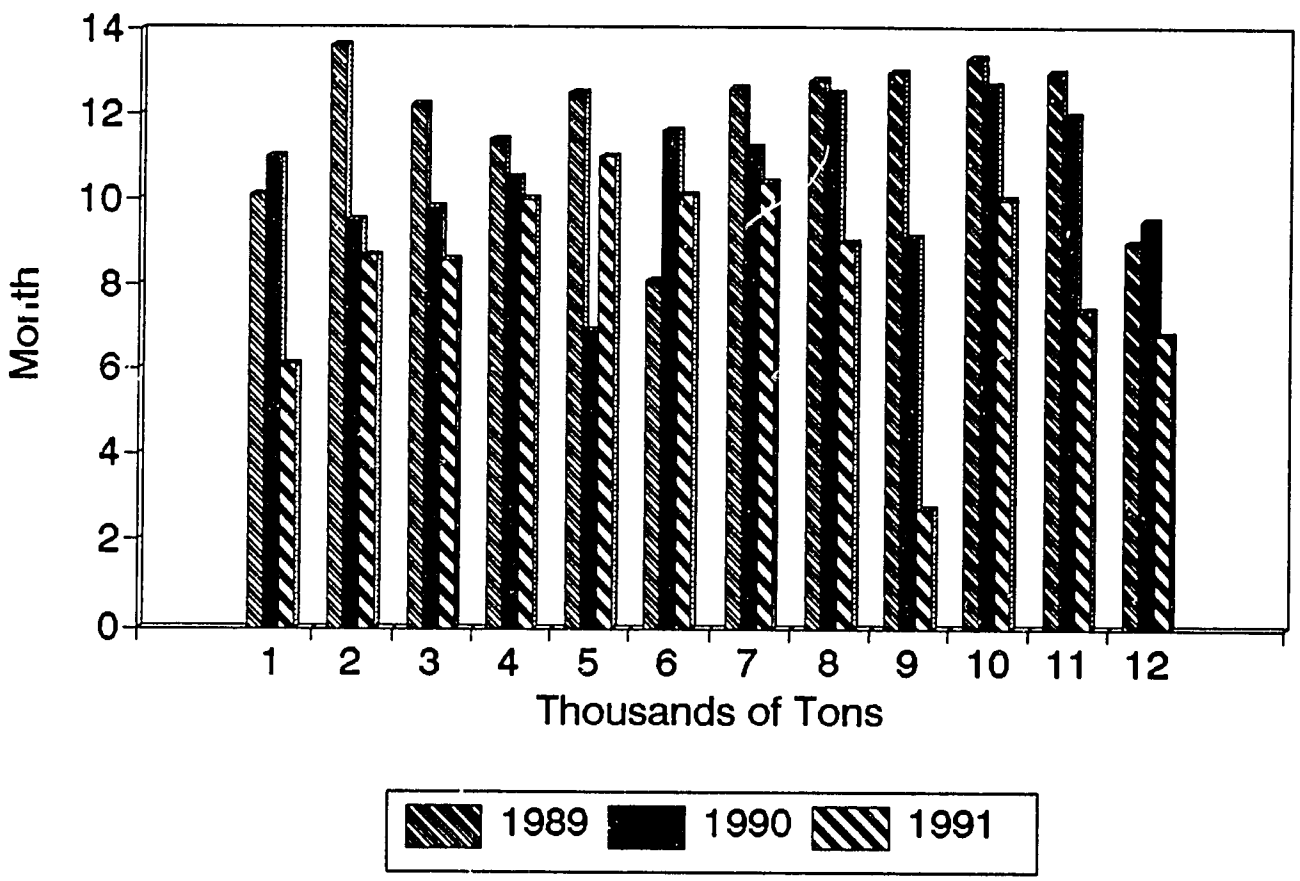
Building Lime Production



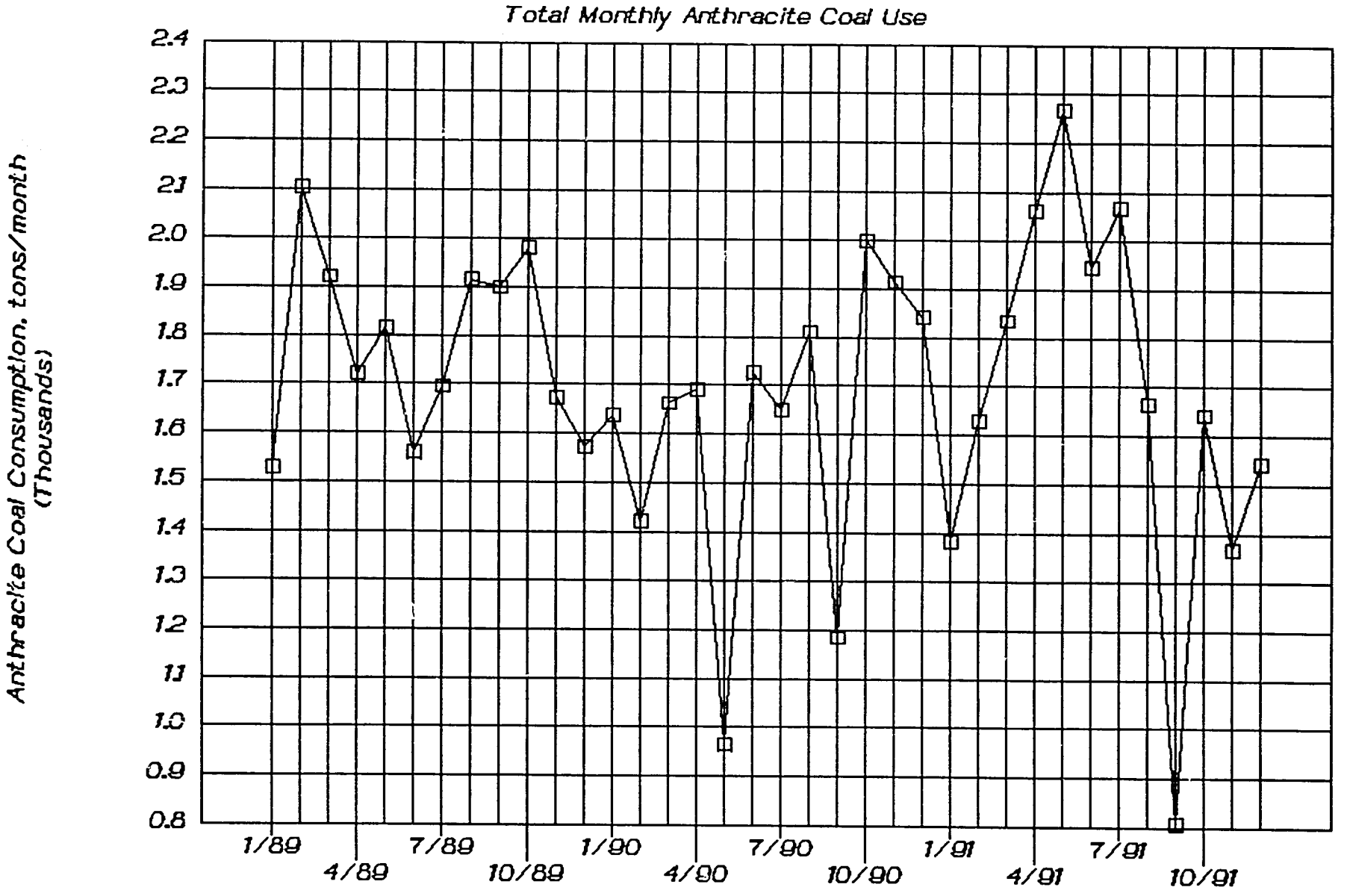
SAULKALNE LIMEBURNING - PRODUCTION



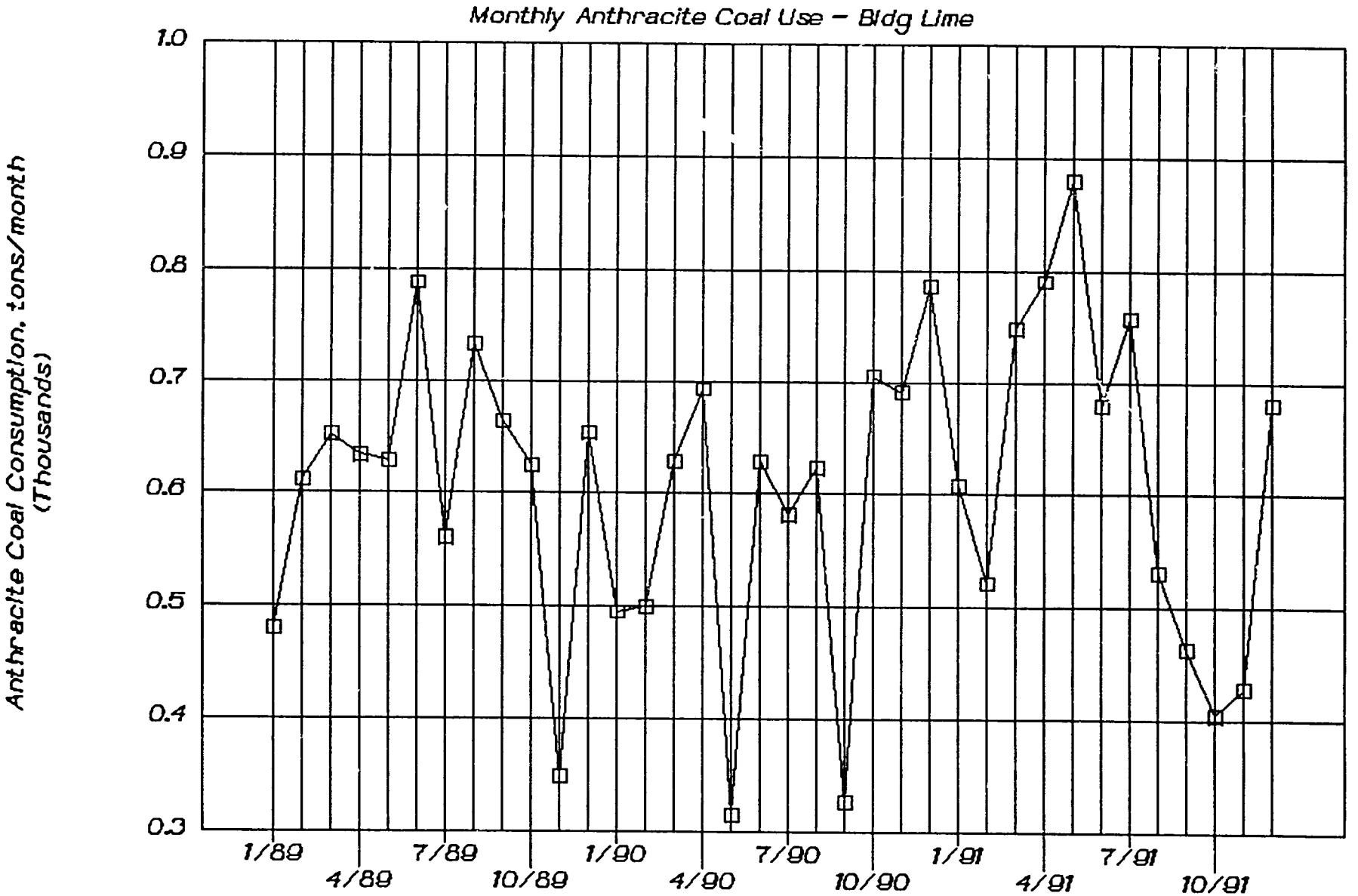
Saulkalne Building Materials Plant
Agricultural Lime Production



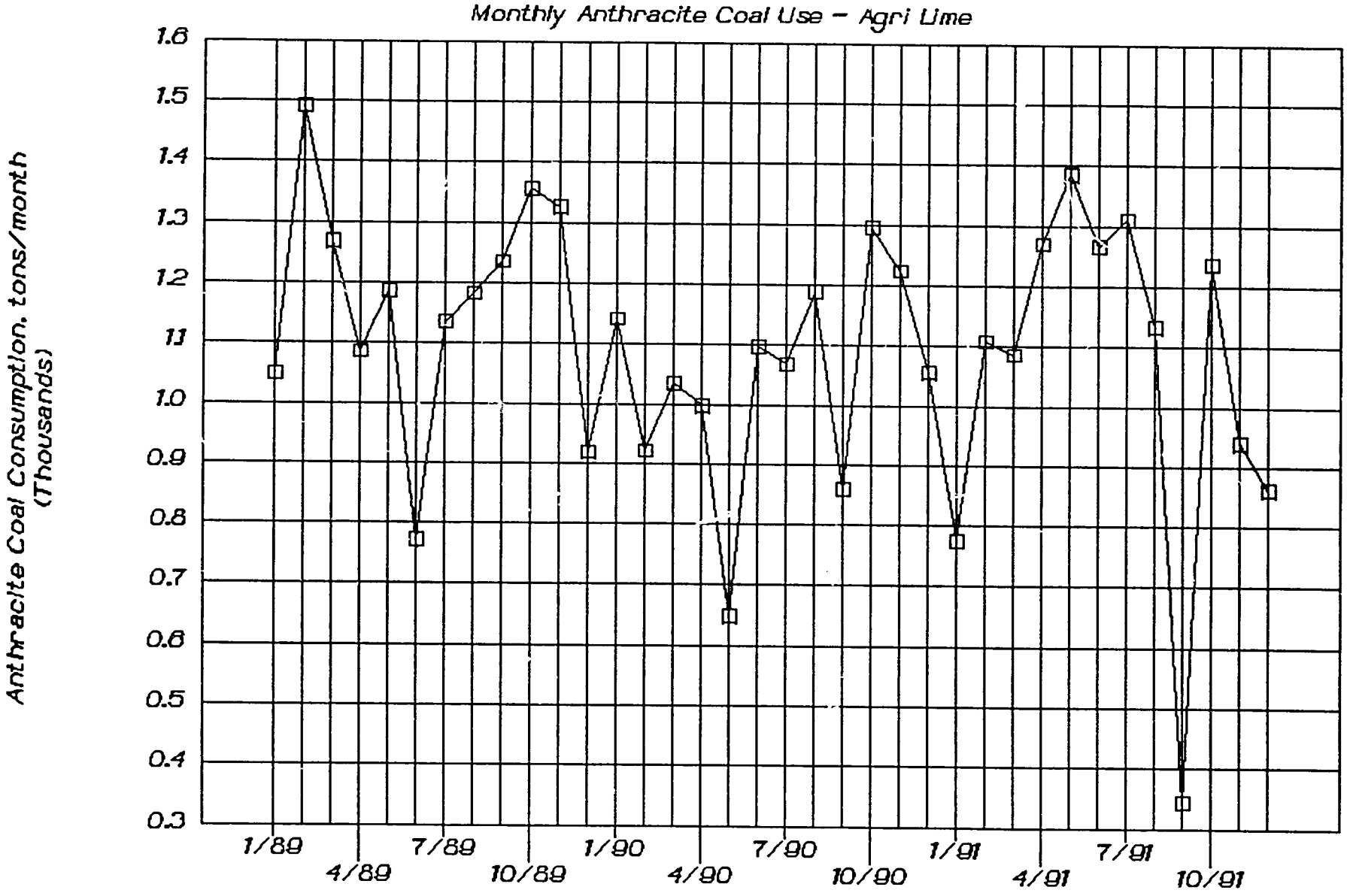
SAULKALNE LIME - ENERGY CONSUMPTION



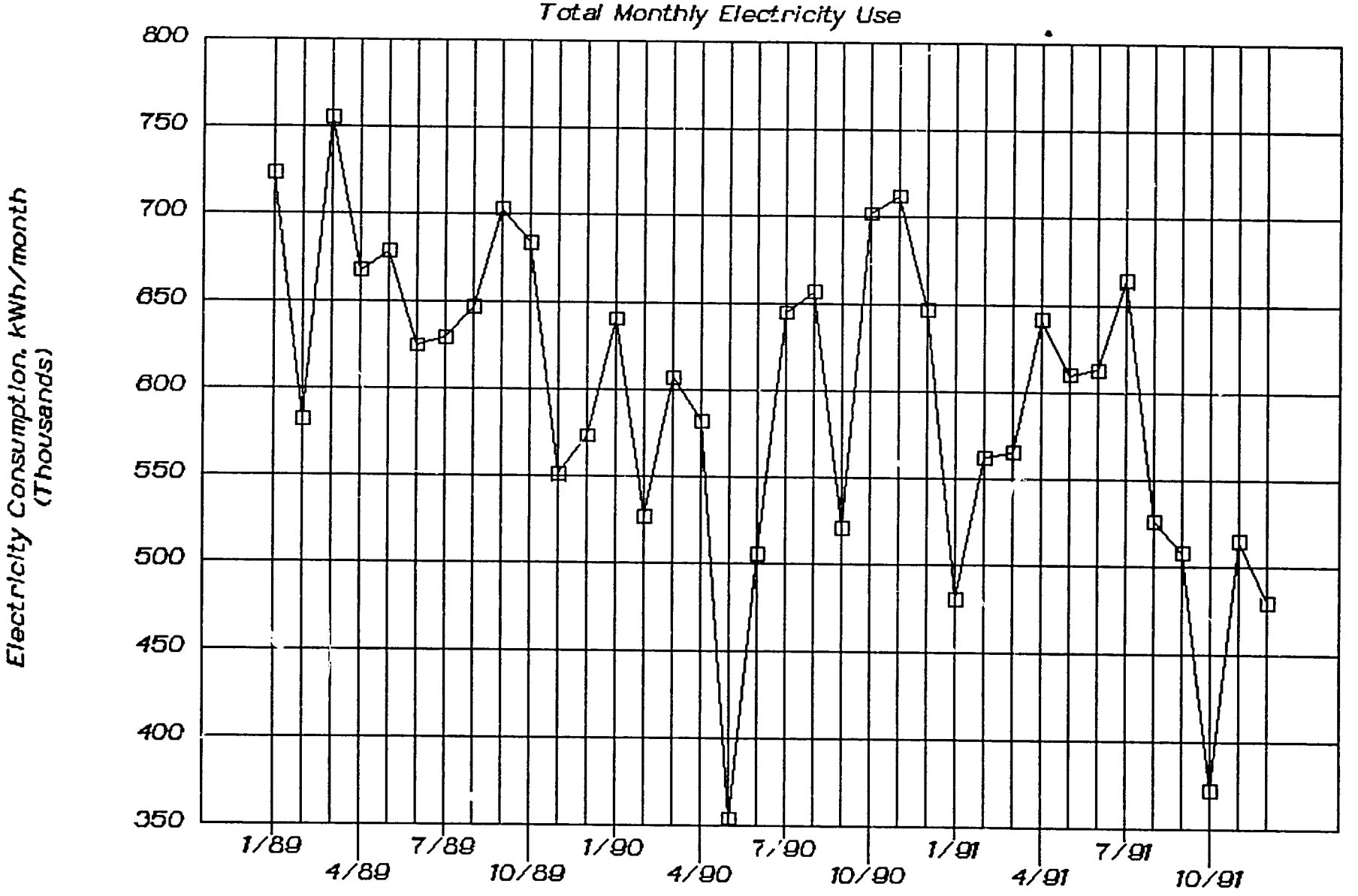
SAULKALNE LIME - ENERGY CONSUMPTION



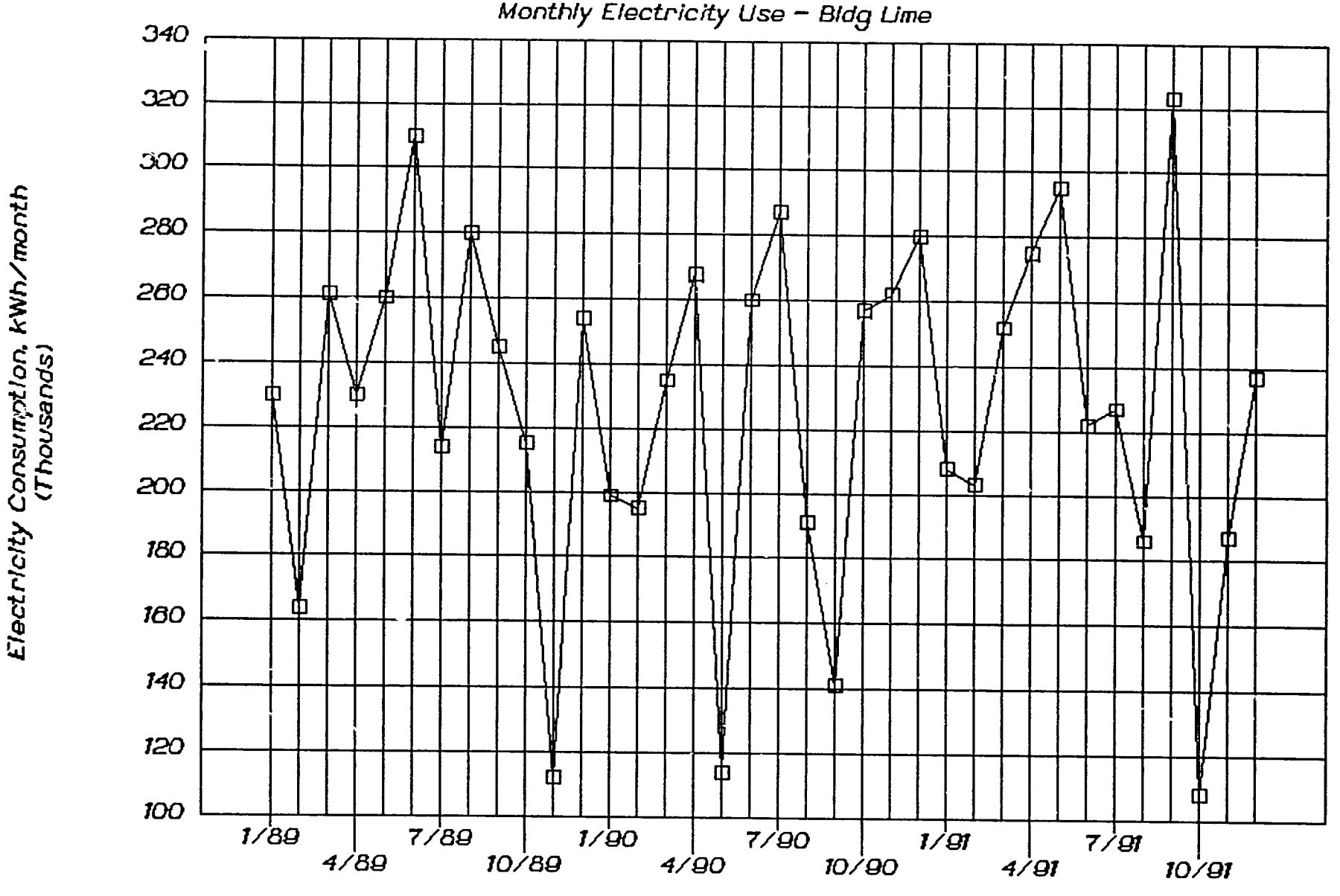
SAULKALNE LIME - ENERGY CONSUMPTION



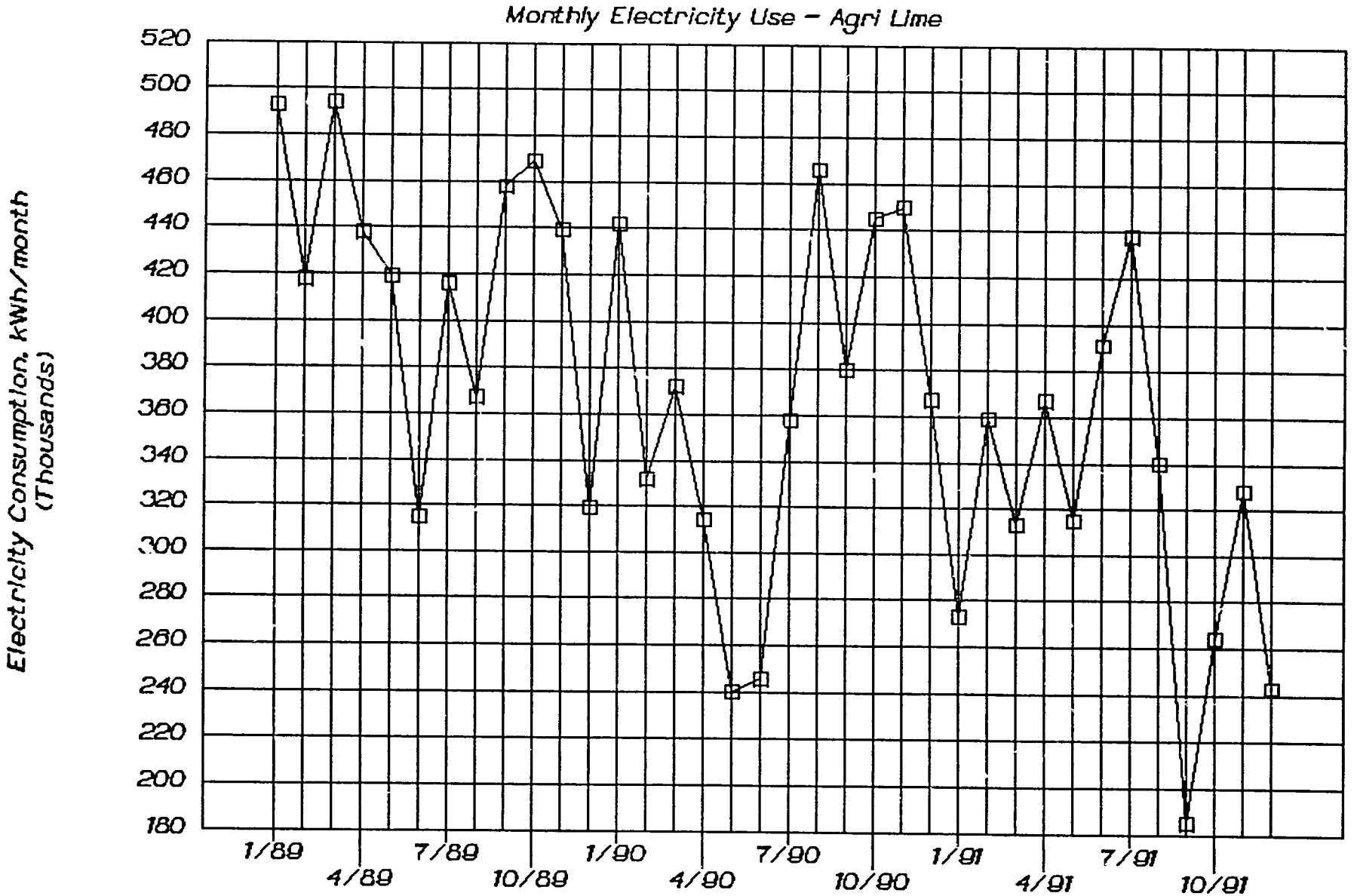
SAULKALNE LIME - ENERGY CONSUMPTION



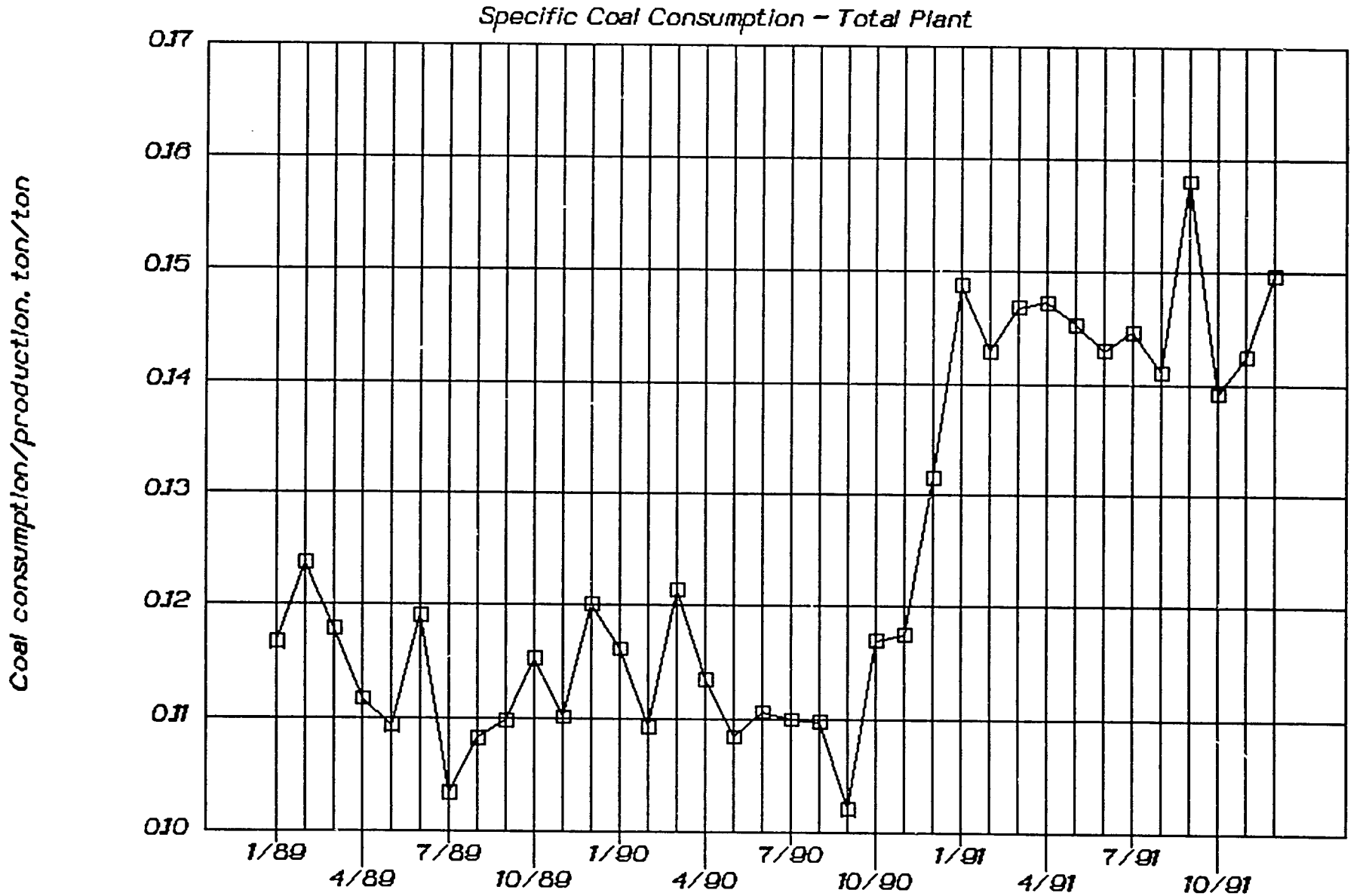
SAULKALNE LIME - ENERGY CONSUMPTION



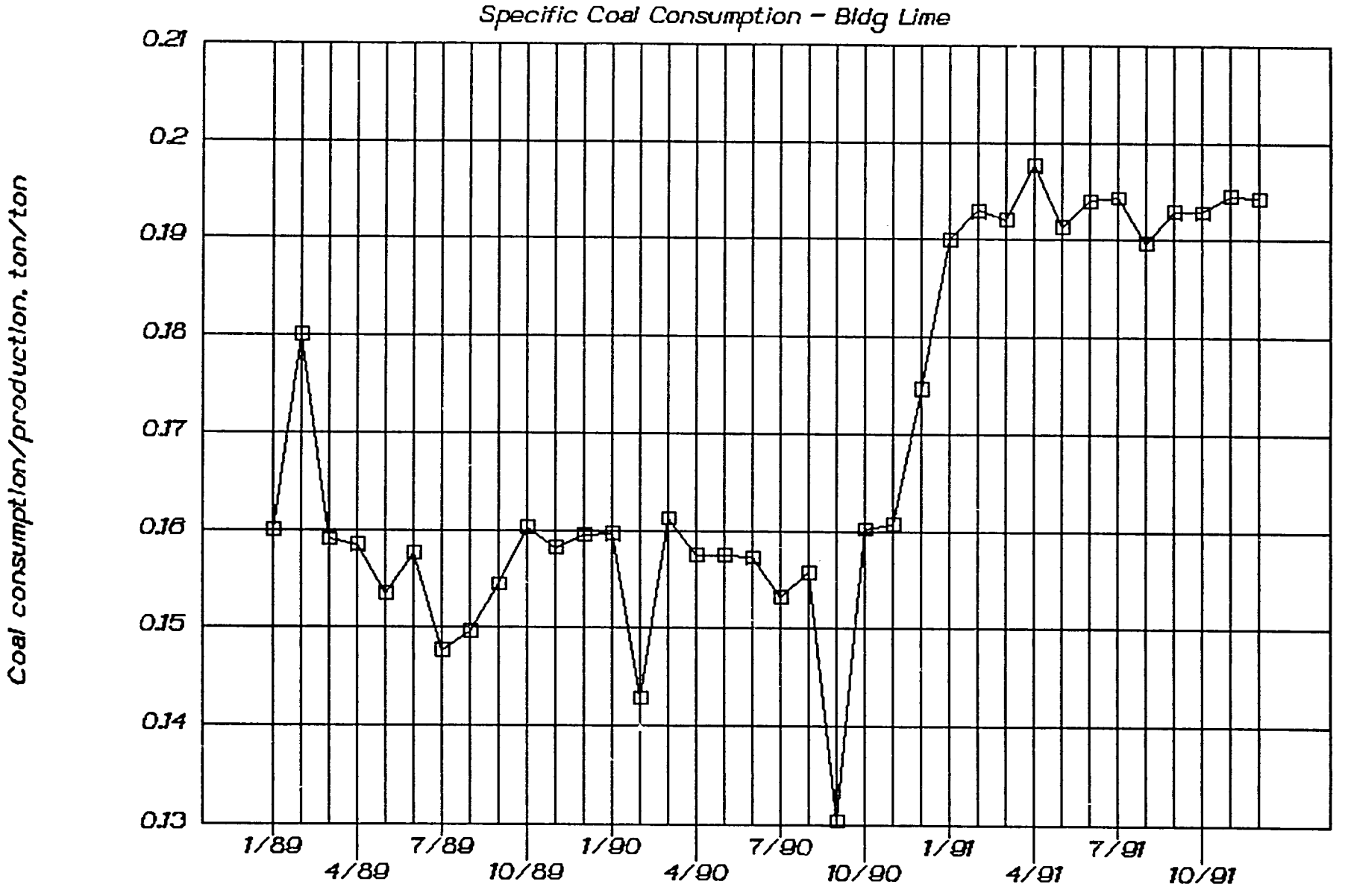
SAULKALNE LIME - ENERGY CONSUMPTION



SAULKALNE LIME - ENERGY INTENSITY

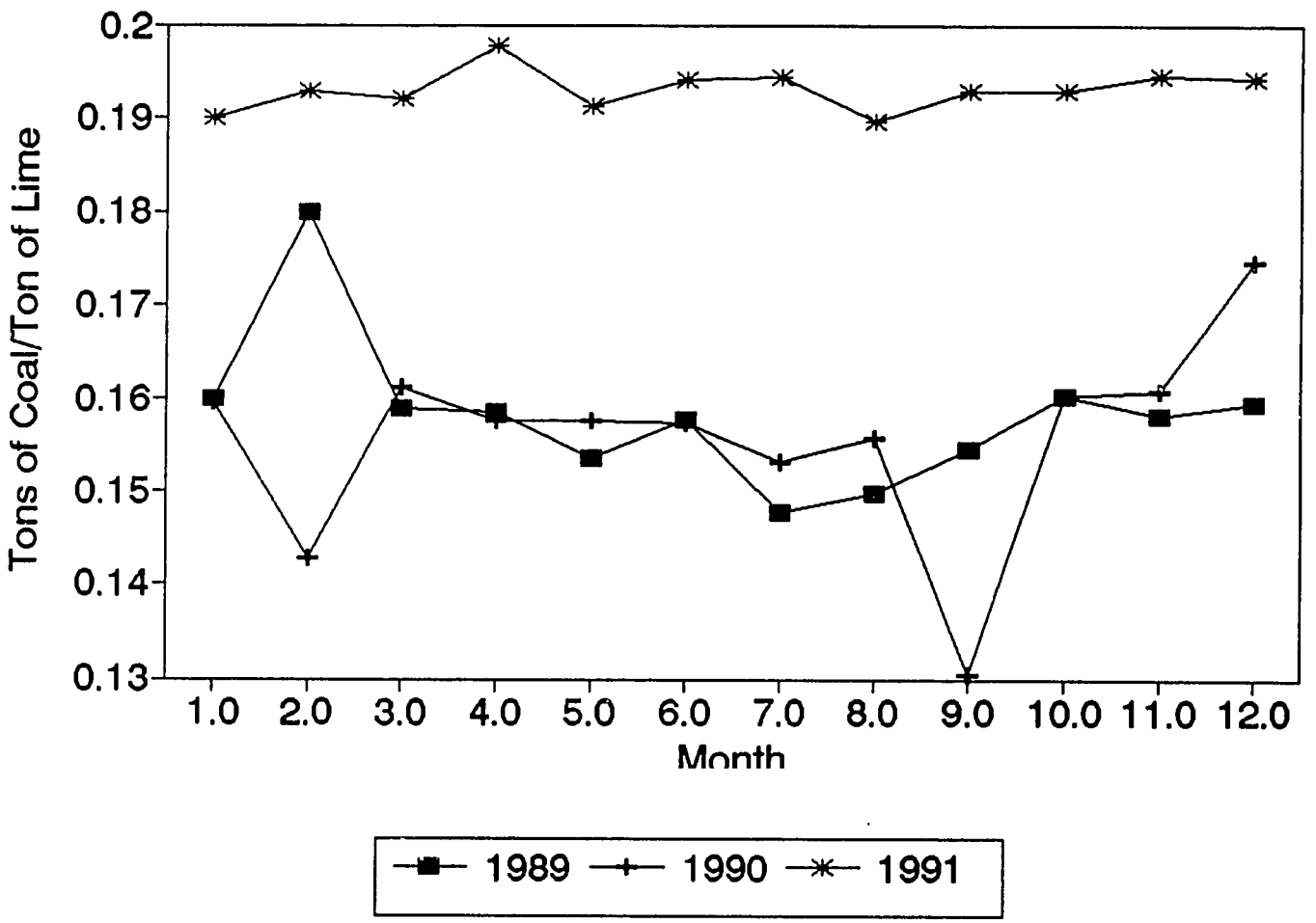


SAULKALNE LIME - ENERGY INTENSITY

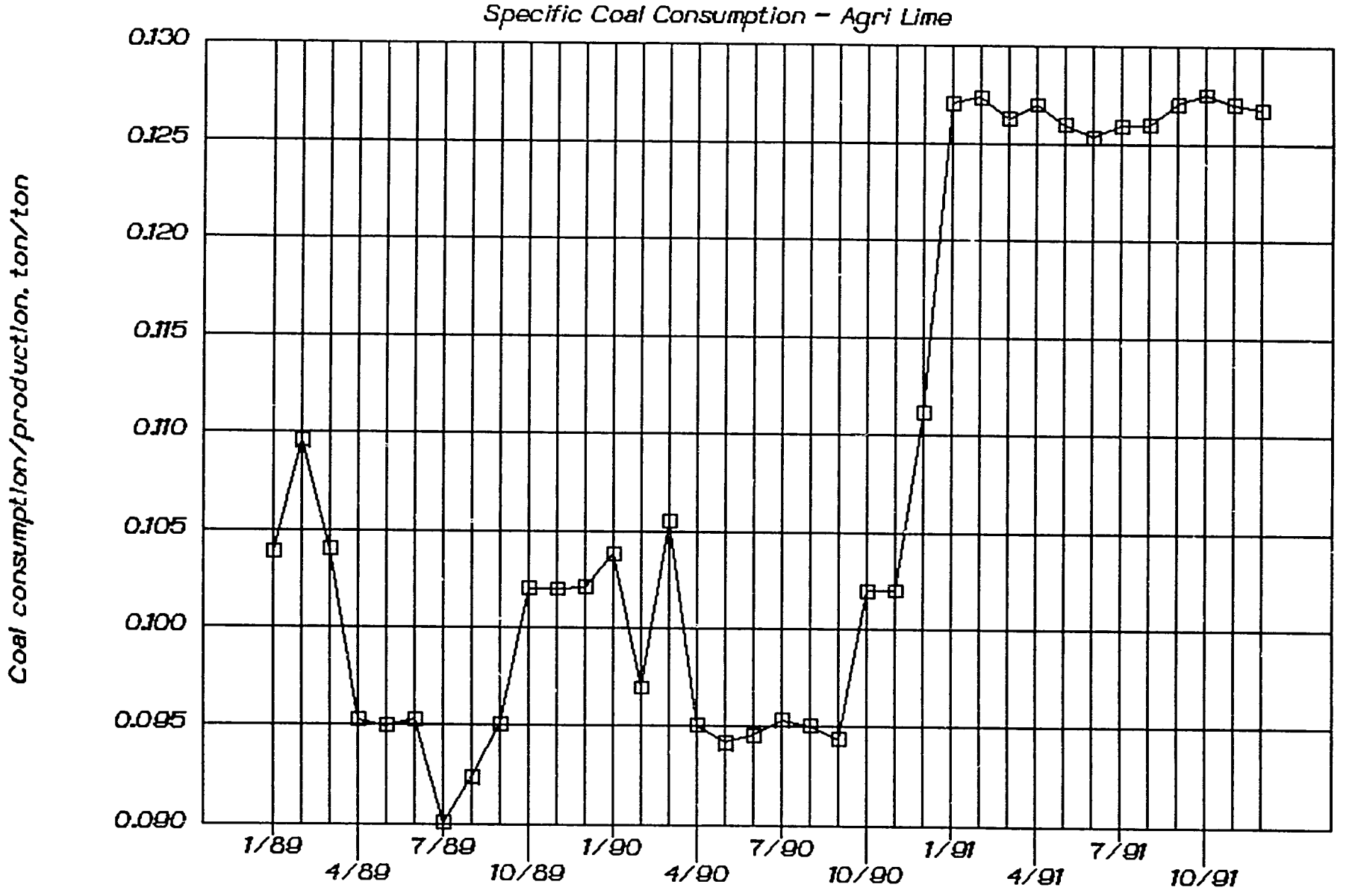


Saulkalne Building Materials Plant

Tons Coal/Ton Building Lime

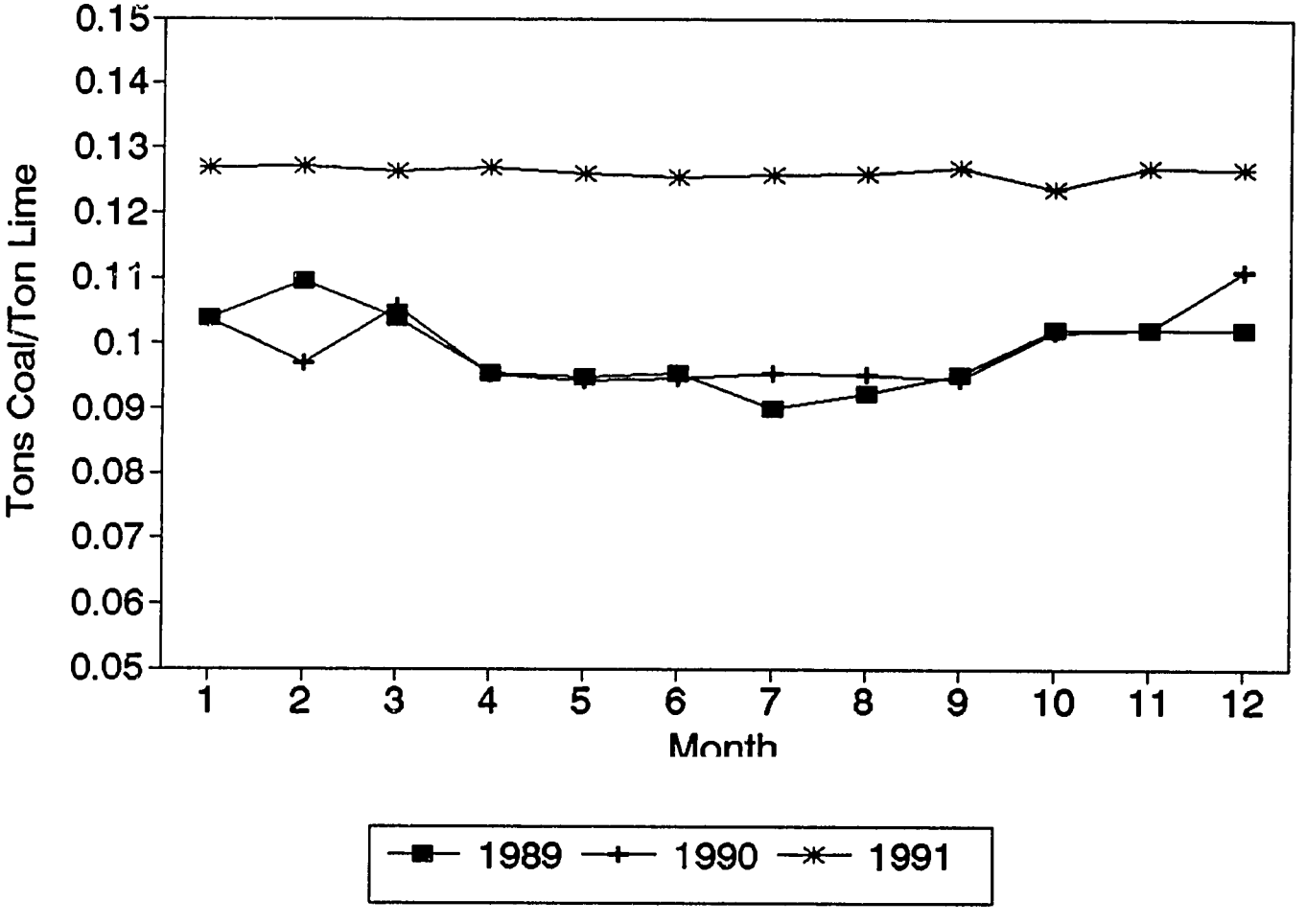


SAULKALNE LIME - ENERGY INTENSITY

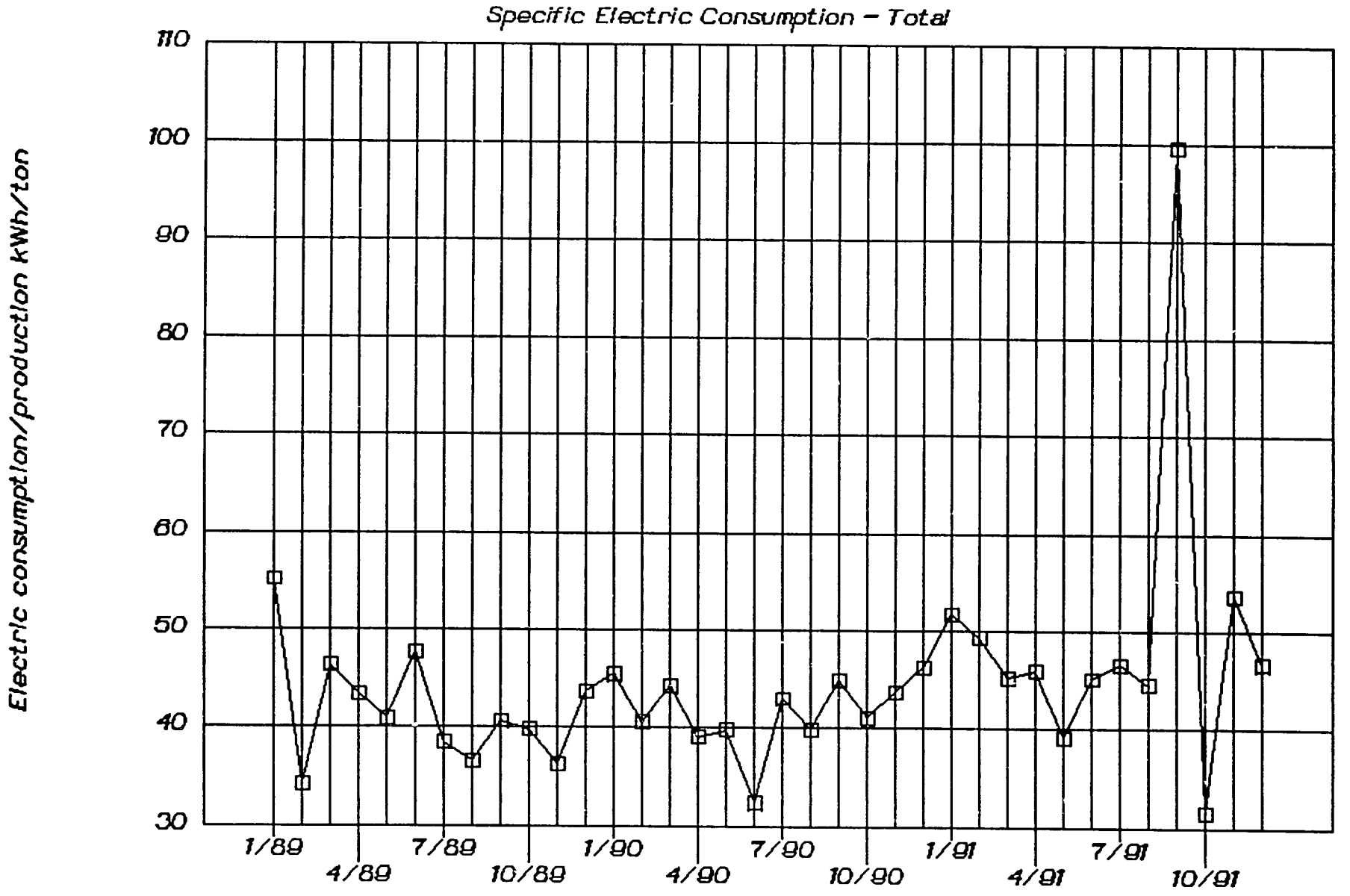


Saulkalne Building Materials Plant

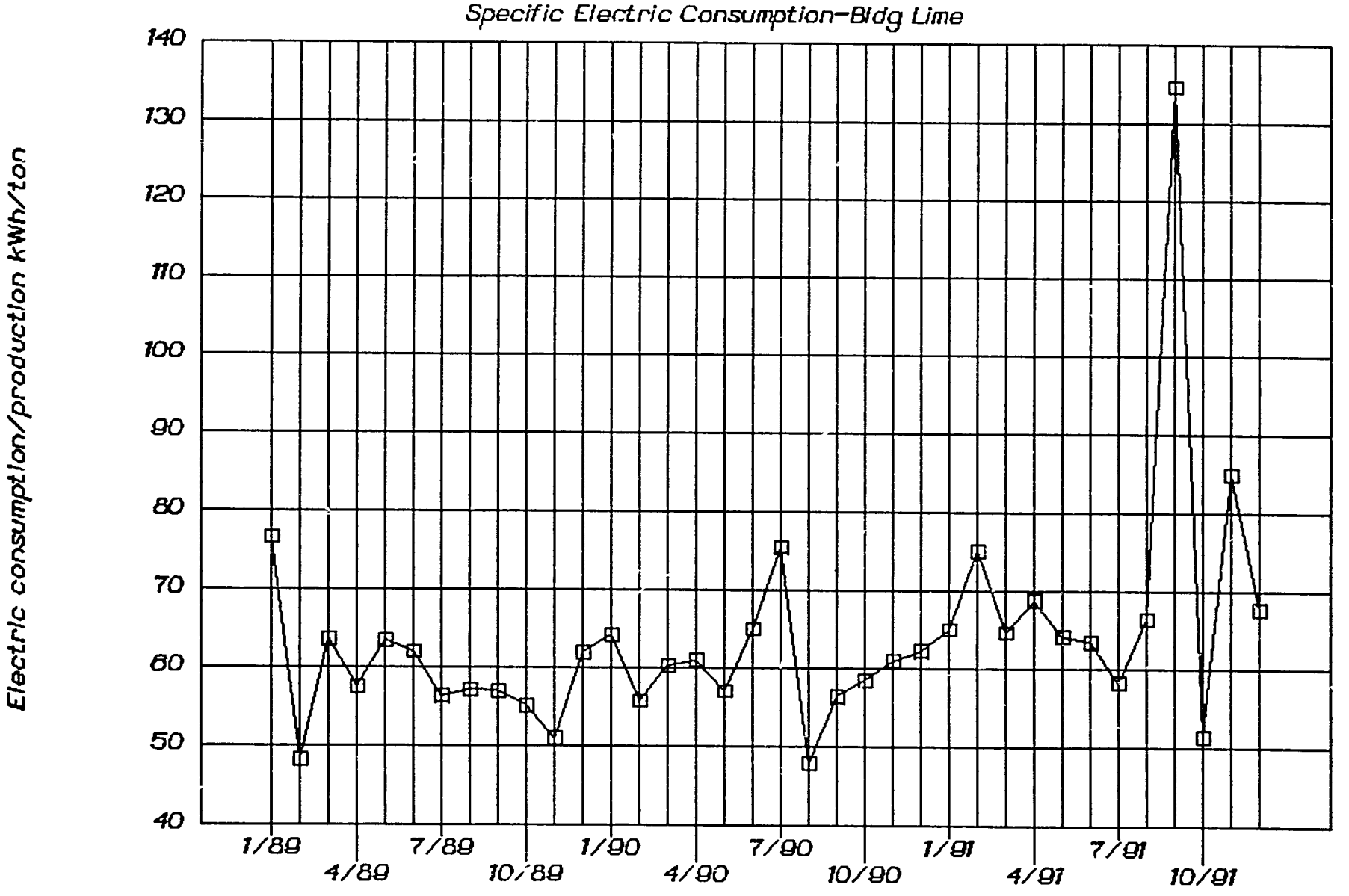
Tons Coal per Ton Agriculture Lime



SAULKALNE LIME - ENERGY INTENSITY

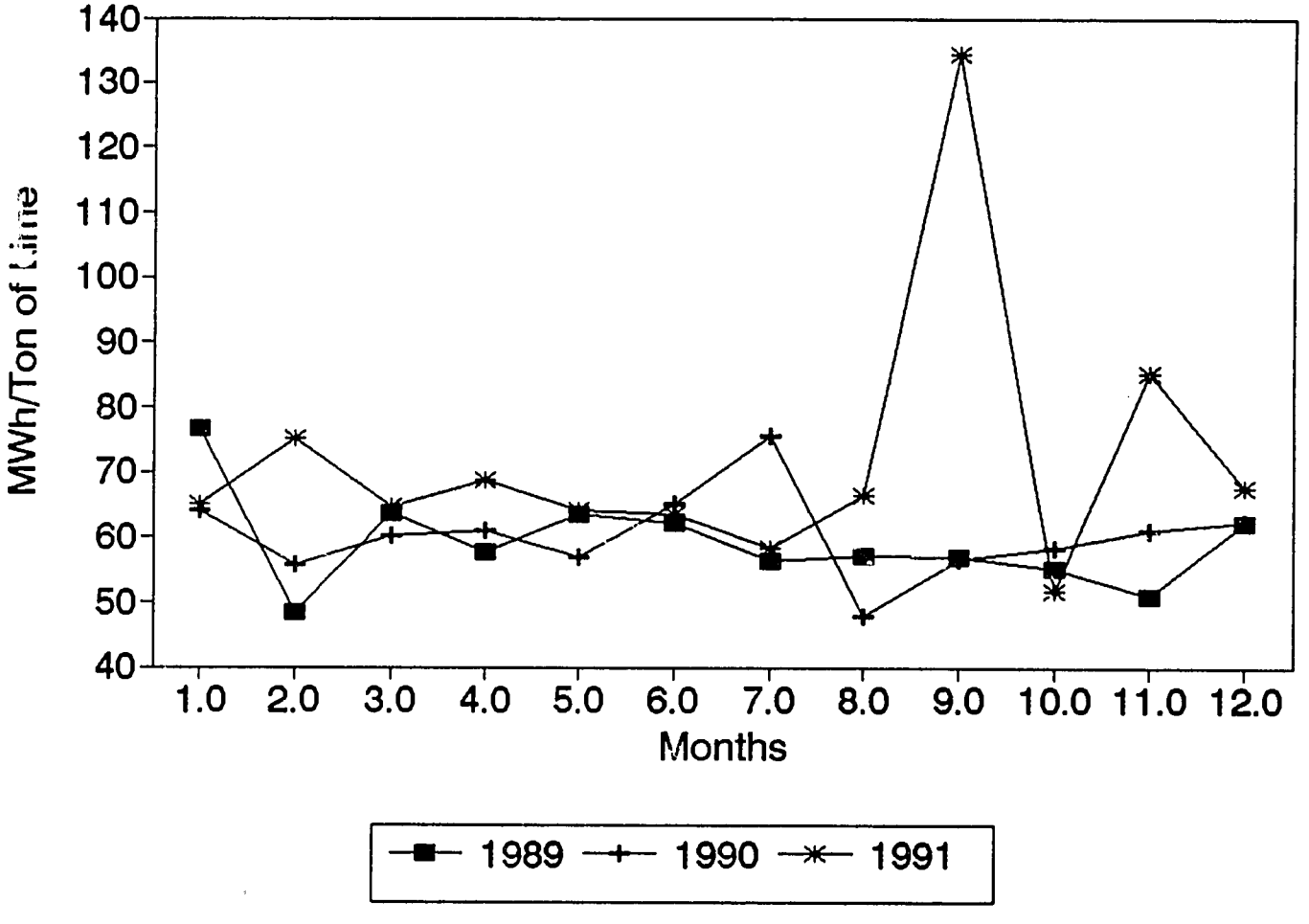


SAULKALNE LIME - ENERGY INTENSITY

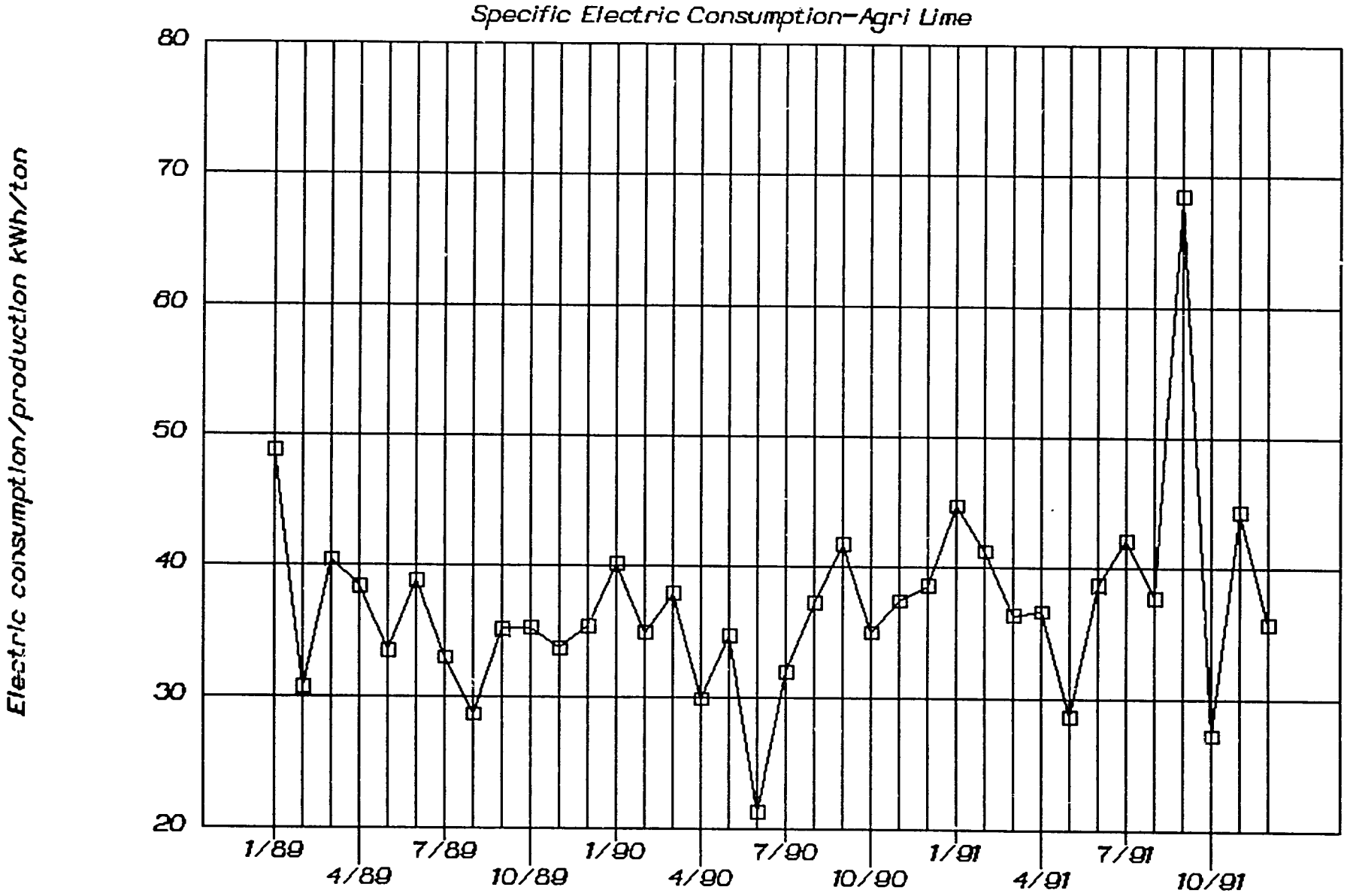


Saulkalne Building Products Plant

kWh/Ton Building Lime

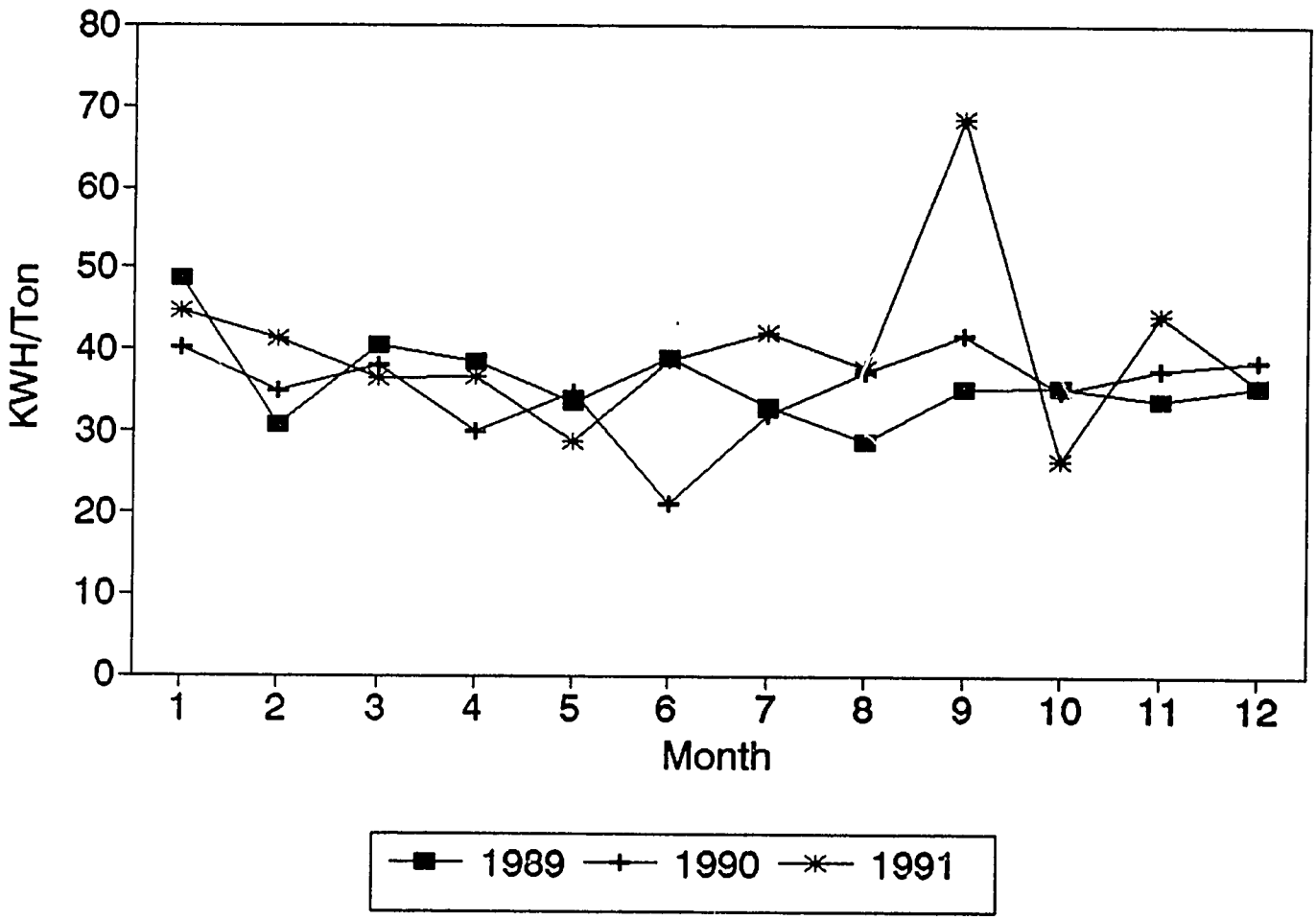


SAULKALNE LIME - ENERGY INTENSITY



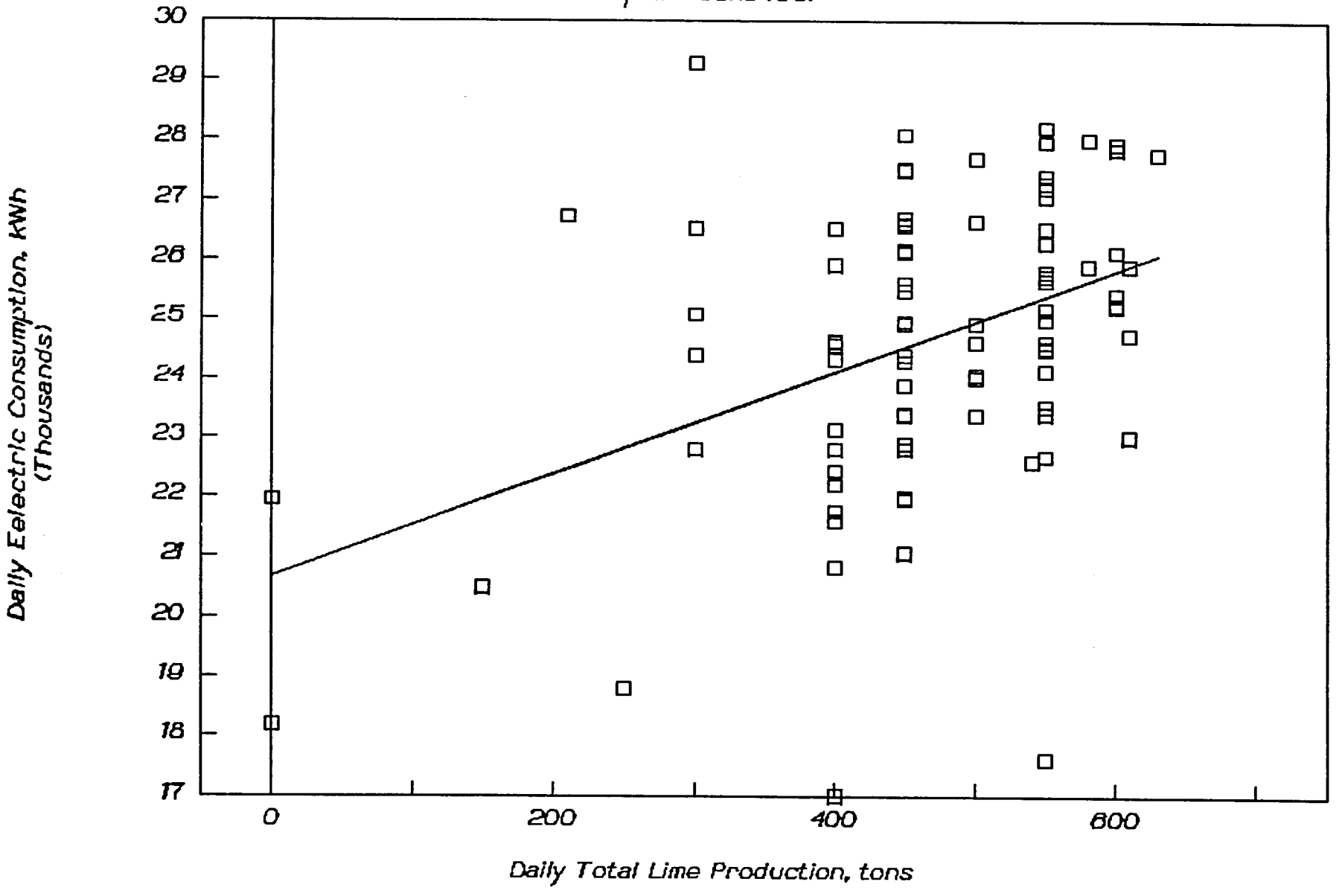
Saulkalne Building Materials Plant

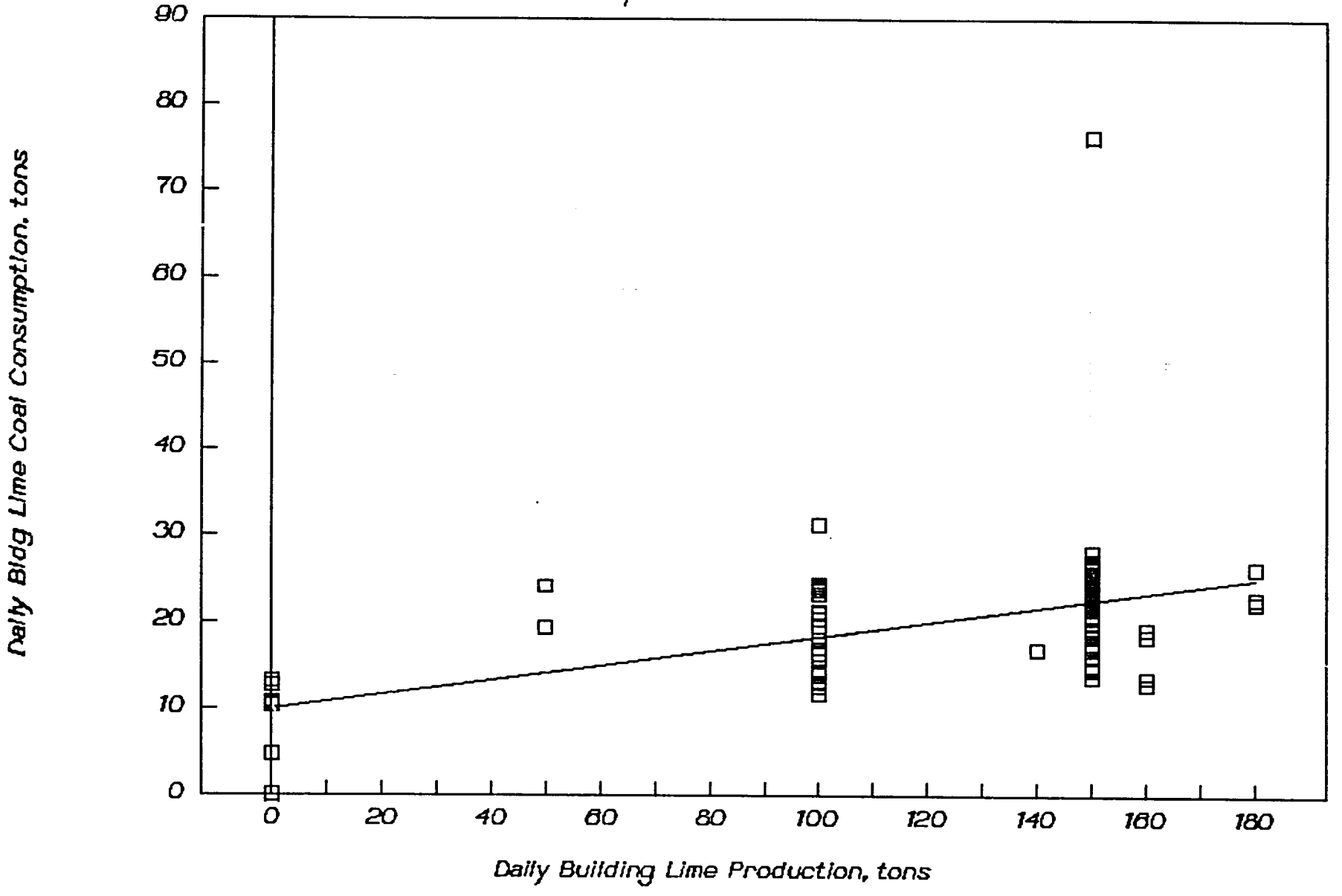
Electricity/Ton Agriculture Lime



SAULKALNE LIME - ENERGY/PRODUCTION

April - June 1991



SAULKALNE LIME - ENERGY/PRODUCTION

April – June 1991