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ENERGY EFFICIENCY AUDIT REPORT
KRKA PHARMACEUTICAL PLANT
NOVO MESTO, SLOVENIA, YUGOSLAVIA

MARCH 1992

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

and

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Belgrade, Yugoslavia

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

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
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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.

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PRELIMINARY ENERGY AUDIT
KRKA , TOVARNA ZDRAVIL, NOVO MESTO

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EXECUTIVE SUMMARY

This report presents the results from a preliminary energy audit carried out by a team of engineers from RCG/Hagler, Bailly, Inc. and TEKON Tehno-Konsalting and Institut Jozef Stefan at Krka Tovarna Zdravil in Novo Mesto, Slovenia, Yugoslavia from May 6 to May 10, 1991. The objectives of the audit were to work with the plant staff to: evaluate energy consumption at the plant; determine the level of energy management practiced; to identify energy conservation actions or opportunities; and identify instrumentation and low-cost equipment needed by the plant to implement the more attractive energy conservation actions.

Primary products of the plant are pharmaceutical drugs, and cosmetics. A summary of the primary energy consumption at the plant based on 1990 data is given below (a terajoule, TJ is 10^{12} Joules). Electricity shown is purchased electricity; an additional 7,700 MWh are co-generated in the plant, using the heavy fuel oil. Cost distribution is illustrative; costs are estimated based on May 1991 prices, and are approximately US $ 3.5 million per year.

	Energy Distribution			Cost Distribution	
	actual units	TJ	%	dinars	%
Electricity	19,600 MWh	235	34	31,262,000	40
Heavy fuel oil	11,500 tonnes	466	66	47,725,000	60
TOTALS		701	100%	78,987,000	100

Krka is a well managed plant, with export-quality production. The good organization is evident as well in the sector for energy and technical maintenance. Staff are technically well qualified and motivated, and are interested and informed about energy. Energy and utilities costs are allocated among all production and administrative departments on a monthly basis. Many energy efficiency projects have been implemented over the years, including condensate heat recovery, boiler blowdown heat recovery, burning of waste solvents in one boiler, computer-based optimization of generator loading, purchase of a high efficiency chiller, and improved steam distribution. Energy efficiency is also integral to new projects in the planning stages at Krka, including variable frequency drives on compressor and mixer motors, replacement of an inefficient thermal oil boiler, and installation of a gas turbine cogeneration system.

During the brief preliminary energy audit work on site, Krka staff worked with the audit team to identify additional energy efficiency

measures. Based on the discussions with management, production and technical staff, inspection of equipment and operating procedures, analysis of plant energy and production data, and measurements of certain process parameters, a list of energy conservation actions have been identified. These are summarized below.

Action ID	Recommendation	Costs (US$) Equipment	Costs (US$) Duties & Instln Costs	Costs (US$) Energy Savings	Years Simple Payback
A.1	Improve steam/fuel metering	6,500	4,000	17,600	0.6
A.2	Thermal oil boiler comb eff	0	500	18,300	0.0
A.3	Boiler air & exhaust temps	0	0	8,800	0.0
A.4	Spray dryer steam preheat	0	10,000	64,000	0.2
A.5	Steam efficiency teams	2,500	10,000	17,600	0.6
B.1	Combustion control blr 1	26,000	16,000	26,500	1.6
B.2	Energy management system	0	50,000	53,100	1.0
C.1	Spray dryer local heat	-	-	-	-
C.2	Spray dryer heat recovery	-	-	-	-
C.3	Adjustable frequency drives	-	-	-	-
C.4	Buildings heat recovery	-	-	-	-
	TOTALS	35,000	90,500	205,900	0.6

CHAPTER 1 -- PLANT DESCRIPTION

Krka is located in Novo Mesto, Slovenia, approximately midway between Ljubljana and Zagreb. This is a medium-sized pharmaceutical/chemical company producing antibiotics, tranquilizers, cosmetics. At a nearby plant glass wool insulation is produced. Krka also operates several thermal springs and health spas in the region. They operate under licenses of Johnson & Johnson, Eli Lilly, ICI, Sandoz and others. Overall 1990 production was worth just over US$ 200 million of which $100 million was exported ($60 million to E Europe and $40 million to the West). Their consolidated income statement for 1990 shows net income of about $9 million on sales of $220 million.

The preliminary energy audit was limited to the main plant where pharmaceutical, medical and cosmetic products are produced. The main parts of the plant covered are described briefly in the following paragraphs.

1.1 Steam Generation

Krka uses four boilers for steam generation, as presented below. Base load and high pressure steam is provided year-round by K1; other boilers are run as necessary, ranging from two low pressure boilers in peak winter periods, to none in the summer season. All boilers use Saacke rotating cup burners.

Boiler Year	Manu-facturer	Steam Production	Steam Pressure	Steam Temperature
K1 1972	Djuro Djakovic	25 t/h max 20 t/h nom	42 bar	450 C
K2 1980	Djuro Djakovic	15 t/h	13 bar	saturated
K3 1965	TPK	5 t/h	13 bar	saturated
K4 1965	TPK	5 t/h	13 bar	saturated

A deaearator provides 105 C feedwater to the boilers. Boiler K1 has an economizer to heat its feedwater to 130 C. K1 has a continuous surface blowdown with heat recovery; boiler water analysis and adjustment of blowdown is performed daily. Sootblowing is performed once every 4-7 days, according to need. Combustion air is taken from the ceiling level of the boiler room,

and mixed with outside air in the fan room below the boiler.

Fuel, feedwater, and steam are metered and recorded hourly manually. However, feedwater and steam flow do not agree; in fact, the steam flow reading is not reliable. An old O_2 probe and sample analysis system installed originally with the boiler is no longer working. The company owns a small portable O_2 meter, but it is rarely used.

1.2 Steam Distribution

Steam is distributed at 4 different pressure levels to various parts of the factory: 40 bar to the turbine and to a pressure reducing station; 10 bar to the pharmaceutical plant, and to a further reducing station; 5 bar to the fermentation systems, and 3 bar for miscellaneous uses, including facility heating systems and sanitary hot water generation. The extraction point on the turbine is too low to feed the 10 bar and 5 bar systems; steam at these pressures is obtained by reducing valves from the high pressure steam, or by reducing the pressure of 13 bar steam from the small boilers (K2 through K4). Unfortunately, there is no steam metering anywhere on the low pressure distribution, and it is not known how much of what steam goes where. A minimum of metering is necessary: at least the steam flow at each pressure level leaving the boilerhouse should be monitored. A more sophisticated, but also more costly, alternative system would meter the steam flow to each unit or department, or at least at the entrance to each building.

In general, the steam distribution system is in very good condition throughout the plant. Leaks are essentially non existent. Some local improvements in insulation are possible; these are addressed in the actions recommended in Chapter 3.

1.3 Electricity Generation/Distribution

Krka generates just under 25% of its electricity consumption. The characteristics of its turbine generator are given below:

Turbine manufacturer:	Jugoturbina
Year:	1972
Maximum power:	3.3 MW
Inlet steam pressure:	39 bar
Inlet steam temperature:	445 C
Extraction pressure:	3 bar
Maximum extraction:	23 t/h
Condensing pressure:	0.05 bar
Maximum condensing flow:	7 t/h
Minimum condensing flow:	2.5 t/h
Generator manufacturer:	Rade Koncar

Generator type:	synchronous
Voltage:	6300 V
Capacity:	4375 kVA

The generation of electricity using the turbine generator is optimized with respect to generation costs versus purchase costs of electricity. The turbine flow varies according to extraction needs, except during the twice daily two-hour peak demand intervals, when maximum condensing flow is put through the turbine. The generator is excited to provide enough reactive power to compensate the system power factor to 0.96-0.97, thus minimizing kVA demand charges. In the summertime, when the need for 3 bar steam falls significantly, the large boiler and steam turbine are taken off line for up to two months, and the small boilers are used to provide necessary process steam.

1.4 High Temperature Thermal Fluid Generation

A high temperature thermal fluid boiler is used to heat circulating oil to temperatures of 280 C for use in two spray dryers. This boiler is fired with a Saacke rotating cup burner, similar to those used on the steam boilers. Fuel is not measured; however circulating oil flow, as well as outlet and return temperatures are measured, allowing calculation of heat output of the boiler. A small economizer is installed in the boiler stack, continuously circulating boiler feedwater from the deaerator.

1.5 Compressed Air

Generation of compressed air accounts for nearly one third of all the electricity consumption at Krka. The great majority of this is low pressure air at 2 to 2.5 bar (30-35 psig) used for bubbling in the fermentation tanks. A flow meter is provided in the main line supplying the fermentation department. Five screw compressors totalling nearly 2 MW (2 x 315 kW; 370 kW; 470 kW; 500 kW) are used to provide the quantity of low pressure air needed. Since capacity control is not built into these compressors, operators must manually select which and how many of the compressors should be operating at any given time. While this is helped by the planning and communications from the fermentation department, the result is nevertheless unsatisfactory: with 3 compressors usually running, the air flow can only be controlled to within 20-25%. This system inevitably also leads to energy waste. Krka is currently evaluating two options for improvement in this system: 1) the purchase of a new centrifugal compressor, with inlet vane control to provide flow modulation as required; and 2) an adjustable frequency speed control system on the motor of one of the existing screw compressors, which would vary the motor speed according to the demand for compressed air.

High pressure compressed air at 10 bar (150 psig) is provided by 3 compressors (90 kW; 145 kW; 200 kW). These compressors unload when the pressure in the system is reached, and cycle according to the air pressure variation. They still consume a residual amount of power (15-20%) when unloaded. Again, it is the operator's choice which compressors and how many to run; procedures should be checked occasionally to ensure that too much operating time is not wasted in the unloaded mode. High pressure air is metered; it is supplied mainly to the final medicine plants and the cosmetics plant.

1.6 Fermentation Department

Of the production departments, fermentation is the greatest energy consumer. In addition to its high consumption of low pressure air, the fermentation process consumes large amounts of electricity for mixing, as well as cooling water for process cooling, and steam for initial heating. Fermentation and other biochemical departments are currently estimated to use approximately 40% of the steam energy in the factory, outside the central power plant. This significant number warrants a better understanding of this consumption. It is recommended that an energy balance on steam consumption be performed for the biochemical departments, identifying the users and measuring, calculating, or estimating their energy consumption. In addition, specific energy consumption ratios be calculated and compared on a regular (monthly) basis. The result will be either a confirmation of the 40% figure and an identification of the major steam users, or the calculation of a new figure, most likely lower, that may well result in a slight savings in energy costs.

Krka is embarking on a major retrofit in the fermentation department, purchasing state-of-the-art equipment to increase production capacity, improve product quality, and reduce energy consumption. The new fermentation reactors will be equipped with adjustable frequency controls on the motors of the mixers, allowing the mixing to be more precisely controlled and reducing electrical power consumption.

1.7 Pharmaceuticals Department

Because of its clean rooms and 100% make-up air areas, this department is a major consumer of both electricity and steam. A major portion of the electricity is consumed in large air handling systems pushing air past filters and coils and in a 350 ton centrifugal chiller, which has recently been purchased to replace older, less efficient reciprocating units. Steam is needed especially in the winter for humidification and heating large quantities of make-up air, and in the summer for the highly inefficient terminal reheat systems, where air is cooled to

dehumidify and heated again to the required temperature. Steam is also used in various sterilization units and autoclaves.

While some energy savings in this department could be obtained by a more intense energy monitoring, the strict requirements of ambient conditions will most likely make it difficult to apply minor savings measures. Enthalpy controls already exist. Among the longer term measures to be considered is the installation of a variable volume air distribution system, or some low temperature air-to-air heat exchangers to recuperate the heat (or cold) of exhaust air, and use it to preheat (or precool) the make-up air. Krka is already thinking of the latter idea, although the payback will most likely be medium to long (4-6 years).

CHAPTER 2 -- ENERGY CONSUMPTION AND EFFICIENCY

Approximate annual energy consumption characteristics are given below. In the following sections, some brief comments on energy consumption, production, and energy management are presented.

Total heavy fuel oil consumption:	11,500 tonnes
Self-generated electricity:	7,700 MWh
Purchased electricity:	19,600 MWh
Peak demand for purchased electricity:	5.8 MW
Annual energy cost:	$ 3.5 million

2.1 Energy Consumption and Production

The analysis of energy consumption and production data provides a good perspective on the operation of the plant. Some of these analyses are already performed by the energy staff at Krka. The graphs in Appendix 1 summarize the energy production and consumption data, are discussed briefly below.

Graph #1 shows monthly variation of purchased electrical and fuel energy, as well as plant production, over the last two years. Graph #2 shows the variation of the composition of total production among three general product categories. These variations could lead to the following observations:

- -- purchased electricity consumption is quite variable from month to month, with some months significantly higher than the mean; also, electricity consumption shows a gradual but consistent increase, without the same increase in mazout consumption or production (both of these effects may be due to self-generated electricity, nevertheless they should be investigated)

- -- production of medical and biochemical products has remained fairly constant, with a slight increase the last few months of 1990

- -- there may be some offset between energy consumption and production (minimum production occurs after the minimum energy consumption); this point is important to understand when doing statistical analysis of the variations

- -- except for the months of low production, the biochemical products consistently make up the greatest portion of the total production.

What is of even more interest is the relation of energy consumption to production. Plotting one versus the other (Graph #3) shows

quite a wide scatter of data. Attempting to draw regression lines, there seems to be very little overall variation: energy consumption seems to be independent of production. This means that energy production is constant regardless of production level, implying that a major part of the energy is used for non-production-related applications, such as lighting and air conditioning. If this is not true in Krka (and it does not appear totally true), then this question should be investigated. Another question that should be asked is why there is such a large scatter in the data: why in a months when about 525 tonnes were produced did the electricity consumption range from 2300 MWh to 3300 MWh, almost 50% higher? (As above, part of the answer may lie with differences in product type and in levels of self generation of electricity.)

Once the data is better understood, and some of the scatter is reduced, graphs such as #3 and #4 can be used to predict energy consumption for production levels, as well as to check the efficiency of production.

A similar kind of analysis can be performed in any specific production area where good data are available. Graphs #5-7 show variations for compressed air use and for spray dryer heat energy consumption. In both of these areas, large variations in data are observed. These extreme variations may be somewhat understandable for compressed air, given the differences in biochemical product types, and given the fact that often what is consumed in one month is counted as production the following month (because of the long production cycle of biochemical products).

For the spray dryers, however, this data should contain much less scatter, since the product is usually the same. Also, Graph #6 shows a relatively high consumption at zero production. For example, if the production is extrapolated to zero, the consumption would be about 3,000 GJ/month. While some "overhead" or "maintenance" consumption is inevitably required, and as discussed in Chapter 3, the efficiency of heat generation for the spray dryers is low, this quantity represents more than half the average energy consumption in the spray dryers. It is altogether too high. One implication is that spray dryer production could be much better planned in order to reduce idling and unnecessary losses.

Graphs #8 and #9 were prepared in an attempt to evaluate the accuracy of Krka's fuel and steam metering. In Graph #8, the metered fuel consumption is plotted along with the fuel consumption based on fuel deliveries on a monthly basis. The error between the two readings is also plotted. In general, the error is slightly higher than should be expected. Also, the error increases significantly during months of low consumption, since fuel

deliveries then become a more significant variable. This implies that further statistical analysis should rather be based on metered fuel than fuel deliveries. Finally, it is noted that metered fuel is usually low compared to fuel delivered.

Graph #9 compares the metering of fuel and steam. Average monthly efficiency calculated from the two meters is plotted and compared to an expected efficiency of 90%. First, significant variation is seen, questioning the accuracy of both meters. Second, either the steam meter is reading high, or the fuel meter is reading low, causing excessively high efficiencies to be calculated. The latter possibility is consistent with the discussion in the previous paragraph.

2.2 Energy Management

In general, energy is very well managed and accounted for at Krka. Between the Technical Director and the Director of the Energy Plant, all energy-related equipment is understood, monitored and maintained. Costs of all forms of energy are calculated regularly, and applied to the production departments according to their energy consumption. As discussed previously, exact steam consumption and exact compressed air consumption is not measured for every department, but is allocated according to empirical formulas; all other energy flows, including electricity, cooling water, chilled water, and thermal fluid are measured and allocated accordingly.

Computer software is used to collect data from electric meters, perform cost calculations for different forms of energy, to determine monthly allocations of energy by department, and to maintain a central data base of energy consumption and historical energy records. In fact, contrary to what is found in many plants in Yugoslavia, where computers need to be purchased to help analyze vast amounts of energy data collected by hand, at Krka, additional metering equipment is recommended to better utilize the capacities of the already installed computer system and the existing experience of the staff in its use.

Krka is actually planning to invest in improving its overall computer-based energy management and accounting system. They are currently in the process of finalizing a contract with a local institute, Jozef Stefan, to develop software to tie in additional metering points (such as new steam meters which Krka is planning to purchase and install) and upgrade the whole energy consumption-to-production analysis.

A final and important point in the energy management discussion applying to Krka is the difficulty of obtaining useful indices when a large variety of products exists. Typically, specific energy

consumption indices have not been performed, due primarily to the complex mix of products. Nevertheless, there are a few products that represent the mainstay of Krka's energy-intensive production, and these should be the starting point for specific energy consumption analysis. A preliminary attempt at this type of analysis is represented by the graphs in Appendix 1 and in the discussion in the previous section.

The company has been active in energy conservation activities, installing heat recovery devices, recovering condensate, reducing peak demand, replacing inefficient equipment with new equipment, manually adjusting combustion controls. They are just finishing a feasibility study for an approximately 6 MW gas turbine cogeneration plant, and are evaluating the possibility of selling to the grid as an independent producer. They are converting to natural gas by the beginning of 1992. The plant seems very professionally run and well managed; equipment maintenance is good.

Nevertheless, there are things to be done. Steam is metered on one of four boilers; fuel is metered on only one. No submetering of steam is performed, and no comparison with production. Electricity is submetered but no specific energy consumption analysis is done. Among the possible instruments useful to the plant would be steam meters for two main production sections, an overall control system for compressed air (this consumes 25% of their electricity), an installed boiler O_2/CO measuring system, some intelligent interfaces to provide additional on-line measurements to their existing computer system, and an improved demand control system or software.

CHAPTER 3 -- ENERGY CONSERVATION RECOMMENDATIONS

In general, Krka shows good awareness of energy and its overall care, especially at the management level. Energy and process fluids (cooling water, chilled water, high and low pressure compressed air) are measured globally, and allocated (many by empirical factors) among the various cost centers, making each production unit explicitly aware of its energy consumption and its relation to the production cost.

There is ample evidence of wise use of energy over the years: a boiler blowdown heat recovery system; an economizer for boiler feedwater preheat installed in the exhaust system of the thermal fluid boiler; a condensate cooler for local sanitary hot water generation; steam distribution lines in excellent condition; burning of waste solvents in a boiler for low pressure steam generation; and good optimization of turbine generator loading according to electricity peak demand periods. In addition, a number of interesting energy conservation projects are in the planning stages.

There are still some things Krka can do to improve or optimize its energy consumption. These energy efficiency recommendations or actions, developed by RCG/Hagler, Bailly as a result of the brief preliminary audit visit, can constitute an important source of cost savings. They can be grouped into three categories: a) energy management at all levels, including operator commitment and awareness; b) short payback investments, dealing largely with improved measurement and control; and 3) additional capital investment in newer, more efficient equipment. These three categories are described in more detail as follows:

A. **Energy management improvement actions:** this first category relates to overall energy management, including monitoring, tracking, and regular analyses of energy consumption relative to production. These actions are usually simple, often imply very little cost, and should be implemented as rapidly as possible. Usually these actions require the awareness and experience of the management to filter down to (or to be imposed on) the operator level, increasing their commitment to improve energy efficiency. Examples include improved control of boiler excess air, regular sootblowing on the large boiler, and improved condensate line maintenance. Some sort of incentive scheme may be usefully applied to obtain more active participation. Actions which fall in this category are coded by "A" preceding the list number. Krka should be able to implement these measures in the next six months, in some cases with assistance from the USAID Emergency Energy Program.

B. **Low-cost and short-term implementable actions:** this second category comprises recommendations usually have paybacks of less than 2 years. Examples of these actions include automated control of combustion efficiency, or improved metering system to allocate steam flow among the major users, providing a better basis for billing and avoiding questions or disagreements on amount of energy used among the different departments. These are also actions in which USAID might be able to participate under this program. Actions of this category are indicated with a "B" preceding a list number.

C. **High cost or long term actions:** this third category and consists principally of technology improvement projects. Actions of this group are shown by a "C" followed by a list number.

Due to the limited time and scope of the preliminary energy audit, measures in the "C" category are not presented in much detail. In some cases, such as cogeneration (which is not treated in this chapter), Krka already has detailed studies on the financial attractiveness of the project. A longer, more detailed energy audit, which would concentrate more deeply on the process, could be expected to yield additional energy-saving recommendations in this category.

3.1 Presentation of Project Forms

Each project identified by the audit team is presented in a stand-alone project form which provides all basic information to qualify the project. The data are provided at the "inventory" level (first order of magnitude approximation), and include the following:

- Description and rationale
- Calculation of savings (energy and others)
- Implementation cost
- Financial analysis limited to the pretax pay-back period
- Scheduling
- Technical risk and reference
- Equipment specification (if required)
- Back-up data and calculations, as necessary.

Action A.1 -- Improve Steam and Fuel Metering

1. PROCESS AREA

Overall power plant energy management and accounting system.

2. STATEMENT OF RECOMMENDATION

Step 1: Improve the monitoring and recording of high pressure steam flow at the boiler outlet. Use this value as the basis of the steam balance for the whole plant. Record daily steam generation totals, and using the daily fuel consumption data, calculate a daily average boiler efficiency. This efficiency should be reported on a daily basis to the boiler engineer, as well as to the power plant (energy) engineer. The efficiency numbers should be evaluated daily, compared to a current standard of 90%, and an explanation given for any significant deviation from the standard. As operating characteristics and monitoring improve over time, the standard should be raised and maintained as high as 92%.

Step 2: Evaluate the performance of the fuel flowmeters. Check their total consumption with respect to fuel deliveries, as well as to steam generated once the steam meter has been replaced. Clean and calibrate these meters.

Step 3: Install flowmeters to measure steam flow at each of the major pressure levels. Using these data, update the plant steam balance and steam cost allocation to the various departments. Eventually, these data can be used to compare with production in the various departments on a monthly basis.

3. DESCRIPTION/RATIONALE

The existing meter for the main steam generated in the power plant is not reliable. It is an orifice meter, and does not perform well at low flowrates, which occur often in the plant. This unreliable reading throws into question all the energy monitoring information. This meter should be the most accurate and reliable in the plant in order to provide a solid base for energy monitoring and accounting operations. A new, more accurate flowmeter, such as proposed in the specification below, will ensure that this important information is properly recorded and analyzed.

4. BENEFITS

4.1 Energy Savings

Energy savings are obtained as a result of management review of the analyzed data, and the resulting instructions to correct or improve energy use. The very fact that the staff know this data is being monitored and analyzed regularly is already partial incentive to optimize operation. The installation of a more rigorous energy management/accounting system can be expected to bring anywhere from 0.5 to 3% reduction in energy consumption for the high pressure boiler.

- Assuming 1% reduction in the 9350 t/y mazout energy consumption:

1/100 x 9350 t/y x din 4150/t x 1/22 $/din = $17,600/y

5. IMPLEMENTATION COSTS

The estimated cost of a new steam flow meter, using either the annubar or orifice plate system is approximately $6,500.

Installation costs are estimated at approximately $500; customs duties and taxes could reach as high as $3,500, for a total cost to the plant of $4,000.

6. PAYBACK

The payback period is approximately 7 months.

7. SCHEDULE

Task 1 -- completion date: May 25, 1991

HBI gets quotations from US manufacturers.

Task 2 -- completion date: June 26, 1991

Krka reviews specifications and makes recommendations for selection of supplier.

Task 3 -- completion date: July 1, 1991

USAID gives clearance for equipment procurement based on HBI financial and economic study and evaluation of quotations.

Task 4 -- completion date: July 8, 1991

HBI sends purchase orders for equipment.

Task 5 -- completion date: August 31, 1991

Shipment of equipment arrives in Yugoslavia. Krka completes a workplan for the installation of the new steam flow meter. Krka also develops a daily calculation and reporting procedure for overall boiler efficiency of the high pressure boiler.

Task 6 -- completion date: September 20, 1991

Krka installs the steam flow meter, and begins daily analysis of its measurements.

Task 7 -- completion date: September 20, 1991

HBI reviews Krka installation, and its first few days of steam flow data.

8. TECHNICAL RISK AND REFERENCE

There is no significant risk involved in the implementation of this project.

9. SPECIFICATION OF EQUIPMENT

Type:	Orifice plate or annubar type steam flowmeter
Physical: sensors	Locally mounted flow, pressure, and temperature sensors 30 m shielded cable to control room Panel mounted display module
Input Steam Flowrate:	5-30 t/h, nominal 6-24 t/h Steam pressure: max 45 bar, nominal 39 bar Steam temperature: max 460 C, nominal 450 C Steam pipe diameter 150 mm (DIN standard)
Output:	Readout: steam flow rate kg/h (or tonnes/h), cumulative steam flowrate Readout: heat flow rate MJ/h (optional) steam pressure (bar) and temperature (C) 4-20 mA to existing chart recorder (steam flow, pressure, temperature)
Power:	input 220V 50Hz
Spares:	to be specified by bidder, adequate for 18 months of operation

Optional quote

Bidder can also quote on simple steam flow meter, with above conditions, without additional option of heat flow measurement (MJ/h)

Action A.2 -- Improve Combustion Efficiency in Thermal Oil Boiler

1. PROCESS AREA

Heat generation: combustion control for the thermal oil boiler

2. STATEMENT OF RECOMMENDATION

Adjust the mechanical linkages connecting the fuel valve and the air damper on the thermal oil boiler to reduce the excess air in the system. This activity should be combined with measurement of oxygen and CO or combustibles in the flue gases to ensure that the proper excess air settings are obtained.

3. DESCRIPTION/RATIONALE

The thermal oil boiler consumes a significant portion of mazout fuel at Krka, totaling approximately 2150 tonnes per year.

Measurements of stack gases on this boiler provided the following results:

	Existing	Improved
Boiler:	Thermal Fluid	Thermal Fluid
Load:	80%	80%
Fuel:	mazout	mazout
O_2:	8.5%	
CO:	3 ppm	< 10 ppm
combustibles:	0.02%	< 0.05%
Smoke No.:	2	2
Stack temperature:	315 C	315 C
CO_2 (calculated):	9%	13.5%
Excess air:	64%	12%
Comb. efficiency:	79.0%	84.7%
Overall efficiency:	78.0%	83.7%

This boiler is operating with an excessively high quantity of excess air. As shown above, adjustment of the air can improve the efficiency, if it is ensured that all other conditions remain constant.

4. BENEFITS

4.1 Energy Savings

Energy savings are calculated based on a 5.7% average improvement of efficiency of heat utilization. This translates to approximately just over 6% savings in fuel consumption. Assuming

some (25%) heat recovery on the economizer, a 4.5% overall fuel savings can be estimated.

- at 4.5% average improvement:

2,150 t/y x 0.045 x din 4150/t x 1/22 $/din = 18,250 $/y

5. IMPLEMENTATION COSTS

Cost of the visit of a qualified boiler technician should not exceed $500. It is expected that no new parts will be needed.

6. PAYBACK

The payback period is approximately 0.03 years, or less than 1 month.

7. SCHEDULE

This task should be undertaken as soon as possible. This savings translates into $1500 per month. Thus even if it is planned to replace this boiler with a high pressure steam loop within a few months, it is still worthwhile to perform this fuel-air adjustment.

8. TECHNICAL RISK AND REFERENCE

This adjustment procedure carries no risk. Depending on the quality of the burner and the mixing of the air, it is possible that a level of 3% oxygen may not be reached without an increase in combustibles and smoke number. In that case, the savings will be correspondingly reduced.

Action A.3 -- Reduce Air Temperature Difference across the Boiler

1. PROCESS AREA

Steam generation system: high pressure boiler

2. STATEMENT OF RECOMMENDATION

Review operating procedures on the high pressure boiler in order to maximize air inlet temperature and minimize the exhaust temperature of boiler gases. Specifically, focus on the following two measures:

(a) increase the frequency of soot blowing in the boiler, in order to keep heat transfer surfaces clean, maximize heat transfer, and minimize the outlet temperature of the exhaust gases

(b) review the arrangement of the boiler combustion air intake system; maximize the air coming from the boilerhouse ceiling area, and minimize the use of direct outside air.

3. DESCRIPTION/RATIONALE

During the audit measurements, the boiler exhaust temperature was measured between 10 and 20 C higher than design conditions of 180 C at full load for the boiler. This may be due to a variety of reasons. It was also discussed that sootblowing is performed only occasionally, perhaps on a weekly basis. While sootblowing more often may not completely solve this problem, it is recommended that sootblowing be performed daily or every two days, in a more concerted attempt to minimize accumulations of soot on heat transfer areas.

The boiler room has an intake manifold for the combustion air fan located at the ceiling level, approximately 10 m above the ground. Air temperature here is easily 5 C higher than at ground level, and up to 30 C higher than outside air temperature. However, the air from this duct is tempered with outside air before reaching the combustion air fan (in fact, most of the air is outside air). Reasons for why this system is no longer in use should be investigated, and the system re-commissioned. All the required ducting is still installed. Use of this system can increase combustion air temperatures by 10 to 20 C.

4. BENEFITS

4.1 Energy Savings

Approximately 1% in efficiency improvement is obtained for every 20 C reduction in delta T between combustion air and exhaust gases. Assuming that with these two measures, a consistent improvement of 10 C over the year could be obtained, an efficiency improvement of 0.5% can be counted on. Savings will be approximately:

9,350 t/y x 0.005 x din 4150/t x 1/22 $/din = 8,800 $/y

5. IMPLEMENTATION COSTS

Implementation costs are minimal, and are not considered.

6. PAYBACK

The payback period for this project is immediate.

7. SCHEDULE

This project should be implemented immediately.

8. TECHNICAL RISK AND REFERENCE

This project presents no risk in its implementation.

Action A.4 -- Use Steam to Preheat Spray Dryer Air

1. PROCESS AREA

Spray dryer for biochemical products

2. STATEMENT OF RECOMMENDATION

Connect a low pressure steam line to the existing preheat coil already installed at the spray dryer air inlet. Connect a condensate line and steam trap to the outlet, and tie into the existing condensate return system. Use this 3 bar steam to provide preheating of air right before it passes across the existing hot oil coils.

Alternately, use the hot water system for preheat. The hot water is currently connected to the preheat coil in question, and all that is needed is to open the valves. Care should be taken that the hot water generator has sufficient capacity to provide the quantity of hot water necessary.

3. DESCRIPTION/RATIONALE

A preheat system is currently connected to the spray dryer inlet, but it is not used. Whether steam or hot water is used for preheat, there are two important advantages:

(a) Generation of steam (and even hot water) is more efficient (90%) than the generation of hot oil (80%).

(b) For the cost of production of 40 bar steam, an amount of electricity will be generated at no cost as the steam passes across the turbine to be reduced to 3 bar.

This system is installed and ready to be used.

4. BENEFITS

4.1 Energy Savings

Energy savings are estimated based on the following assumptions:

-- energy of 2150 tonnes x 40 GJ/tonne = 86000 GJ/y is used in the spray dryer, but at an efficiency of 75%

-- preheat will supply 25% of this energy

-- 2800 MJ/tonne of steam

-- 140 kWh/tonne of steam, marginal generation from extraction according to the turbine diagram

With this data, the amount of electricity generated due to the additional steam passing across the turbine can be estimated:

86,000 GJ/y x 0.75 x 0.25 x 1/2.8 t/GJ x 140 kWh/t

= 808,000 kWh/y @ $0.08/kWh = $ 64,000/y

5. IMPLEMENTATION COSTS

Implementation costs are considered insignificant for hot water implementation. If steam is used however, control and safety valves should be installed. Estimated cost would then be approximately $10,000.

6. PAYBACK

The payback period for this project is 0.2 years, or 2 months.

7. SCHEDULE

This project should be implemented immediately, especially since the summer season, during which there is an excess of 3 bar steam, is coming up.

8. TECHNICAL RISK AND REFERENCE

This project presents no risk in its implementation.

Action A.5 -- Set Up Steam System Efficiency Teams

1. PROCESS AREA

Steam and condensate system throughout the plant (this activity is already in the planning stages at Krka).

2. STATEMENT OF RECOMMENDATION

Set up one or more teams to methodically review the steam and condensate system, identifying condensate to be returned, insulation that should be improved, steam leaks that should be repaired, and steam traps to repair or replace.

2.1 Evaluation of Condensate Return

Review all condensate users and check their condensate drain systems. Check for condensate quality and quantity; identify amounts which must be dumped due to contamination. Identify which users are connected to which intermediate condensate storage tanks. Evaluate flash steam losses at intermediate condensate stations, and check the possibility of recovering heat from the condensate systems to avoid flash steam losses. Check condensate storage tanks and return piping for leaks.

2.2 Steam Trap Testing Program

Inventory all steam traps. Begin a regular testing program using the ultrasonic test instrument, ensuring that every trap is tested on a regular basis at least twice per year. Tag or otherwise identify each malfunctioning trap and schedule its repair or replacement as soon as possible.

2.3 Review Steam Line Insulation

Review quality of insulation in the major user areas. Replace or upgrade insulation as necessary. Consider the use of specially made insulation pieces allowing easy removal and re-installation for valves and fittings. This should be looked at especially for the main steam distribution headers in the boilerhouse area.

3. DESCRIPTION/RATIONALE

Overall, the steam distribution system is in very good condition. Steam leaks are essentially non-existent. Only a few instances of potential improvement were found. In the main steam distribution room, where two or three steam headers are located, many valves and

fittings are not insulated. This causes a high temperature in the whole area around the room, affecting the life of small motors and equipment in the area, and contributing to energy losses. While it is understandable that maintenance must often be performed on these valves and fittings, that is not sufficient cause to leave them uninsulated: removable insulation should still pay back in one year or less.

Steam distribution in the older departments, such as synthesis and fermentation, while not as well maintained as in the central plant is adequately insulated, with valves and fittings leak-free and in good condition. For the most part, these departments perform their own maintenance on the systems in their area.

While condensate lines exist from all the departments in the factory, calculations by the audit team in conjunction with the boiler engineer showed an average of barely 50% condensate returned from outside the central plant over the last year. This is due to a number of reasons, including: 1) contamination of condensate, resulting in its disposal despite a condensate treatment (demineralization) station; 2) flash losses, due to malfunctioning traps and poorly designed collectors; and 3) poor operating practice and unknown reasons. Since steam flow to the different departments is not known, there is no easy way to perform a condensate balance to better identify the problem areas.

Krka has already begun setting up a team to check and evaluate steam and condensate systems throughout the factory. Among their activities should be the following: 1) identify quantities of condensate for different modes of operation in the various departments, and trace them to the condensate collection tanks; 2) determine the quality problems of the condensate, and develop ways to avoid contamination; 3) inventory, and test on a regular basis, all steam traps in the factory, tagging malfunctioning traps and following up their prompt repair or replacement; and 4) develop other ways to reduce flash steam losses at condensate collection points. The successful installation of a condensate subcooling system, with heat recovered for hot water heating is a good model to follow at other condensate collection points.

Use of portable instruments will allow the testing of steam traps, boiler water, and electrical equipment to ensure that equipment is operating in optimum condition. While the operation is generally good, the use of instruments provides a basis for an optimization of operation, offering energy savings of several percent. In addition, regular testing of plant equipment improves the staff knowledge and understanding of the equipment, and can serve as a basis for a better preventive maintenance program.

4. BENEFITS

4.1 Energy Savings

Energy savings are estimated only: experience has generally shown possibilities of improvement of 1 to 5% in situations where efficiency teams are assigned to carefully review the distribution systems. In the case of Krka, this quantity is estimated to be 1%, based on the fuel consumed for steam generation.

Leaking steam traps identified/repaired:

9,350 t/y x 0.01 x din 4150/t x 1/22 $/din = 17,600 $/y

5. IMPLEMENTATION COSTS

Implementation costs include handheld thermometer, perhaps an ultrasonic tester, as well as spares for steam traps, piping, and valves. Portable instruments may cost on the order of $2,500, while equipment and spares depend on the findings of the efficiency teams. A figure of $10,000 should easily cover the major losses. Thus, the total implementation cost is estimated at $12,500.

6. PAYBACK

The payback period for this project is 0.7 years, or 8 months.

7. SCHEDULE

This project, already in the planning stage, should be pursued immediately.

8. TECHNICAL RISK AND REFERENCE

This project presents no risk in its implementation.

Action B.1 -- Improve Combustion Control in Main Boiler

1. PROCESS AREA

Steam generation: combustion control for the high pressure boiler

2. STATEMENT OF RECOMMENDATION

Install an automatic exhaust oxygen trim control system to fine tune the fuel/air ratio at the burners. The system will provide a secondary adjustment of fuel flow relative to air flow in order to maintain a manually set O_2 setpoint value. The system should also provide continuous recording of O_2 values at the mounting box. In addition, instantaneous measurements of both CO and O_2 should be provided in the control room. Operators should adjust the minimum values of O_2 in the exhaust gas depending on its CO content.

At the earliest opportunity, even before installing the O_2 trim system, Krka should have the mechanical linkages adjusted on the two burners serving the high pressure boiler. As discussed below, this linkage is not sufficiently reducing the air flow at lower boiler loads, causing operation at excess air levels that are too high and resulting in fuel waste.

3. DESCRIPTION/RATIONALE

The steam boilers consume a majority of the mazout fuel at Krka, accounting for approximately 9,350 tonnes out of the 11,500 tonnes total annual consumption.

Measurements performed on the high pressure boiler during the audit showed a significant variation in exhaust O_2 levels over time, due to the wide variations in boiler load. In addition, O_2 levels were found to be slightly higher than design at 80% load, and significantly higher than design at 60% load. While the higher excess air at lower load could possibly be reduced by adjustment of the mechanical linkage, a consistent trim based on an O_2 setpoint would ensure continuous operation at optimum conditions, regardless of boiler load.

Flue gas measurements were performed on boilers K1 and K3 which were operating during the audit visit. Results of measurements are given below (approximately 1% radiation, convection and blowdown losses are assumed in order to calculate overall efficiency).

Boiler:	K1	K1	K3
Load:	65%	82%	50%
Fuel:	mazout	mazout	mazout
O_2:	5.1%	2.9%	2.0%
CO:	6 ppm	12 ppm	3 ppm
combustibles:	0.04%	0.14%	0.02%
Smoke No.:	2	2.5	2.5
Stack temperature:	194 C	204 C	195
CO_2 (calculated):	12%	13.6%	14.3%
Excess air:	30%	15%	10%
Comb. efficiency:	90.0%	90.6%	91.4%
Overall efficiency:	89.0%	89.6%	90.4%

The following comments and conclusions result from these measurements:

- Measurements on boiler K1 show that at high load, O_2 levels and excess air are slightly higher than expected (design data shows O_2 levels should be approximately 2% in the exhaust gases), but the smoke number is acceptable. The combustibles are at a relatively high level, thus making it difficult to argue for reduction in excess air without improving the fuel atomization at the burner. With proper burner maintenance and conditions, however, the excess air should be reduced.

- At a lower load, excess air rises. This is due to the poor adjustment of the mechanical linkages relating the fuel valve and the air damper. Upon observation, it was noted that for small changes in the fuel flow, air flow did not change at all. The mechanical linkage should be adjusted, removing the play, and excess air reduced. The burners should be capable of operating at close to 2% exhaust O_2 at this load.

- Stack temperatures are relatively high. Design stack temperatures are approximately 180 C at full load. Sootblowing frequency should be increased to try to reduce this temperature.

- The small boiler shows good operation with very low excess air even at low loads. This should be a model for the other two small boilers that were not tested during the audit visit.

4. BENEFITS

4.1 Energy Savings

Energy savings are calculated at approximately 1.5% of the total annual fuel consumption, based on a 0.5% efficiency improvement at 80% load and a 1.4% efficiency improvement at 60% load and below.

- at 1.5% average improvement:

9,350 t/y x 0.02 x din 4150/t x 1/22 $/din = 26,500 $/y

5. IMPLEMENTATION COSTS

The installed cost of the systems is estimated at $ 42,000.

	Cost of Equipment (USAID project)	Duties, taxes, install'n (plant)	TOTAL COSTS
O_2 Trim Control System	$ 16,000	$ 10,000	$ 26,000
CO Sensor/Analyzer	10,000	6,000	16,000
TOTAL	26,000	16,000	42,000

6. PAYBACK

The payback period is approximately 1.6 years, or 19 months.

7. SCHEDULE

Task 1 -- completion date: May 25, 1991

HBI gets quotations from US manufacturers.

Task 2 -- completion date: June 26, 1991

Krka reviews specifications and makes recommendations for selection of supplier.

Task 3 -- completion date: July 1, 1991

USAID gives clearance for equipment procurement based on HBI financial and economic study and evaluation of quotations.

Task 4 -- completion date: July 8, 1991

HBI sends purchase orders for equipment.

Task 5 -- completion date: August 31, 1991

Shipment of equipment arrives in Yugoslavia. Krka prepares a workplan for installation and startup of the system. Krka develops new format for data collection in the boiler control room to include O_2 and CO measurement logging, as well as a brief training program for boiler technicians to work with the new system.

Task 6-- completion date: September 20, 1991

Krka presents results of initial operation tests using the new O_2 trim control system. O_2 and CO values are used to show the improvements in the boiler efficiency.

Task 7-- completion date: September 20, 1991

HBI reviews Krka operating procedures and results, and assists in making additional energy-saving recommendations based on the test results.

8. TECHNICAL RISK AND REFERENCE

Proper operation of the instruments presents no risk to the company. As part of the operating prccedures mentioned in Task 6, instructions for instrument operation should be translated or adapted into Slovenian, and a detailed training session should be provided to the operators.

9. SPECIFICATION OF EQUIPMENT

General Description

A remote (stack) sensing/analyzing/control unit for a steam boiler 20 t/hr, 40 Bar (50 million Btu/h, 600 psi) which will measure O_2 and CO on a continuous basis with remote board mounted two (2) pen strip chart recording. The O_2 signal is the control point for the fuel/air trim system, which will preferably act on the fuel The Sensing/Analyzing unit must be suitable for harsh environments.

Bidders should include in their bid:

> If their product requires any additional utilities, IE. Cooling water, steam, compressed air?
>
> Best price, delivery, terms of payment, warranties, cost for and availability of installation/training support in Hungary.

List of users with telephone # and name of contact.

Physical:	Stack-mounted sampling probe Remote board with sample conditioner and O_2 and CO continuous recording Panel mounted O_2 and CO meters for control room 5 m from sampling probe to remote board; 15 m to control room
Input:	Exhaust gases, stack temperature max 600 C, nominal 180 C
Output:	O_2: 0-21%, continuous recording plus panel display CO: 0-2000 ppm, continuous recording plus panel display 4-20 mA signal for control room readout, both O_2 and CO Control signal for trim on fuel or air flow based on O_2 measurement (to be specified by the bidder)
Power:	220V 50Hz
Accessories:	Other control elements to be specified by the bidder
Spares:	to be specified by the bidder for at least 2 years of continuous operation

Action B.2 -- Improve Overall Energy Monitoring System

1. PROCESS AREA

Overall plant: energy management and accounting system.

2. STATEMENT OF RECOMMENDATION

Update the existing computerized energy monitoring system to make it plant-wide and to allow centralization of a wide variety of production and energy consumption data. Among the functions that should be considered for such a system are included the following:

(a) improve electrical demand monitoring, turbine generator optimization, and calculation of electricity costs

(b) automate inputs from electricity (kWh) meters throughout the plant on a monthly, and eventually, on a daily basis

(c) allow for inputs from steam, water and fuel meters on a daily or monthly basis

(d) allow daily production data from all the different departments to be entered into the centralized system

(e) output specific energy consumption parameters, variations and statistical analysis.

Use this system initially to calculate the electrical side of the consumption, where expensive metering does not need to be added. Eventually, build up the system with additional steam meters to properly cover the thermal energy side.

Use this system as a management tool to more closely supervise the energy consumption of the various departments relative to their production.

3. DESCRIPTION/RATIONALE

A simple computerized energy management system currently exists at Krka. This system is focused specifically on the turbine generator. It needs software improvements for this application, and it should be expanded to cover at least the important energy flows in the plant.

Electricity consumption is measured throughout the plant by over 100 electric meters. Each 6 kV motor, and all the major 400 V

panels have their own meters. These meters are tied into a management information system computer, but because of the large number, they are not analyzed regularly, except for the monthly readings which are used for cost center billing purposes.

Information of the type presented in Appendix 1 and discussed in Chapter 2 is not normally analyzed at Krka. An automated system that will allow some of these types of parameters to be readily available to management can help to instill a greater awareness and carefulness on the part of the production staff.

4. BENEFITS

4.1 Energy Savings

Energy savings are obtained as a result of management review of the analyzed data, and the resulting instructions to correct or improve energy use. The installation of a more rigorous energy management/accounting system can be expected to bring anywhere from 0.5 to 3% reduction in energy consumption.

- Assuming 2% reduction in the 19,600 MWh/y electric consumption:

  2/100 x 19,600 MWh/y x 1000 kWh/MWh x $0.08 kWh = $31,400/y

- Assuming 1% reduction in the 11,500 t/y mazout consumption:

  1/100 x 11,500 t/y x din 4150/t x 1/22 $/din = $21,700/y

Total savings are estimated at $ 53,100.

5. IMPLEMENTATION COSTS

The cost of a centralized energy management and monitoring system can vary widely depending on the size and sophistication of the system. It is estimated that an adequate system costing approximately $50,000 can be installed to perform all the necessary functions at Krka.

6. PAYBACK

The payback period is approximately 1 year.

7. SCHEDULE

Apparently, the design of such a system is already in the planning stages at Krka. Initial discussions have begun with Institut Jozef Stefan to define and configure such a system. These discussions should be pursued: the local expertise of the Institut appears to be the surest way for Krka to obtain good energy efficiency experience and proper technical support over the long term.

8. TECHNICAL RISK AND REFERENCE

There is no significant risk involved in the implementation of this project. Nevertheless, it is recommended that a great deal of planning effort go into the proper design of such a system. As in any computerized system, a proper understanding of the limitations of the data entering the analysis is the key to making proper use of the analyzed data.

Action C.1 -- Localize Spray Dryer Heat Generation

Current consumption of fuel for generation of hot air for the spray dryers is estimated to cost approximately $400,000 annually. Krka is aware of the inefficiency (and fire danger) of the existing heat generation system for the spray dryers. They are planning to change over to high pressure steam heating, along with low pressure steam preheating as presented in Action A.4. This method, while more efficient, still presents problems of reliability and distribution losses.

Since Krka will be converting to gas over the next two years, it is recommended that the local generation of spray dryer heat be considered. A gas-fired air heater located at the inlet of the spray dryer would be the most efficient, safe, inexpensive, and reliable method for providing heat for the spray dryers.

Such a system could claim energy savings of 15 to 20% of the existing energy input. This savings should be evaluated with respect to the costs of setting up a gas-fired air heater at the spray dryer intake.

When such a system is being evaluated, the burner considered should be capable of handling preheated combustion air of 60 C (see Action C.2).

Action C.2 -- Recover Heat from Spray Dryer Exhaust

As discussed in Action C.1, spray dryer operation costs approximately $400,000 in energy per year. Of this, about 25% is wasted in hot air generation, 50% goes to process drying, and about 25% is rejected as hot air. Recovering this heat could provide energy savings of $30,000 to $35,000 per year.

The costs of heat recovery would be high, however, and payback would most likely be close to 3 years. An important consideration in the installation costs is the relative consumption between the two spray dryers, something not considered during the preliminary audit. If two completely separate systems are required, costs will nearly double. If only one system is installed, savings may be significantly lower.

Furthermore, maintenance and environmental issues must be addressed. For example, cleaning of the heat exchange surfaces could become a significant maintenance problem, as the dust clogs the surfaces. More importantly, exhaust gas quality must be considered. Currently, the exhaust gas is being sprayed with water, reducing the particulate emissions, but also cooling it and making heat recovery less attractive.

Krka has considered such an investment in the past; it may be worthwhile to re-evaluate this project in light of current energy prices, and with regard to the construction work that is expected to take place on the spray dryer when the hot oil system is replaced.

Action C.3 -- Install Variable Frequency Drives for Air Compressors

Air compressors at Krka consume over one-third of the electrical energy at the plant. The majority of this energy goes to the low pressure (2 bar) air compressors. Not only are these screw compressors very large consumers, they have no individual capacity modulation capability. Each compressor operates at either full capacity or at zero load. Since the consumption of air is variable with production, the compressor operators are always trying to provide the closest combination of different compressors to match the load.

This manual control provides slow response to increases in air requirements, and can result in problems with the production process. In addition, a significant amount of energy can be wasted by running excessive compressor load in order to cover potential peak periods.

The installation of a variable speed drive using frequency variation to electronically change the motor speed in response to a control signal (air pressure, for example) will significantly improve this problem. A minimum of one, and preferably two, compressors should be equipped with this ability to vary capacity efficiently.

Krka is planning to purchase a new centrifugal compressor with an adjustable frequency drive. This will provide a major step in better meeting process requirements and improving energy efficiency. Based on the operating experience with this compressor, decisions to purchase an additional compressor or drive can be made.

It should be noted that Krka is also planning to purchase adjustable frequency drives for the motors of the mixing paddles in the fermentation tanks of the biochemical facility. This is part of an overall process upgrade, and will provide better production control as well as energy savings.

Action C.4 -- Building Air Heat Recovery

A large portion of the heating and cooling energy used in the medicine production facility goes to providing 100% outside air for very specific ventilation applications and requirements. This means that the energy imparted to air supplied to these rooms is soon wasted as the air is vented to the outside.

The typical solution to such a problem is to use the outgoing air to preheat the incoming air. Thus, in the winter, if the air leaving the rooms is at 22 C, and the inlet air is at 0 C, energy requirements for heating can be reduced by 60% if a heat exchanger is used. Heat pipe heat exchangers are often used in such an application, since the low temperature difference requires very high heat transfer coefficients.

A heat pipe heat exchanger application would be quite expensive however, and a more thorough study should be performed. Such a study should take into account the seasonal variation of ambient temperatures, the number of 100% outside air applications, the total volume of air to be heated, the possibility to use the same system to pre-cool air in the summer, and the physical installation requirements and constraints, including purge requirements to avoid contamination.

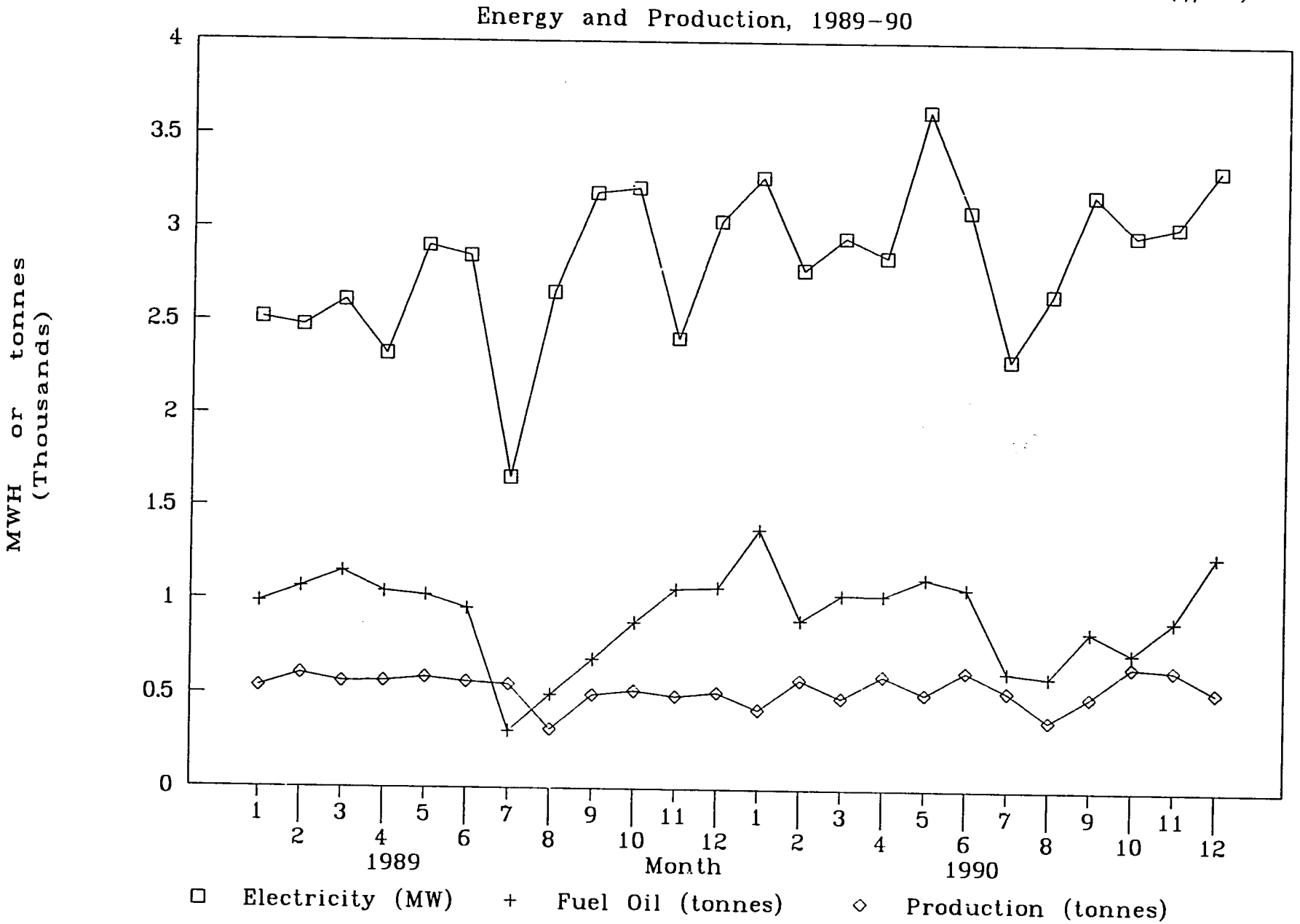
Typical paybacks range from 3 to 5 years on similar low temperature air-to-air heat recovery systems. A brief study will immediately show whether such an action is worth pursuing for Krka.

KRKA, TOVARNA ZDRAVIL, NOVO MESTO

APPENDIX 1 -- ENERGY AND PRODUCTION GRAPHS

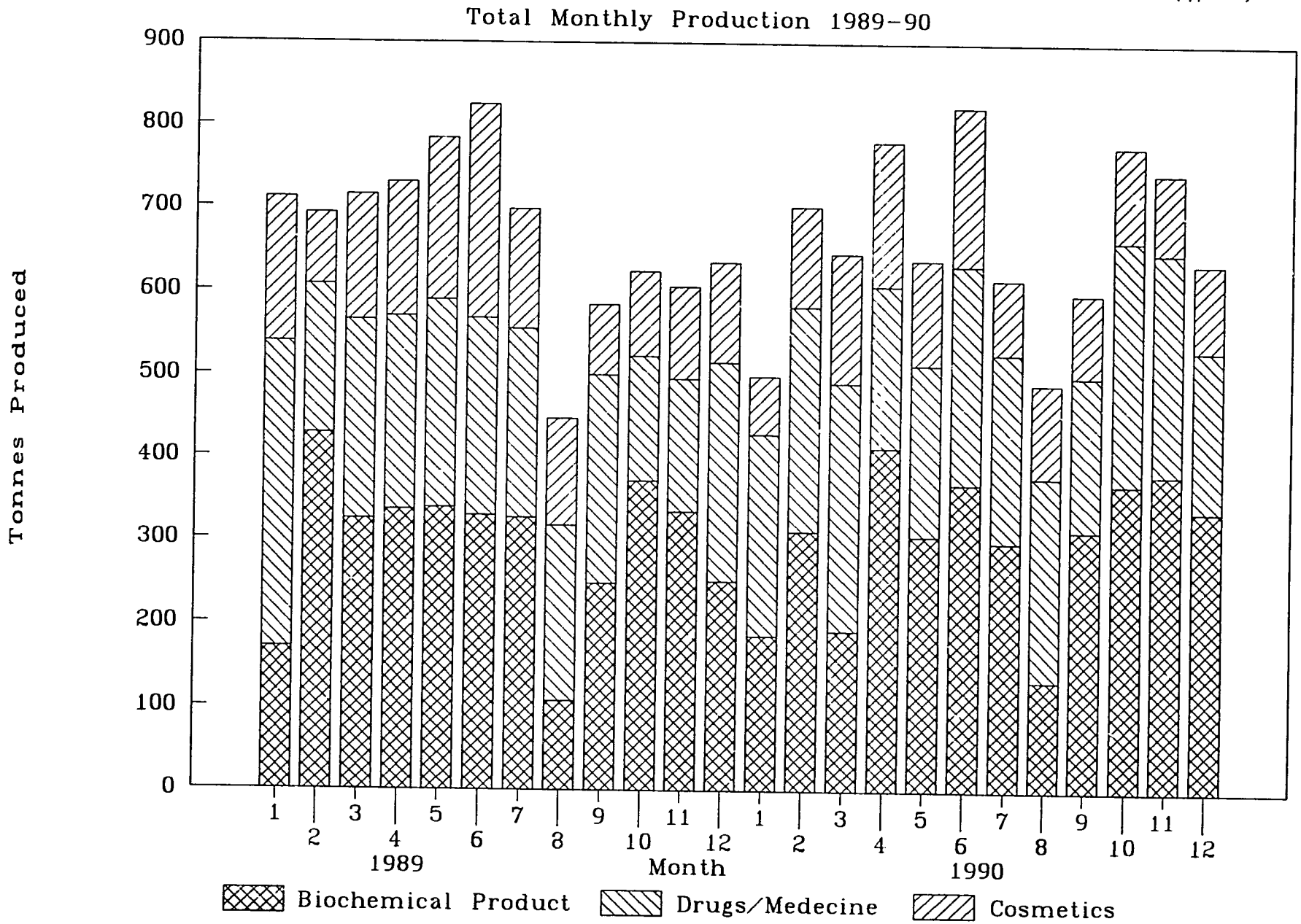
(Note: Cosmetics production is excluded in all graphs except Graph #2)

KRKA, Tovarna Zdravil, Novo Mesto (#1)

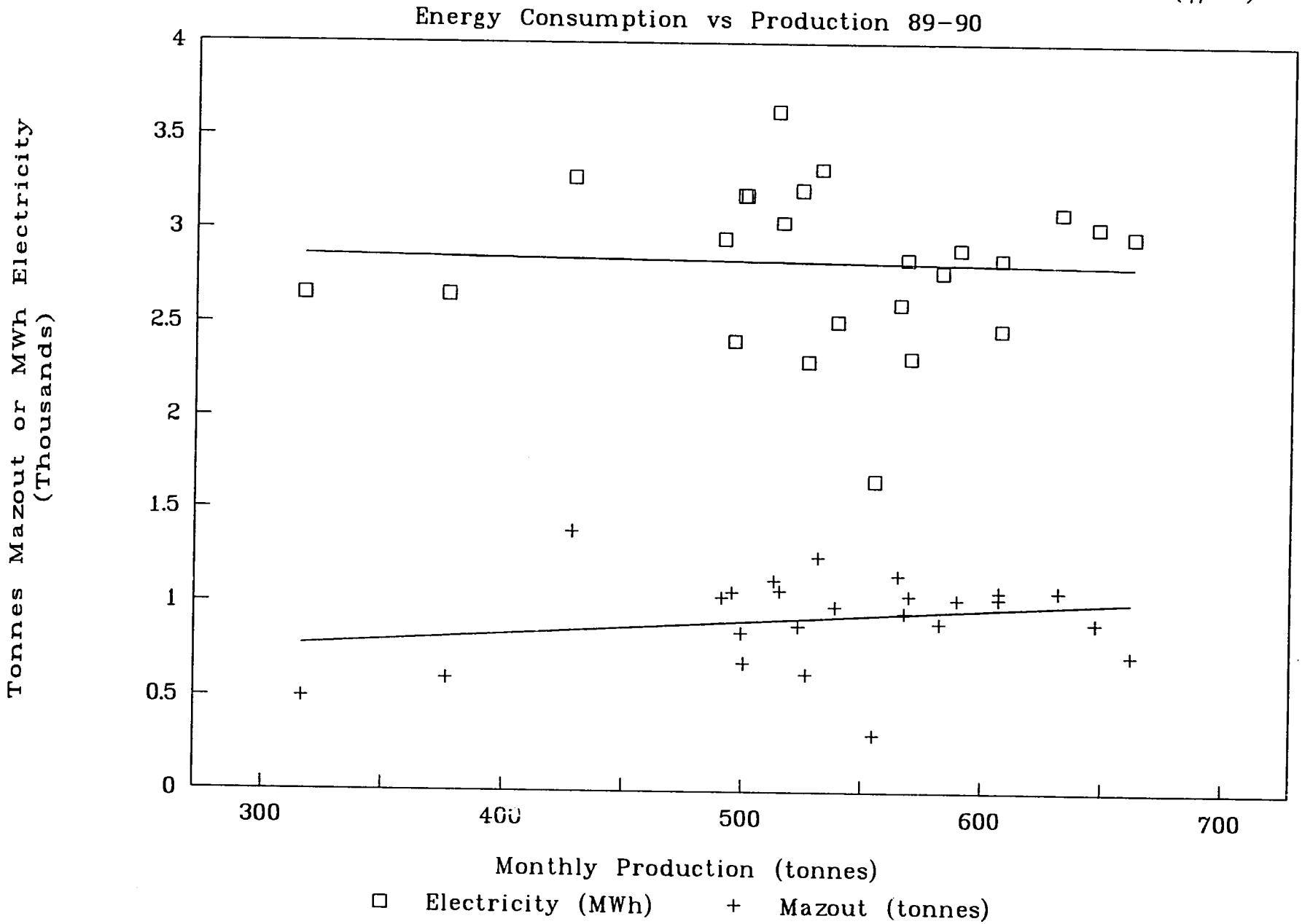


dh.

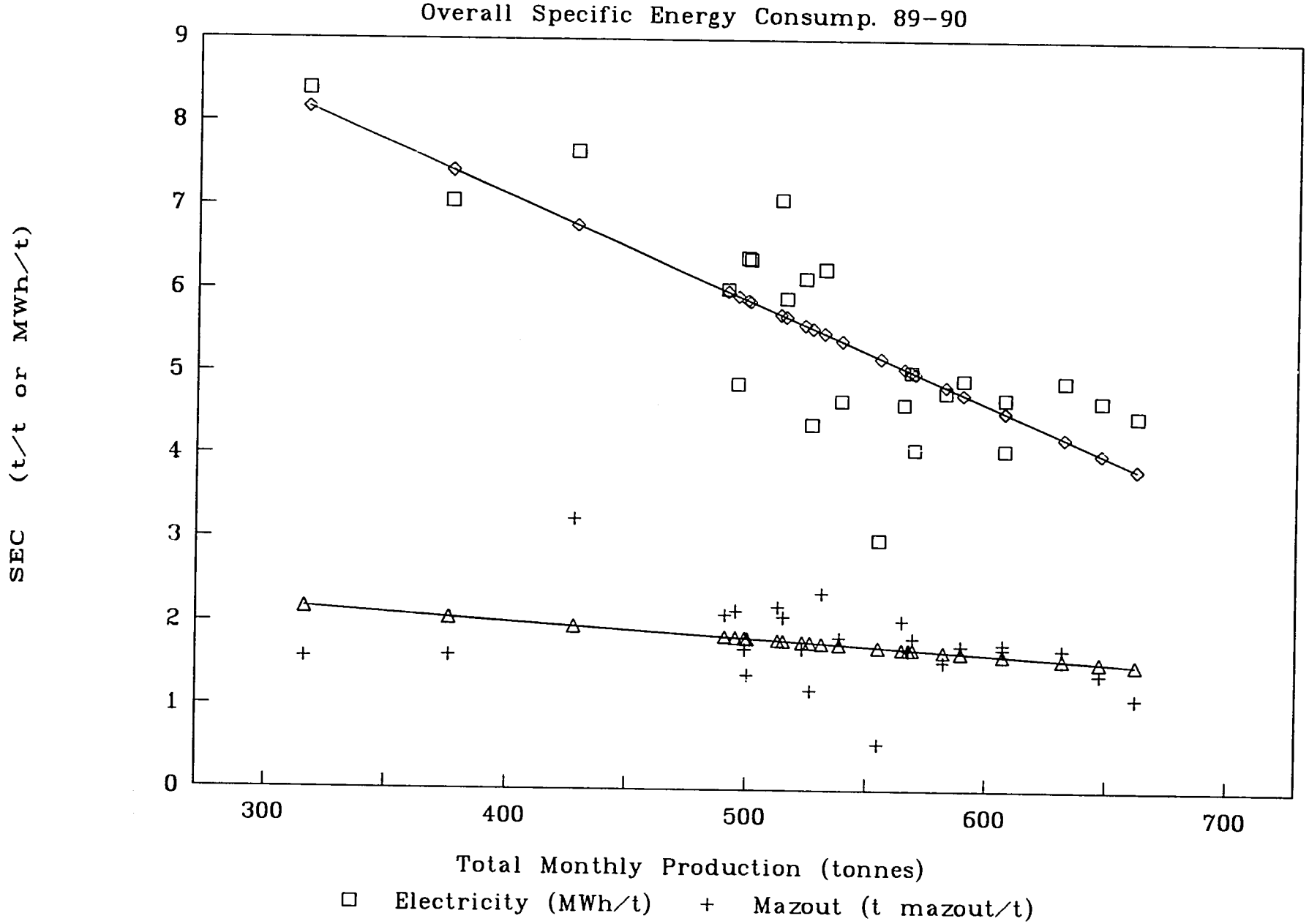
KRKA, Tovarna Zdravil, Novo Mesto (#2)



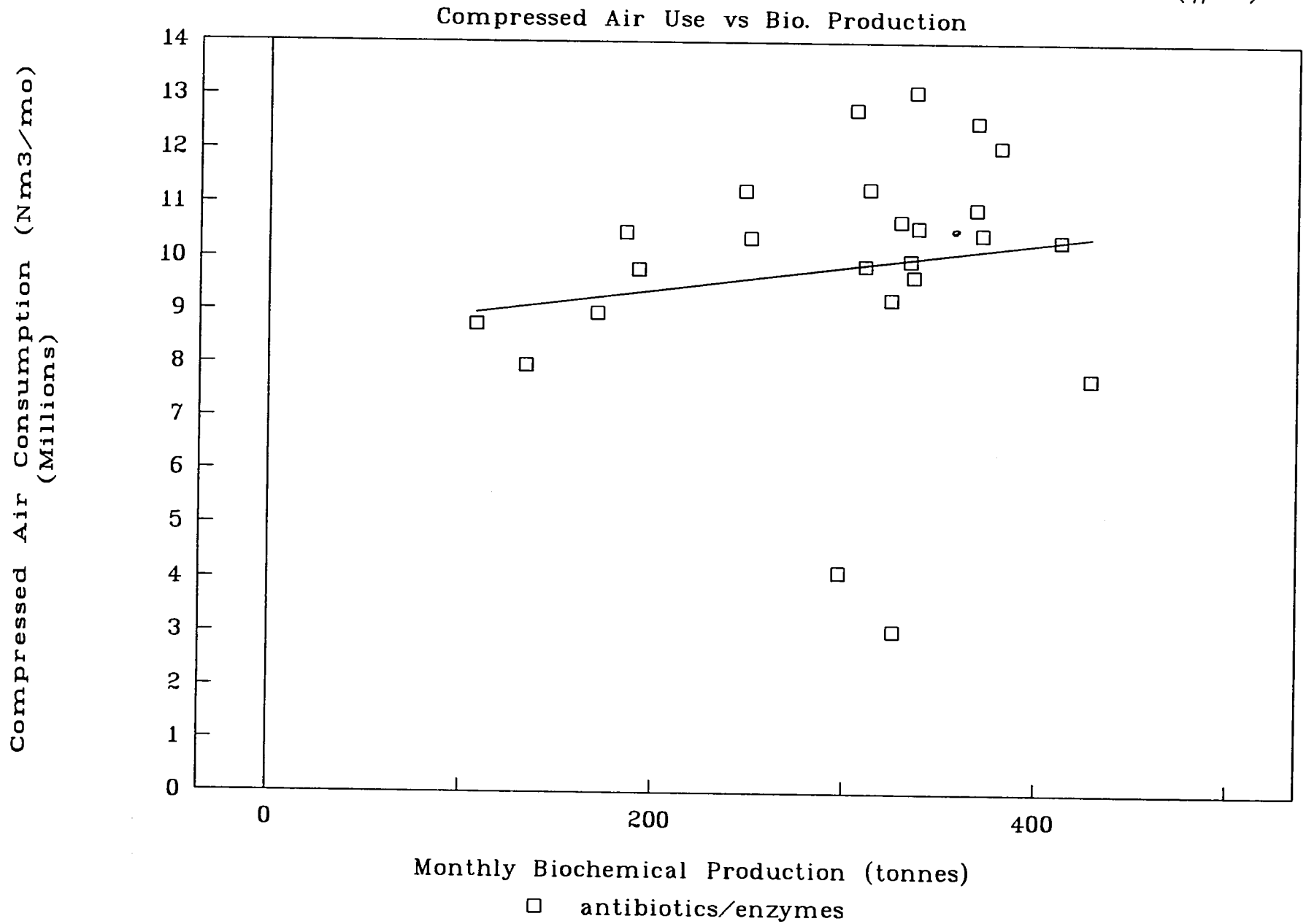
KRKA, Tovarna Zdravil, Novo Mesto (#3)



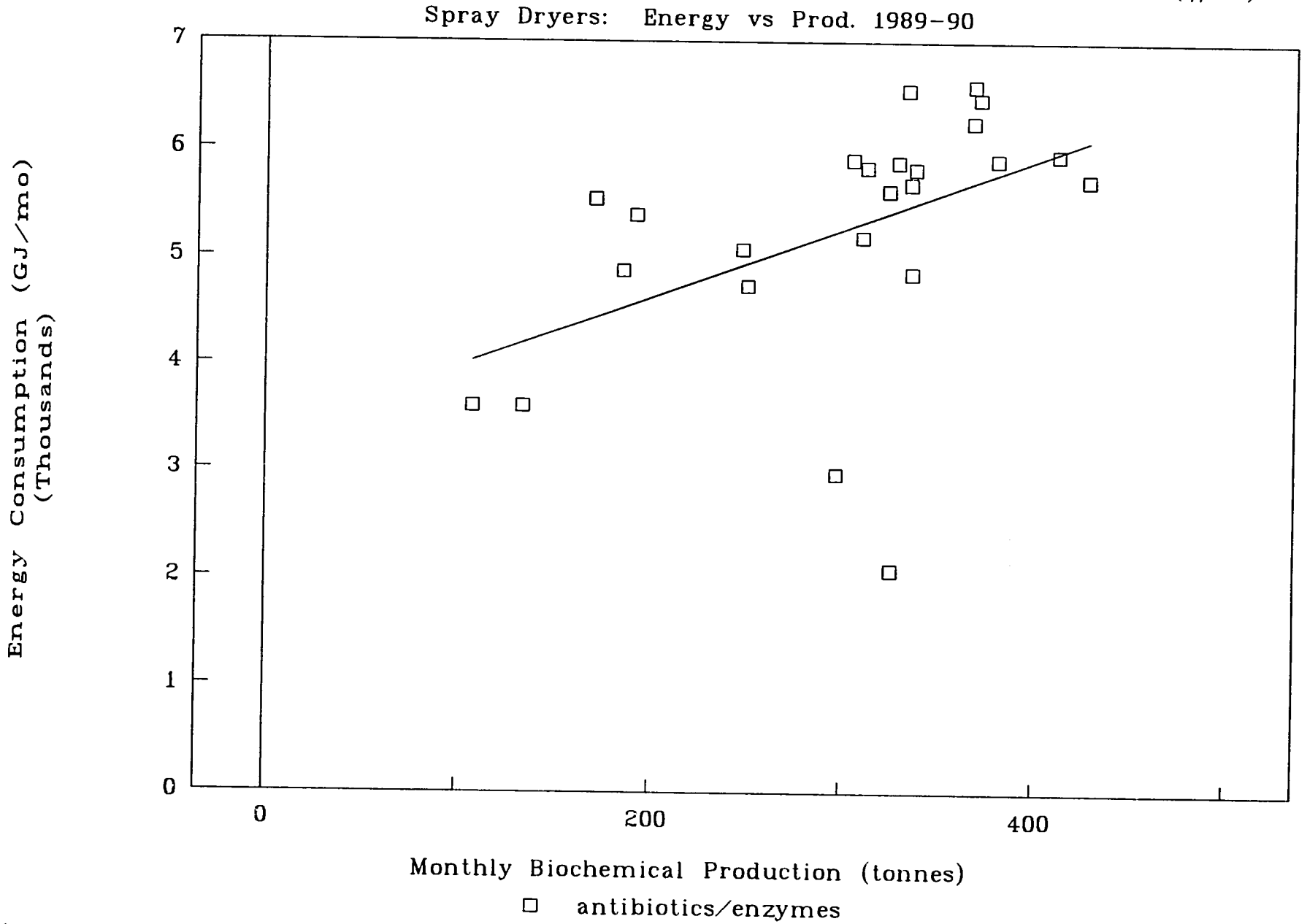
KRKA, Tovarna Zdravil, Novo Mesto (#4)



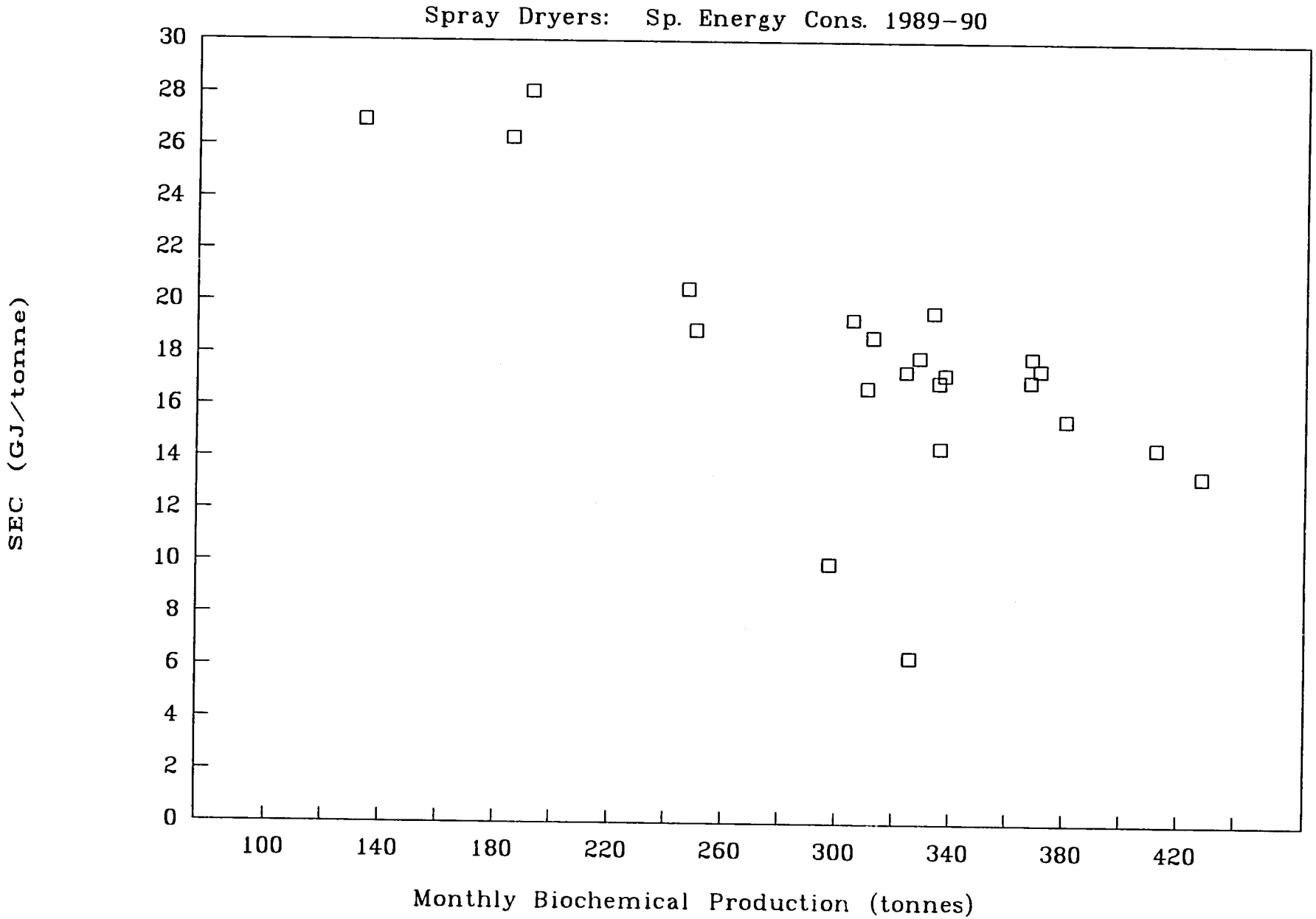
KRKA, Tovarna Zdravil, Novo Mesto (#5)



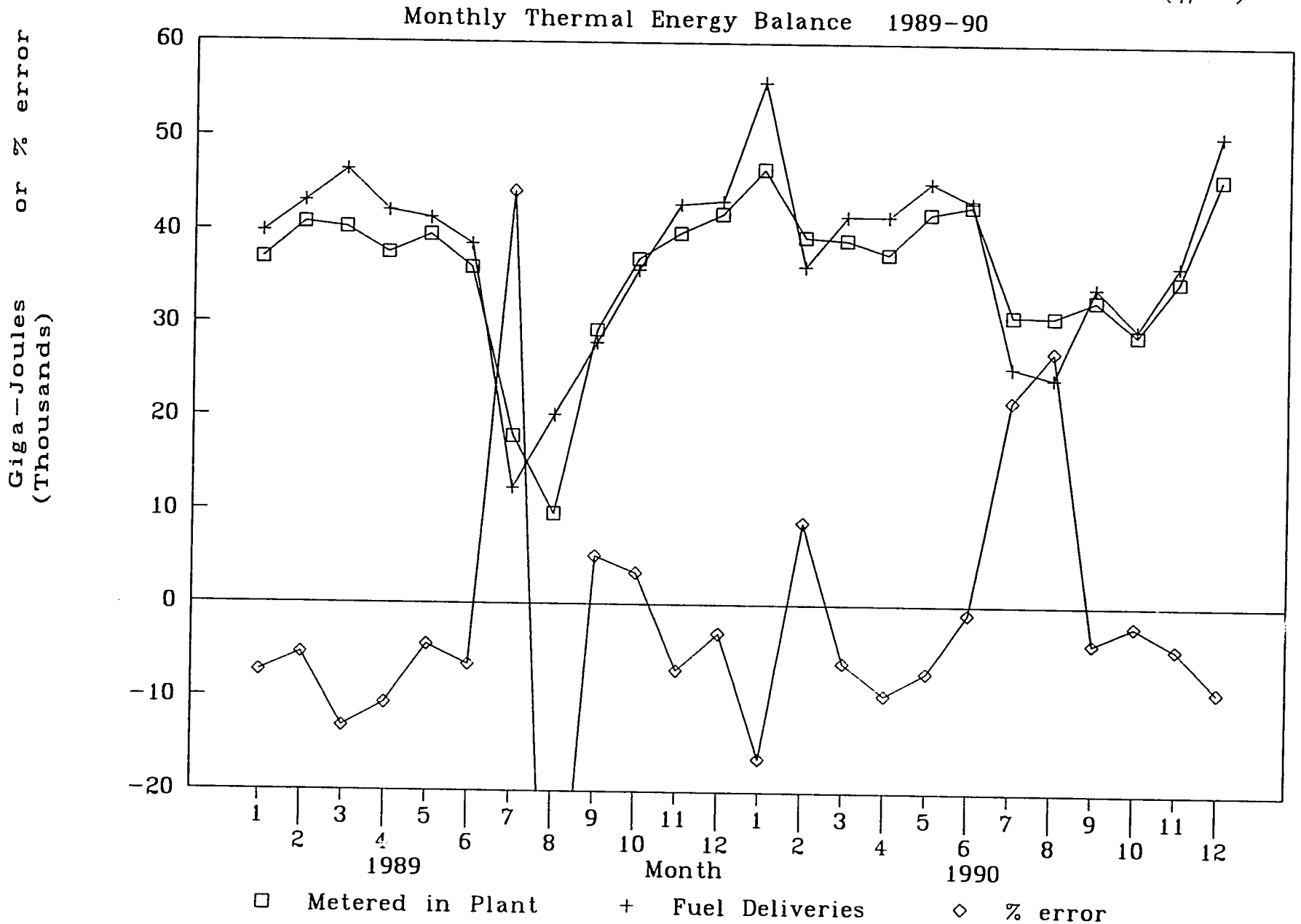
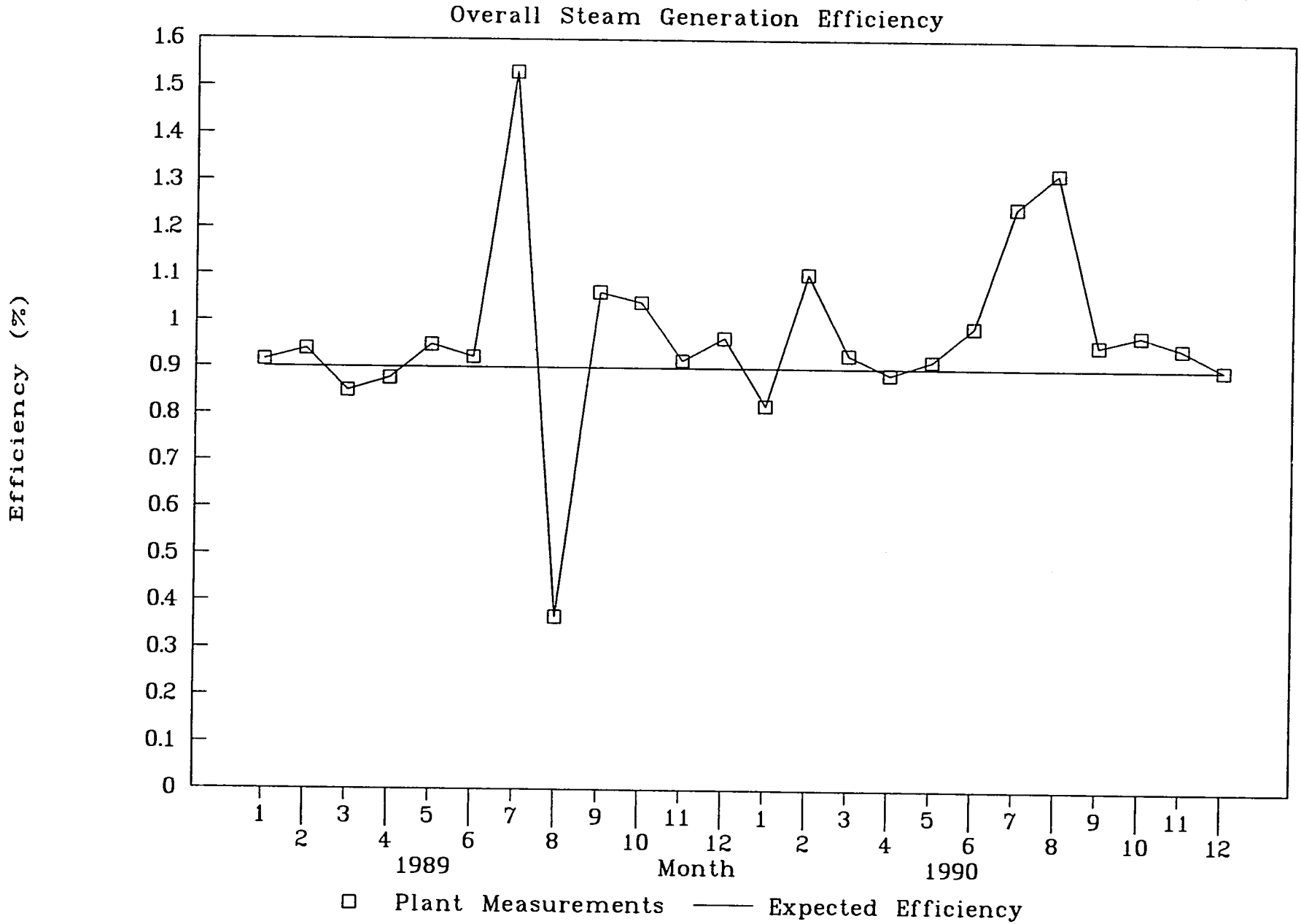
KRKA, Tovarna Zdravil, Novo Mesto (#6)



KRKA, Tovarna Zdravil, Novo Mesto (#7)



Krka, Tovarna Zdravil, Novo Mesto (#8)



KRKA, Tovarna Zdravil, Novo Mesto (#9)