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ENERGY EFFICIENCY AUDIT REPORT
TERMOELEKTRANA-TOPLANA "NOVI SAD"
DISTRICT HEATING PLANT
NOVI SAD, VOJVODINA, YUGOSLAVIA

MARCH 1992

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

and

TEKON Tehno-Konsalting
Belgrade, Yugoslavia

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

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
BUREAU FOR EUROPE
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ENERGY & INFRASTRUCTURE DIVISION
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QUALITY ASSURANCE

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

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PRELIMINARY ENERGY AUDIT
TE-TO "NOVI SAD"

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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 at the Termoelektarna-Toplana (TE-TO) "Novi Sad" in Novi Sad, Vojvodina, Yugoslavia from April 16 through April 19, 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.

TE-TO "Novi Sad" was designed as a cogeneration plant, using a steam topping cycle to generate electricity, while providing district heating to the city of Novi Sad in the winter and process steam to the local refinery throughout the year. During the winter, the plant operates in cogeneration mode; the rest of the year it often operates in the condensing mode as a normal steam electric power plant. A summary of the primary energy consumption at the plant based on 1990 data is given below (a terajoule, TJ is 10^{12} Joules). The small amount of electricity purchased at the plant during the annual maintenance period is not included. Cost distribution is illustrative; costs are estimated based on March 1991 prices converted to U.S. dollars at the March 1991 rate, and are approximately US $ 67 million per year.

	Energy Distribution			Cost Distribution	
	actual units	TJ	%	US $	%
Natural gas	271,300,000 Stm^3	9,034	87	58,183,000	87
Heavy fuel oil	33,800 tonnes	1,370	13	8,814,000	13
TOTALS		10,404	100%	66,997,000	100

During the brief preliminary energy audit work on site, TE-TO "Novi Sad" 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	Duties & Instln Costs	Energy Savings	Years Simple Payback
A.1	Improve energy monitoring	10,000	incl.	186,000	0.1
A.2	Steam efficiency teams	3,500	2,000	56,300	0.1
B.1	Boiler combustion eff	54,000	31,500	134,000	0.6
B.2	Feed pump at lower speed	150,000	incl.	256,000	0.6
C.1	Proc. optim/control system	250,000	incl.	345,000	0.7
C.2	Return condensate	300,000	incl.	650,000	0.5
	TOTALS	767,500	33,500	2,618,600	0.3

CHAPTER 1 -- PLANT DESCRIPTION

The Termoelektrana-Toplana (TE-TO) "Novi Sad" is located on the Danube River just outside the city of Novi Sad, capital of the province of Vojvodina. The plant is of Yugoslav design with all Russian equipment, constructed in 1981. It owned by the public utility Elektroprivreda Beograd, and is connected to the main distribution grid.

The preliminary energy audit covered only the boundaries of the plant. Plant control over process steam, hot water for district heating, and electricity produced ends at its boundaries, where distribution companies or end users take over. Metering is performed at these boundaries.

1.1 Equipment Description

A brief description of the main equipment in the plant is provided below.

Boiler K-1:	420 t/h (140 bar; 560 C)
Boiler K-2:	420 t/h (140 bar; 560 C)
Boiler K-3:	500 t/h (140 bar; 560 C)
Turbine-Generator TG-1	maximum steam inlet flow: 760 t/h process extraction condition: 15 bar; 260 C max process extraction flow: 320 t/h heating extraction: 0.4 to 2.5 bar, depend. on load max heating extraction: 144 MWth maximum condensing: 320 t/h minimum condensing: 30 t/h generator rating: 165 MW (194 MVA)
Turbine-Generator TG-2	maximum steam inlet flow: 760 t/h no process extraction heating extraction: 0.4 to 2.5 bar, depend. on load max heating extraction: 204 MWth maximum condensing: 320 t/h minimum condensing: 30 t/h generator rating: 120 MW (150 MVA)

Major Electric Motors	boiler feed water pumps:	3 x 4000 kW
	boiler feed water pumps:	2 x 5000 kW
	i.d. boiler fans (2-speed):	6 x 500/1000 kW
	f.d. boiler fans (2-speed):	6 x 320/ 640 kW
	circulating pumps (2-speed):	2 x 315/ 500 kW
	circulating pumps (2-speed):	2 x 500/1000 kW
	water treatment pumps:	2 x 1600
	hot water pumps: (2-speed):	4 x 500/1600 kW
	hot water pumps: (2-speed):	2 x 320/ 630 kW
	condensate pumps:	8 x 250 kW

1.2 Plant Operation

TE-TO "Novi Sad" was originally designed as a cogeneration facility, whose primary objectives would be to provide hot water for district heating to the city of Novi Sad, and process steam to the industrial area near the plant. Electricity generated during this process would supply the local Vojvodina grid at little additional cost.

However, the district heating load is lower than anticipated, and the only industrial user is the nearby refinery, taking only one fourth of the TE-TO design process steam load. The plant now belongs to the large Belgrade distribution company, and competes with much larger power plants for electricity production. Thus, the plant operates at fairly low loads, except for two or three winter months during the peak heating season. In effect, for most of the year, TE-TO is really a small electricity generating plant, rather than a cogeneration facility. An overall monthly view of plant operation and production is presented in the graphs of Appendix 1.

The TE-TO staff attempt to maximize the efficiency of the plant by manually operating the equipment in the mode which provides the greatest operating efficiency given the following constraints:

-- district heating load, dependent solely on the weather

-- process steam load, dependent on refinery operation, and increasing slightly during the winter

-- minimum load for the boilers, which is approximately 60% of maximum load

-- dispatch planning at the control center of the electric distribution company, which may assign TE-TO an electricity production depending on the needs of the grid.

Several problems are faced by the TE-TO staff in their efforts to maximize plant operating efficiency:

- lack of instrumentation on the boilers, particularly CO meters to optimize combustion efficiency
- lack of software to optimize or assist in optimization of equipment loading given the required operating parameters of the plant at a certain time
- the design of the plant, which does not lend itself to efficient operation at partial loads: fans are equipped with 2-speed motors, but boiler feed pumps and some of the circulating pumps have a single operating speed only.

1.3 Prices for Energy Sold

Despite the advantages of cogeneration mode operation, TE-TO "Novi Sad" provides its customers with relatively high-priced energy. This is primarily for two reasons: high-priced gas and fuel oil are used as fuels; and large fixed costs arise from the operation due in part to a large labor force at the plant. The plant finds it difficult to compete with other electric generating stations in the distribution system: other plants are mainly fueled by coal and hydroelectric energy.

TE-TO "Novi Sad" price policy is to charge for steam and hot water at the normal cost of generation; a constant factor is used to calculate fuel consumption (99.345 Stm^3/tonne of steam, and 113.338 Stm^3/MWth of hot water). Electricity prices then reflect the savings obtained by cogeneration. Prices for energy produced at TE-TO "Novi Sad" in March 1991 were as follows:

Process steam	d/tonne	US$/tonne
- fuel cost	277.00	21.31
- fixed cost	72.00	5.53
- total cost	349.00	26.84
Thermal energy	**d/GJ**	**US$/GJ**
- fuel cost	87.91	6.76
- fixed cost	23.20	1.78
- total cost	111.11	8.54
Electrical energy	**d/kWh**	**US$/kWh**
- fuel cost	0.840	0.065
- fixed cost	0.186	0.014
- total cost	1.026	0.079

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.

	1988	1989	1990
Energy Use			
Gas consumption (million Stm^3)	280	270	270
Fuel oil consumption (tonnes)	77,000	62,000	34,000
Energy Production			
Process steam (tonnes)	491,000	423,000	335,000
Hot water (MWhth)	373,000	367,000	363,000
Electricity (MWhe)	955,000	863,000	786,000

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 management staff at TE-TO "Novi Sad." The audit team obtained some of this data for review to obtain a better understanding of operating procedures at the plant. These data were analyzed and are presented graphically in the appendices: Appendix 1 contains two graphs summarizing production and energy consumption in 1989 and 1990; Appendix 2 presents 11 graphs analyzing daily production and consumption data for the first quarter of 1991.

Graphs #1 and #2 show the monthly variation of purchased natural gas and fuel oil energy, as well as plant production, over the last two years. These graphs are useful to show general trends, such as summer versus winter operation, and relative production of steam, hot water, and electricity.

More detail can be seen in the graphs of Appendix 2. Graph #3 presents the daily variation of production of the three main energy products of TE-TO "Novi Sad." It also implies that electricity production is not totally tied to process steam and hot water production. While these trends are interesting, a closer analysis of the specific energy consumption (SEC) is required to gain a better understanding of the processes.

Graphs #4-7 show the variation production and SEC of the different energy forms plotted against their production. This allows a better observation of trends, especially since it is usual that SEC is dependent on production levels. In the case of TE-TO "Novi Sad", however, not much variation is seen. SEC relations are

relatively flat for all three products, although some slight decrease is seen as production increases. Data for process steam and hot water show a slight scatter, but not much. This is probably due to the fact that the plant uses relatively constant factors to convert both of these to heat units. Electricity is much more of a dependent variable, however, and the electricity graphs #6 and #7 do show a bit more variation and scatter. One objective in improved energy management is to evaluate the electricity consumption in this way, compare it to the historical trends, and attempt to explain any anomaly from the trend. For example, there are variations of 10-15% visible in these graphs. While this is a small amount, the large amount of fuel consumed in the plant makes every percentage point of significant interest.

The plant staff calculate every day a heat rate for the plant, in kJ/kWh. This quantity, shown in Graph #8, is analogous to the specific energy consumption plotted in Graph #7. It varies quite a bit from day to day. A large part of the variation is likely due to varying hot water generation, which affects the efficiency of electricity generation. This is seen in Graph #9, which helps explain that some of the variation is attributed to hot water generation. Looking at the overall contribution to electricity generation in Graph #10, it is clear that the variation of the energy generated by the steam extracted for hot water varies significantly; however, additional steam is condensed to keep the total electric generation relatively constant. While this may be less efficient, it may be dictated, as mentioned before, by dispatcher planning or by requirements for minimum boiler loading.

The last three graphs address the issue of electricity consumption internal to the plant. This takes into account all the electric motors for the pumps and fans within the complex itself. Graph #11 shows the variation of this consumption over time; Graph #12 describes it as a percentage of the overall generation over time; and Graph #13 provides a plot relative to production levels. The variations of internal electricity consumption shown in these graphs are significant, sometimes as high as 15 to 20%. This implies that perhaps with a better control, or optimization of equipment operation some savings could be achieved.

2.2 Energy Management

In general, the staff of TE-TO "Novi Sad" are well aware of energy efficiency and its applications to their plant. Daily readings are taken and reported to all technical management staff at the plant. This data is also reviewed on a daily basis.

At the same time, management sometimes feels that it has little

control over energy efficiency, since total electrical generation is dictated by the dispatcher, and since a very detailed contract for steam with the refinery limits the interest to improve energy efficiency much.

Nevertheless, the graphs described in the previous section show that there is still some room for improvement. Some improvement can certainly be made with careful manual control over operations; additional improvements can probably only come with a better centralized automated operating and control system. What management should begin to do, in addition to continuing analysis of their daily sheets, is to look at the historical trends of what levels of energy efficiency have been achieved, and use the best of these efficiencies as operating targets for the future.

CHAPTER 3 -- ENERGY CONSERVATION RECOMMENDATIONS

There are a number of actions that TE-TO "Novi Sad" can undertake 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, more awareness in setting operation regimes for equipment, and improved steam and 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. TE-TO "Novi Sad" 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 installation of CO meters. 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. 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 Energy Monitoring/Control

1. PROCESS AREA

Overall plant energy management

2. STATEMENT OF RECOMMENDATION

Set up a program to reduce internal electricity consumption. This program should include the following components:

- -- historical analysis of daily electricity consumption over the past two years, including review of the records to determine the major equipment that was operating
- -- measurement and analysis of more detailed data on which equipment is operating for how long, and its total kWh consumption, on a continuing daily basis
- -- operation of the minimum equipment required, and of the optimum or most efficient equipment
- -- setting of a target of 3% reduction in internal energy consumption over the coming year
- -- instruction to the operating staff of the goals of this program; improving of operating and maintenance procedures.

3. DESCRIPTION/RATIONALE

The data in Graphs #11-13 of Appendix 2 show that there is significant variation, as high as 15-20%, in the consumption of electricity for internal uses at the TE-TO "Novi Sad" complex. It has been shown that for a given operating mode one day can utilize significantly less electricity than another. Management should make a concerted attempt to understand and to begin to reduce this variation, making the consumption more consistent, and lower.

Because of the large fuel consumption at the plant, even small percent improvements can translate into significant cost savings. The key to such a program is a management commitment, and the setting of a target. A target of 3% is suggested above; this may be less, if the management feels it will be too difficult to achieve, or more if a greater challenge is desired.

Furthermore, it will be extremely useful to obtain better operating data on the pumps and manv other motors throughout the complex: if

ever the plant decides to implement an automated process control system (such as described in Action C.1) this information will be a basic prerequisite.

4. BENEFITS

4.1 Energy Savings

Potential energy savings are estimated based on the 3% target mentioned above. Assuming that internal energy use is 10% of total annual electricity generation, the savings can be calculated as follows:

786,000 MWh x 0.10 x 0.03 x $79/kWh = $186,000

5. IMPLEMENTATION COSTS

Implementation costs will include the use of a computer for data analysis ($5000), staff to perform some of the analyses, as well as increased measurements, and some additional management time to review the procedures and the progress of the program. Total estimated initial cost is approximately $10,000.

6. PAYBACK

The payback period for this project is 0.1 years, or less than 1 month.

7. SCHEDULE

This activity can and should be implemented immediately.

8. TECHNICAL RISK AND REFERENCE

This project presents no risk in its implementation.

Action A.2 -- Set Up Steam System Efficiency Team

1. PROCESS AREA

Steam and condensate system throughout the plant

2. STATEMENT OF RECOMMENDATION

Develop an inventory of all internal steam uses at the generating plant. Set up a special team to methodically review the steam and condensate system on a regular basis, 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. Ensure that condensate is being returned. In the fuel oil tank heating area, evaluate the feasibility of setting up a condensate return line to return even the small amount of condensate back to the plant. Evaluate flash steam losses at intermediate condensate stations, and make sure that these losses are minimized.

2.2 Steam Trap Testing Program

Inventory all steam traps. Begin a regular testing program using an 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. Identify hot spots on overhead piping and equipment by using an infrared pyrometer. Replace or upgrade insulation as necessary. Consider the use of specially made insulation pieces allowing easy removal and re-installation for valves and fittings.

2.4 Eliminate Steam Leaks

Identify, tag, and repair steam leaks, beginning with the most serious. Maintain an ongoing check on leaks, and repair them as soon as is possible.

3. DESCRIPTION/RATIONALE

In general, the Toplana Novi Sad steam distribution system is in good condition. There are few leaks, and the insulation appears adequate. Nevertheless, there are always small improvements that can be made, both in energy efficiency, and in avoiding maintenance problems. Regular preventive maintenance is the most cost-effective technique for ensuring both of the above. The Toplana has adequate staff that can be assigned to this task; simple equipment such as thermometers and ultrasonic testers should be provided them.

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 steam and condensate distribution systems. In the case of the Toplana, this range is high, since very little of the heat energy remains in the plant; most of it is exported in the form of process steam or hot water. Nevertheless, even a fraction of a percent savings can make a substantial impact on the energy costs.

- at a savings of 0.25% on an equivalent fuel oil basis:

250,000 t/y x 0.0025 x $130/tonne = 81,300 $/y

This savings will be reduced by additional annual maintenance and spare parts costs, estimated at approximately $25,000. Net savings is therefore $56,300.

5. IMPLEMENTATION COSTS

Implementation costs include handheld thermometer, an ultrasonic tester, an infrared pyrometer, as well as spares for steam traps, piping, and valves. The installed cost of the systems is estimated at $ 42,000.

	Cost of Equipment (USAID project)	Duties, taxes, install'n (plant)	TOTAL COSTS
Ultrasonic tester	$ 1,400	$ 800	$ 2,200
Infrared Pyrometer	2,100	1,200	3,300
TOTAL	3,500	2,000	5,500

6. PAYBACK

The payback period for this project is 0.1 years, or 1 month.

7. SCHEDULE

Task 1 -- completion date: May 25, 1991

HBI gets quotations from US manufacturers.

Task 2 -- completion date: July 1, 1991

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

Task 3 -- completion date: July 8, 1991

HBI sends purchase orders for equipment.

Task 4 -- completion date: August 31, 1991

Shipment of equipment arrives in Yugoslavia. Toplana Novi Sad prepares a workplan for use of the new instrument, including responsibility for its use and maintenance.

Task 5-- completion date: September 20, 1991

Toplana Novi Sad presents results of initial operation tests of the boilers using the new exhaust gas analyzer. Boiler efficiencies are calculated and savings possibilities are evaluated.

Task 6-- completion date: September 20, 1991

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

8. TECHNICAL RISK AND REFERENCE

This project presents no risk in its implementation.

9. SPECIFICATIONS

Ultrasonic Tester

Type:	Ultrasonic detector
Physical:	Pistol-type detector/stethoscope, with minimum 4" probe, extendable to 15"
Output:	Analog meter on pistol and audible sound converter for use with earphones; 10/1 sensitivity calibration dial
Power:	9 V battery, optionally rechargeable
Accessories:	lightweight plug-in headset, carrying case; tone-generator and rubber focusing extension optional

Infrared Pyrometer

Type:	Hand-held infrared temperature measuring device
Physical:	Pistol or camera type shape; to include sighting scope and carrying case
Input:	Closest distance to focal point estimated at 2-3 m; typical target size beyond focal point is "D"/50 Adjustable emissivity
Temp. range:	-30 to 1,400 C
Output:	Digital readout, degrees C
Power:	9 V battery, optionally rechargeable

Action B.1 -- Monitor CO to Optimize Boiler Combustion Efficiency

1. PROCESS AREA

Steam generation: combustion efficiency improvement for all boilers

2. STATEMENT OF RECOMMENDATION

Install carbon monoxide sensors in each exhaust gas duct of each boiler. Also install a control room display for CO level in the exhaust, as well as strip chart recorder to monitor the consistency and the changes over time of stack CO.

Use the exhaust CO information as the basis for optimizing excess air to the burners. Excess air should be reduced to the minimum level which still yields a CO level lower than 25-50 ppm for natural gas combustion, and slightly higher than that level for fuel oil combustion. For example, if the oxygen measurement in the stack is 2.7% O2 and the CO level is less than 5 ppm, the amount of combustion air should be reduced either until O2 reaches the range of 1.5 to 2%, or until CO reaches a level of 25-50 ppm.

This type of adjustment should be checked regularly by the operators during their shift responsibility. Displayed CO level should be entered into the logbook hourly.

3. DESCRIPTION/RATIONALE

Measurements were only taken at one of the boilers, K1, since it was the only one operating. Results are tabulated below.

	RCG/HBI	Brel Zagreb	Target
Date:	28-3-91	31-2-87	
Boiler:	K1	K1	K1
Load:	80%	?%	80%
Fuel:	natural gas	natural gas	natural gas
O_2:	2.4%	2.5%	1.8%
CO:	0 ppm	76 ppm	< 50 ppm
combustibles:	0.0%	0.0%	0.0%
Stack temperature:	140 C	C	140 C
CO_2 (calculated):	10.9%	10.4%	%
Excess air:	11.7%	12.2%	8.5%
Comb. efficiency:	94.1%	94.1%	94.3%

Te-TO "Novi Sad's" three boilers, at 400 to 500 tonnes/hour of

steam each, represent a very high instantaneous fuel consumption. At these fuel consumption rates, even a small (0.1%) change in operating efficiency can result in a significant energy cost difference. Currently, the boilers are operated at approximately 12-15% excess air; the operators are unwilling to reduce the air further since they have no idea about the completeness of combustion at such a low excess air level. The CO analyzers and meters proposed here will provide such a measurement, and allow the boilers to be operated much closer to the optmimum. Target conditions are also shown above.

4. BENEFITS

4.1 Energy Savings

Energy savings are calculated based on a 0.2% average annual improvement of efficiency of heat utilization for both mazout and natural gas over all three boilers. Equivalent tonnes of fuel are used in the calculation.

- at 0.2% average improvement:

$67 million/y x 0.002 = 134,000 $/y

5. IMPLEMENTATION COSTS

Total implementation costs are estimated at $ 85,500.

	Cost of Equipment (USAID project)	Duties, taxes, install'n (plant)	TOTAL COSTS
CO sensors/analyzers (6)	$ 48,000	$ 28,000	$ 76,000
Charts/readout displays (3)	6,000	3,500	9,500
TOTAL	54,000	31,500	85,500

6. PAYBACK

The payback period is approximately 0.6 years, or 8 months.

7. SCHEDULE

Task 1 -- completion date: May 25, 1991

HBI gets quotations from US manufacturers.

Task 2 -- completion date: July 1, 1991

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

Task 3 -- completion date: July 8, 1991

HBI sends purchase orders for equipment.

Task 4 -- completion date: August 31, 1991

Shipment of equipment arrives in Yugoslavia. TE-TO "Novi Sad" prepares a workplan for use of the new instruments, including responsibility for their use and maintenance.

Task 5-- completion date: September 20, 1991

TE-TO "Novi Sad" presents results of initial operation tests of the boilers using the new exhaust gas CO analyzers. Boiler efficiencies are calculated and savings possibilities are evaluated.

Task 6-- completion date: September 20, 1991

HBI reviews TE-TO "Novi Sad" 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 procedures mentioned in Task 5, instructions for instrument operation should be translated or adapted into Serbian, and a detailed training session should be provided to the operators.

9. SPECIFICATION OF EQUIPMENT

Specification of CO Analysis System

Reference:	TNS-1
General Description:	An extractive CO analysis system is required in boiler exhaust gases in Yugoslavia. The system is required for three boilers, each with two exhaust stacks.
Number:	Six (6) complete systems are required
Physical:	Stack-mounted sampling probe, minimum 0.6 m length Stack approximate dimensions (5 ft x 12 ft)

	Local board with sample conditioning/analysis system, weatherproof CO remote display in control room Ambient temperature conditions: -5 to 60 C 20 ft from sampling probe to remote board 150 ft to control room
Input Conditions:	Exhaust gases, stack temperature max 400 C, nominal 200 C Fuels: No. 6 fuel oil, maximum 3% sulfur; natural gas Stack draft: +/- 10 inches H2O
Output Required:	CO: 0-2000 ppm Strip chart recorder Adjustable alarm level
Power:	220V 50Hz
Accessories:	Manual calibration port
Spares:	to be specified by the bidder for at least 2 years of continuous operation
Note:	All equipment to be of U.S. manufacture in accordance with U.S. Government Federal Acquisition Regulations (FAR).

Please include with your bid:

Best price, delivery, terms of payment, warranties, cost for and availability of installation/training requirements in Yugoslavia

List of users of similar equipment, with telephone # and name of contact.

Action B.2 -- Operate One Boiler Feed Pump at Lower Speed

1. PROCESS AREA

Steam generation: boiler feedwater system

2. STATEMENT OF RECOMMENDATION

Convert one of the existing boiler feedwater pumps to a lower speed operation. This can be performed in one of two ways:

(a) replace part or all of the drive system connecting the motor to the pump to provide approximately half the rotational speed to the pump

(b) replace the existing 4000 kW electric motor on the pump drive with a new motor designed at approximately 2000 kW, and rotating at half the speed of the existing motor.

3. DESCRIPTION/RATIONALE

TE-TO "Novi Sad" is equipped with 5 boiler feed pumps; 3 with motors of 4000 kW and two with motors of 5000 kW. In the inter-season operation (spring and fall) there is no good way to achieve a match between the boiler load and the feed pump operation. The result is that flow control is achieved by throttling, and energy is wasted. During the preliminary audit visit, the boiler feed pumps were operating at 250 bar, while the required pressure in the boilers was only 160 bar.

If the flow in the pumping system could be controlled in a manner other than throttling, for example, with speed control, the energy lost across the control valves could be saved. While a speed control system would be extremely expensive, a small step toward a wider controllability could be taken with a lower speed motor, or a power transmission system that would provide a lower speed to the pump.

4. BENEFITS

4.1 Energy Savings

Energy savings are estimated only: actual pump curves should be studied in order to determine the exact performance of the system. Time did not permit this during the preliminary energy audit visit. Several assumptions as described below are used to illustrate the savings potential.

- existing condition: 2 motors of 4000 kW running at 70% load; total load is 5600 kW

- new condition: 1 motor of 4000 kw and 1 motor of 2000 kW running at 80% load; total load is 4800 kW

- new motor or drive can be used approximately 4000 hr/yr

The energy savings can be estimated as follows:

(5600-4800) kW x 4000 h/y x $0.08/h = $ 256,000/y

5. IMPLEMENTATION COSTS

Implementation costs will depend on whether the existing coupling between the motor and pump can be modified. The maximum cost of this action would entail complete replacement (or rewinding) of one 4000 kW motor by a 2000 kW motor. This total cost is estimated at $150,000, including installation.

6. PAYBACK

The payback period for this project is 0.6 years, or 6 months.

7. SCHEDULE

This project should be investigated as soon as possible, as it offers attractive possibilities for energy and cost savings.

8. TECHNICAL RISK AND REFERENCE

In the process of proceeding with this project, the following should be carefully taken into account:

-- actual ammeter readings and measurements on the various feedwater pumps, and at various outlet feedwater pressures

-- actual pump performance curves

-- installation requirements and physical limitations.

Work on this project can proceed at any time, since the total load is never so high as to need more than 3 boiler feedwater pumps in operating at a time.

Action C.1 -- Install Process Optimization/Control System

1. PROCESS AREA

Overall plant operation

2. STATEMENT OF RECOMMENDATION

Purchase and install a computer-based process control system, that will automatically pick the most efficient modes of operation and configurations of equipment to match the given load at any time. Such a system would eventually have stored the performance curves of all the major plant equipment, from boilers and turbine generators, all the way to electric motors of 100 kW and higher. Contract with a company to provide or modify the software program to apply to the TE-TO equipment, and to transfer the operating data of this equipment into the computer software.

3. DESCRIPTION/RATIONALE

Automatic selection and operation of equipment can provide a small improvement in energy efficiency. However, because of the large energy flows in a system the size of TE-TO "Novi Sad," even small incremental improvements can bring substantial cost savings.

Along with the computer hardware and software, control hardware will also be necessary to install, resulting in significant installation costs.

TE-TO "Novi Sad" staff is well aware of the need for optimization of equipment operation. Detailed operational data on its boilers and turbines have already been measured by the institute staff of Elektroprivreda Zagreb; however, this institution has not yet responded with a system to apply this data to practical automatic operation. The TE-TO staff continue to operate the equipment manually to the best of their abilities. Even if such a system is initially set up only for the boilers and turbines, it can provide good savings. Eventually, the system should include all the main electricity consuming equipment in the plant.

4. BENEFITS

4.1 Energy Savings

Energy savings for process control and optimization system can vary from a fraction of a percent to several percent of the energy consumption. In the case of TE-TO "Novi Sad" this amount is

estimated at 1/2 percent of energy consumption on an annual basis.

- 1/2 percent of the annual cost of $67 million would be worth approximately $345,000

5. IMPLEMENTATION COSTS

Implementation costs will vary widely depending on the scope and sophistication of such a system. A budget number for a medium-level system of approximately $250,000, including hardware is estimated.

6. PAYBACK

The payback period for this project is 0.7 years, or 9 months.

7. SCHEDULE

This project should continue to build slowly on the work already begun.

8. TECHNICAL RISK AND REFERENCE

This project entails no risk to the plant.

Action C.2 -- Return Condensate from Process Steam

1. PROCESS AREA

Process steam sold to refinery

2. STATEMENT OF RECOMMENDATION

Proceed with evaluation of ways to utilize the condensate, or its heat value, from the process steam sold to the refinery. Consider using available tanks to hold condensate and check for contamination. Consider use of heat exchangers to recover heat in the condensate and use it for make-up water preheat.

3. DESCRIPTION/RATIONALE

Nearly 8-10% of the heat in the steam sent to the refinery remains in the condensate that currently goes to drain because of chemical contamination in certain refinery heat exchangers. This results in a significant waste of energy, as well as additional costs of water treatment.

A study by the TE-TO staff apparently showed that the recovery of this condensate is not economically worthwhile. However, with the recent energy price increases, this study should be updated, and additional options evaluated. It is true that TE-TO "Novi Sad" may have little interest in this project, since the costs are passed on to the refinery, but both refinery and the generating plant could benefit from a solution to the condensate return.

4. BENEFITS

4.1 Energy Savings

Energy savings are estimated conservatively at 8% of the heat energy in the steam, based on 1990 total process steam sales of 335,000 tonnes, or 1.1 million GJ. The savings would be approximately 97,000 GJ, equal to approximately $600,000, at current fuel prices at TE-TO "Novi Sad". In addition, at the current cost of treated water (27 din/m^3 = $2.07/$m^3$ in March 1991), possible additional savings of $700,000 could be obtained of all of the condensate could be returned.

5. IMPLEMENTATION COSTS

Implementation costs will vary widely depending on the solution proposed. A budget of $250,000 would provide a 6 month payback

only on the heat recovery portion, and less than a 3-month payback if the condensate itself is recovered.

6. PAYBACK

The payback period for this project is 0.5 years, or 6 months.

7. SCHEDULE

This project should begin with a review of the previous study and the proposed solutions, along with the new energy costs and financial situation.

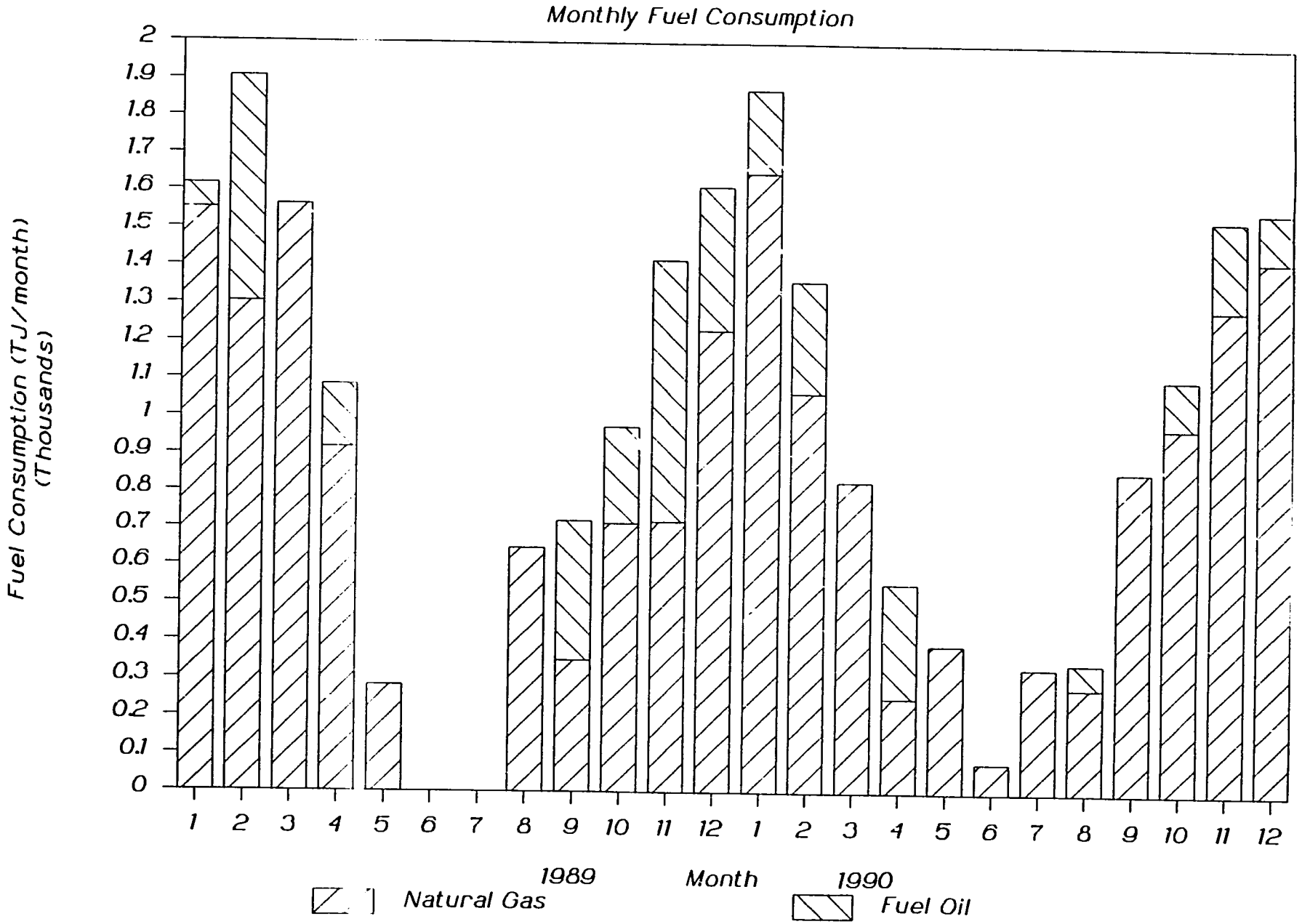
8. TECHNICAL RISK AND REFERENCE

This project entails no risk to the plant.

TERMOELEKTRANA-TOPLANA "NOVI SAD"

APPENDIX 1 -- ENERGY AND PRODUCTION GRAPHS (MONTHLY DATA)

TE-TO "Novi Sad" (1989-90) (#1)



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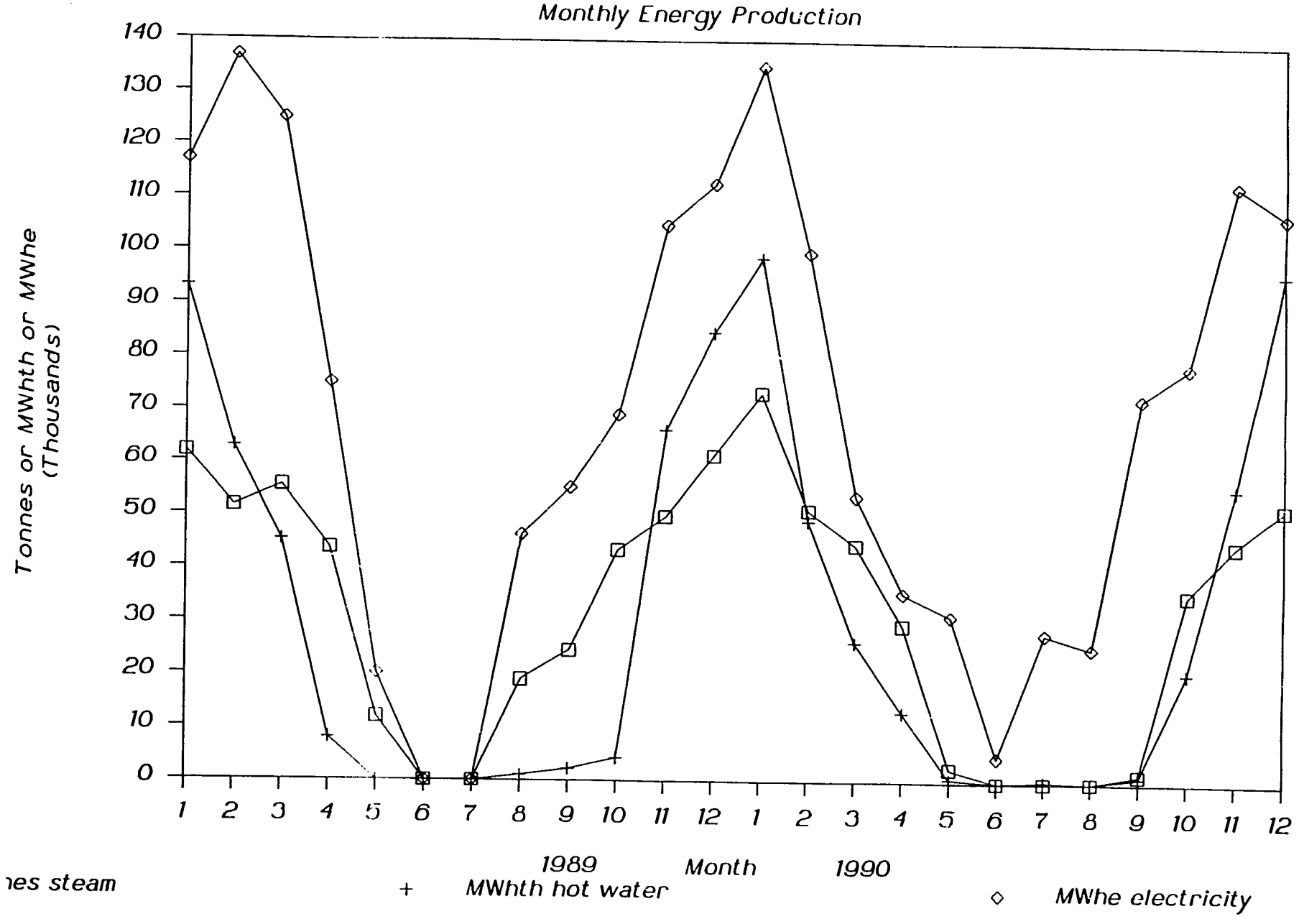
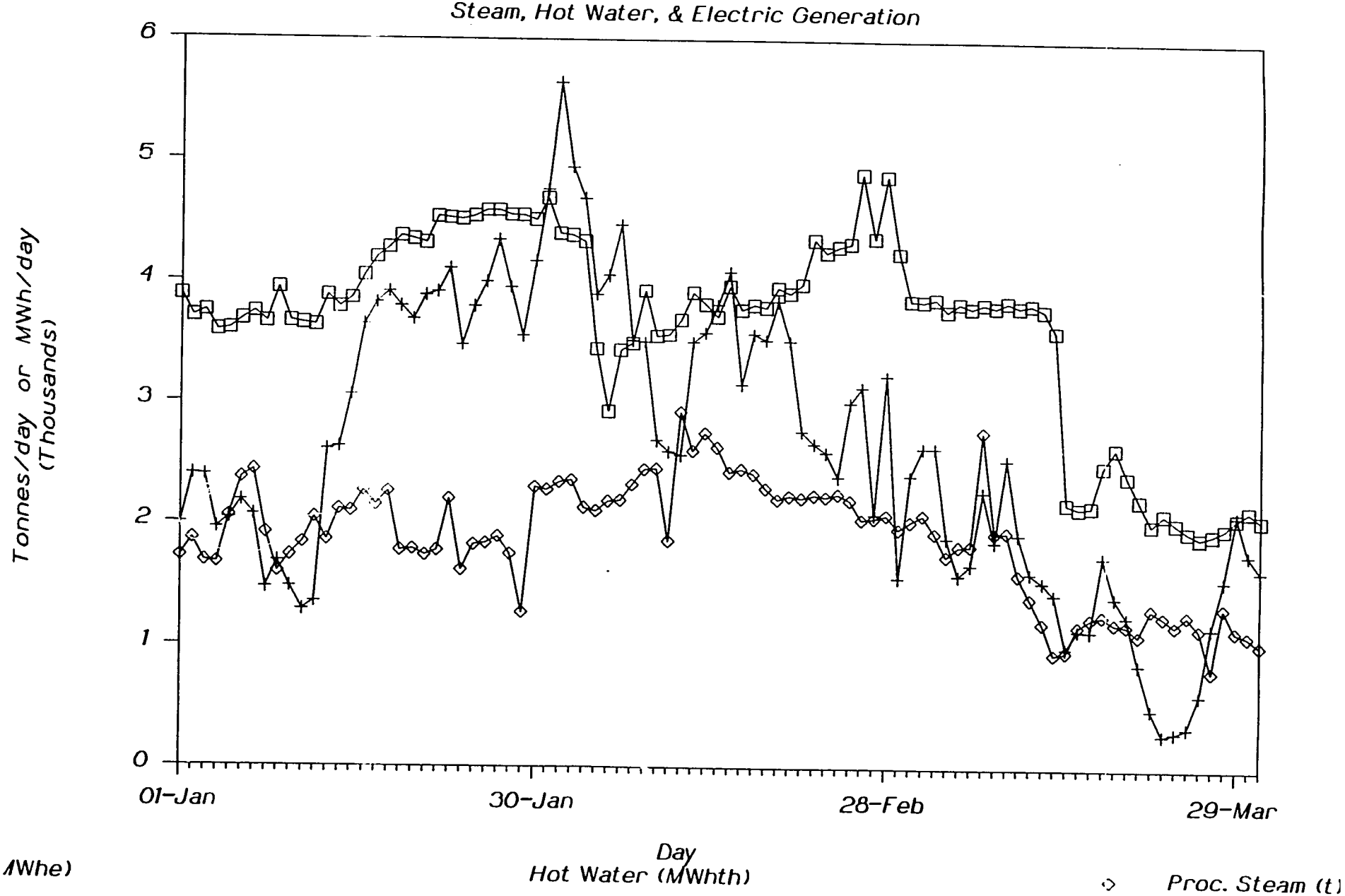


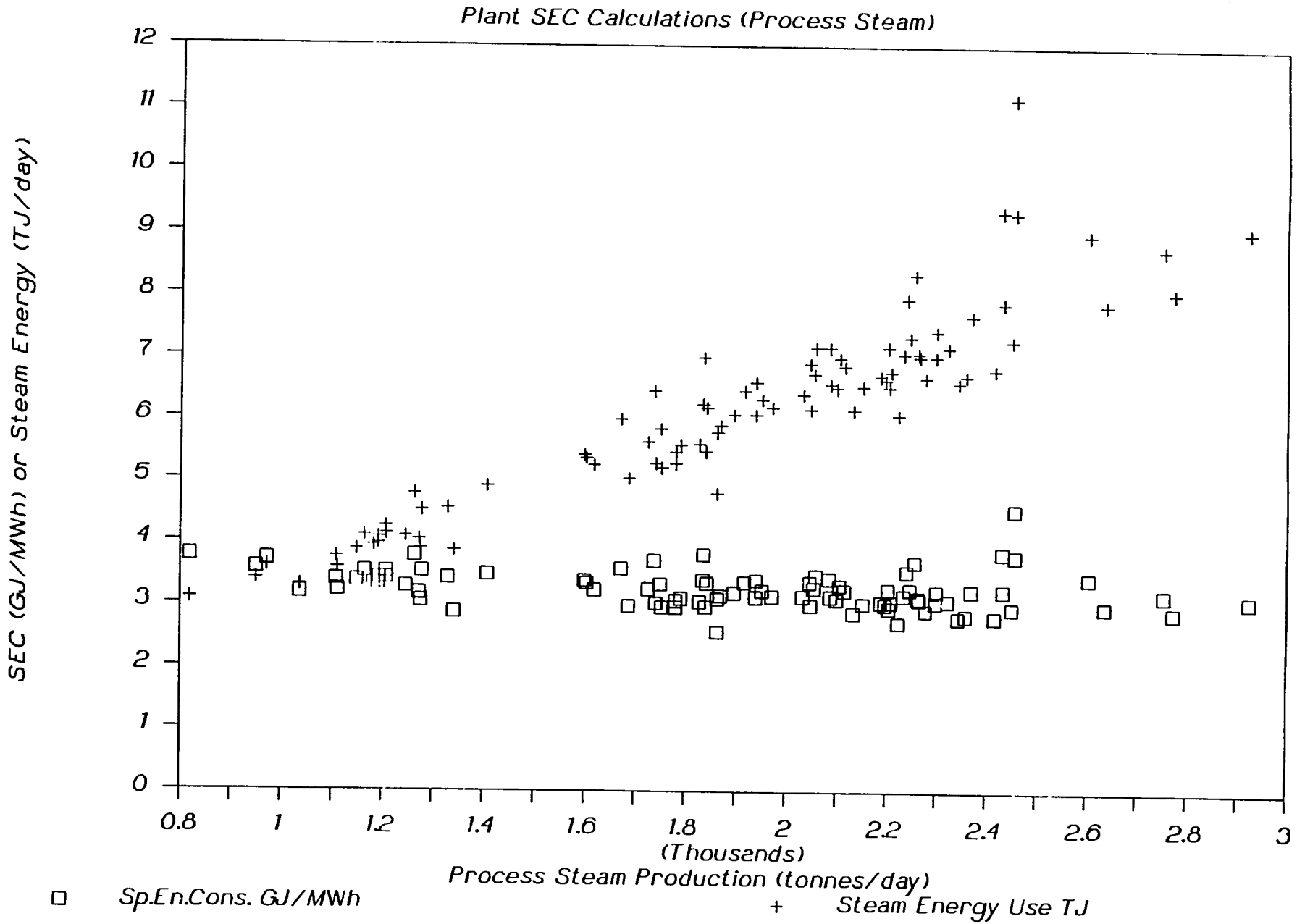
TERMOELEKTRANA-TOPLANA "NOVI SAD"

APPENDIX 2 -- ENERGY AND PRODUCTION GRAPHS (DAILY DATA)

TE-TO "Novi Sad" (Jan-March 1991) (#3)



TE-TO "Novi Sad" (Jan-March 1991) (#4)



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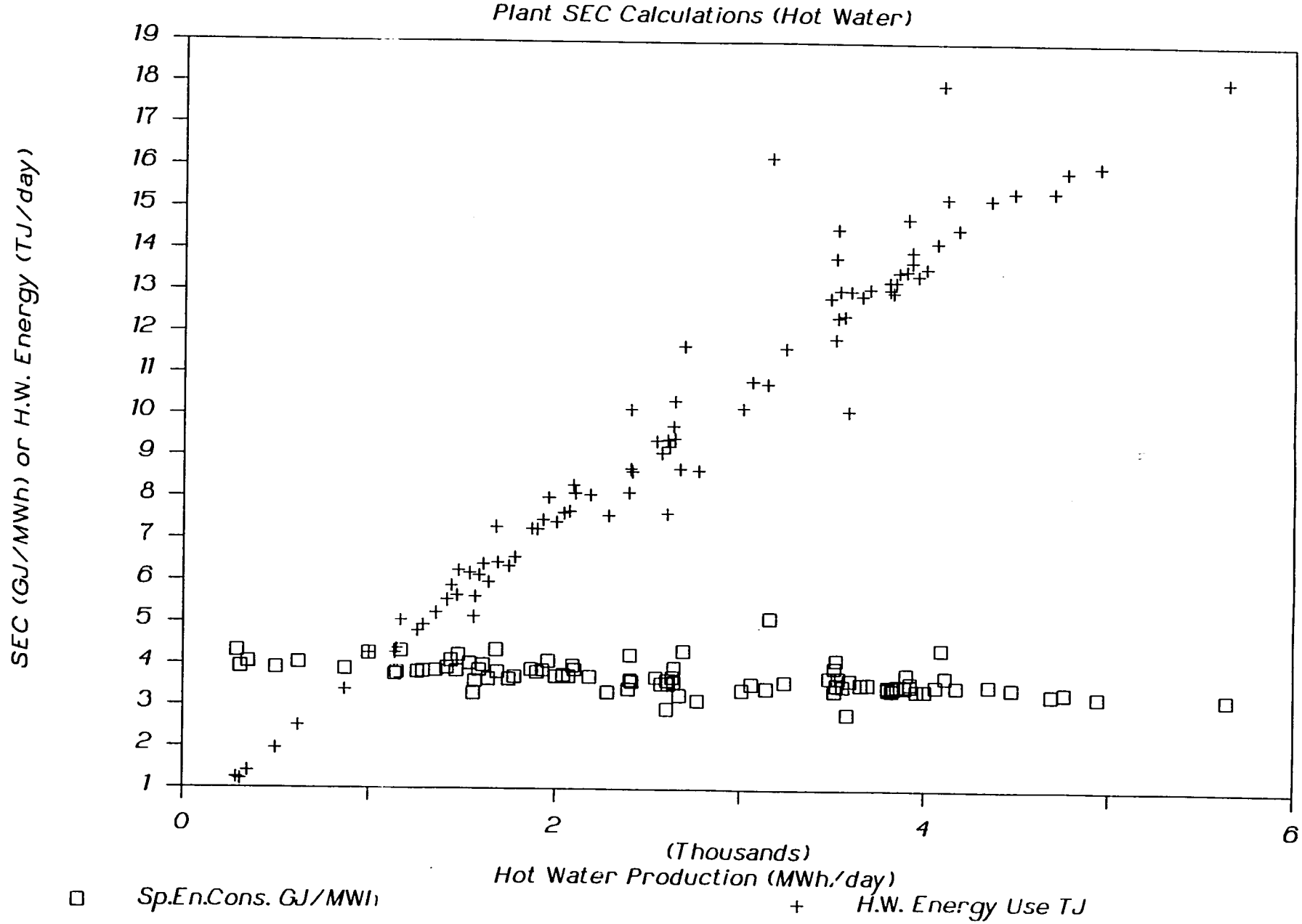

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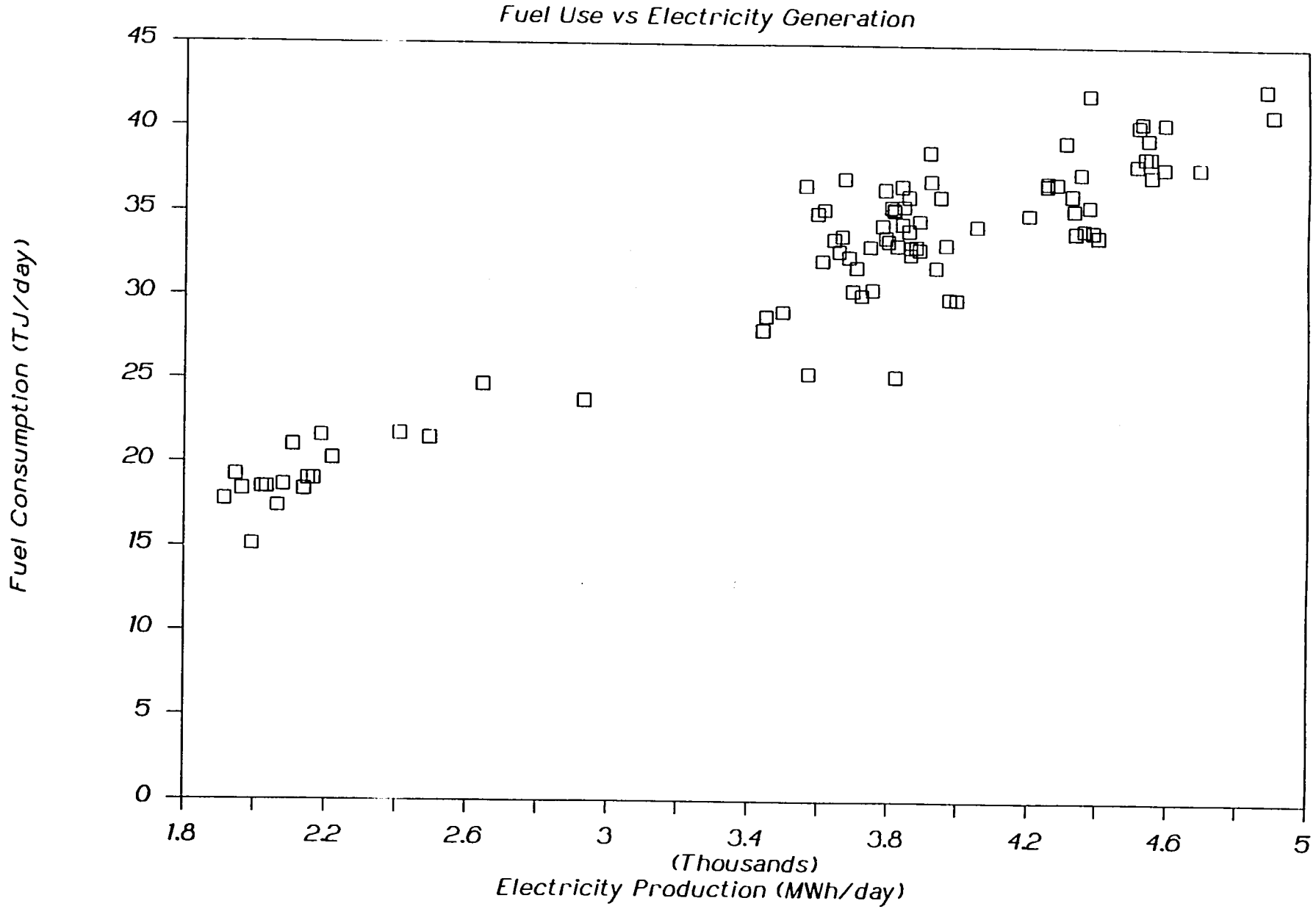

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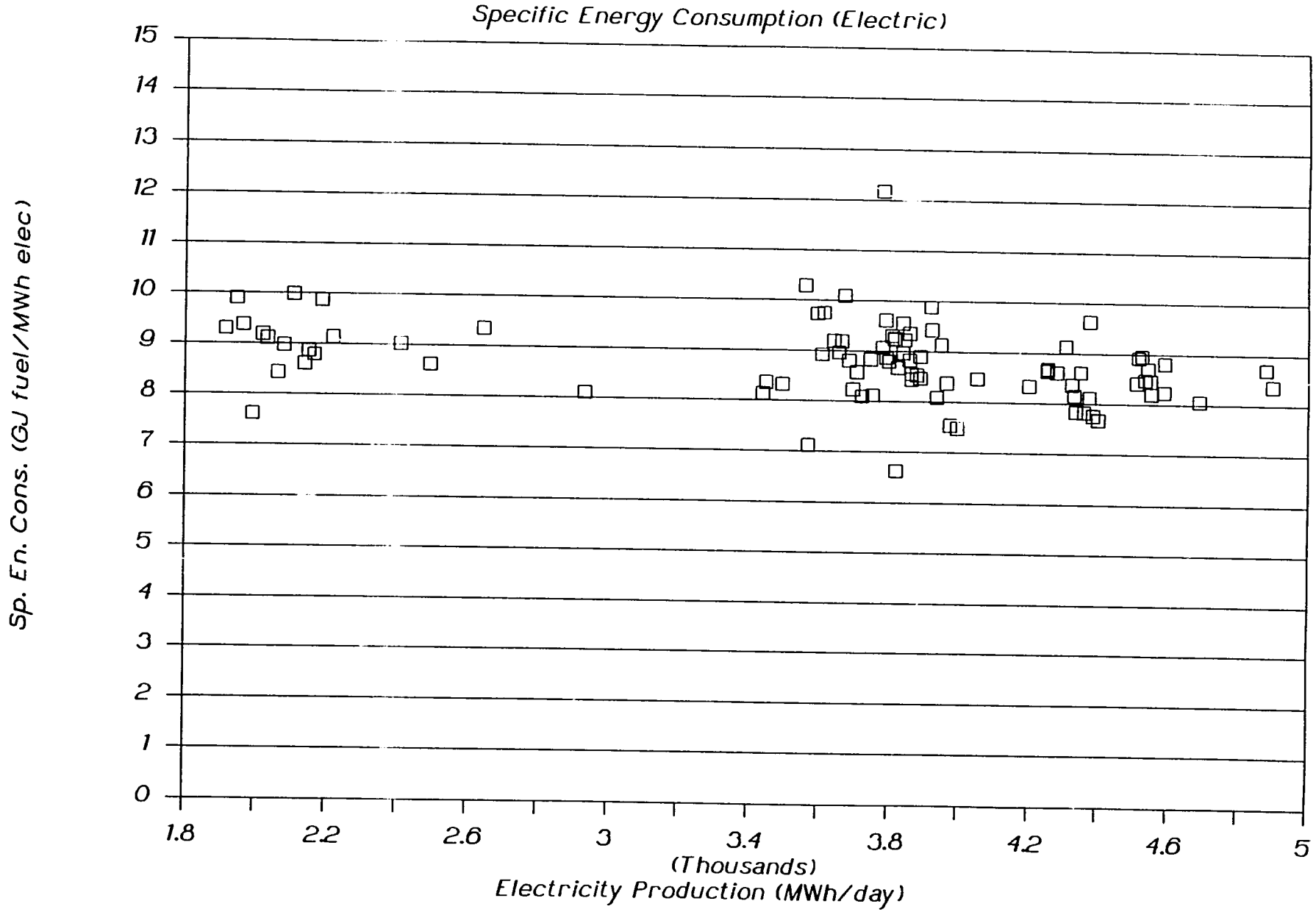

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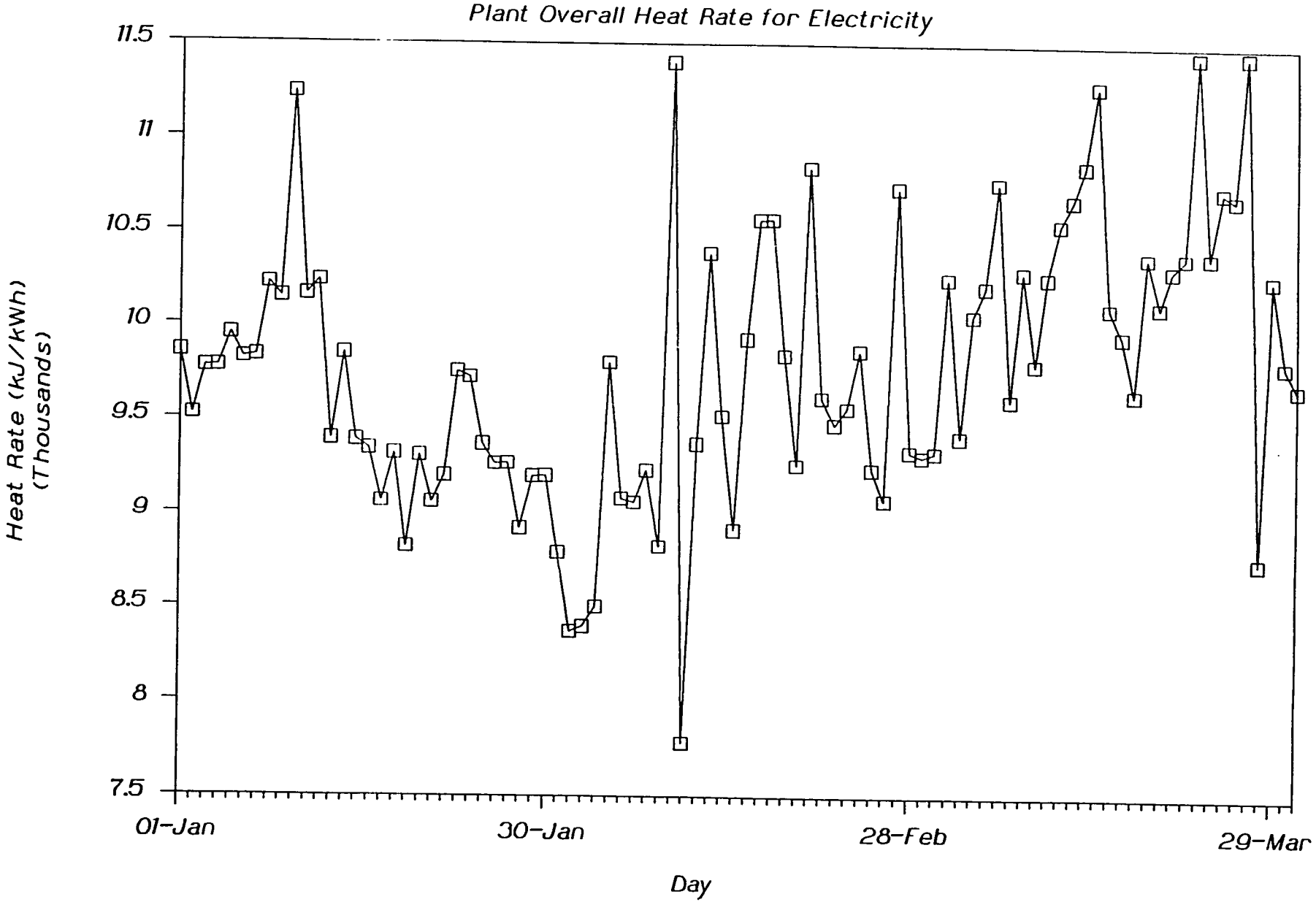

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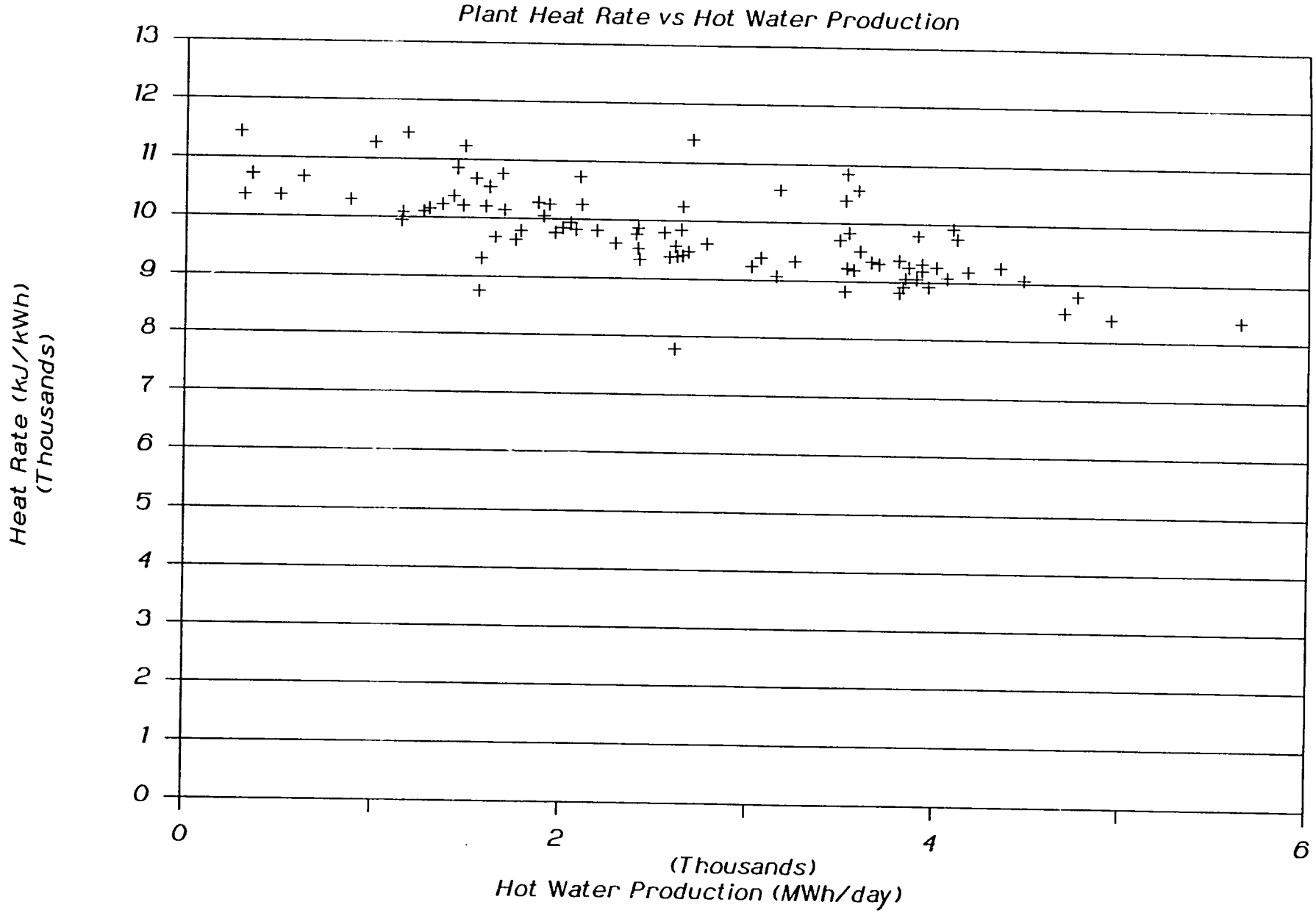
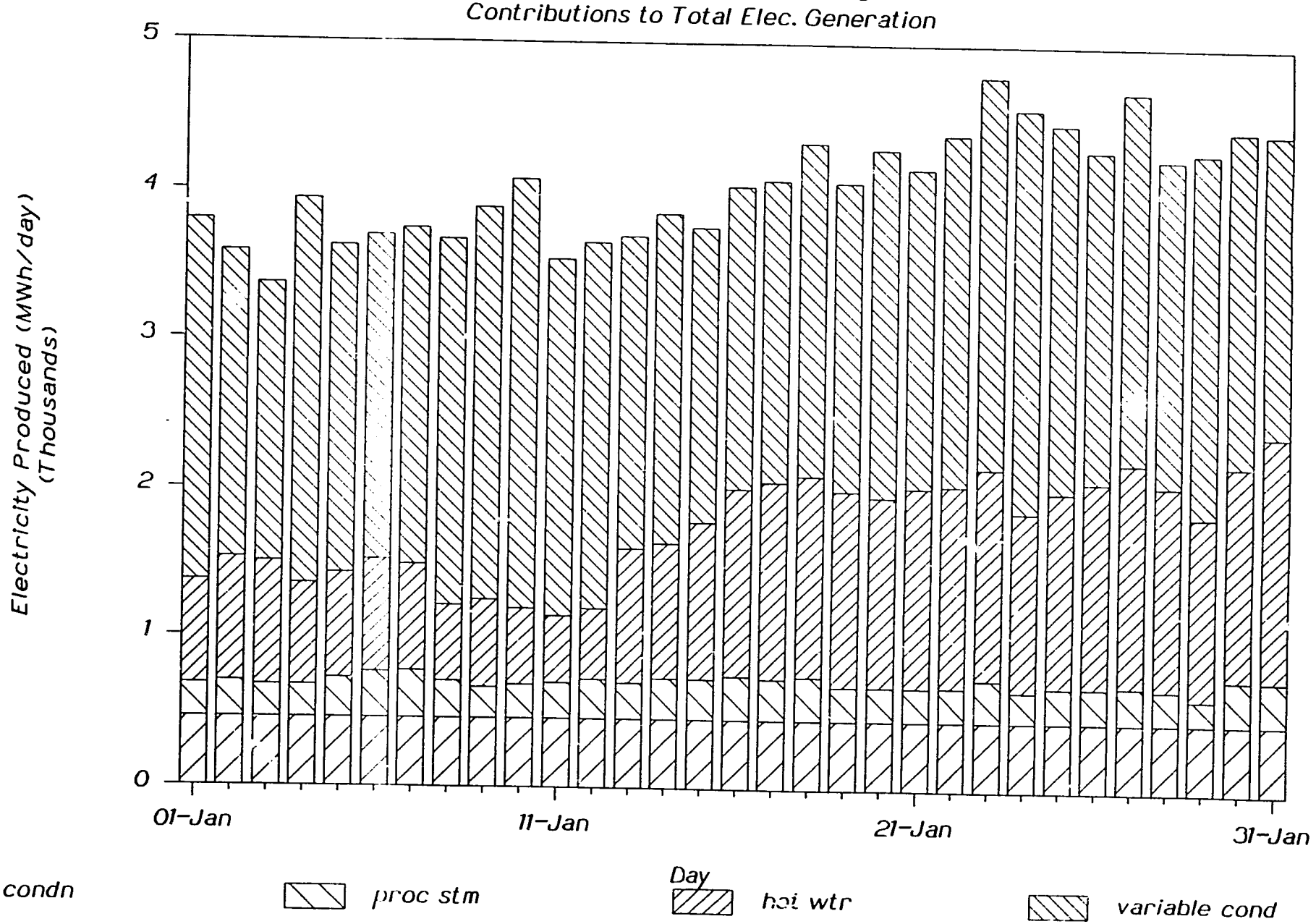


28.

TE-TO "Novi Sad" (January 1991) (#10)

Contributions to Total Elec. Generation



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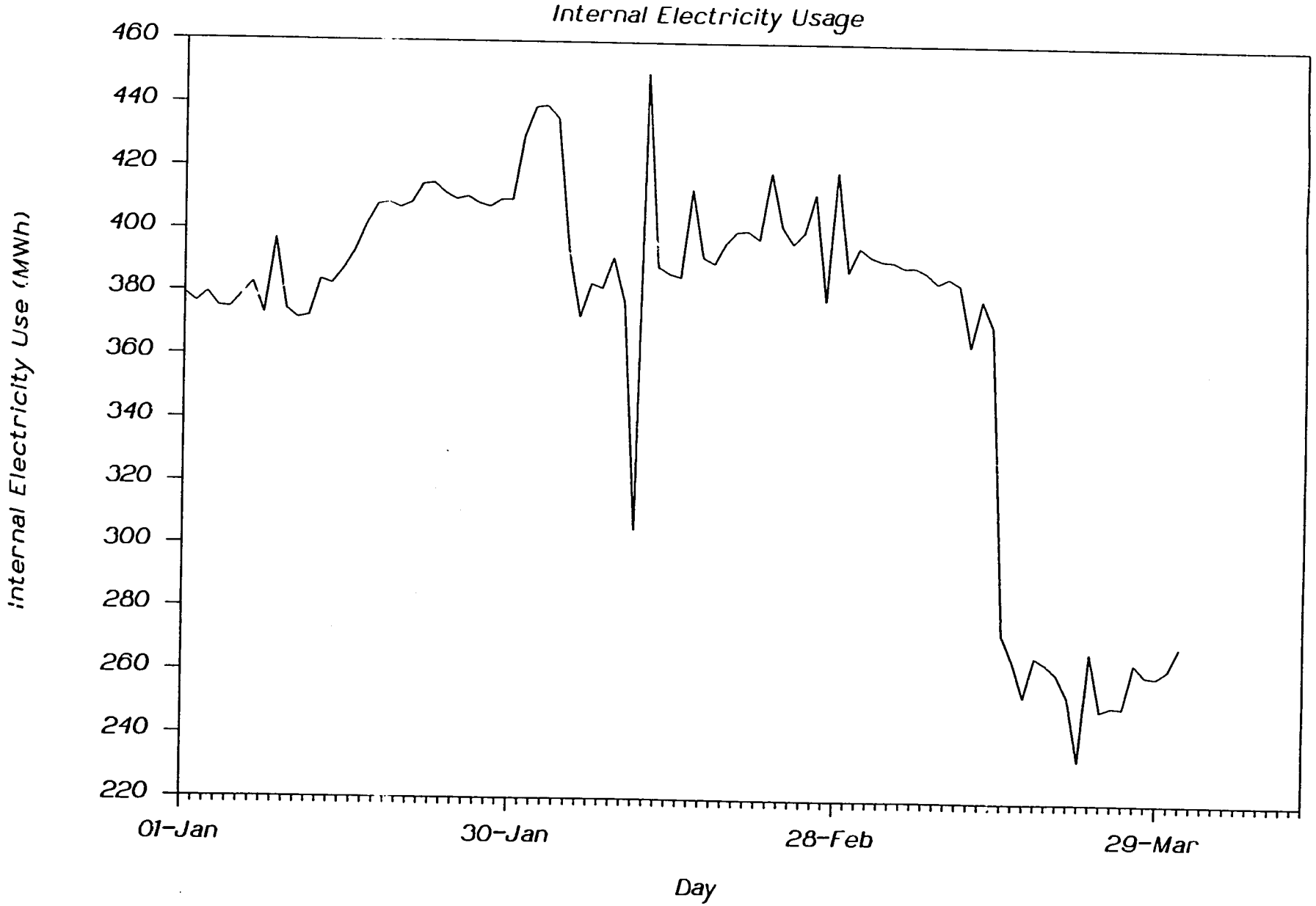

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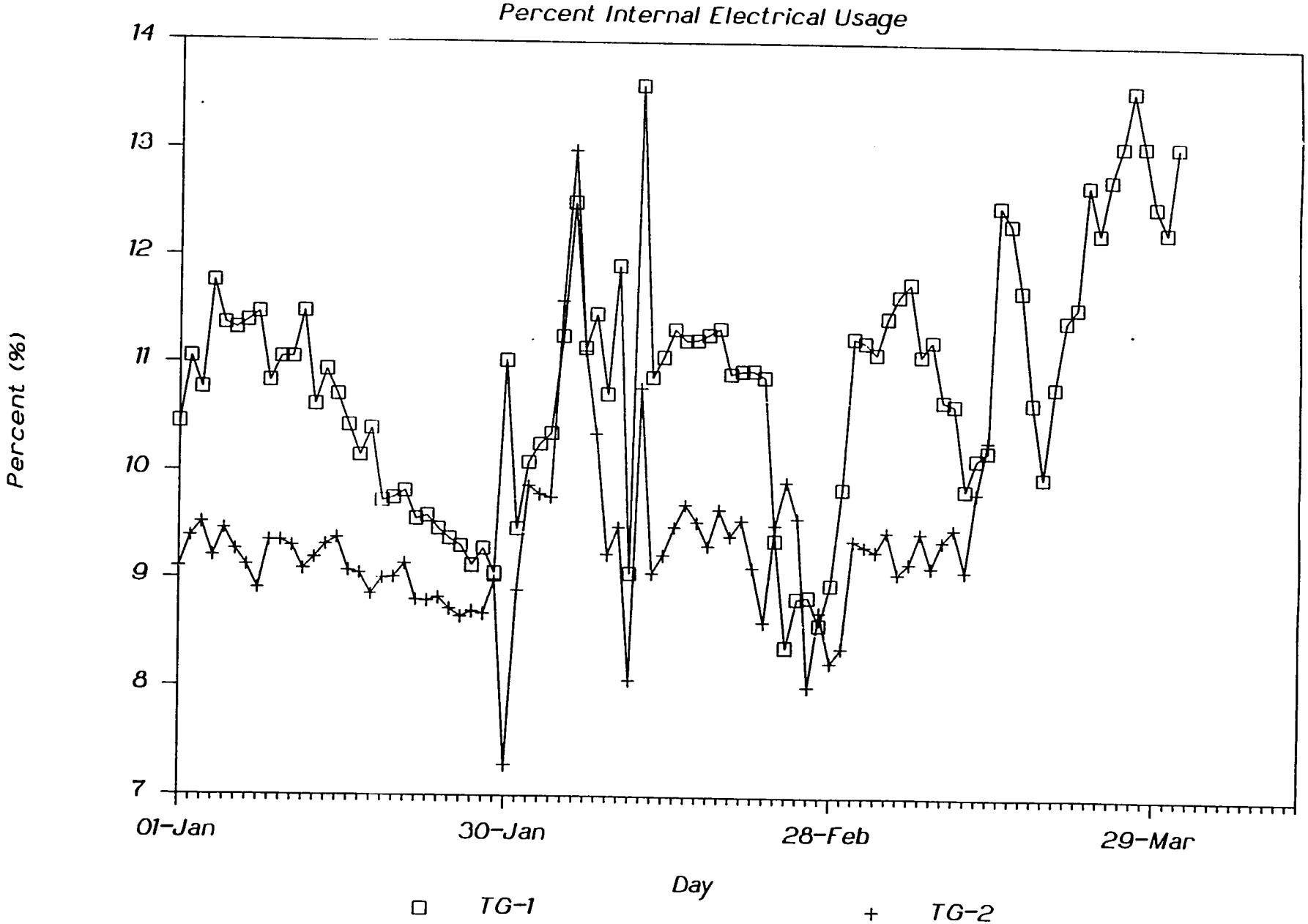

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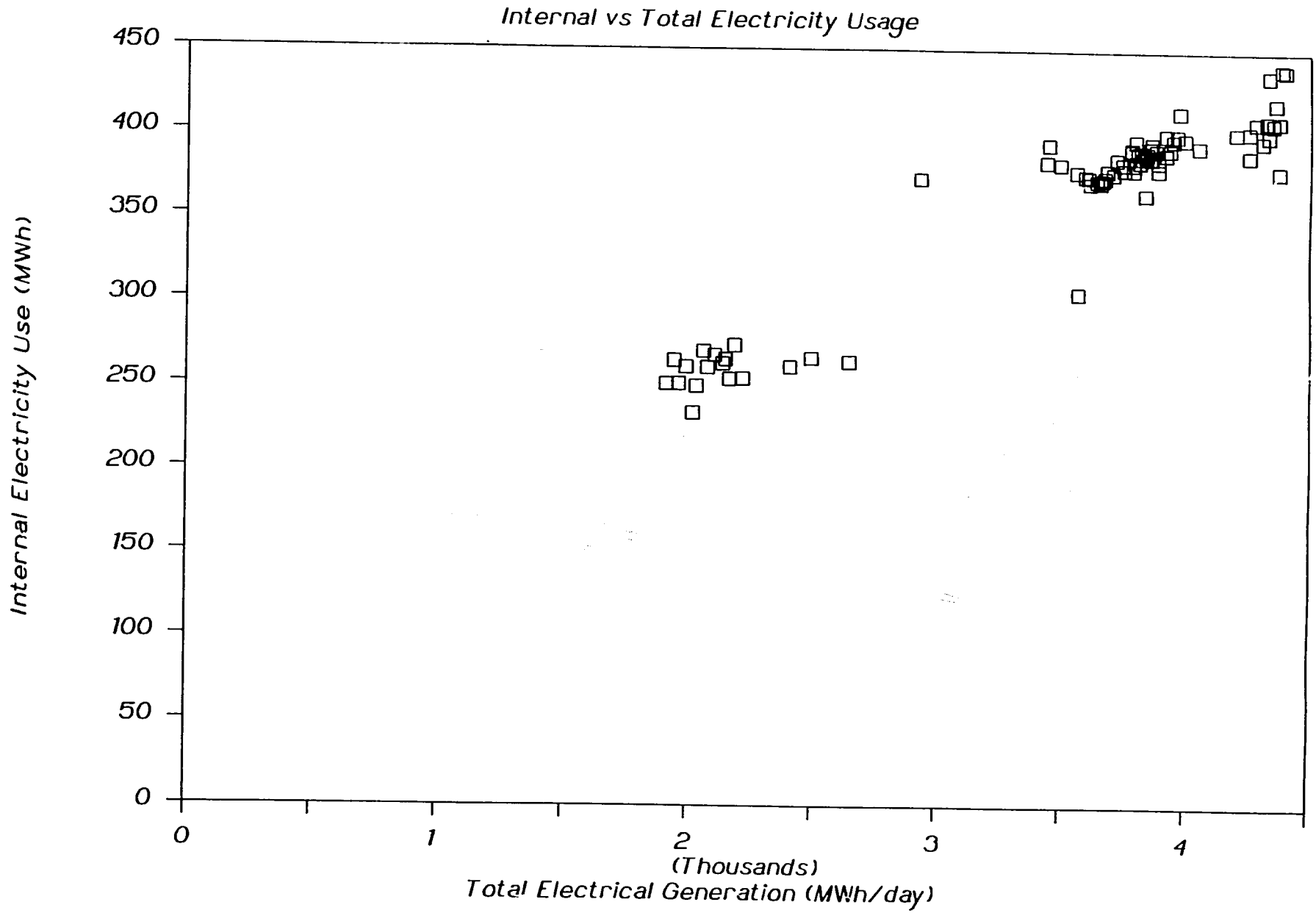

42.