PN-ABL-029
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ENERGY EFFICIENCY AUDIT REPORT
FOVAROSI TAVFUTO MUVEK (FOTAV)
DISTRICT HEATING WORKS
BUDAPEST, HUNGARY

MARCH 1992

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

and

EGI CONTRACTING & ENGINEERING
Budapest, Hungary

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

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
BUREAU FOR EUROPE
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USAID Contract EUR-0015-C-00-1007-00

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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.

PRELIMINARY ENERGY AUDIT
DISTRICT HEATING WORKS OF BUDAPEST

CONTENTS

DESCRIPTION	PAGE
I. EXECUTIVE SUMMARY	1
II. INTRODUCTION	3
III. ENERGY CONSUMPTION ANALYSIS - FOTAV SYSTEM	8
IV. ENERGY CONSUMPTION ANALYSIS - FOTAV E-P (NORTHEAST)	10
V. SHORT-TERM RECOMMENDATION - DEMAND-SIDE MANAGEMENT	13
VI. LONG-TERM RECOMMENDATION - COGENERATION	20
APPENDIX 1: GRAPHICAL PRESENTATION OF HISTORICAL DATA	
APPENDIX 2: PROJECT FORMS FOR D.S.M. PILOT PROJECT	

DRAFT
Preliminary Energy Audit
FOVAROSI TAVFUTO MUVEK (FOTAV)
DISTRICT HEATING WORKS OF BUDAPEST
Budapest, Hungary

by
RCG/Hagler, Bailly, Inc. and EGI Contracting & Engineering

I. EXECUTIVE SUMMARY

1.1 Introduction

A team of engineers from RCG/Hagler, Bailly, Inc. and EGI Engineering & Contracting visited FOVAROSI TAVFUTO MUVEK (FOTAV) ESZAK-PESTI UZEMIGAZGATOSAG (District Heating Works of Budapest, North-East Section) from April 19-26, 1991 to work together with FOTAV E-P staff to identify and implement improvements to energy efficiency, a preliminary energy audit.

FOTAV 1990 energy costs for the total Budapest system were:

1.	Heat:	Ft 7,000 million,	$97.2 million
2.	Electricity:	Ft 200 million,	$2.7 million
	TOTAL	Ft 7,200 million,	$100.0 million

Costs for 1991 are expected to be about 30% higher.

Based on consumption in 1990 and energy prices prevailing at the time of the visit, total energy costs for 1991 at FOTAV E-P (Ujpalota and Furedi stations) are estimated as Ft 770 million ($10.7 million), with the primary energy forms being natural gas (97% of costs) and electricity, (3% of costs).

RCG/Hagler, Bailly estimates the potential for short-term energy efficiency improvement on the supply-side at FOTAV E-P as less than 1%, without significant investment. However, the potential for demand-side efficiency improvement is 15-30% of total energy use (about $20 million per year), through conversion to a meterable and controllable heating system in residential apartment buildings and small commercial establishments, together with a heating tariff based on consumption, rather than a fixed annual charge (based on apartment cubic meters, at present).

During the course of the audit, the RCG/Hagler, Bailly team worked together with the staff of FOTAV to develop a pilot demand-side management program, to measure boiler efficiency at Ujpalota, and to analyze energy usage data and degree-day weather data.

1.2 Brief Description of Recommendations

1. Short-term: Demand-side Management

FOTAV should implement a demand-side management to help customers cope with the transition to a market-based thermal energy supply system. The program should have many elements, including pricing, information, metering, control equipment, and load reduction:

1. Institute energy usage-based district heating tariff and cost allocation system

2. Install meters on heating systems in apartments

3. Install automatic, thermostatic control valves on radiators in apartments

4. Carry out customer information campaign

5. Install meters on domestic hot water systems in apartments

6. Install cost-effective heat loss reduction equipment, such as weatherstripping, insulation, vestibule doors, or window treatments.

RCG/Hagler, Bailly estimates that the ultimate economic benefits from a full-scale DSM program at FOTAV would amount to $20 million per year, at an economic internal rate of return of at least 22%, based on a total cost of $108 million.

2. Long-term: Cogeneration

FOTAV should evaluate the feasibility of installing gas turbine cogeneration systems on their district heating stations. This would require the installation of a gas turbine generator and waste heat boiler. Such projects would be good candidates for funding under programs for energy efficiency and environmental benefication, as funded by development institutions.

For example, RCG/Hagler, Bailly estimates that the Ujpalota power station could be repowered by a cogeneration unit consisting of a 20-25MW gas turbine generator and waste heat boiler, which would generate electricity during the heating season only. This project would require a capital investment of $18 million, and would offer economic benefits of $3.6 million per year, for an economic internal rate of return of at least 17%.

II. INTRODUCTION

2.1 Introduction to FOTAV

FOTAV is a municipal company, owned by local government, and has been providing heat for Budapest for more than 30 years. Today, they provide heat to 240,000 homes, 5,000 municipal customers, and 430 industrial customers. The peak system load is 2,600 MW (thermal, MWth). Of this heat, approximately 2/3 is purchased from the electric utility (MVMT companies), in the form of heat extracted from steam turbogenerators (cogeneration). The remaining 1/3 of the heat is generated in boilers owned and operated by FOTAV.

There are 15 FOTAV heat generation plants, with a total of about 45 boilers, of various sizes from 2-200 MWth. A typical boiler is the Soviet PVTM, with 12 burners each 7 MW. All plants are now fueled by natural gas and distribute hot water as the heat transfer medium. In those cases in which FOTAV sells steam, the steam is supplied by MVMT. FOTAV does operate some small boilers at its heating stations, but only for deaeration and pressurizing.

Heat is supplied in a primary loop at a maximum temperature of 150C - 180C, depending on the system. The primary system consists of 450 km of transmission pipes, ranging in diameter from 50mm up to 900mm, fed by pumps from 70-500 kW. Design conditions are based on -15C, and the supply temperature is based on ambient temperature. In the last 5 years, the highest necessary supply temperature was 136C.

The primary system feeds 2,500 substations, each of which heats 50-230 homes. Each substation consists of heat exchangers for space heating and domestic hot water, and is metered by an energy meter (flow and temperature drop across the heat exchanger). The secondary distribution loop from the heat exchangers to the individual apartments is designed for a 90C supply and 70C return.
There are no storage tanks in the primary loop. In the secondary loop, there is no storage for space heating. There is a tank for domestic hot water in many buildings.

Space temperature in the apartments (flats) is maintained by FOTAV by adjusting the hot water primary loop supply temperature according to the outside ambient temperature. FOTAV is required to maintain space temperature at 20C or higher, and FOTAV

technicians make spot checks of temperature in each flat, on the average of twice per heating season.

FOTAV sells heat according to a district heating tariff which is controlled by the Government. The tariff has seven categories of service, in the following groups:

- Industrial customers are billed based on metered heat consumption according to a demand and energy tariff.
- Large municipal and commercial customers are billed based on metered consumption.
- Small municipal and commercial customers are billed on a lump-sum annual basis, according to their cubic meters volume of heated space.
- Residential customers are billed on a lump-sum annual basis, according to their cubic meters volume of heated space.

The heating season is October 15 - April 15, and the flat charge (annual payment) does not depend on the weather. However, if cold weather occurs requiring heat supply outside the season, FOTAV can bill for an additional amount.

FOTAV's costs for residential heat supply exceeded its revenues by some 150% in 1990 (the base tariff was 61.2 Ft/m3, whereas the cost was estimated as 140 Ft/m3). The cost of this subsidy is borne 40% by the local taxpayers (City of Budapest) and 60% by the national government.

A fundamental basis for the subsidy is the Government policy of energy price regulation. Natural gas fuel prices are controlled by the Government, and are much lower for residential use than for industrial use. District heating tariffs follow a similar philosophy. FOTAV purchases gas at the industrial tariff, and then sells heat to the residential sector at a price which is designed to correspond to the residential gas price. Thus residential district heating tariffs are lower than the energy cost of the delivered heat, representing a subsidy to the residential sector.

With the flat rate for energy on an annual basis, the individual customers have no incentive to conserve energy. Thus, the responsibility for energy efficiency has been borne by FOTAV. Over the past 15 years, the company has taken several actions to reduce specific energy consumption:

- Reduced average space temperature from 23C to 21C, and more recently 20C.
- Improved efficiency in boiler plants by an average of 5% through improved combustion techniques, primarily closed loop O2 monitoring and trim, based on Siemens technology.
- Upgraded insulation of transmission systems.
- Built a manufacturing plant to produce modern insulation systems, based on foam technologies.
- Installed system improvements to keep insulation dry.
- Equipped substations with automatic temperature control, based on local conditions at the substation.
- Successful in changing building codes to outlaw the uncontrollable one-pipe system[1] in apartment design.
- Conversion to variable volume flow in two heating plants on 200 kW pumps.

FOTAV has carried out some experiments in demand-side management (DSM), such as weatherstripping, thermostatic valves, and retrofits of one-pipe systems. DSM is the primary area in which FOTAV requests assistance from the U.S.

2.2 FOTAV E-P, NorthEast section

FOTAV E-P supplies heat to apartment buildings in the Northeast section of Budapest. The company has two heating stations, Ujpalota and Furedi, that supply hot water to separate groups of buildings in a primary loop. In the basement of each building (or pair of buildings, in some cases), a distribution substation of heat exchangers is located that transfer heat from the primary water loop to the secondary water loop within the building. Separate heat exchangers are used for space heating and domestic

[1] In the one-pipe system, a single pipe carries the hot water through each radiator in series as the pipe makes its way up through the floors of the building. If a resident shuts off the flow of hot water to his radiator, flow through the entire system (his neighbors on the other floors) will stop. The two-pipe system has a header and collector, so that each radiator is fed in parallel and may be shut off by a valve. Approximately 50,000 homes supplied by FOTAV have the one-pipe system.

water heating.

Energy meters, flow and temperature drop, are used to measure the demand taken by the building from the primary loop. These energy meters are monitored and recorded by FOTAV E-P, but are not yet used for billing purposes. One energy meter is installed per building (or pair of buildings).

FOTAV E-P estimates that 1/3 of the demand for heat is used for domestic hot water, over the course of the entire year. RCG/Hagler, Bailly confirms this estimate (see section III of this report).

2.3 Activities of the energy audit

A team of senior engineers from RCG/Hagler, Bailly, Inc. and EGI Contracting & Engineering, carried out site activities at FOTAV E-P from April 19-26, 1991 to work together with FOTAV to develop a demand-side management (DSM) pilot demonstration project. During this period, the project was reviewed by Robert ARCHER, A.I.D. Project Officer, who provided significant valuable contributions to many aspects of the project design. The project has received top management attention within the company, having been reviewed and approved by three FOTAV Directors:

Imre SCHILLER, Chief Engineer for Development
Imre SCHEITHAUER, Head of Energetic Department
Matyas FARKAS, Chief Engineer for Services

The project manager for the effort at the North-East district is VENCZEL Antal, Manager of FOTAV E-P, assisted by PAPP Zoltan, FOTAV E-P Engineer. The RCG/Hagler, Bailly team consisted of:

David KEITH, RCG/Hagler, Bailly, Project Director
Pascal HABAY, RCG/Hagler, Bailly, Manager for Hungary
LONTAY Zoltan, EGI Project Manager

The RCG/Hagler, Bailly team presented its recommendations together with a letter of authorization signed by Mr. ARCHER, to Mr. SCHILLER April 26, 1991.

The RCG/Hagler, Bailly team observed that the standard of management and engineering expertise available at FOTAV is excellent. Technical staff is very knowledgeable about energy conservation in general, and are up to date on the latest advances achieved by Western European district heating companies. The RCG/Hagler, Bailly team expects that this staff, with a

market-driven focus, design guidelines, and a few additional instruments, tools, and equipment, will be fully capable of implementing a full-scale demand-side management program.

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

III. ENERGY CONSUMPTION ANALYSIS - FOTAV SYSTEM

3.1 Energy supply costs

Natural Gas

Effective 7 November 1990, the natural gas tariff paid by FOTAV E-P is:

Demand: 280 Ft/MJ/hr annual fee
Consumption:
From 1 Oct - 31 Mar: 0.264 Ft/MJ
From 1 Apr - 30 Sep: 0.259 Ft/MJ

In comparison, the Government-controlled tariffs for district heating for the upcoming 1991/92 season are:

Residential: 0.242 Ft/MJ,
Small commercial: 0.380 Ft/MJ

Electricity

As of May 1991, the following electricity tariff was in effect (converted based on Ft 72 = $1.00):

Demand charge: Ft 370 per kW per month ($5.14)
Energy charge:
On-peak (peak) Ft 4.50 per kWh ($0.063)
On-peak (day) Ft 3.00 per kWh ($0.042)
Off-peak (night) Ft 2.25 per kWh ($0.031)

Total costs

FOTAV 1990 energy costs for the total system were:

1.	Heat:	Ft 7,000 million,	$97.2 million
2.	Electricity:	Ft 200 million,	$2.7 million
	TOTAL	Ft 7,200 million,	$100.0 million

Costs in 1991 are expected to be about 30% higher ($130 million), because of increased energy prices for the 1991/92 heating season.

3.2 Estimate of final energy demand

The distribution of final energy demand among the energy consuming sectors (residential, commercial, industrial) was not

provided by FOTAV. RCG/Hagler, Bailly has made a number of assumptions and has made an estimate of final energy demand for the purposes of this report, as follows:

RESIDENTIAL

Average residence heated space = 200 cubic meters
Economic cost of heat supply = Ft140/cubic meter (in 1990)
Annual cost of heat supply = 28,000 Ft/customer ($389)
Residential homes heated = 240,000

Annual cost of supplying customers = Ft 6,720 million
Annual energy cost (70%) = Ft 4,700 million ($65 million)

COMMERCIAL AND MUNICIPAL

Average heated space = 3,000 cubic meters
Economic cost of heat supply = Ft140/cubic meter (in 1990)
Annual cost of heat supply = 420,000 Ft/customer ($5,833)
Locations heated = 5,000

Annual cost of supplying customers = Ft 2,100 million
Annual energy cost (70%) = Ft 1,500 million ($20 million)

INDUSTRIAL

Annual energy cost = Ft 1,000 million
(by subtracting residential, commercial and municipal from system total of Ft 7,200 million)
Annual cost of supplying customers = Ft 1,400 million
Locations heated = 430
Annual cost of heat supply = Ft 3.3 million/customer ($46,000)

IV. ENERGY CONSUMPTION ANALYSIS - FOTAV E-P (NORTH EAST)

4.1 Graphical analysis of energy efficiency

A graphical presentation prepared by RCG/Hagler, Bailly of basic data received from FOTAV E-P on energy consumption, production, specific energy consumption, and other key parameters is attached as Appendix 1 to this report.

These graphs are provided for use by the staff of FOTAV E-P in identifying variations in energy efficiency. The analysis is a tool to point the way for more detailed investigations, in order to optimize performance. These detailed investigations are beyond the scope of the current study. However, a
A few observations are offered:

1. The total annual energy cost for FOTAV E-P is about $10.7 million, in 1991 energy prices. The energy cost in summer is about $300,000 per month, which represents only the domestic hot water load. Assuming the hot water load is approximately constant for each month, the annual cost breakdown is:

Space heating	$7.1 million (67%)
Domestic hot water	$3.6 million (33%)

2. Station efficiency (GJ output/GJ input) is consistently very good. Efficiency is higher for the Furedi station (89.7% in 1991) than the Ujpalota station (88.1% in 1991)[2]. Efficiency was improved for both stations in 1991, as compared to 1989, mainly through installation of combustion control systems to reduce excess air, based on continuous O2 analyzers.

3. Specific heat consumption of the system (system efficiency) averaged about 310 GJ heat delivered per degree-day[3], based on monthly data for 1989-91.

4. Specific heat consumption of the system (GJ per degree-day), on a monthly basis, is consistently higher for Furedi than

[2] The Ujpalota station has a concrete stack, which limits the exhaust gas temperature to 168C. The Furedi station has a steel stack, and is able to achieve a stack temperature of 120C or less (109C was observed during the audit).

[3] Degree-days in degrees C, based on 20C reference temperature.

Ujpalota, by about 1-2%.

5. The variability of specific heat consumption of the system is significant. This high variability indicates that there is opportunity for energy savings through improved control. For example, for days with an average ambient temperature of 0C (20 degree-days per day):

   1. In 1989/90 and 1990/91, Ujpalota delivered heat from 4,800 to 6,200 GJ/day, a variability of about ±13% about a mean value of 5,500.

   2. In 1989/90 and 1990/91, Furedi delivered heat from 5,000 to 6,500 GJ/day, a variability of about ±13% about a mean value of 5,750.

4.2 Observations during energy audit

On April 22, 1991, the RCG/Hagler, Bailly team made measurements of combustion efficiency and boiler efficiency at the Ujpalota power station. On the test day, only Boiler #2 was in operation. The boiler efficiency was 91.5% (LHV). This level of efficiency is considered very good, and so no adjustments to air/fuel ratio were carried out. Excess air was observed as 16%. The following parameters were observed:

Ambient temperature	12C
Water supply temp	111C
Water return temp	53.5C
Flow rate of water	663 m3/hr
Boiler outlet pressure	10.7 bar
Burners in operation	9 (out of 12 installed)
Exhaust gas temperature	143C
Exhaust gas oxygen	3.1% (16% XS air)
Heat output	43.2 MWth (155.5 GJ/hr)
Gas flow	5000 nm3/hr (170.0 GJ/hr)
Calculations:	
Combustion efficiency	93.8% (LHV basis)
(see calculation on following page)	
Boiler efficiency	91.5% (heat output/gas input)

Installation of a complete O2 control system could reduce excess air from 16% to about 8%, which is the level obtained at the Furedi station, which has the complete Siemens O2 system installed. This will improve combustion efficiency to 94.1%, a savings of 0.3%, or annual savings of about $32,000.

FOTAV – District Heating Works of Budapest
Combustion Calculations – Molal Basis

Date of test: 22 April 1991
Time of test: 1230

RCG/Hagler, Bailly, Inc.
FOTAV – District Heating Works of Budapest (North East) – UJPALOTA

Boiler #2
Fuel 5000 nm3/hr

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

Line	Fuel Constit	Per Fuel Unit, lb	Mol Wt Divisor	MolesFuel Constit	O2 Multiplr	O2 Moles TheoReqd	CO2 + SO	O2	N2	H2O	CO
1	C to CO2	70.00	12.00	5.83	1.00	5.83	5.83				
2	C to CO	0.00	12.00	0.00	0.50	0.00					0.00
3	CO to CO2	0.00	28.00	0.00	0.50	0.00	0.00				
4	C unburnd	0.00	12.00	0.00	0.00	0.00					
5	H2	23.00	2.00	11.50	0.50	5.75				11.50	
6	S	0.00	32.00	0.00	1.00	0.00	0.00				
7	O2 deduct	-1.00	32.00	-0.03	1.00	-0.03					
8	N2	6.00	28.00	0.21		0.00			0.21		
9	CO2		44.00	0.00		0.00	0.00				
10	H2O	0.00	18.00	0.00		0.00				0.00	
11	Ash	0.00		0.00		0.00					
12	Sum	100.00		17.52		11.55					
	Total air =		116.0% (from stack test)								
13	O2 (theo) reqd = O2, line 12					11.55					
14	O2 (excess) = (Total air -1) * line 12					1.85					
15	O2 (total) supplied = lines 13+14					13.40		1.85			
	Total Air (TA) = line 15/line 13					116.0%					
16	N2 supplied = 3.76*O2,line 15					50.39			50.39		
17	Air (dry) supplied = O2+N2					63.79					
18	H2O in air = moles dry air *A/(B-A)					1.35				1.35	
19	Air (wet) supplied = lines 17+18					65.14					
20	Flue gas constituents = lines 1 to 18, total						5.83	1.85	50.60	12.85	0.00 ---->

INPUT TABLE – FUEL AND CONDITIONS

LINE					
		Natural Gas, Budapest			
a	Fuel analysis as fired (AF), % by wt or vol				
	C=	70.0%	CO=	0.0%	
	H2=	23.0%			
	S=	0.0%			
b	O2=	1.0%			
	N2=	6.0%			
	H2O=	0.0%			
	Ash=	0.0%			
	TOTAL=	100.00%			
	Flue gas analysis by test				
	CO2=	10.1%			
c	CO=	0	PPM, =	0.000%	
	O2=	3.1%			
d	Total air (TA), based on above CO2 test				
	TA=	116%			
e	Lines f,g,h for gaseous fuels only				
f	Wt, fuel unit + sum (moles each * mol wt), lb				
g	Mol wt of fuel + line f / 100				
h	Density of fuel = line g/394 (lb/cuft)				
i	Higher heat value, fuel	12197	, Btu/lb =	22000	
j	%C in refuse				
k	Combustibles unburned, % of fuel			0.00%	
l	Stack temp, degrees C		a	143	
m	Ambient temp, dry bulb, degrees C			12	

		Wet Flue Gas	Dry Flue Gas
	Total Moles	71.133761	58.281619

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

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

								Conversion to metric units	
22	Fuel unit 100.00 lb	Flue gas constituents:	CO2 + SO	O2	N2	H2O	CO	Btu Total	kcal total	kJoules total
23	MCp, Molal specific heat, mean, t2 to t1		9.81	8.14	7.17	7.06	7.09			
24	In dry flue gas, moles each, line 20*MCp*(t2-t1)		13500	3550	8559		0.00	102641	25866	108287
25	In H2O in air, moles H2O, line 18*MCp*(t2-t1)					2251		2251	567	2374
26	In sens heat, H2O in fuel, moles, lines (5+10)*MCp*(t2-t1)					19139		19139	4823	20191
27	In latent heat, H2O in fuel, moles, lines (5+10)*1040*18					215280		215280	54251	227120
28	Total in wet flue gas							339311	85506	357973
29	Due to carbon in refuse, line k*14,100							0	0	0
30	Due to unburned CO in flue gas; moles C to CO*12*9755							0	0	0
31	Total flue gas losses + unburned combustible = lines 28+29+30							339311	85506	357973
32	Higher heat value (HHV) of fuel unit= 100 * line i for solid & liquid fuels							2200000	554400	2321000
	= 394 * line i * 100 for gaseous fuels									
33	Stack and combustible loss, % of heat input, 100*line 31/line 32							15.4%	15.4%	15.4%
34	Combustion efficiency, HHV, % of heat input 100-line 33							84.6%	84.6%	84.6%
35	Combustion efficiency, LHV basis (line 27 taken out from heat value and losses)							93.8%	93.8%	93.8%

V. SHORT-TERM RECOMMENDATION: IMPLEMENT DEMAND-SIDE MANAGEMENT PROGRAM FOR ENERGY EFFICIENCY IMPROVEMENT

1. STATEMENT OF RECOMMENDATION

FOTAV should implement a demand-side management to help customers cope with the transition to a market-based thermal energy pricing system. The program should have many elements, including pricing, information, metering, control equipment, and load reduction.

2. DESCRIPTION/RATIONALE

The system of energy pricing for district heating in Budapest is based on the volume (cubic meters) of heated space, not on actual energy consumption. This design was installed because it has lower capital costs than a meterable system, and because of prevailing social views toward energy supply at the time. Such a system offers no incentive for energy efficiency, because the billpayer receives no benefit, should he take control actions to save energy.

As a further cost-reduction in the initial design, approximately 20% of the homes in the FOTAV system (50,000 flats) were built with heating elements connected in the so-called one-pipe system. This system (now outlawed) is uncontrollable - the resident has no equipment by which he can take reduce the flow of heat. In these flats, the introduction of an energy-based tariff would be frustrating the resident would be doomed to consume.

FOTAV should take the lead in organizing a demand-side management (DSM) program. This program should be seen as a partnership between FOTAV and its customers to assist in the transition to a market-based system for the supply of heat. DSM should be seen as a long-term corporate strategy for FOTAV, as a logical counterpoint to the increase of prices which will be required to reflect the economic cost of service to the residential sector.

The program should have many elements, including:

- <u>Pricing</u> - establish a tariff that offers an incentive for the customer to limit energy consumption
- <u>Information</u> - educate the consumer regarding the new tariff and at the same time provide information on ways

to conserve energy

- Metering - a method of metering energy consumption on a building basis (each building has 50-200 flats) is already installed; a method of metering for the allocation of this consumption to the individual flats is required

- Control equipment - control devices are needed on heating systems. Manual valves can shut off radiators but 2-way thermostatic valves cost only slightly more and offer automatic energy savings

- Load reduction - there appear to be cost-effective opportunities to reduce heat loss through the building envelope, such as by weatherstripping, insulation, window treatments, vestibule doors, and other retrofits.

3. BENEFITS

The project benefits the economy of Hungary by reducing the demand for natural gas, most of which is imported. These calculations are based on the estimates developed in section 3, according to the following assumptions are made :

Average residence heated space = 200 cubic meters
Economic cost of heat supply = Ft140/cubic meter (in 1990)
Annual cost of heat supply = 28,000 Ft/customer ($389)
Residential homes heated = 240,000
Annual energy cost of heat supply to residential customers = Ft 4,700 million per year ($65 million)

3.1 For apartments connected to TWO-PIPE SYSTEMS (190,000 homes, 79%), RCG/Hagler, Bailly estimates the total energy conservation potential as 30%, as follows:

1. Conversion to a meterable system with a tariff based on the cost of residential service can reduce energy consumption by 10% after consumer awareness is complete. Benefit = Ft 350 million per year ($5 million).

2. Conversion to a controllable system based on thermostats can reduce energy consumption by 10%. Benefit = Ft 350 million per year ($5 million).

3. Implementation of cost-effective load reduction investments (insulation, weatherstripping, window treatments) can reduce energy consumption by 10%. Benefit = Ft 350 million per year ($5 million).

3.2 For apartments connected to ONE-PIPE SYSTEMS (50,000 homes, 21%), RCG/Hagler, Bailly estimates the total energy conservation potential as 40%, as follows:

1. Conversion to a controllable system based on a radiator bypass and thermostats can reduce energy consumption by 20%. Benefit = Ft 200 million per year ($2.7 million).

2. Conversion to a meterable system with a tariff based on the cost of residential service can reduce energy consumption by 10% after consumer awareness is complete. Benefit = Ft 100 million per year ($1.3 million).

3. Implementation of cost-effective load reduction investments (insulation, weatherstripping, window treatments) can reduce energy consumption by 10%. Benefit = Ft 100 million per year ($1.3 million).

4. IMPLEMENTATION COSTS

4.1 Fixed costs to design and operate a five-year DSM program, to carry out information campaigns, and promote a partnership with the customers are estimated as follows:

Year 1 (91/92) = $0.5 million
Year 2 (92/93) = $1.0 million
Year 3 (93/94) = $2.0 million
Year 4 (94/95) = $2.0 million
Year 5 (96/97) = $1.0 million

4.2 For apartments connected to TWO-PIPE SYSTEMS (190,000 homes), RCG/Hagler, Bailly estimates the following costs:

1. Conversion to a meterable heat and hot water system with a tariff based on the cost of residential service would cost $100 per customer, with an annual servicing/reading cost of $50 per customer. Total investment cost for 190,000 customers = $19 million.

2. Conversion to a controllable system based on thermostats would cost $100 per customer. Total cost for 190,000 customers = $19 million.

3. Implementation of cost-effective load reduction programs would cost $200 per customer. Total cost for 190,000 customers = $38 million.

4.3 For apartments connected to ONE-PIPE SYSTEMS (50,000 homes), RCG/Hagler, Bailly estimates the following benefits:

1. Conversion to a controllable system based on a radiator bypass and thermostats would cost $200 per customer. Total cost for 50,000 customers = $10 million.

2. Conversion to a meterable heat and hot water system with a tariff based on the cost of residential service would cost $100 per customer, with an annual servicing/meter reading cost of $50 per customer. Total investment cost for 50,000 customers = $5 million.

3. Implementation of cost-effective load reduction programs would cost $200 per customer. Total cost for 50,000 customers = $10 million.

5. FINANCIAL AND ECONOMIC ANALYSIS

Detailed discounted cashflow economic and financial analysis is shown in the tables on the following pages. The economic rate of return of the project is 22-24%.

The financial payback analysis for the project as a whole is as follows.

	US$M COST	US$M/YR BENEFIT	YEARS PAYBACK
TWO-PIPE SYSTEMS			
1. Meters	19	5	3.8
2. Controls	19	5	3.8
3. Load reduction	38	5	7.6
ONE PIPE SYSTEMS			
1. Controls	10	2.7	3.7
2. Meters	5	1.3	3.7
3. Load reduction	10	1.3	7.6
PROGRAM FIXED COSTS	7		
	---	----	---
TOTAL	108	20.3	5.3

U.S.A.I.D. Emergency Energy Program for Hungary
FOTAV: District Heating Works of Budapest
RCG/Hagler, Bailly, Inc.
Financial & Economic analysis
22-May-91

For 1-pipe systems: 200 m3 apartment volume

Assumptions:

$50.00	for each valve
$50.00	for each heat allocation meter (electronic)
35%	savings for monthly readable meter
$10.00	for each heat allocation meter (fluid)
25%	savings for annually readable meter
72	Ft = US$1.00
10%	savings for potable hot water consumption meter

Case 1 - electronic heat allocation metering

Year	0	1	2	3	4	5	6	7	8	9	10
Installation cost											
Valves	10800										
Heat Meters	10800										
Water meters	5000										
Installation	12000										
Total	38600										
O&M cost		600	600	600	600	600	600	600	600	600	600
Cost of supply (heat)											
Fin Tariff	104	Ft/m3/yr, based on tariff for 91/92 heating season									
Econ cost	140	Ft/m3/yr, based on study using 90/91 border prices for gas (by FOTAV)									
Cost of supply (hot water, based on FOTAV estimate of 1/3 of total energy)											
Fin Tariff	10000	Ft/yr									
Econ cost	14000	Ft/yr									
Energy savings	35%	heat,	10%	hot water							
Financial		8280	8280	8280	8280	8280	8280	8280	8280	8280	8280
Economic		11200	11200	11200	11200	11200	11200	11200	11200	11200	11200
Net benefits											
Financial	-38600	7680	7680	7680	7680	7680	7680	7680	7680	7680	7680
Economic	-38600	10600	10600	10600	10600	10600	10600	10600	10600	10600	10600
Project evaluation criteria											
Financial	5.03	years payback period									
Economic	24.4%	economic internal rate of return, 10 year planning horizon									

U.S.A.I.D. Emergency Energy Program for Hungary
FOTAV: District Heating Works of Budapest
RCG/Hagler, Bailly, Inc.
Financial & Economic analysis
22-May-91

For 1-pipe systems: 200 m3 apartment volume

Assumptions:

$50.00	for each valve
$50.00	for each heat allocation meter (electronic)
35%	savings for monthly readable meter
$10.00	for each heat allocation meter (fluid)
25%	savings for annually readable meter
72	Ft = US$1.00
10%	savings for potable hot water consumption meter

Case 2 - fluid heat allocation metering

Year	0	1	2	3	4	5	6	7	8	9	10
Installation cost											
Valves	10800										
Heat Meters	2160										
Water meters	5000										
Installation	12000										
Total	29960										
O&M cost		600	600	600	600	600	600	600	600	600	600
Cost of supply (heat)											
Fin Tariff	104	Ft/m3/yr, based on tariff for 91/92 heating season									
Econ cost	140	Ft/m3/yr, based on study using 90/91 border prices for gas (by FOTAV)									
Cost of supply (hot water, based on FOTAV estimate of 1/3 of total energy)											
Fin Tariff	10000	Ft/yr									
Econ cost	14000	Ft/yr									
Energy savings	25%	heat,	10%	hot water							
Financial		6200	6200	6200	6200	6200	6200	6200	6200	6200	6200
Economic		8400	8400	8400	8400	8400	8400	8400	8400	8400	8400
Net benefits											
Financial	-29960	5600	5600	5600	5600	5600	5600	5600	5600	5600	5600
Economic	-29960	7800	7800	7800	7800	7800	7800	7800	7800	7800	7800
Project evaluation criteria											
Financial	5.35	years payback period									
Economic	22.7%	economic internal rate of return, 10 year planning horizon									

10

6. IMPLEMENTATION SCHEDULE

A five-year program is recommended, beginning in 1992. During the 1991/92 heating season, a pilot demonstration is recommended in a sample building.

7. PHASE 1 - DETAILS AND SPECIFICATION OF EQUIPMENT

Refer to APPENDIX 2 for PROJECT ACTION FORM, which provides the details of the equipment for the pilot demonstration, to be procured under the U.S. Emergency Energy Program.

VI. LONG-TERM RECOMMENDATION: INSTALL COGENERATION SYSTEMS TO IMPROVE THERMODYNAMIC EFFICIENCY

1. STATEMENT OF RECOMMENDATION

FOTAV should evaluate the feasibility of installing gas turbine cogeneration systems on their district heating stations.

2. DESCRIPTION/RATIONALE

In the heating stations operated by FOTAV, hot water is generated directly in natural gas fired boilers. While the "First Law" thermodynamic efficiency of the existing stations is very good (nearly 90% based on LHV), the "Second Law" thermodynamic efficiency is poor because of the low temperature of the water delivered by the stations.

The opportunity exists to repower these stations as cogeneration stations with a gas turbine generator providing waste heat to a heat recovery boiler. In this way, electric power can be generated without additional fuel consumption, providing a higher "Second Law" thermodynamic efficiency.

Modern aeroderivative gas turbines, such as the GE LM-2500, have improved pressure ratios and firing temperatures to achieve a thermodynamic efficiency of about 35% at full-load and 30% at half-load (as compared to 20% at full-load for 1st generation gas turbines). These turbines have lower exhaust temperatures (375C) and are not favored for combined cycle powerplants which must generate steam from the waste heat, but the exhaust temperature is still sufficient for the low-temperature district heating application.

For a system efficiency of 90%, to achieve the same exhaust gas temperature and excess air conditions, it may be necessary to have auxiliary burners in the waste heat boiler to make use of the excess oxygen in the turbine exhaust. In addition, because of the low heat available per volume of gas, the waste heat boiler must have a much larger heat transfer surface than the existing boilers.

Assuming the system efficiency of 90% and a gas turbine generator efficiency of 33%, the electrical output will correspond to 36% of the thermal output. Taking the case of the Ujpalota station is taken as typical:

Typical winter day:	5,000 GJ/day
Typical summer day:	1,000 GJ/day

the resulting electrical output is as follows:

Typical winter day:	500 MWh/day (20 MW)
Typical summer day:	100 GJ/day (4 MW)

The load in winter, about 20 MW, is appropriately sized for a LM-2500 aeroderivative unit. However, the load in summer would be far too small to make efficient use of this unit. A smaller unit (such as manufactured by Solar Turbines) could be installed for use in summer.

3. BENEFITS

Economic benefits are estimated as reduced importation of electric energy from the Soviet Union. As RCG/Hagler, Bailly understands the present arrangement, the average cost of imported electricity is about US$0.055/kWh.

Financial benefits are estimated as electricity sales to the MVMT grid. A detailed analysis should be carried out to determine the magnitude of the benefits, according to the MVMT tariff, which has seasonal and time of day rates. For the purposes of this screening analysis, an average financial benefit of 3 Ft/kWh is assumed ($0.041/kWh).

Because of the uncertainty regarding the sizing of the unit, a system used only during the winter heating season is assumed.

Average heating load:	4,000 GJ/day
Electric generation:	400 MWh/day
Heating season:	180 days/year
Seasonal generation:	72,000 MWh/yr
Energy benefits:	
Economic benefit:	$3.96 million/yr
Financial benefit:	$2.95 million/yr

4. IMPLEMENTATION COSTS

Costs are estimated as $600 per kilowatt (electric) for the gas turbine generator, electrical switchgear and substation, and waste heat boiler. Installation costs are estimated as a further 20%, for a total installed cost of $720/kW.

With the proper sizing of the turbine/waste heat boiler, no additional fuel costs are required to generate the electricity. Operations and maintenance costs are estimated as $0.005/kWh.

Peak capacity:	25 MW
Capital cost:	$18 million
Incremental O&M cost:	$360,000/year

5. FINANCIAL AND ECONOMIC ANALYSIS

The financial analysis requires investigation of financing (debt or equity) and also consideration of tax implications. For the purposes of this report, a simple payback analysis is used for the financial analysis:

Capital investment:	$18 million
Electricity sales:	$2.95 million/yr
Increased O&M cost:	$0.36 million/yr
Net income:	$2.59 million
Payback period:	6.9 years

The economic analysis is indicated on the following page. A standard conversion factor of 0.8 has been used on local costs, to indicate that Hungary has not yet reached parity with Western economies (there is a shadow price of local labor and other costs).

The project economic net present value is over $9 million, with an economic internal rate of return of 17.6%. The economic analysis indicates that this project would be favorable to Hungary, and warrants further study as a possible project for funding by funds for energy and the environment by development banks.

6. IMPLEMENTATION SCHEDULE

1991/92: Full engineering and economic feasibility study.

1992/93: Arrange financing

1993/94: Begin engineering design, order gas turbine generator

1994/95: Procure major equipment and begin construction

1996/97: Complete construction

1997/98: Plant commissioning and full operation

U.S.A.I.D. Emergency Energy Program for Hungary
FOTAV: District Heating Works of Budapest
RCG/Hagler, Bailly, Inc.
Recommendation – Install Cogeneration System
Financial & Economic analysis
05-Jun-91
For installation of gas turbine and waste heat boiler
Assumptions:

$450	per kilowatt for gas turbine (FOREIGN)
$270	per kilowatt for waste heat boiler and installation (LOCAL)
0.80	standard conversion factor on local costs
3.00	years construction period
10.0%	discount rate
25.0	MW plant capacity
72,000	MWh annual electric generation
$0.053	per kilowatt-hour economic benefit
$0.005	per kilowatt-hour O&M cost

Economic costs and benefits, expressed in 1991 US$ 000

Year	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
COSTS																						
Engineering	1,800																					
Construction		4,995	11,655																			
Operations & Maintenance				360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360	360
BENEFITS																						
Electricity sales				3,960	3,960	3,960	3,960	3,960	3,960	3,960	3,960	3,960	3,960	3,960	3,960	3,960	3,960	3,960	3,960	3,960	3,960	3,960
NET BENEFITS	(1,800)	(4,995)	(11,655)	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600	3,600
NPV	9,506																					
IRR	17.6%																					

23

APPENDIX 1
GRAPHICAL PRESENTATION OF HISTORICAL ENERGY CONSUMPTION AND EFFICIENCY DATA

FOTAV ESZAK-PESTI

District Heating Works of Budapest, North-East Section

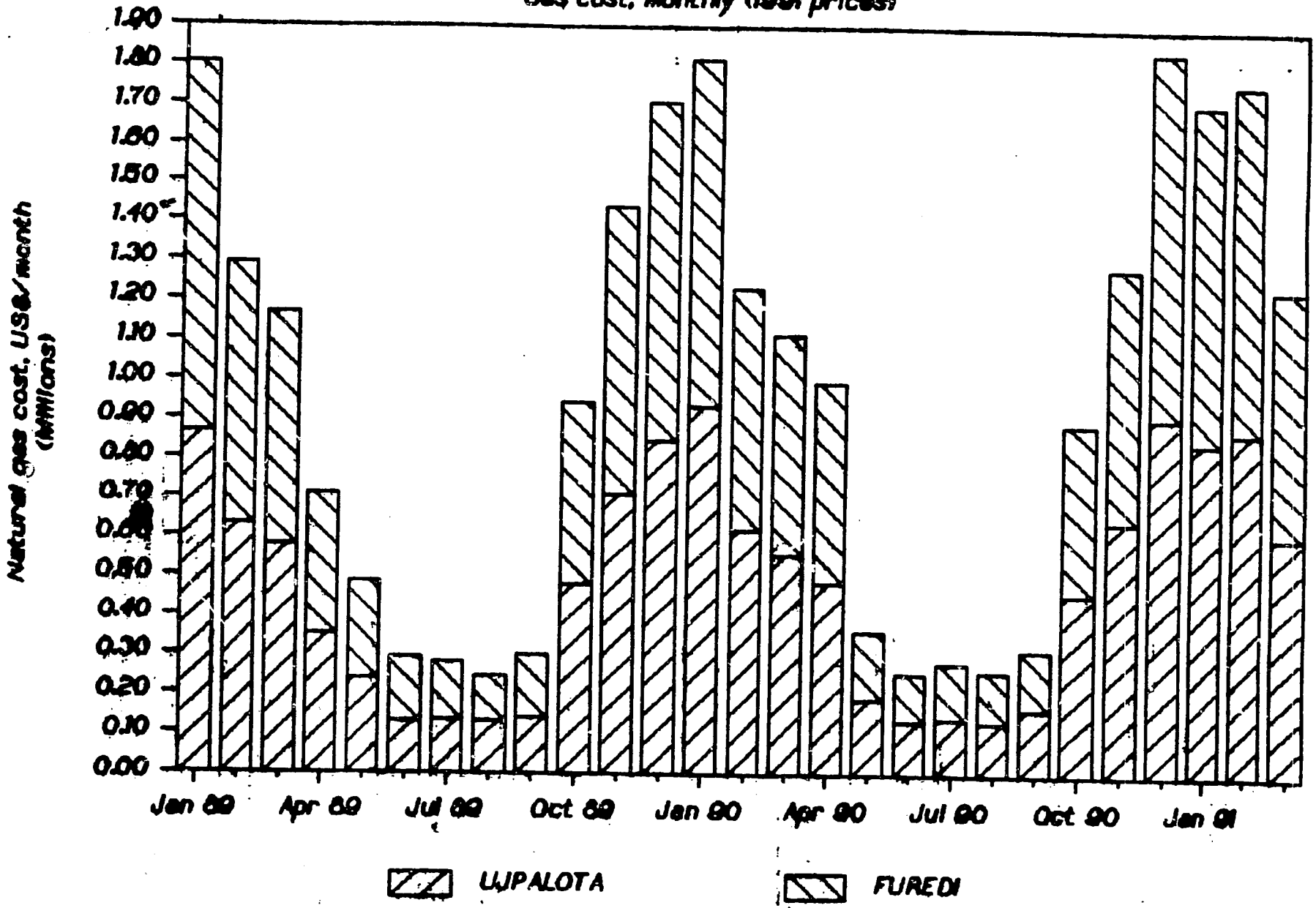
FOTAV ESZAK-PESTI

District Heating Works of Budapest, North-East Section

MONTHLY DATA
JANUARY 1989 - MARCH 1991

FOTAV Eszak-pesti 1989-91

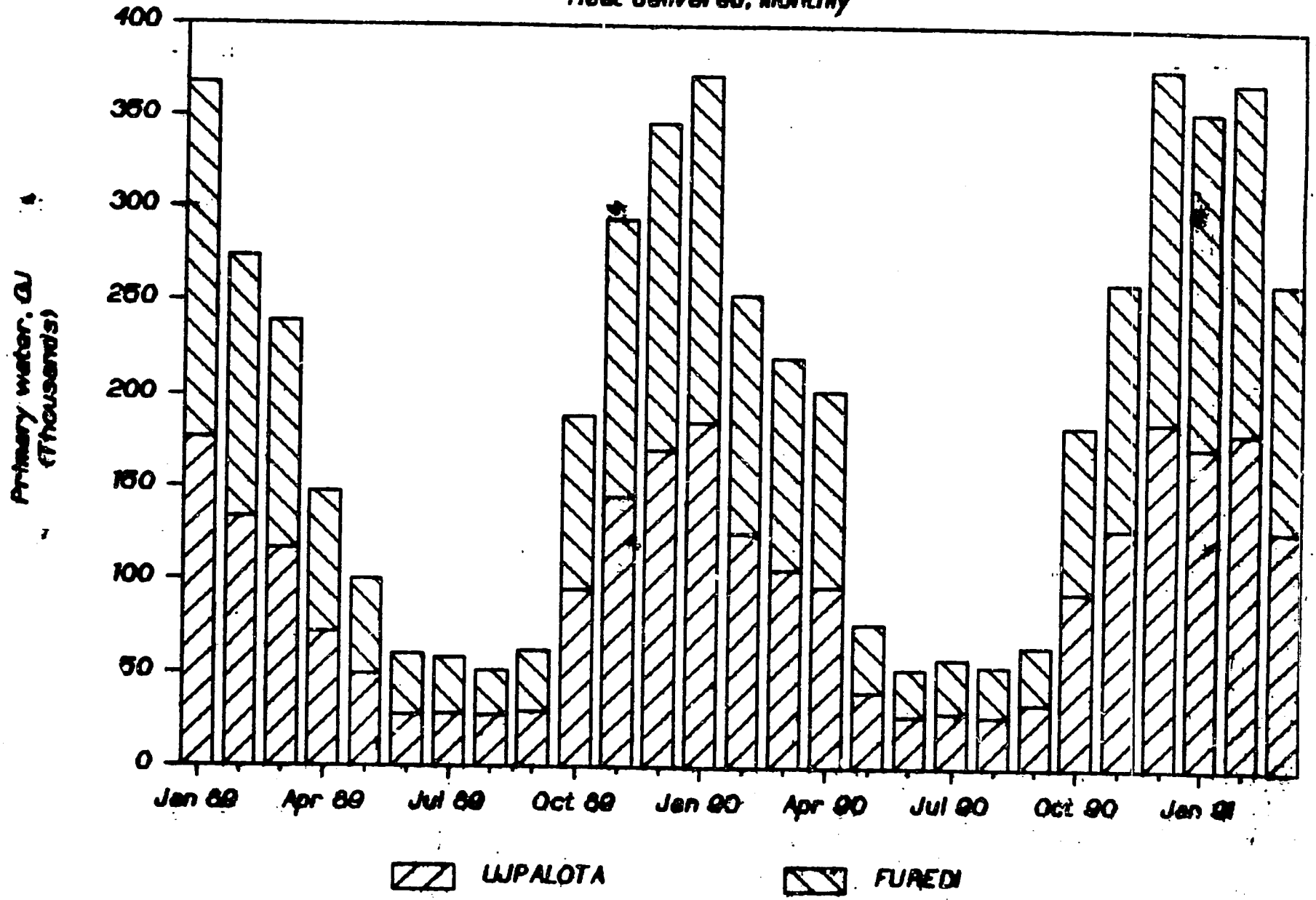
Gas cost, monthly (1991 prices)



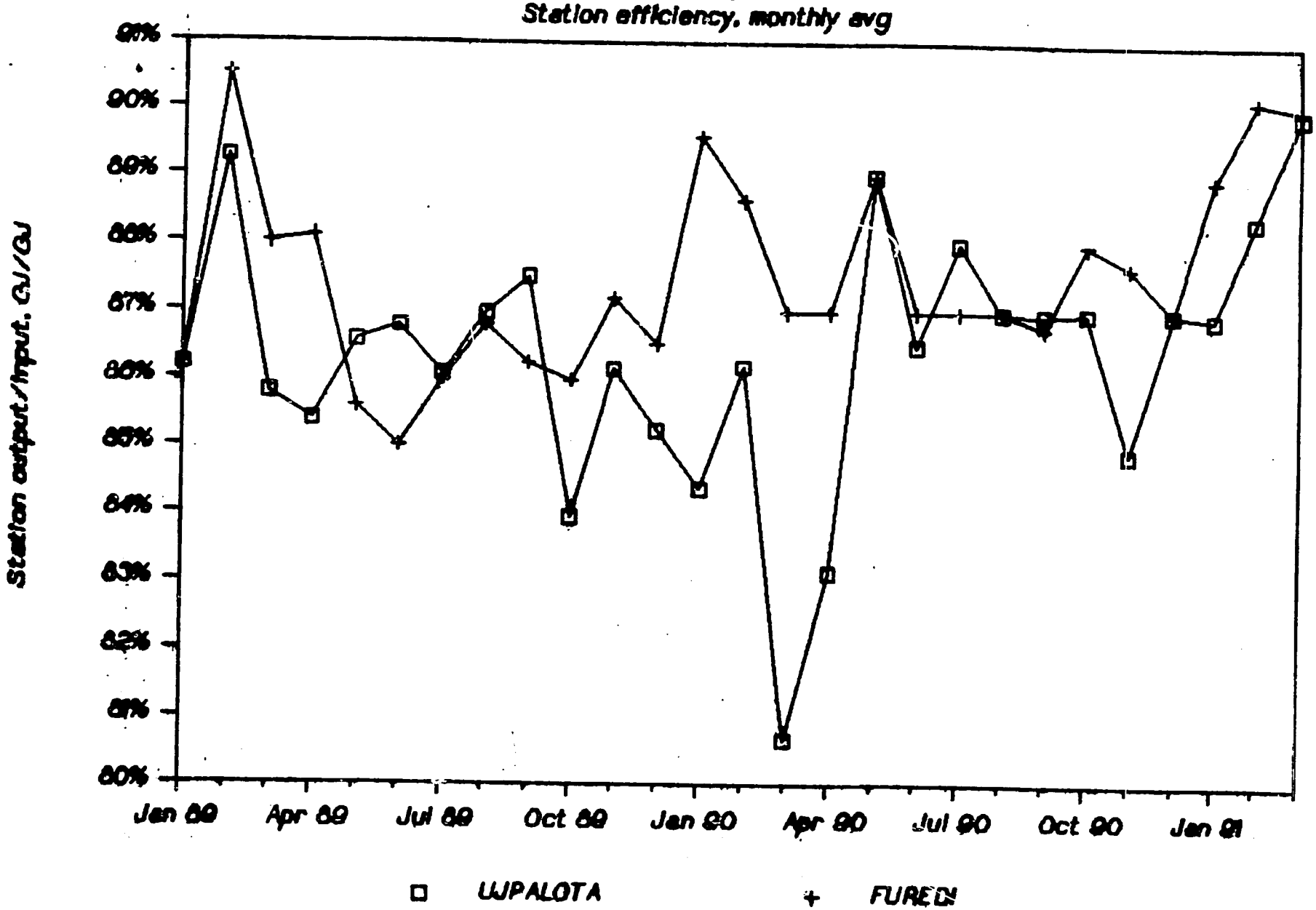
26

FOTAV Eszak-pesti 1989-91

Heat delivered, monthly

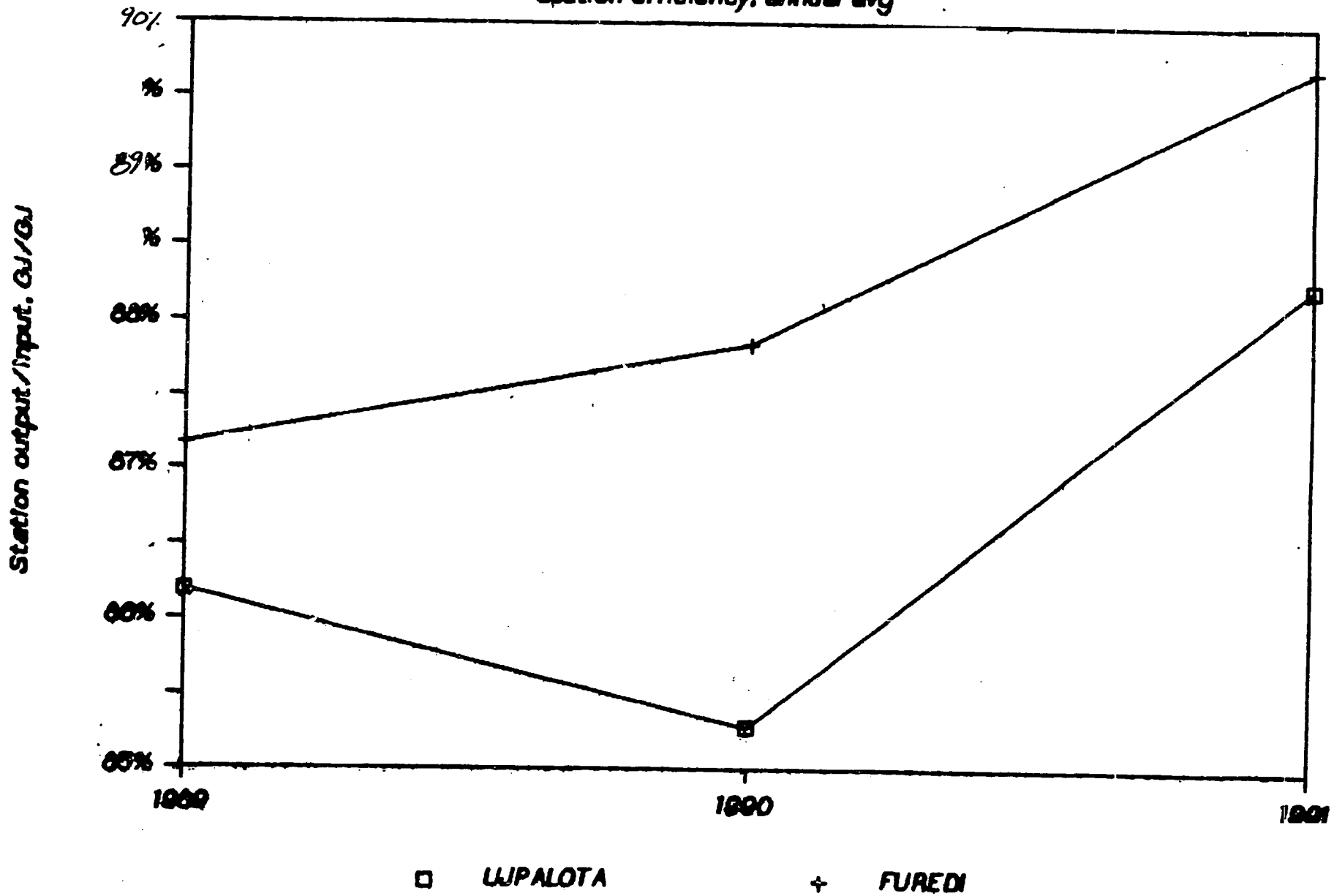


FOTAV Eszak-pesti 1989-91



FOTAV Eszak-pesti 1989-91

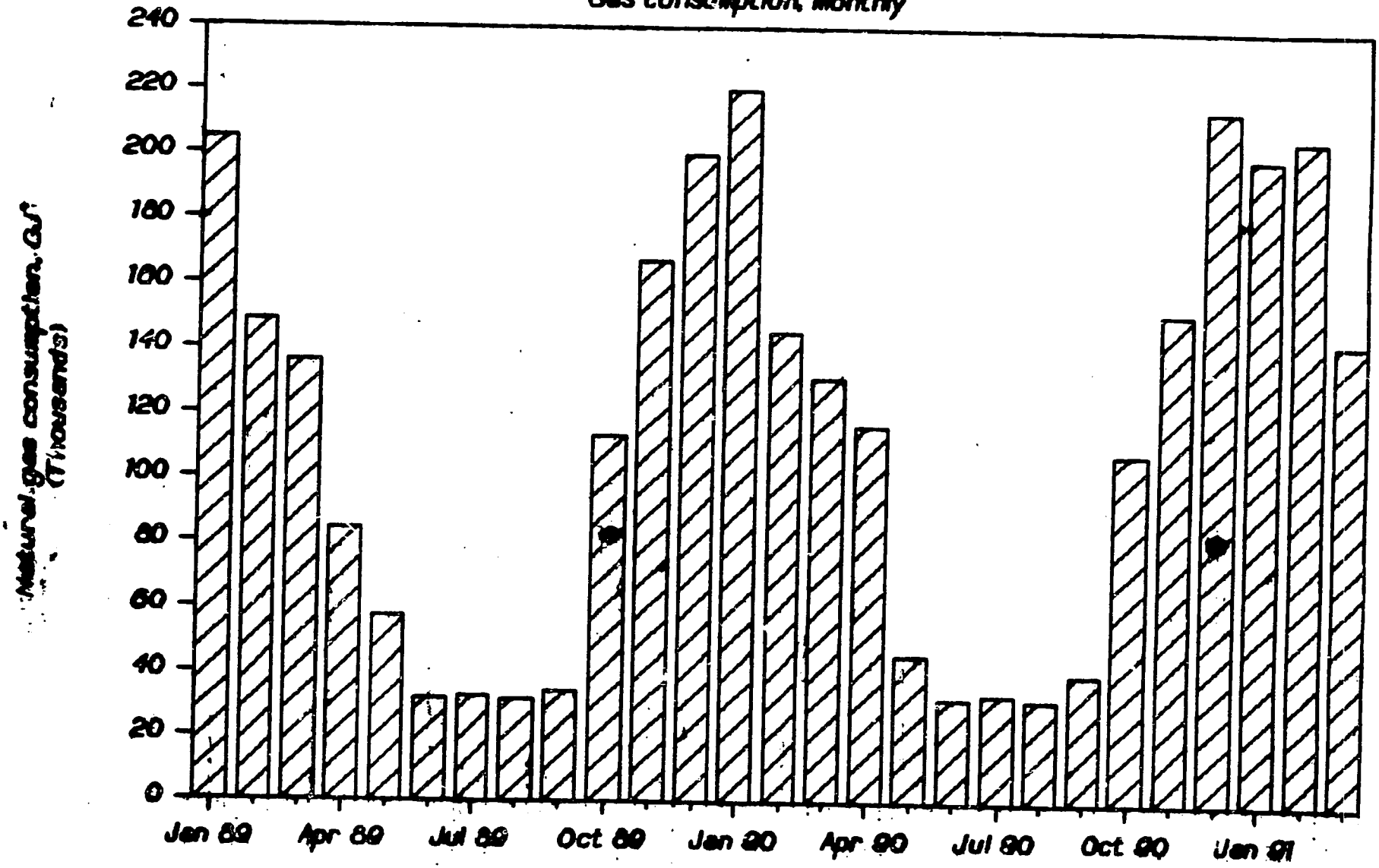
Station efficiency, annual avg



29

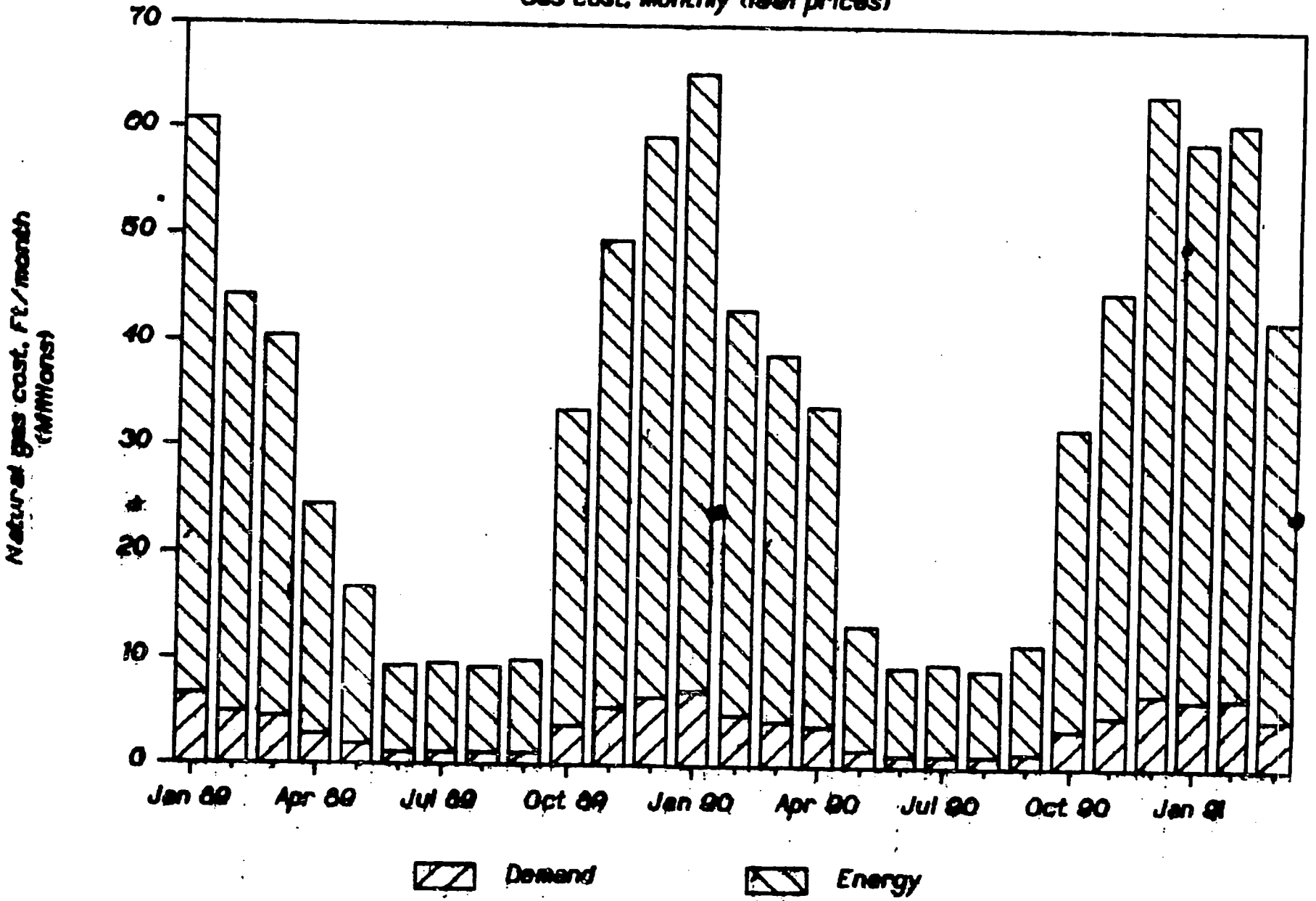
UJPALOTA 1989-91

Gas consumption, monthly



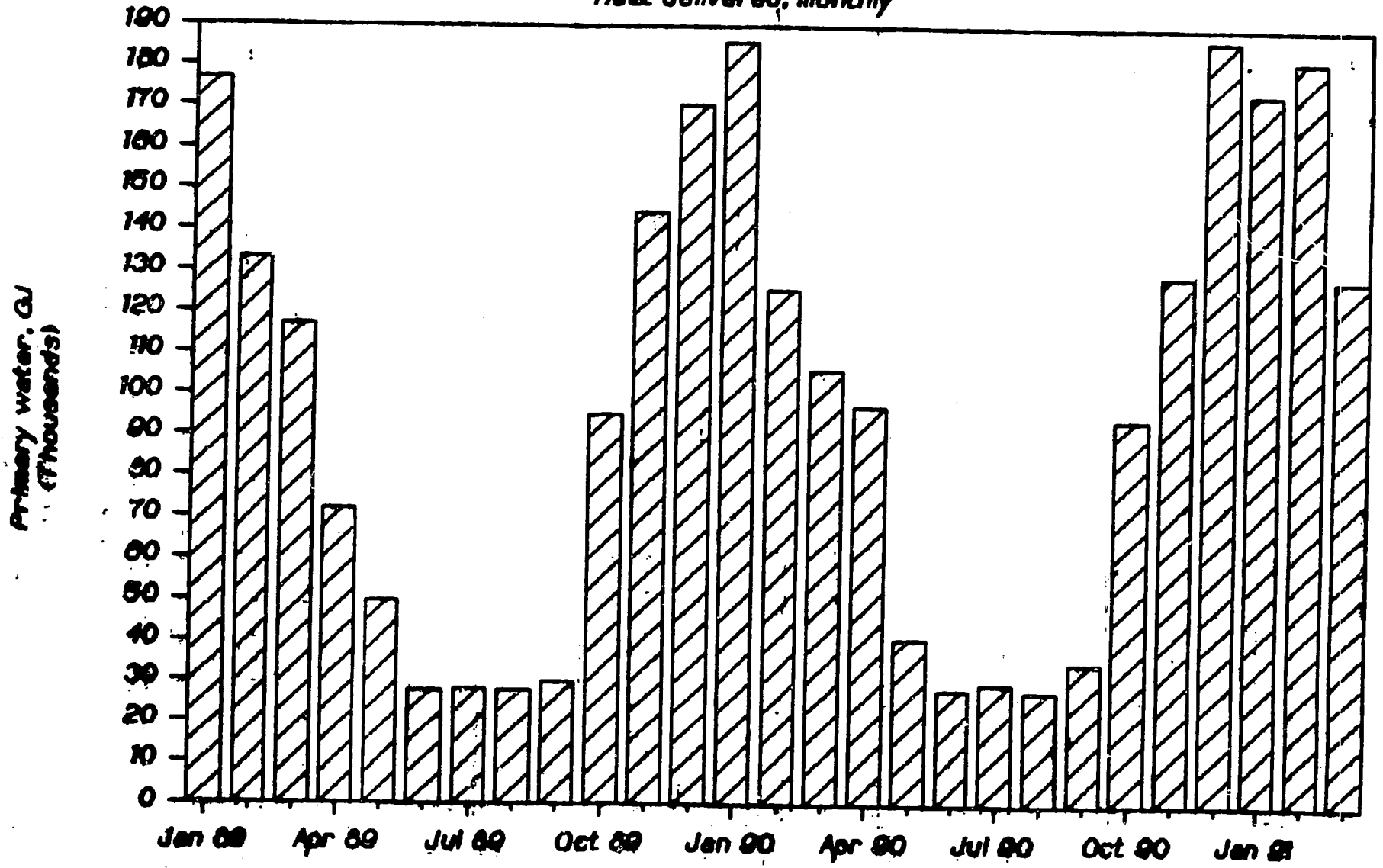
UJPALOTA 1989–91

Gas cost, monthly (1991 prices)



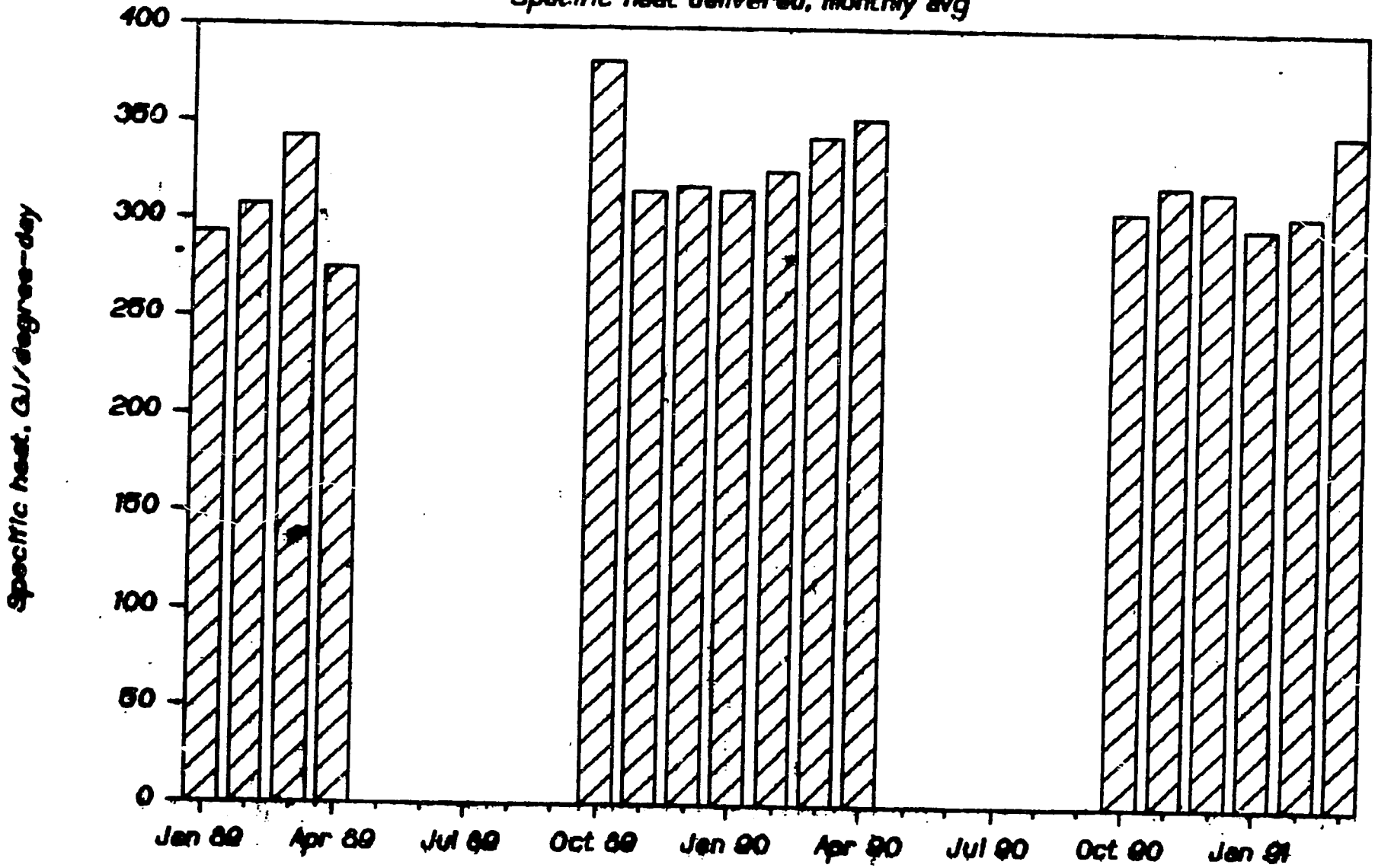
UJPALOTA 1989-91

Heat delivered, monthly



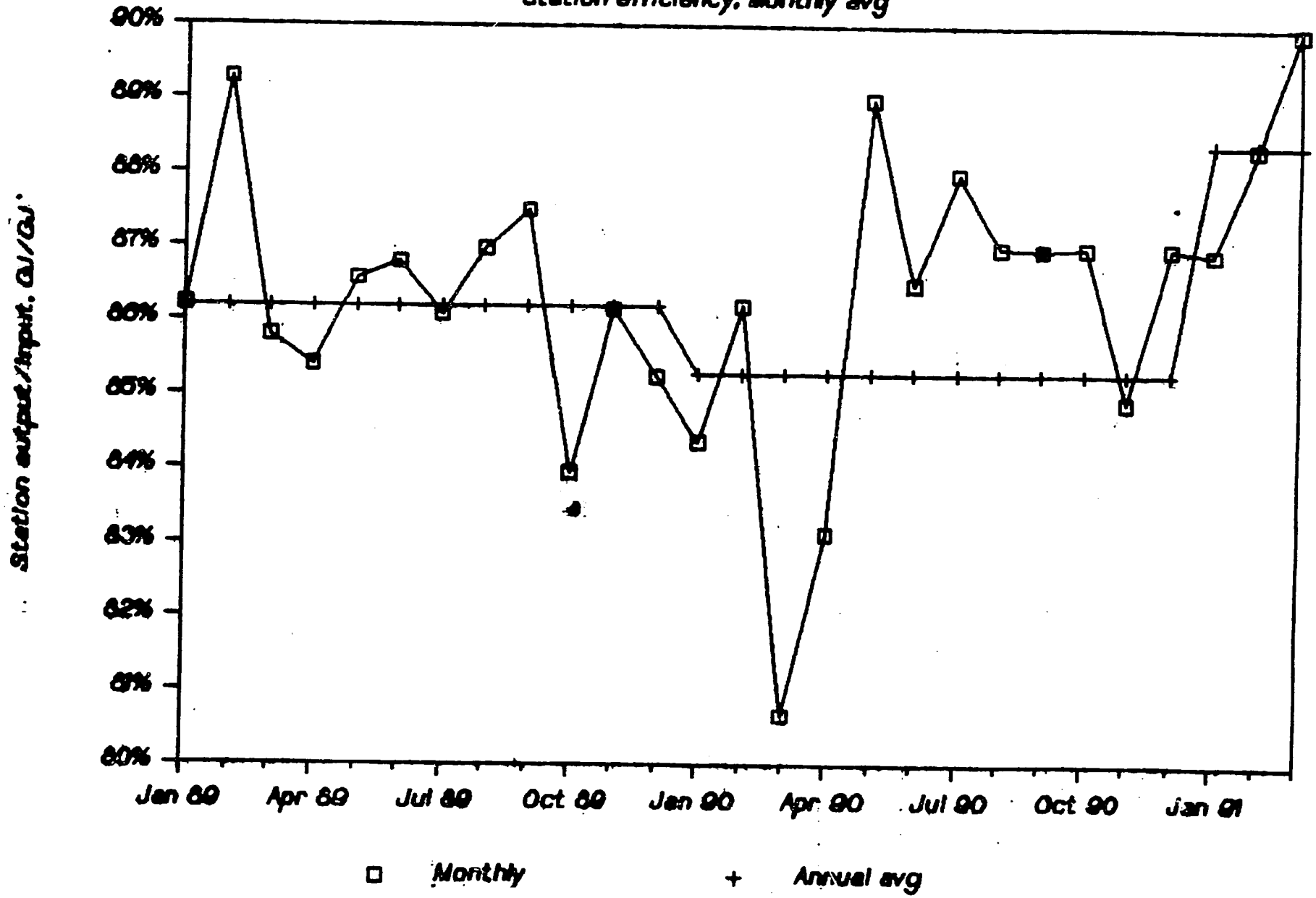
UJPALOTA 1989-91

Specific heat delivered, monthly avg



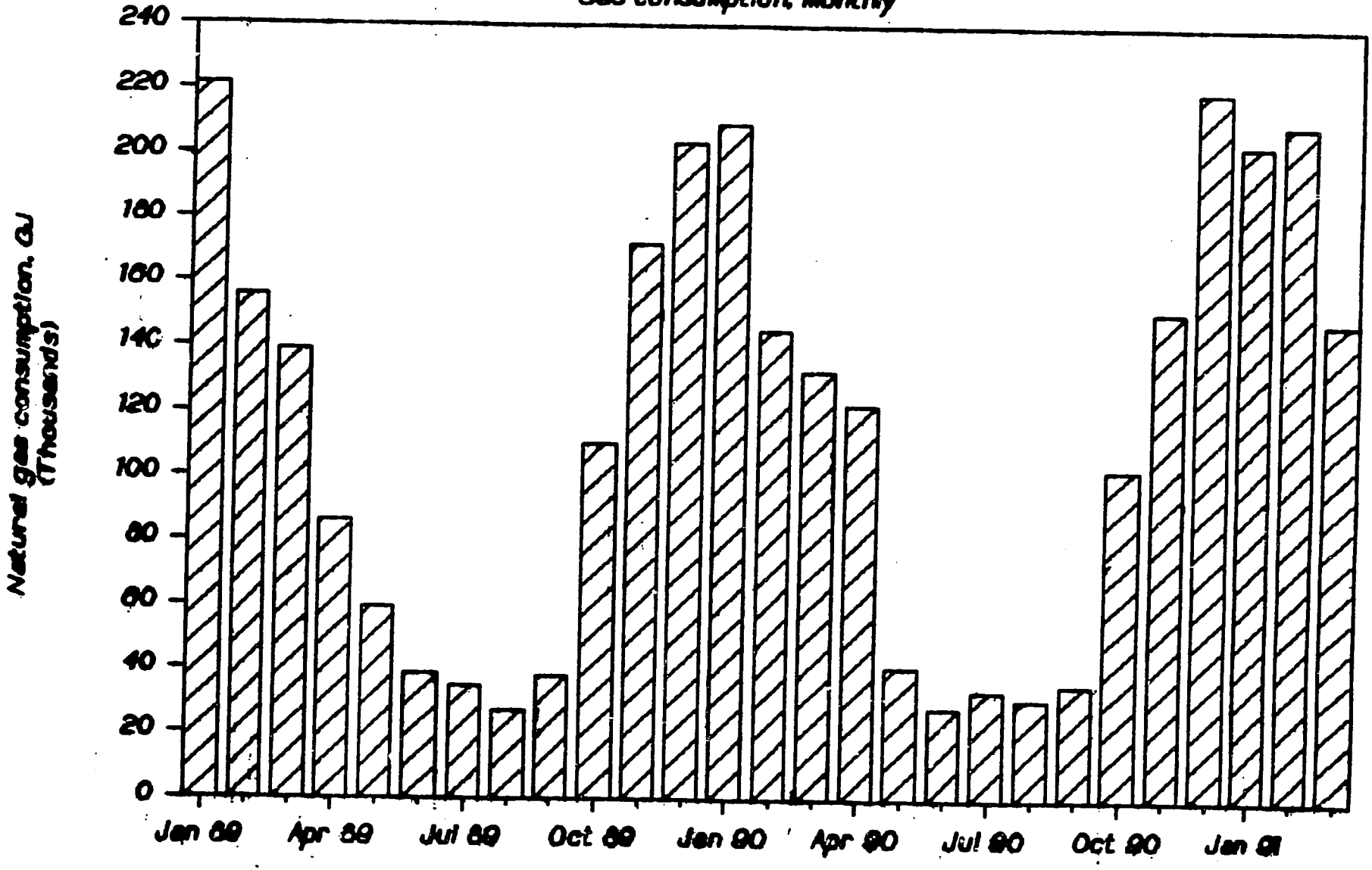
UJPALOTA 1989-91

Station efficiency, monthly avg



FUREDI 1989-91

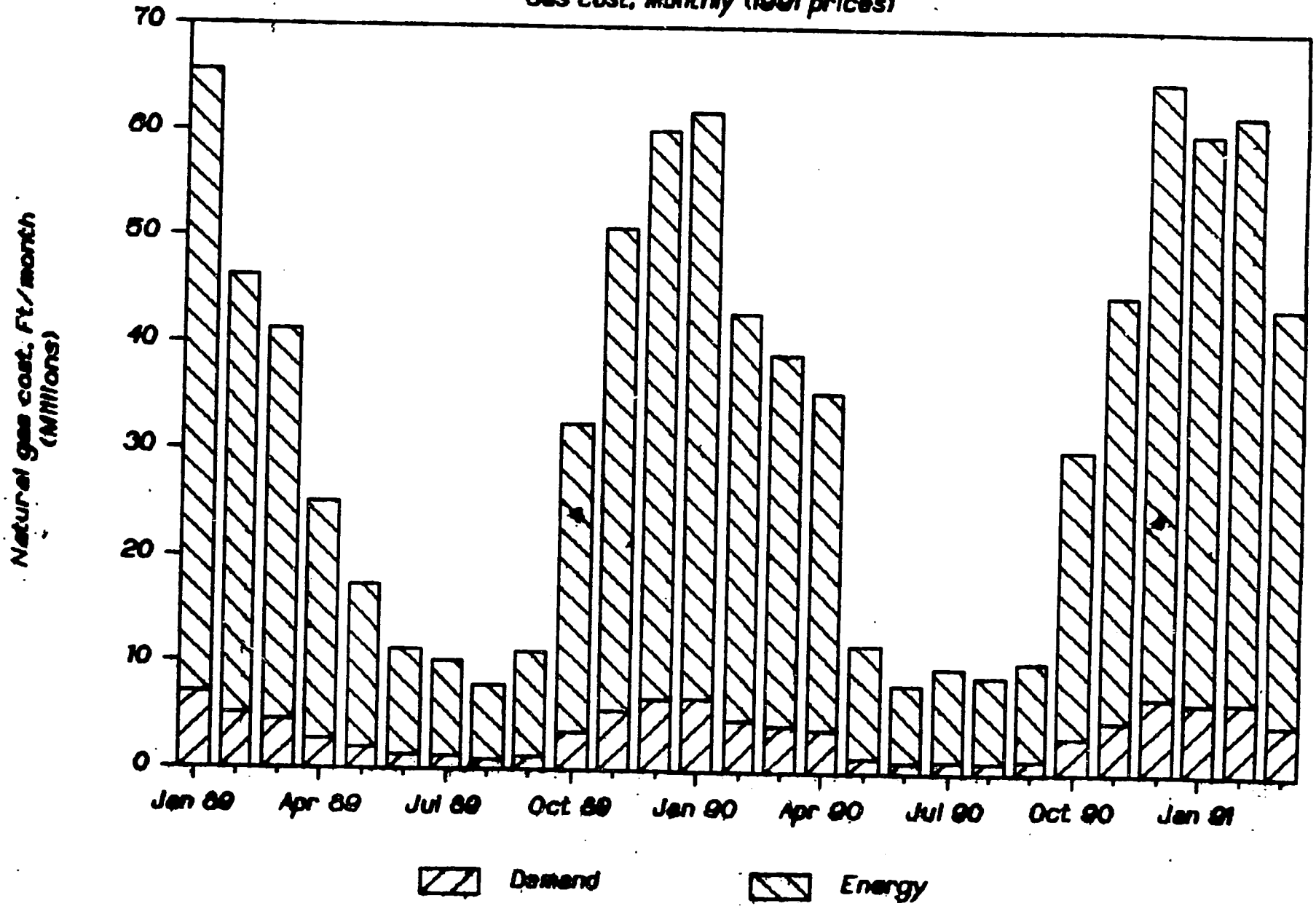
Gas consumption, monthly



35

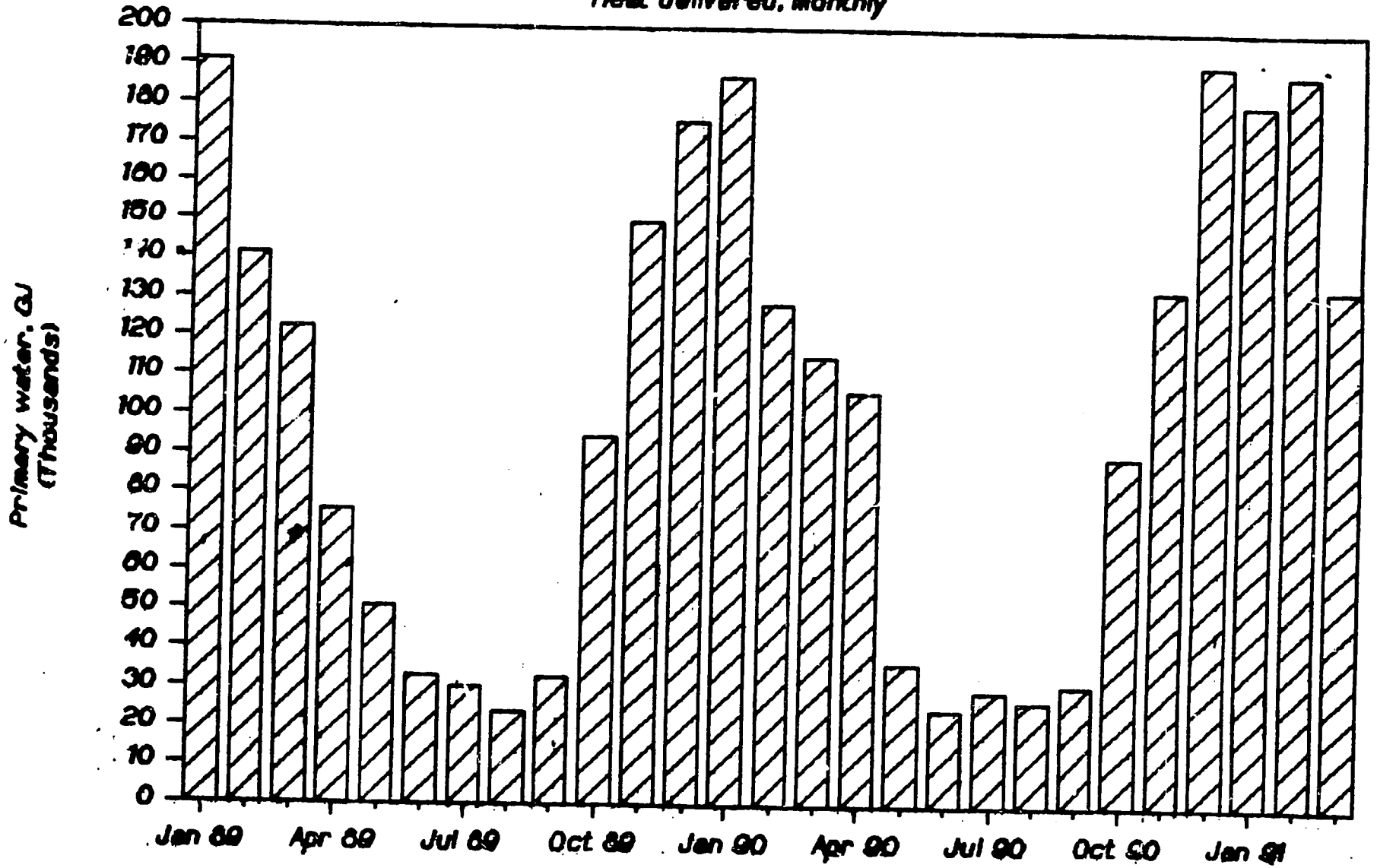
FUREDI 1989-91

Gas cost, monthly (1991 prices)



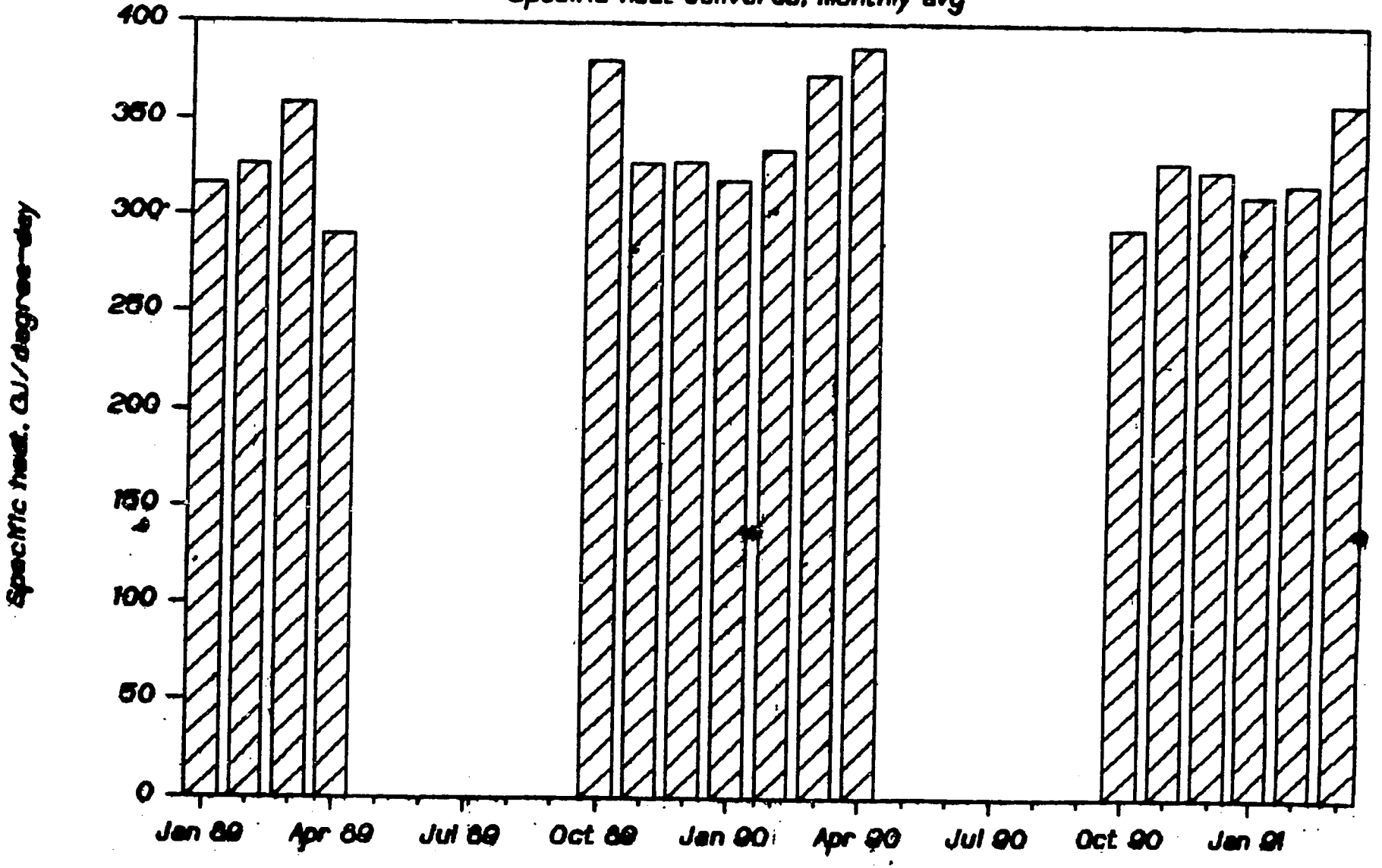
FUREDI 1989-91

Heat delivered, monthly



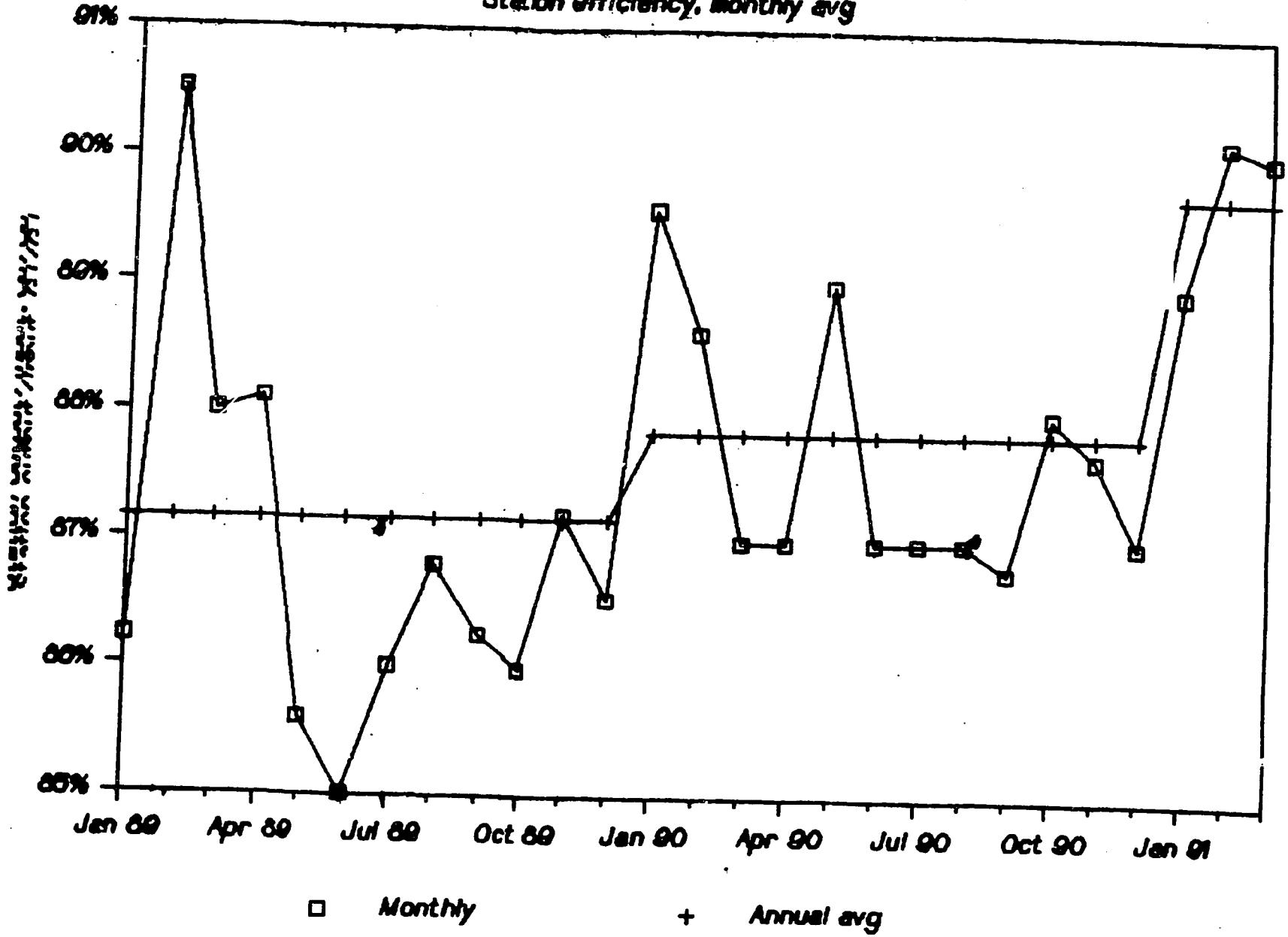
FUREDI 1989-91

Specific heat delivered, monthly avg



FUREDI 1989-91

Station efficiency, monthly avg



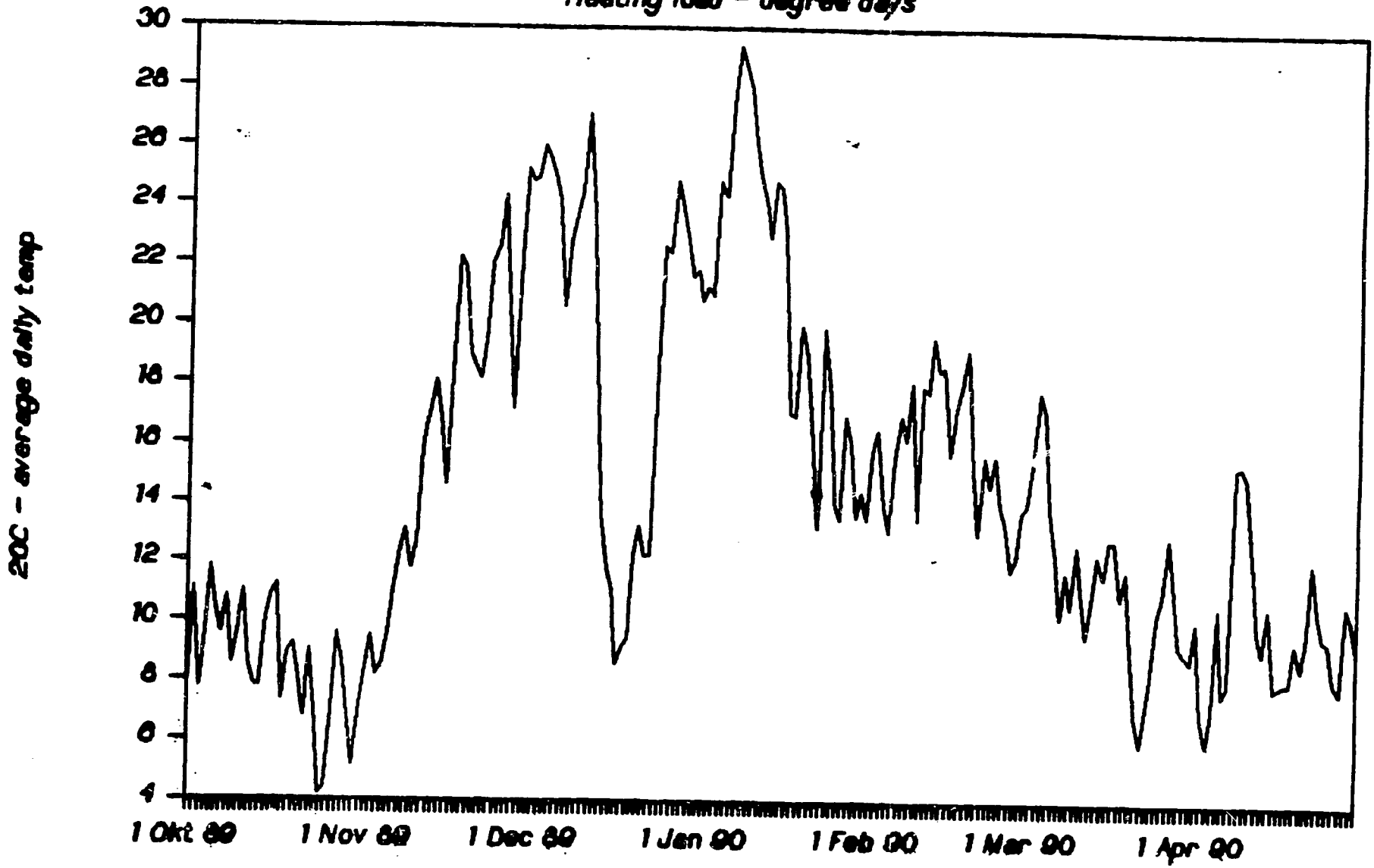
FOTAV ESZAK-PESTI

District Heating Works of Budapest, North-East Section

DAILY DATA
UJPALOTA HEAT GENERATION STATION
1989/90 HEATING SEASON

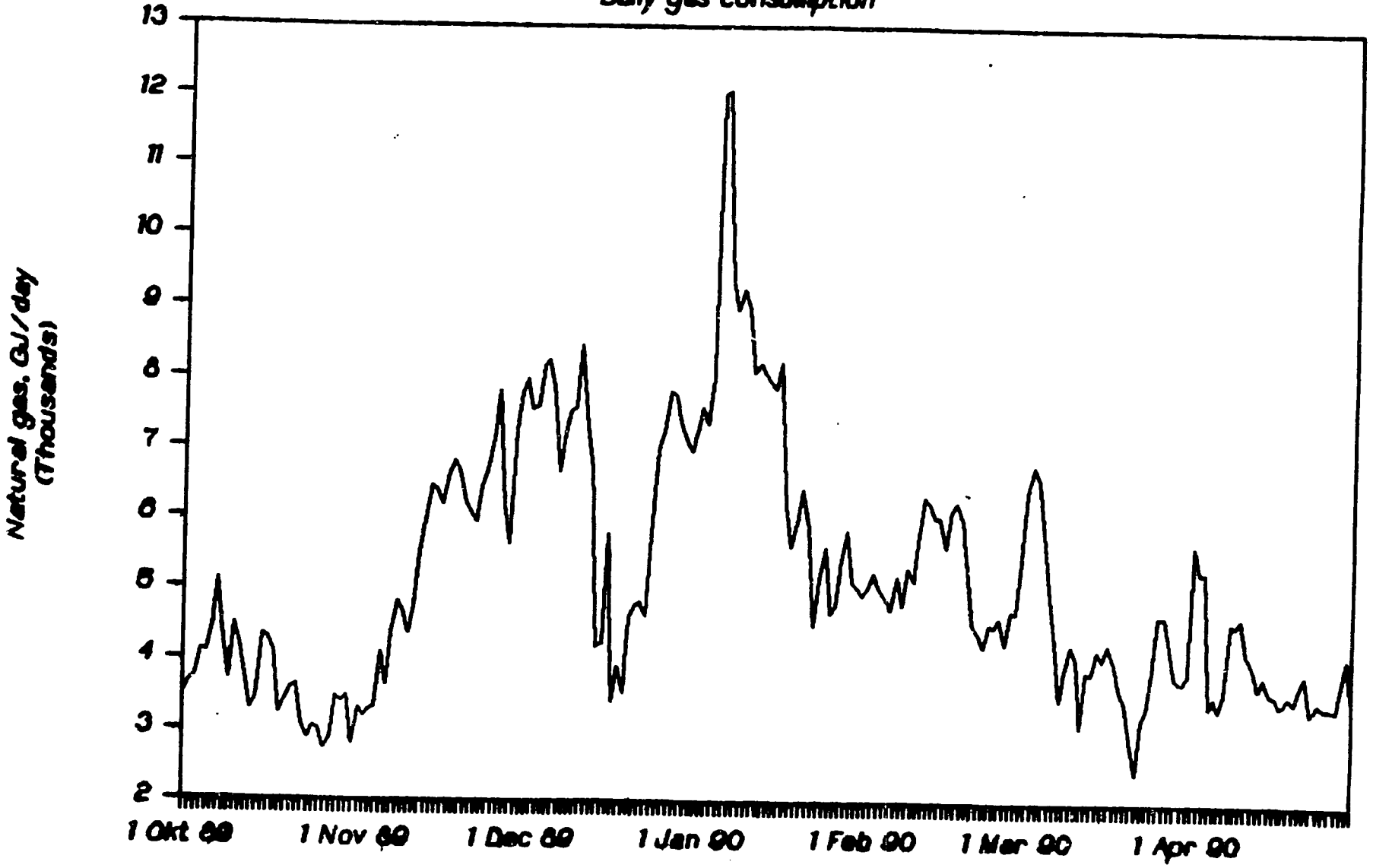
UJPALOTA 1989/90

Heating load – degree days



UJPALOTA 1989/90

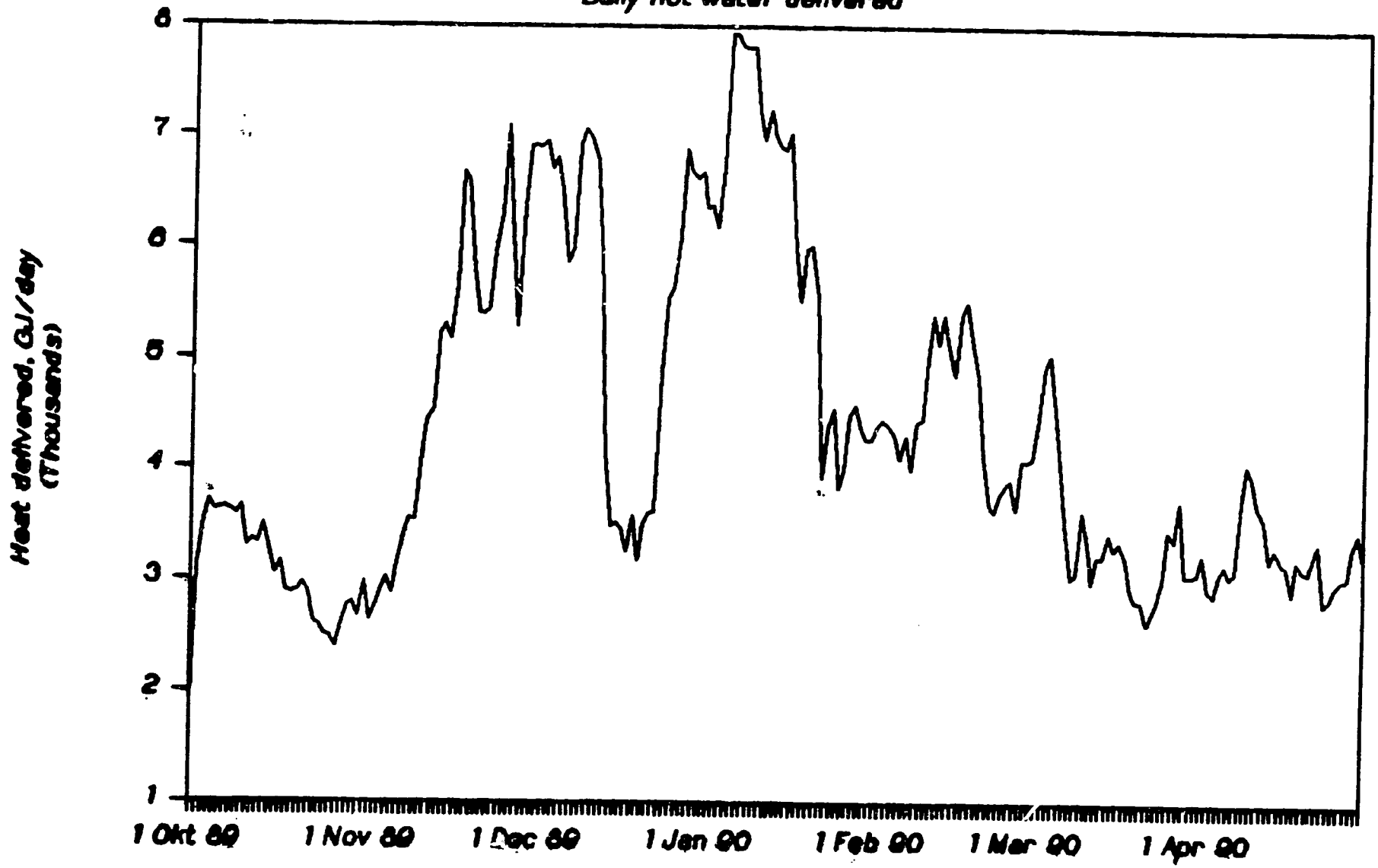
Daily gas consumption



14.

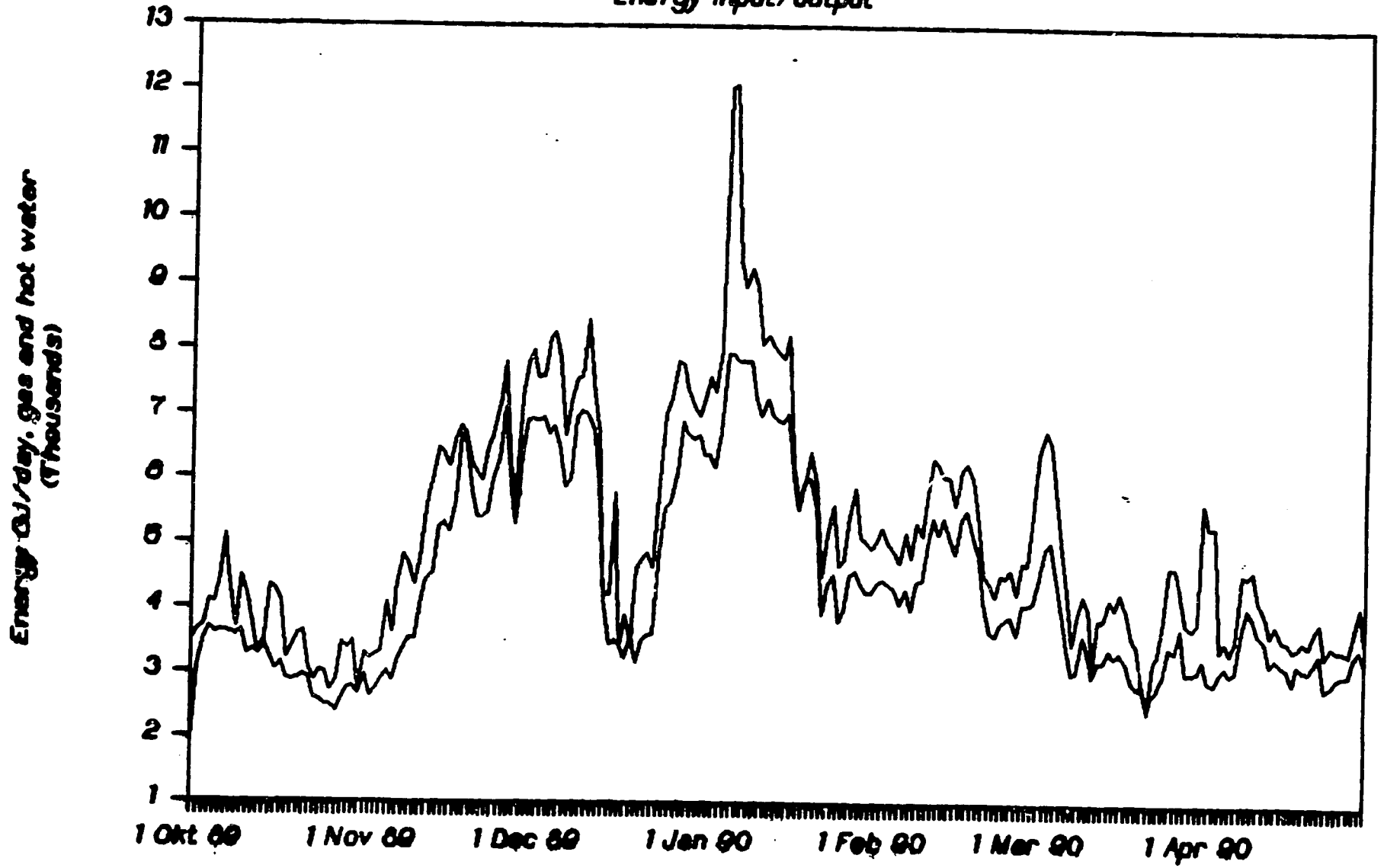
UJPALOTA 1989/90

Daily hot water delivered



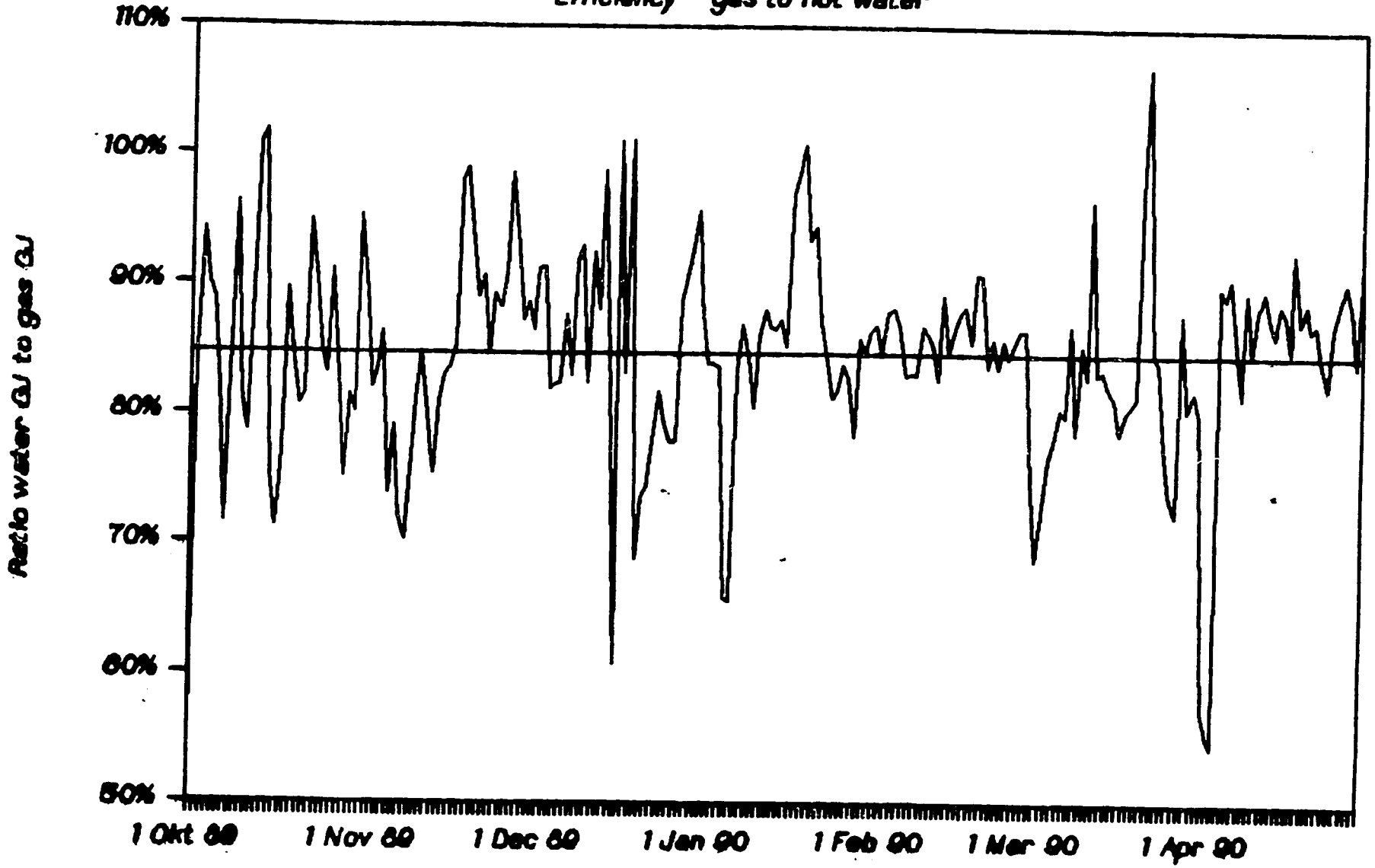
UJPALOTA 1989/90

Energy input/output



UJPALOTA 1989/90

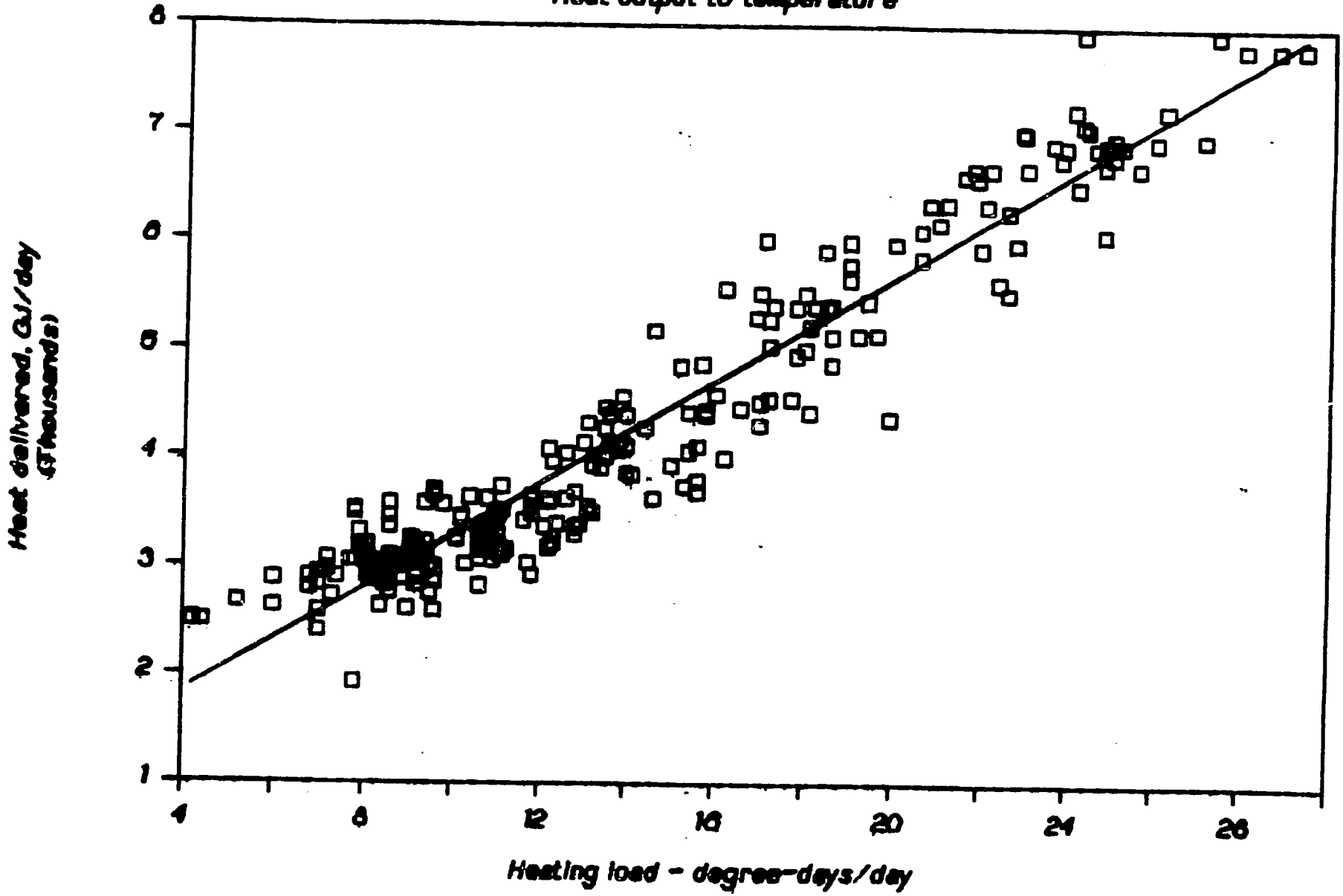
Efficiency – gas to hot water



45

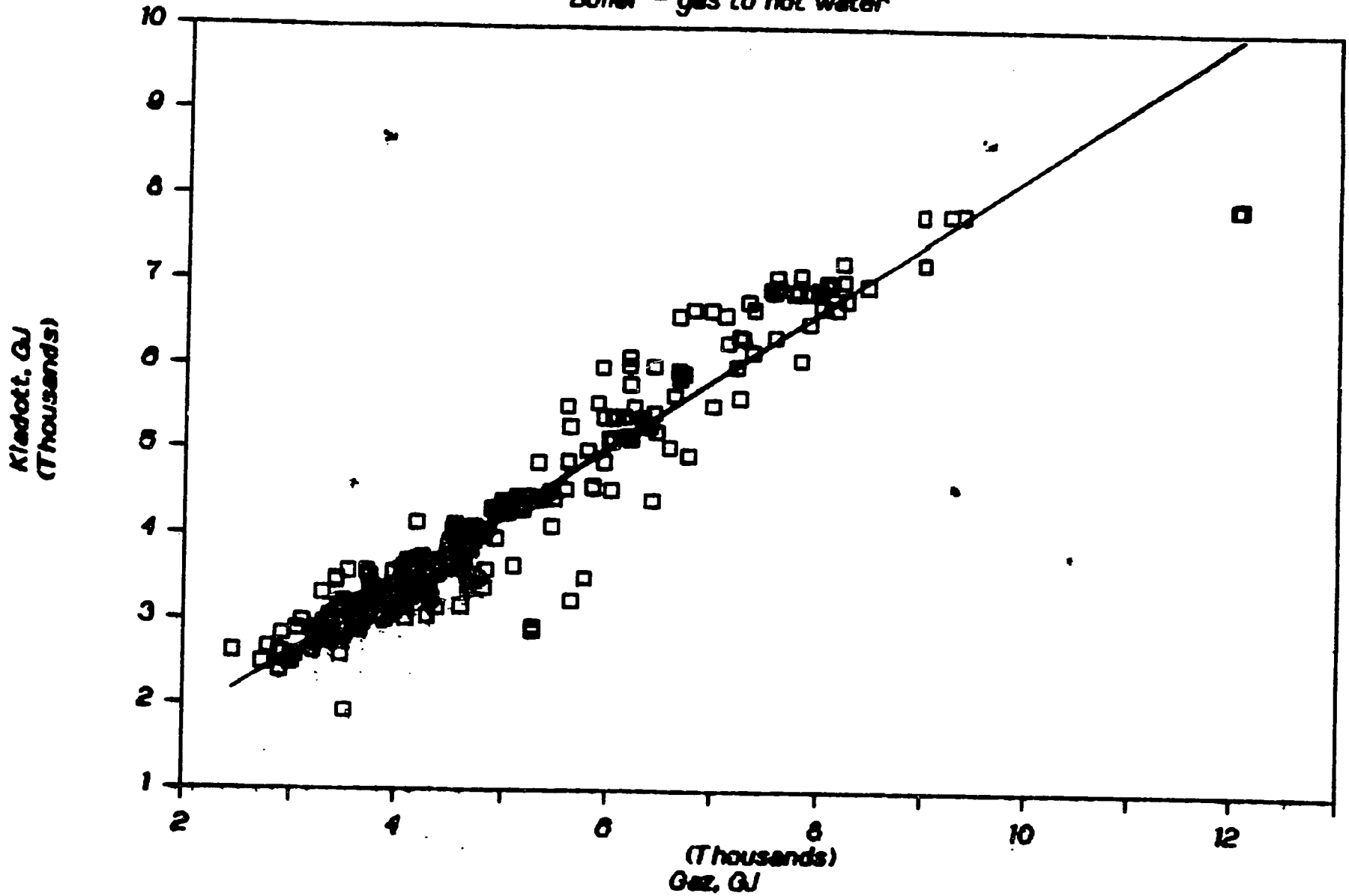
UJPALOTA 1989/90

Heat output to temperature



UJPALOTA 1989/90

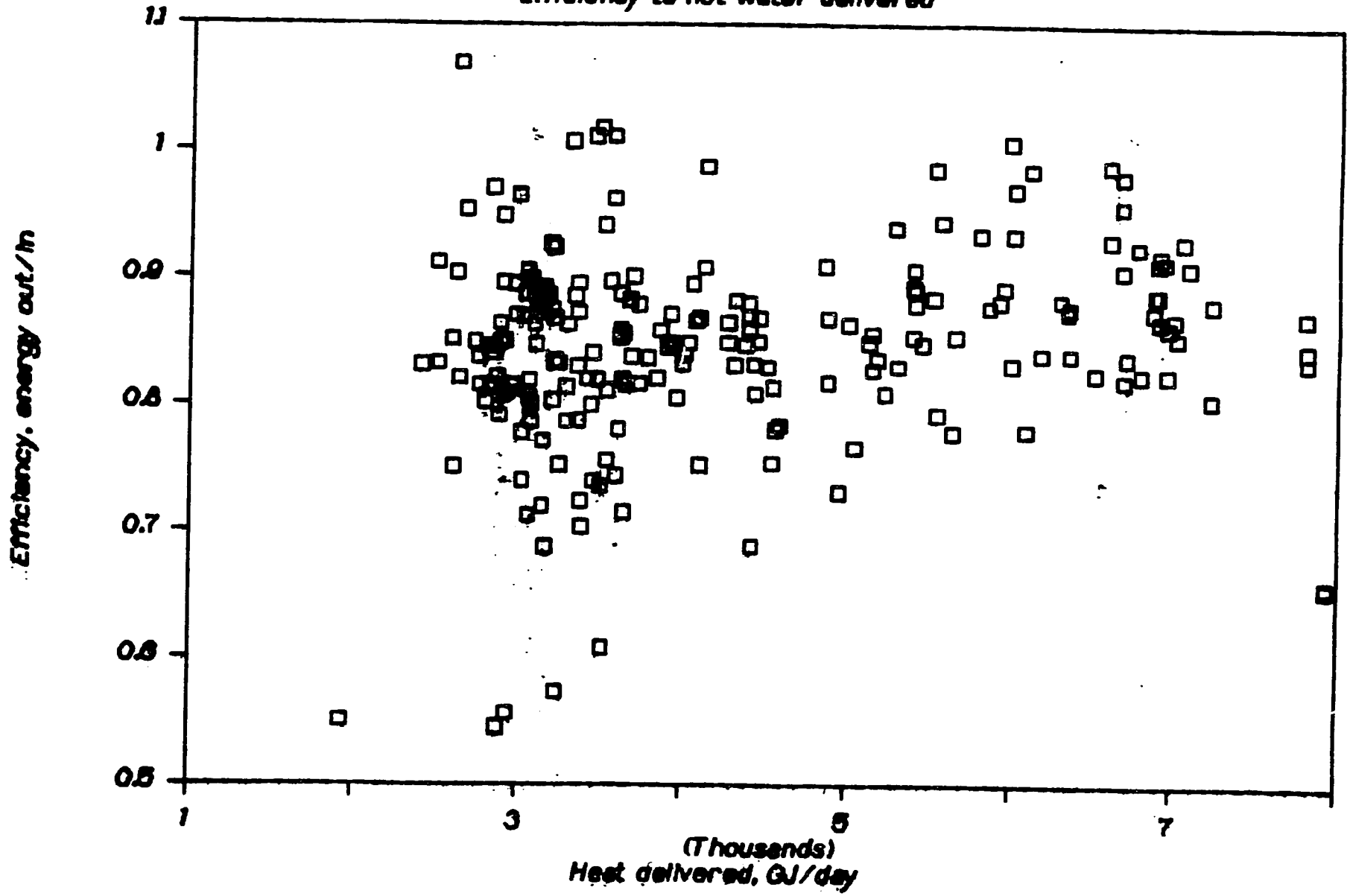
Boiler – gas to hot water



47

UJPALOTA 1989/90

Efficiency to hot water delivered



48.

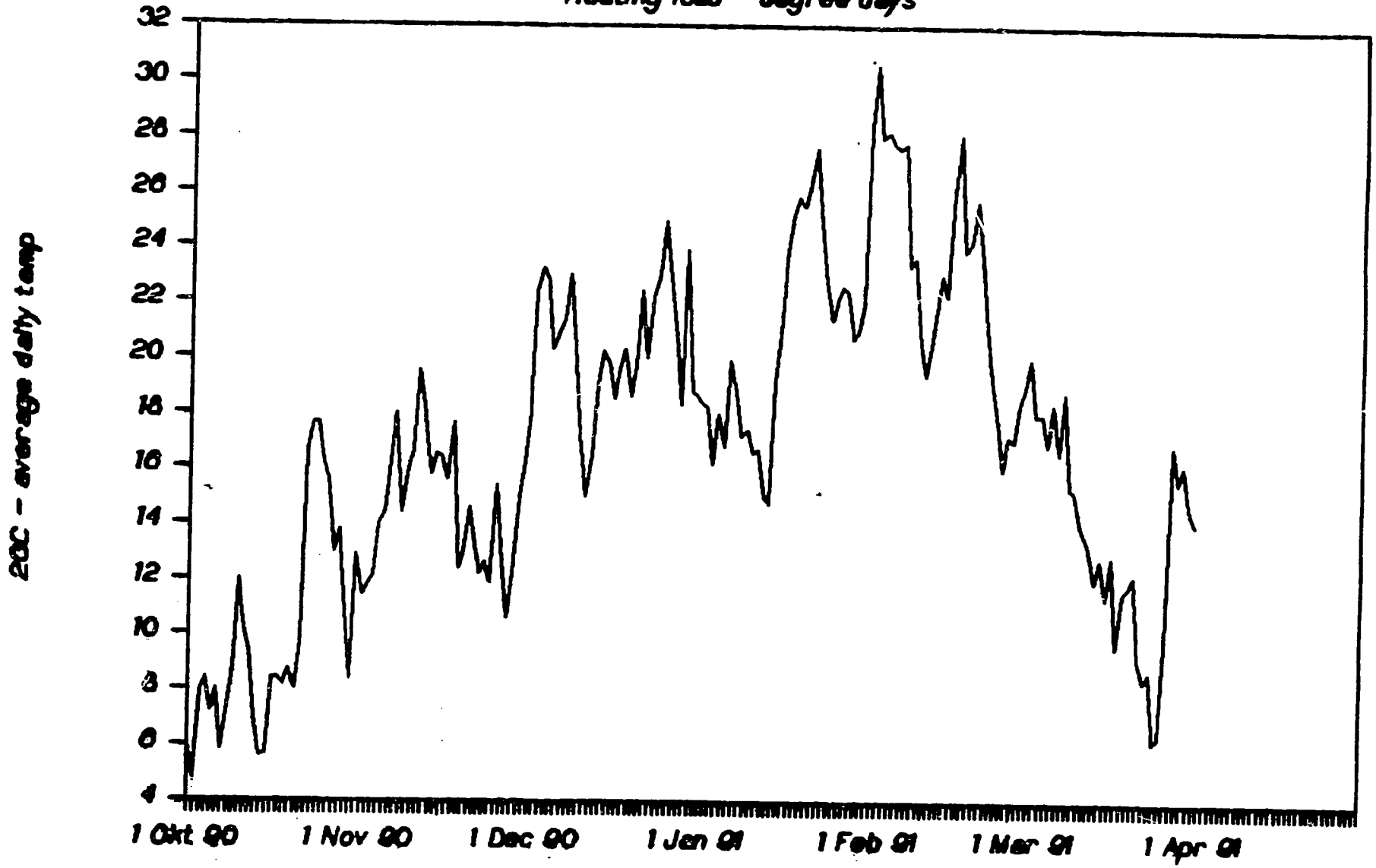
FOTAV ESZAK-PESTI

District Heating Works of Budapest, North-East Section

DAILY DATA
UJPALOTA HEAT GENERATION STATION
1990/91 HEATING SEASON

UJPALOTA 1990/91

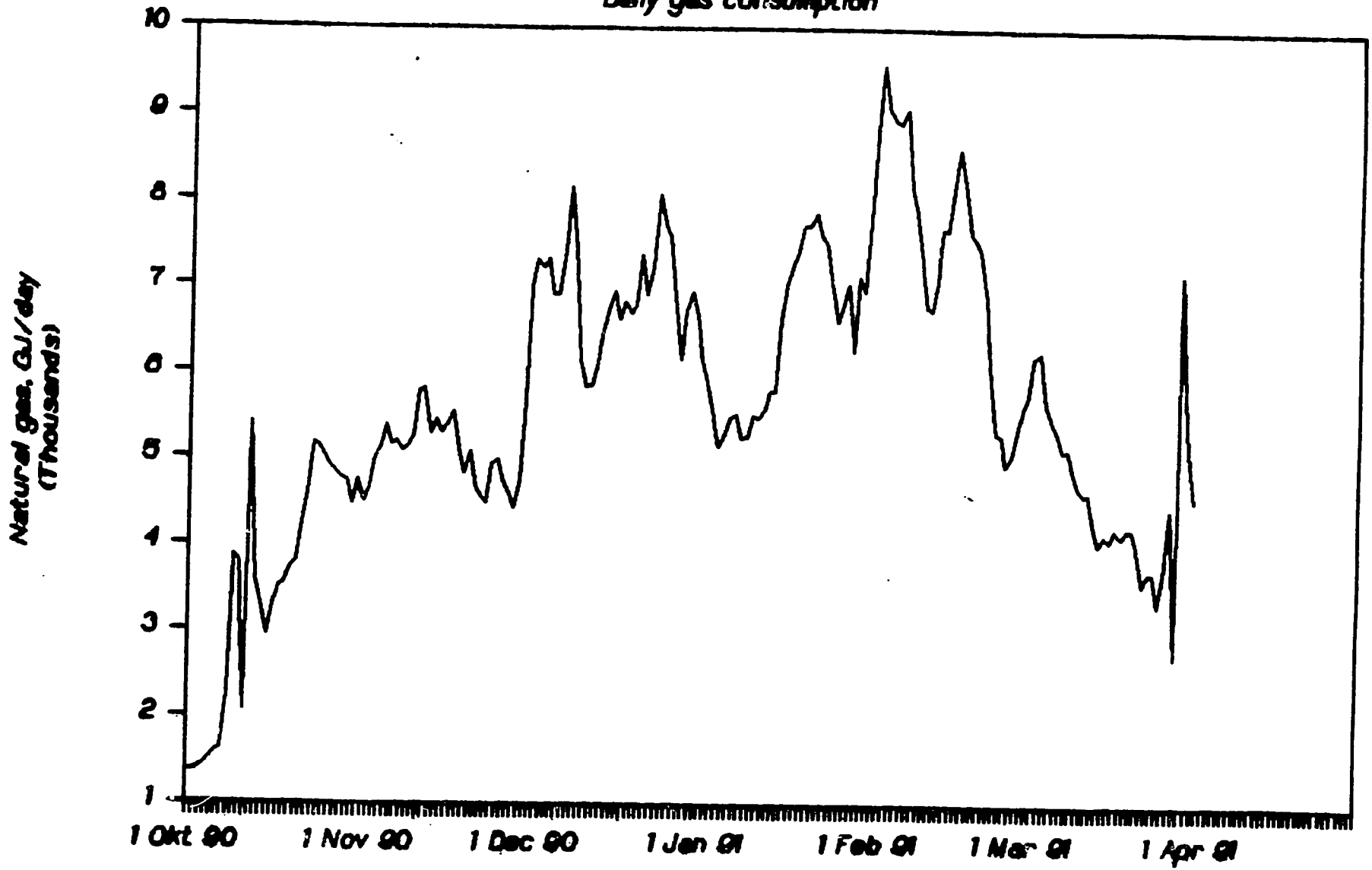
Heating load – degree days



5.2

UJPALOTA 1990/91

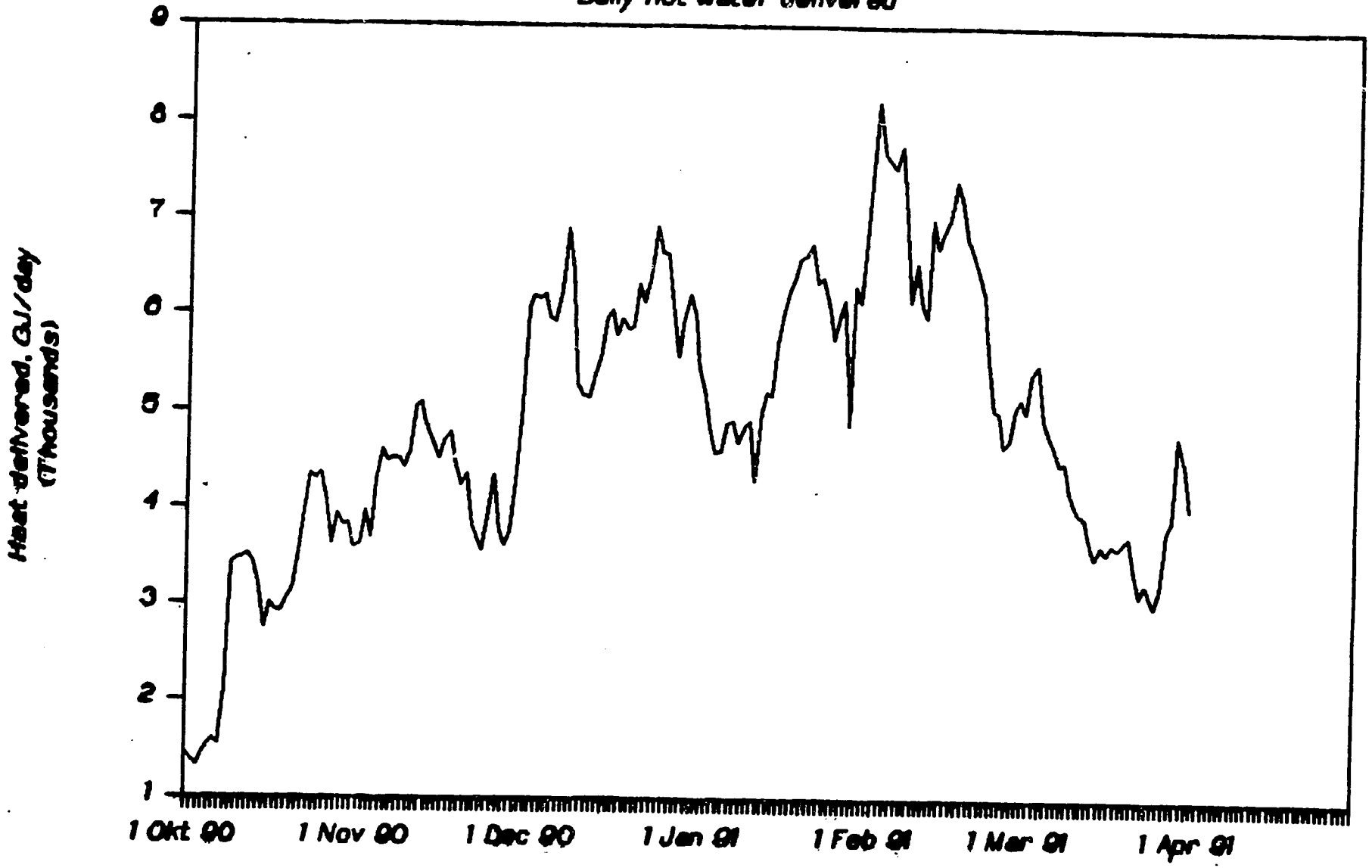
Daily gas consumption



151

UJPALOTA 1990/91

Daily hot water delivered



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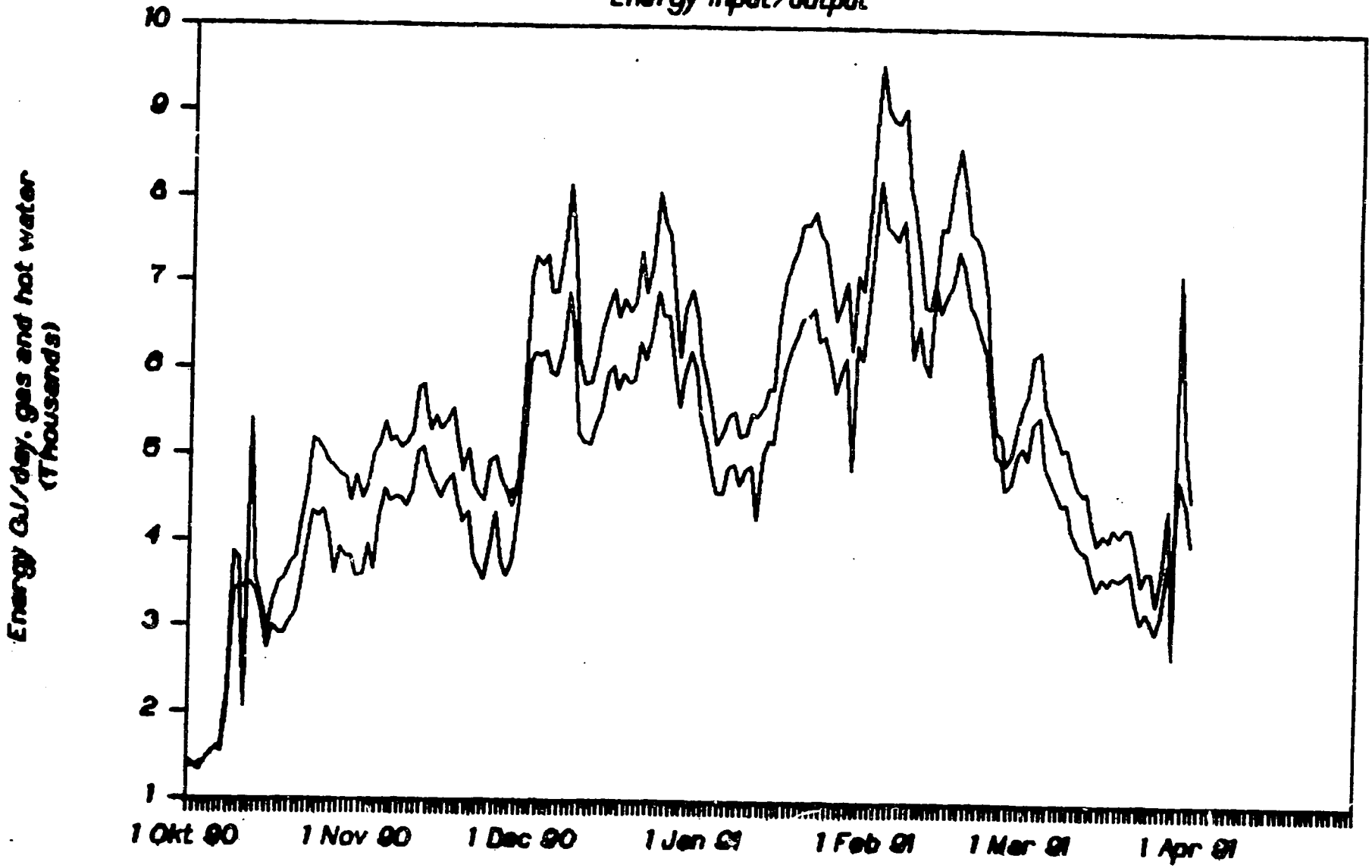
UJPALOTA 1990/91

Energy input/output



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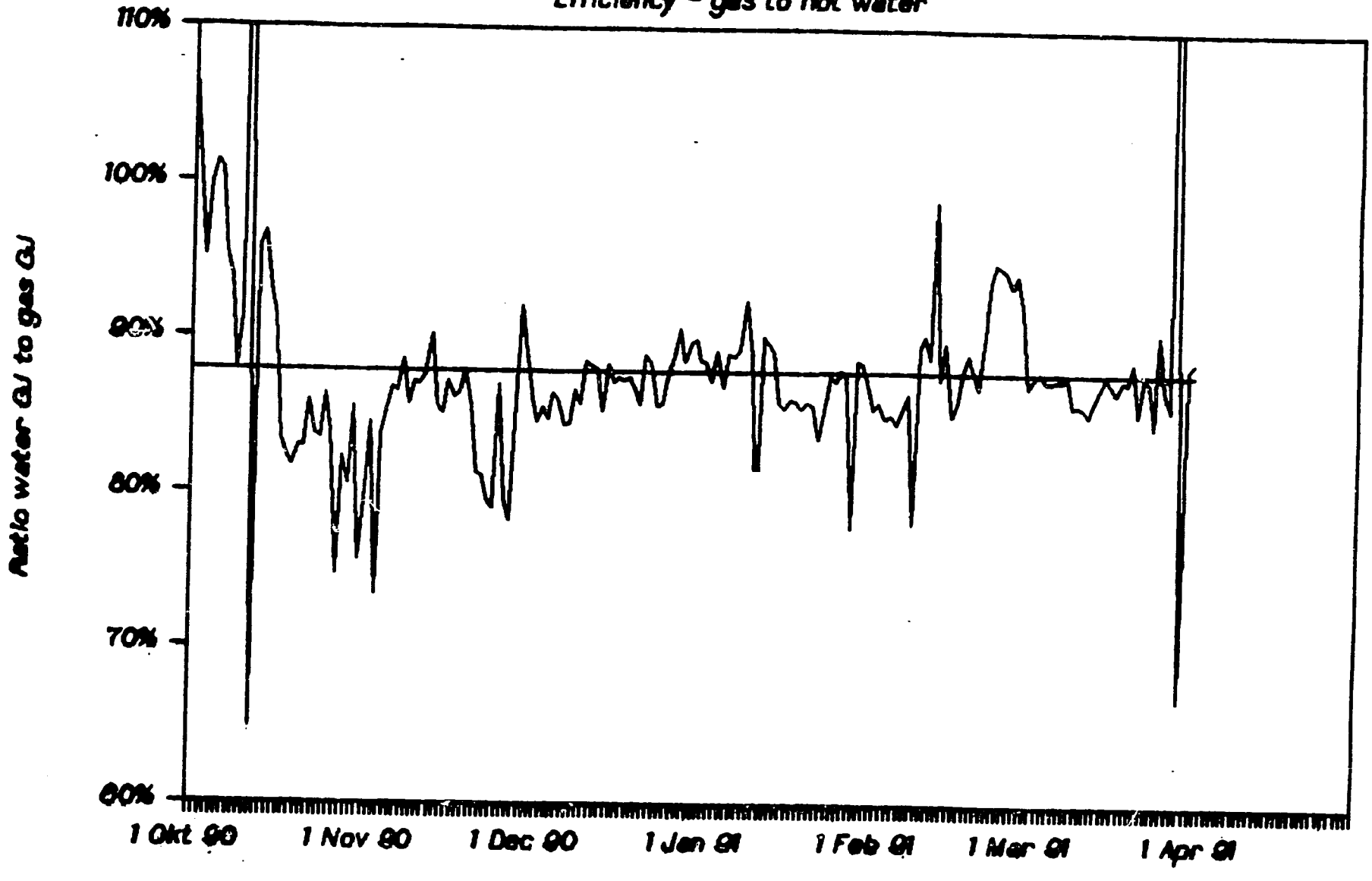
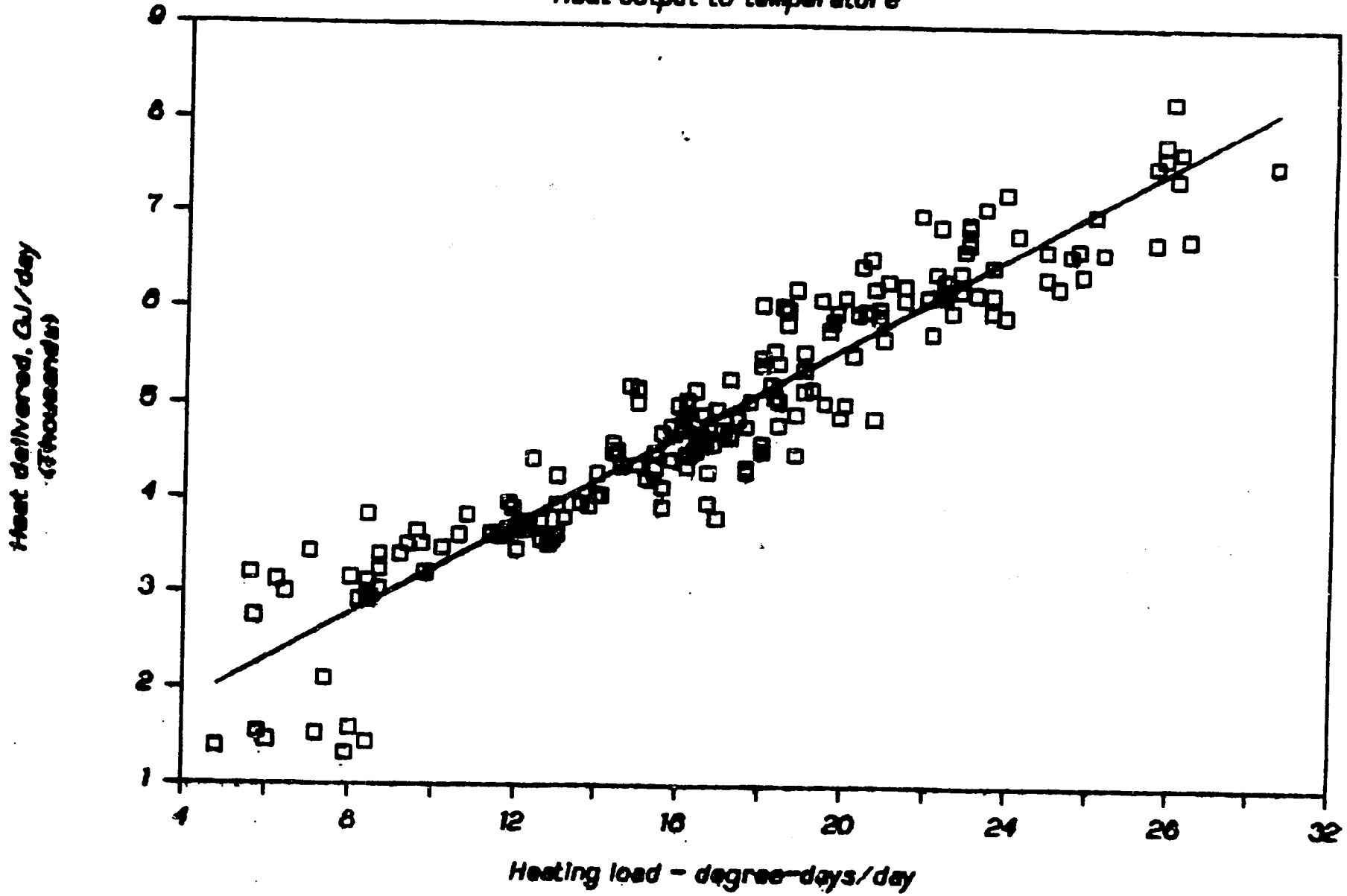
UJPALOTA 1990/91

Efficiency – gas to hot water



UJPALOTA 1990/91

Heat output to temperature



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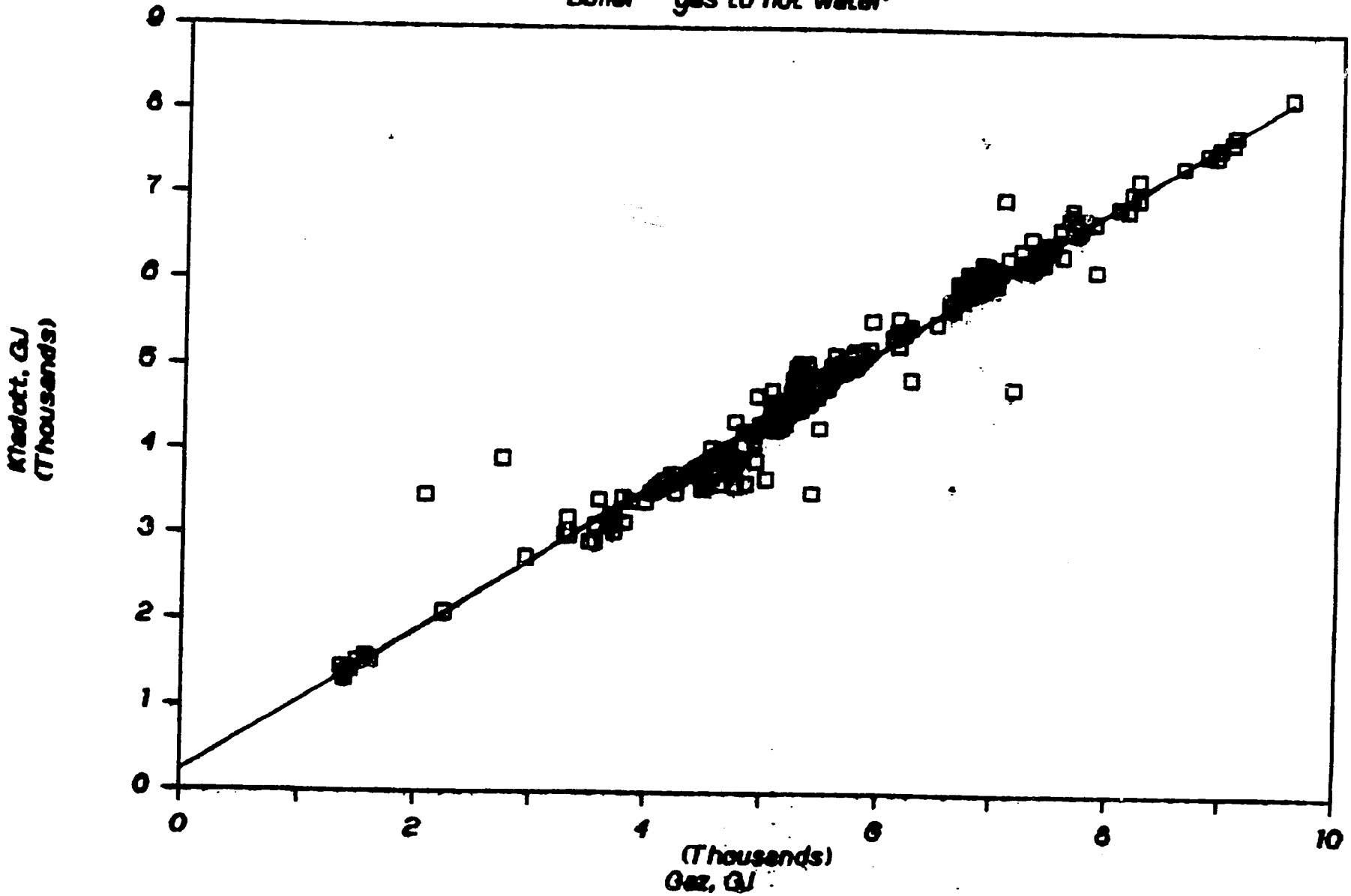
UJPALOTA 1990/91

Boiler – gas to hot water



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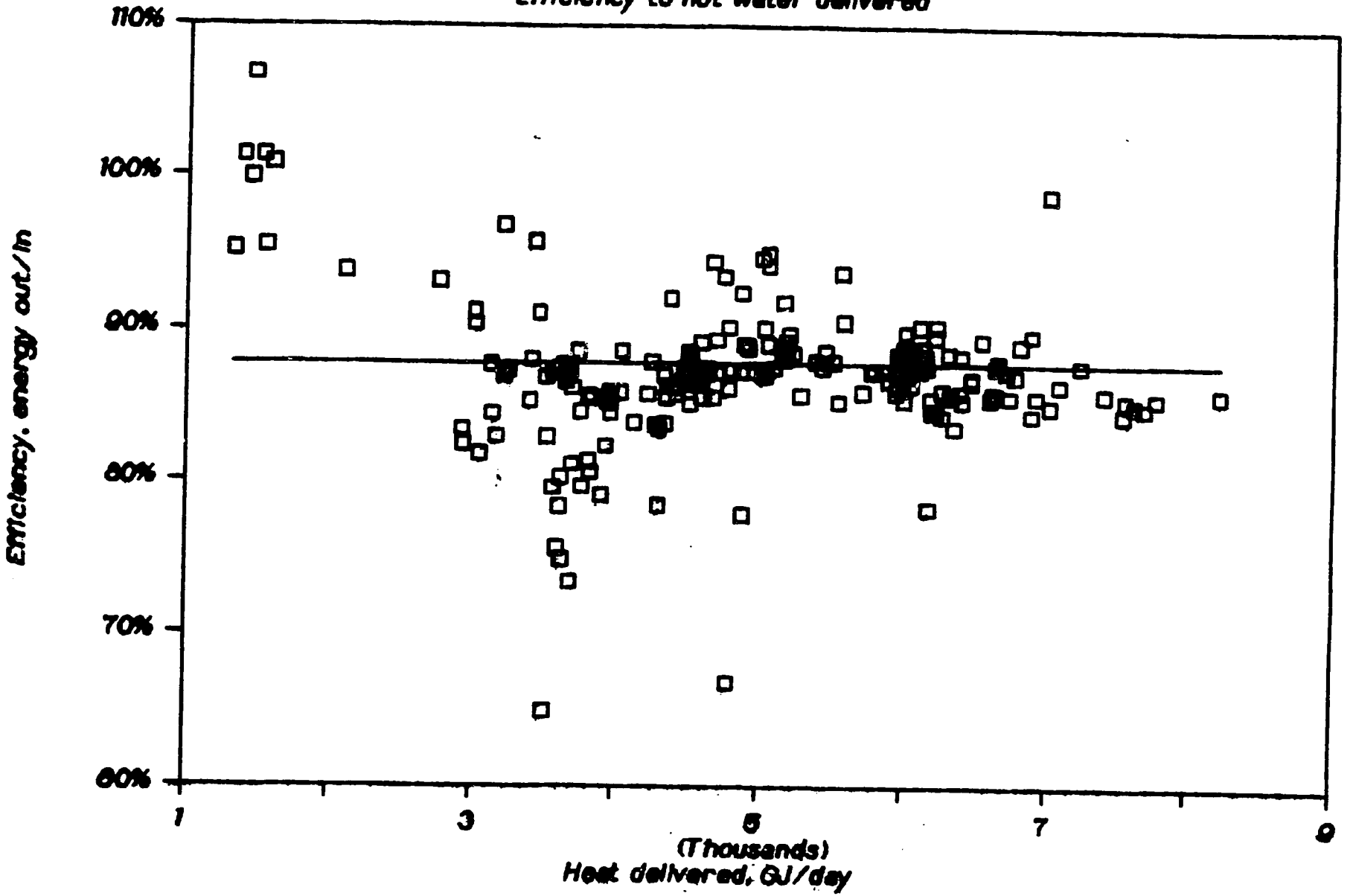
UJPALOTA 1990/91

Efficiency to hot water delivered



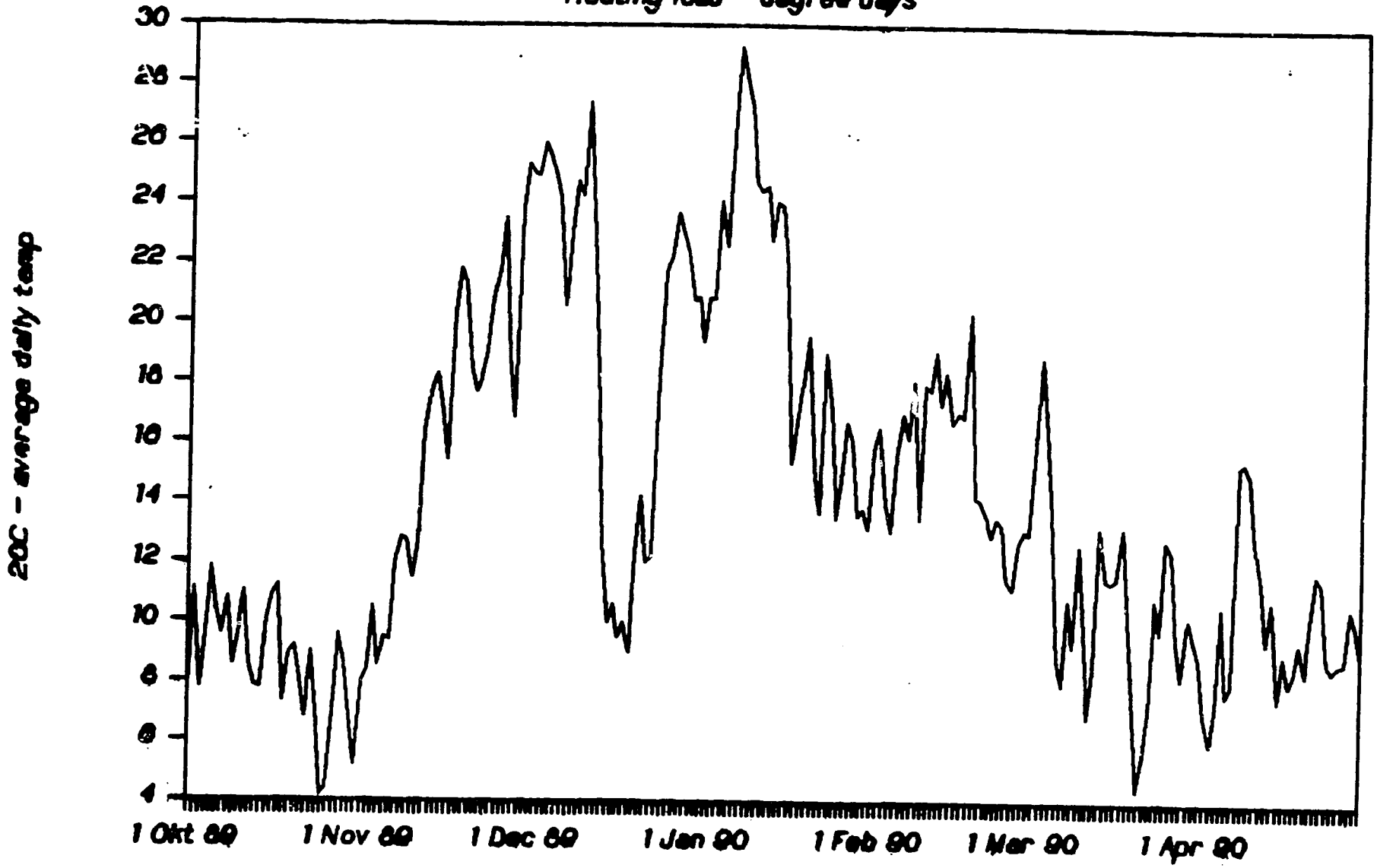
FOTAV ESZAK-PESTI

District Heating Works of Budapest, North-East Section

DAILY DATA
FUREDI HEAT GENERATION STATION
1989/90 HEATING SEASON

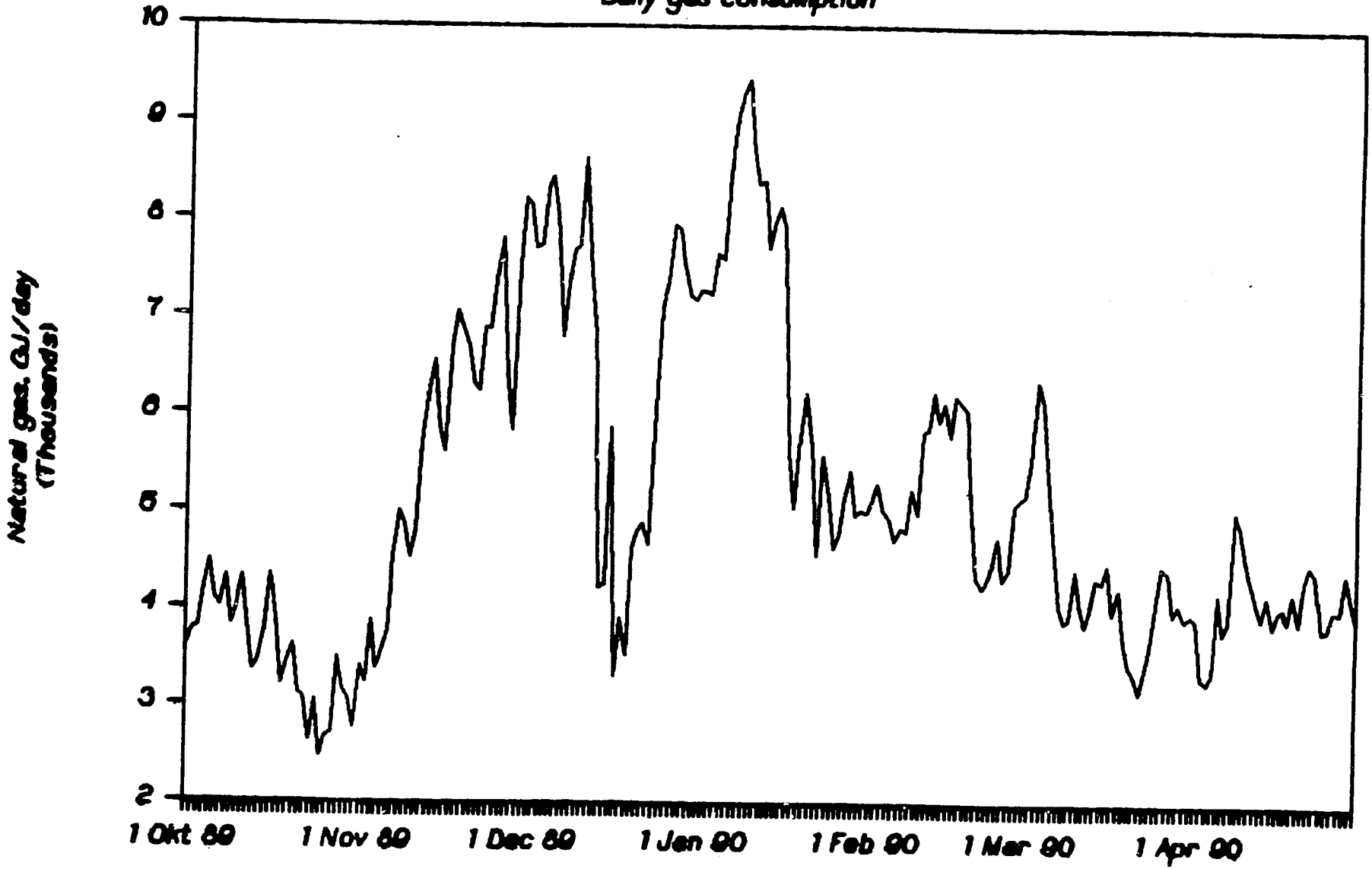
FUREDI 1989/90

Heating load – degree days



FUREDI 1989/90

Daily gas consumption



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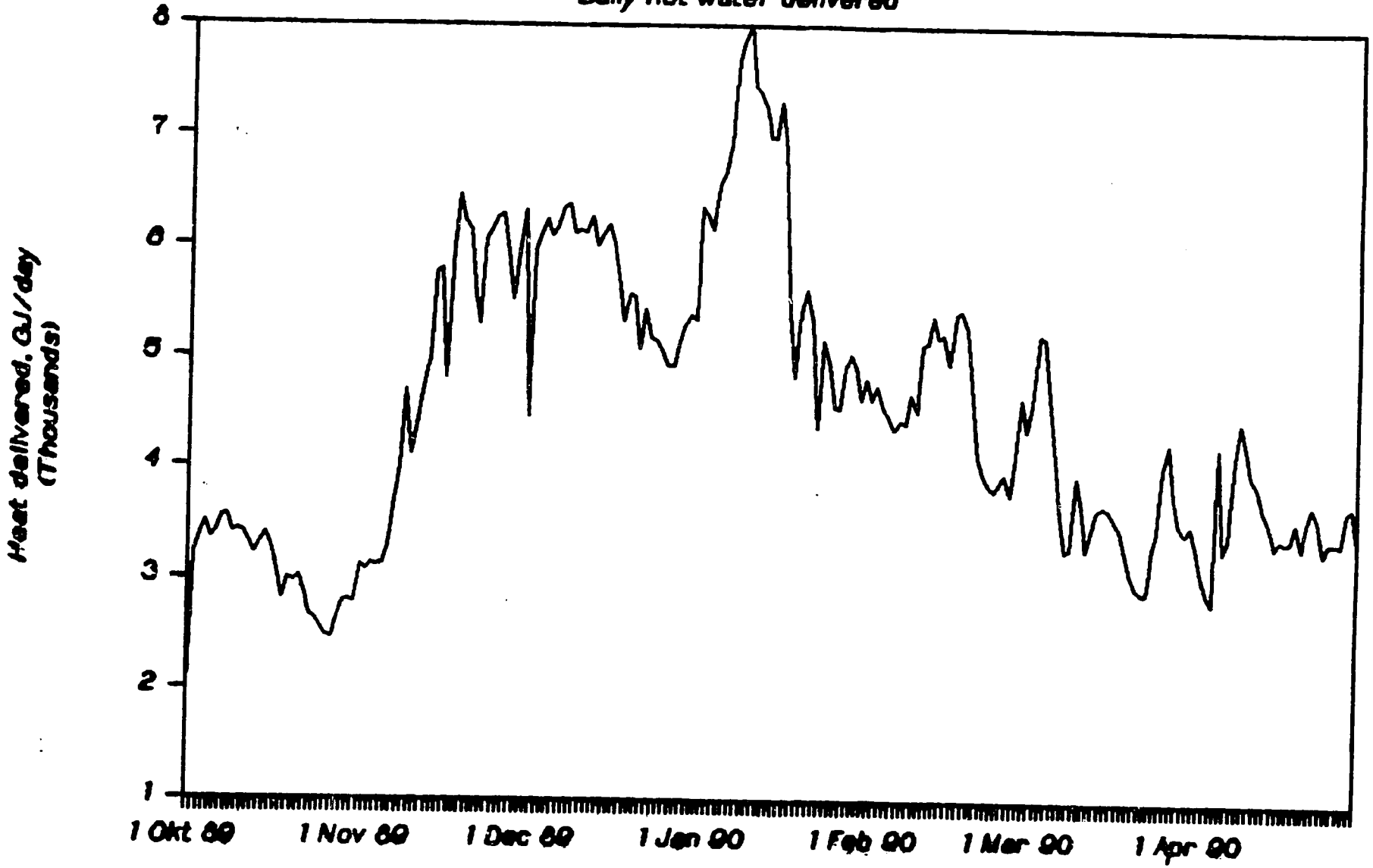
FUREDI 1989/90

Daily hot water delivered



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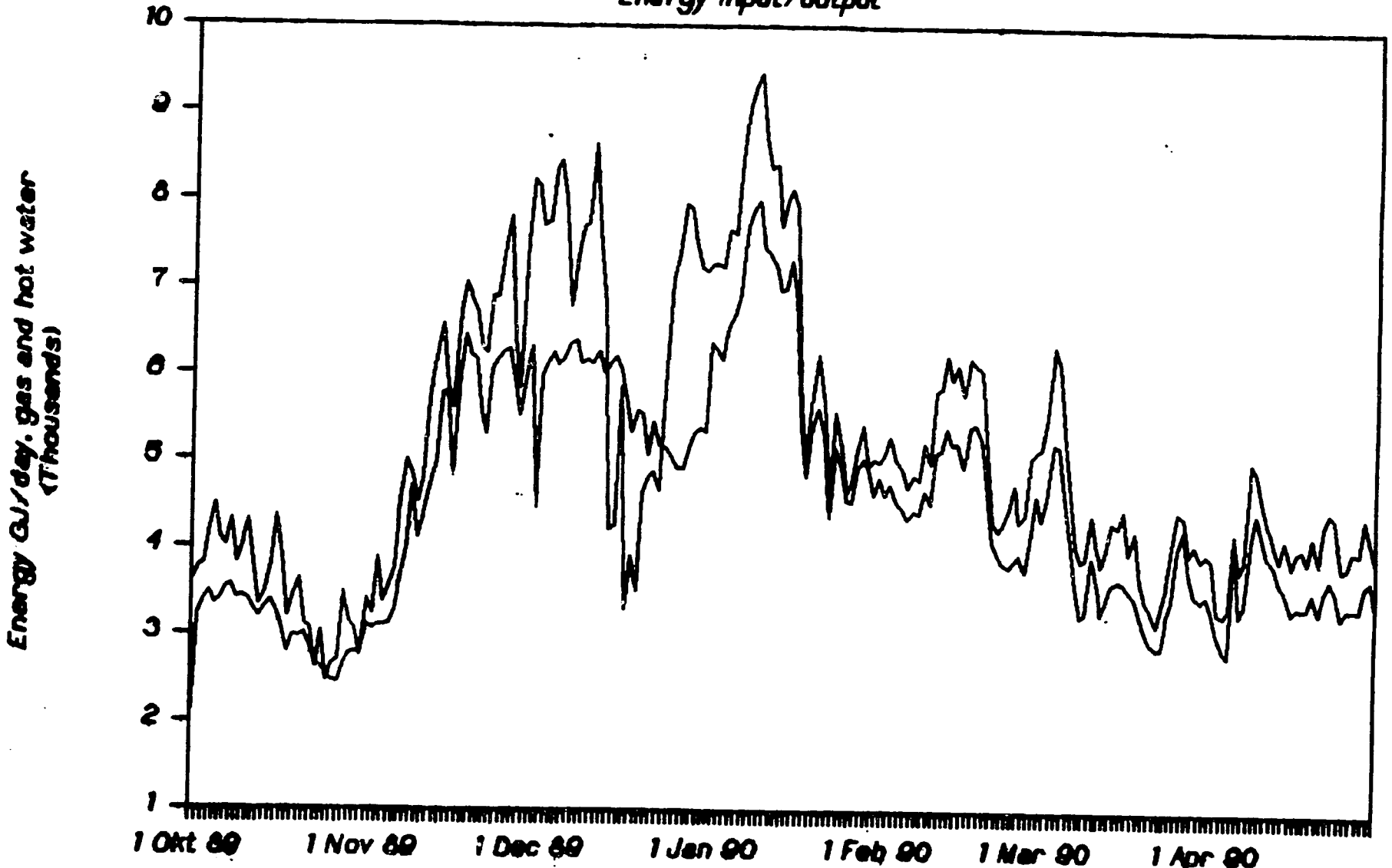
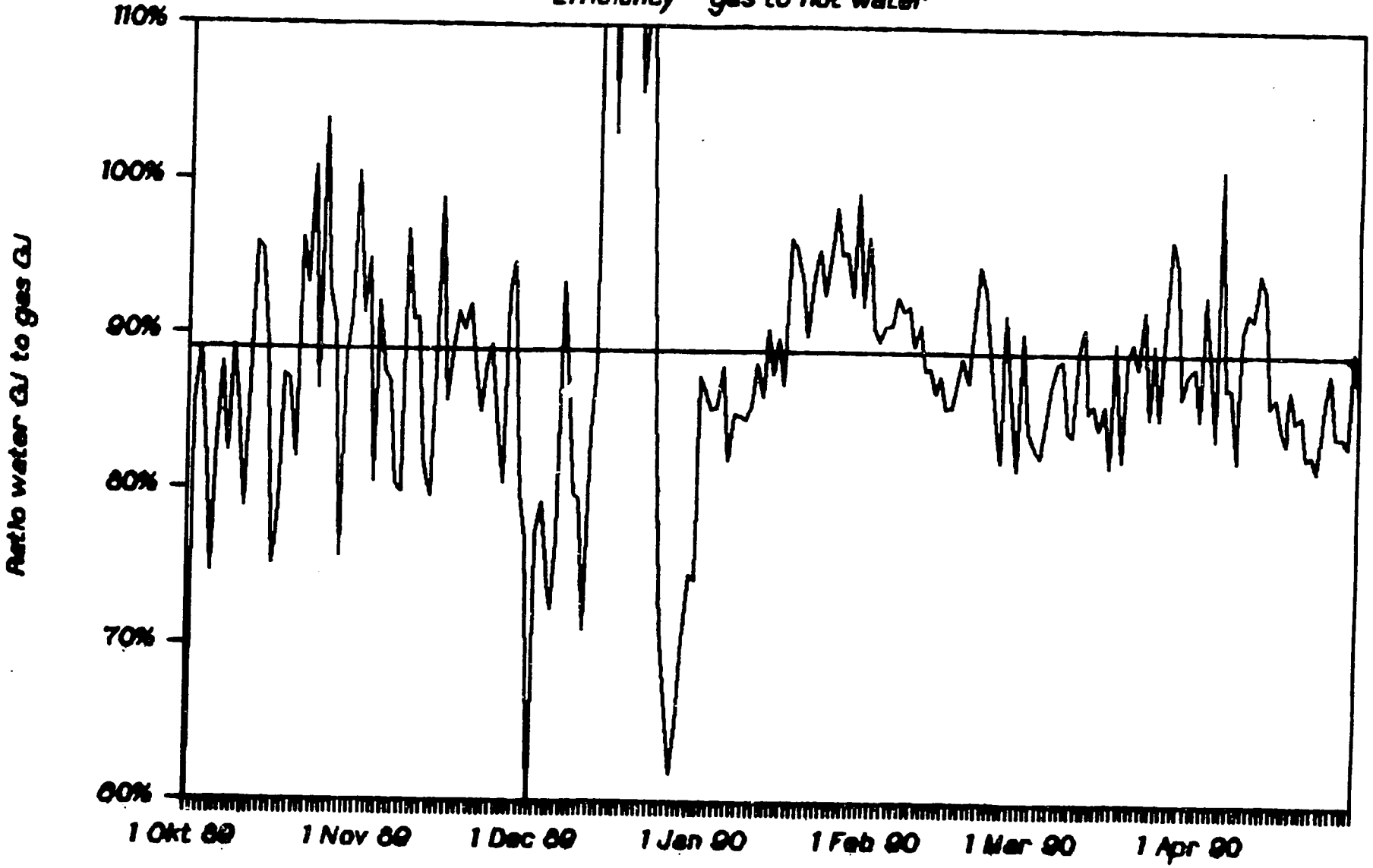
FUREDI 1989/90

Energy input/output



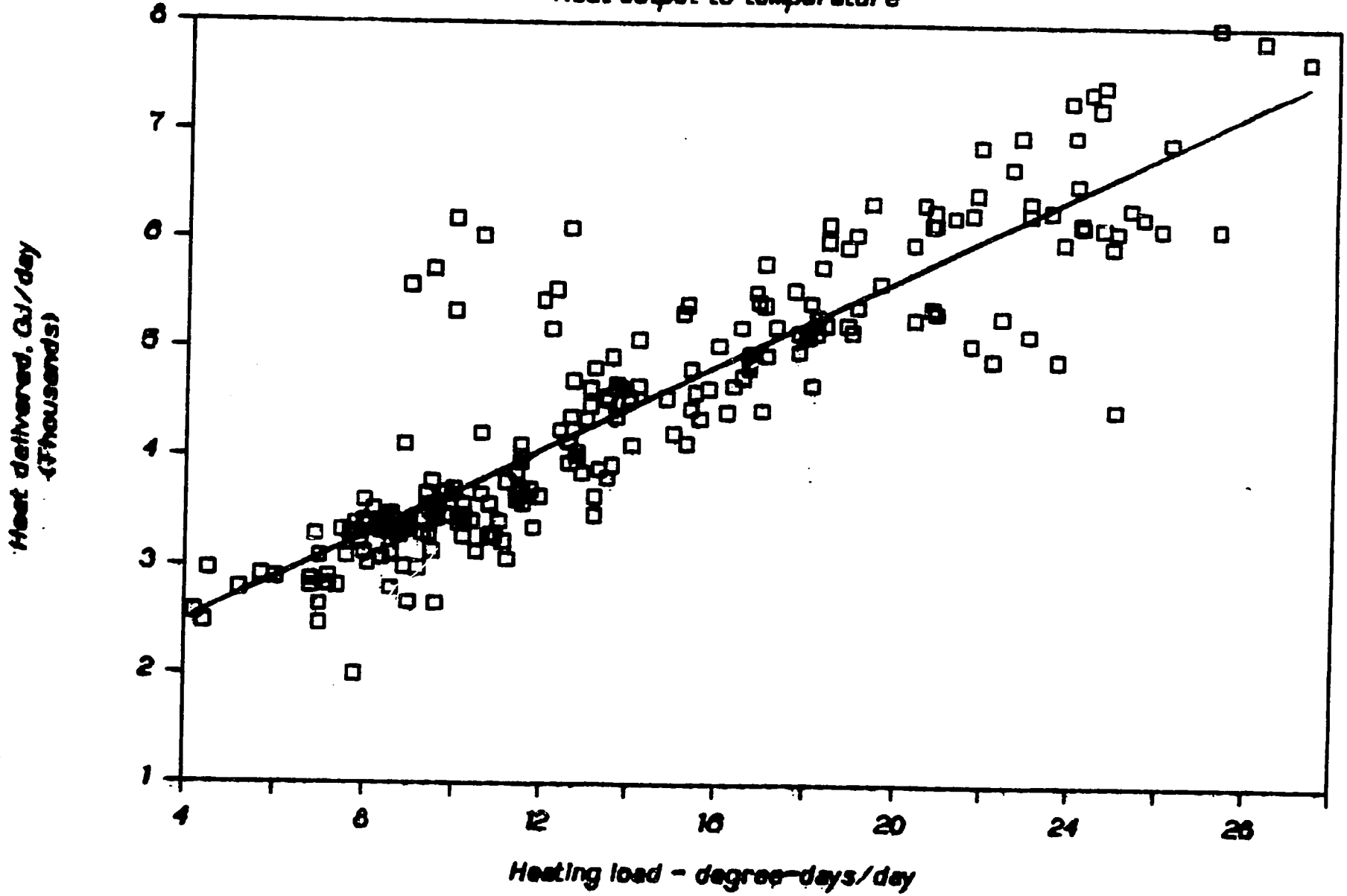
FUREDI 1989/90

Efficiency - gas to hot water



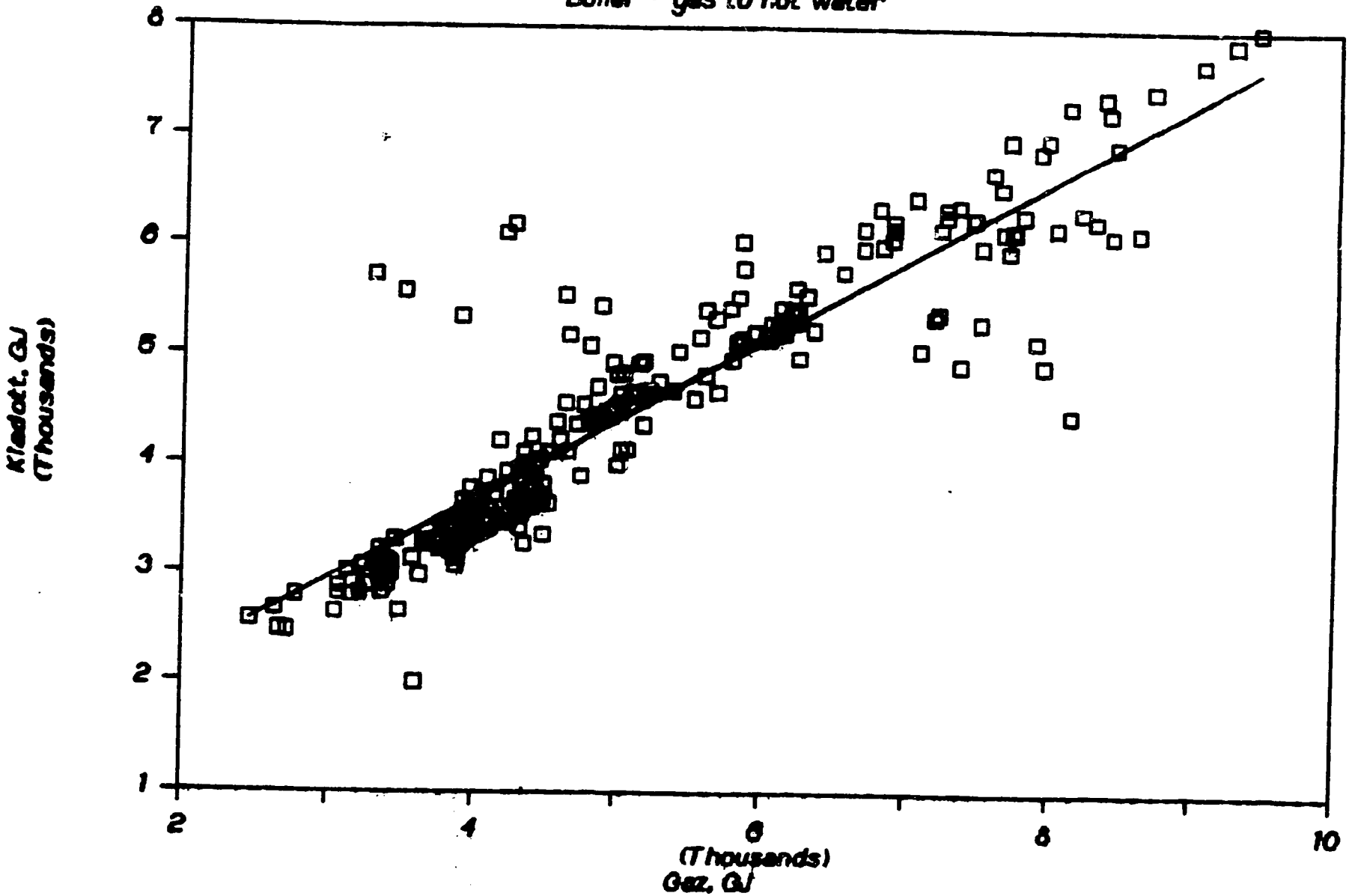
FUREDI 1989/90

Heat output to temperature



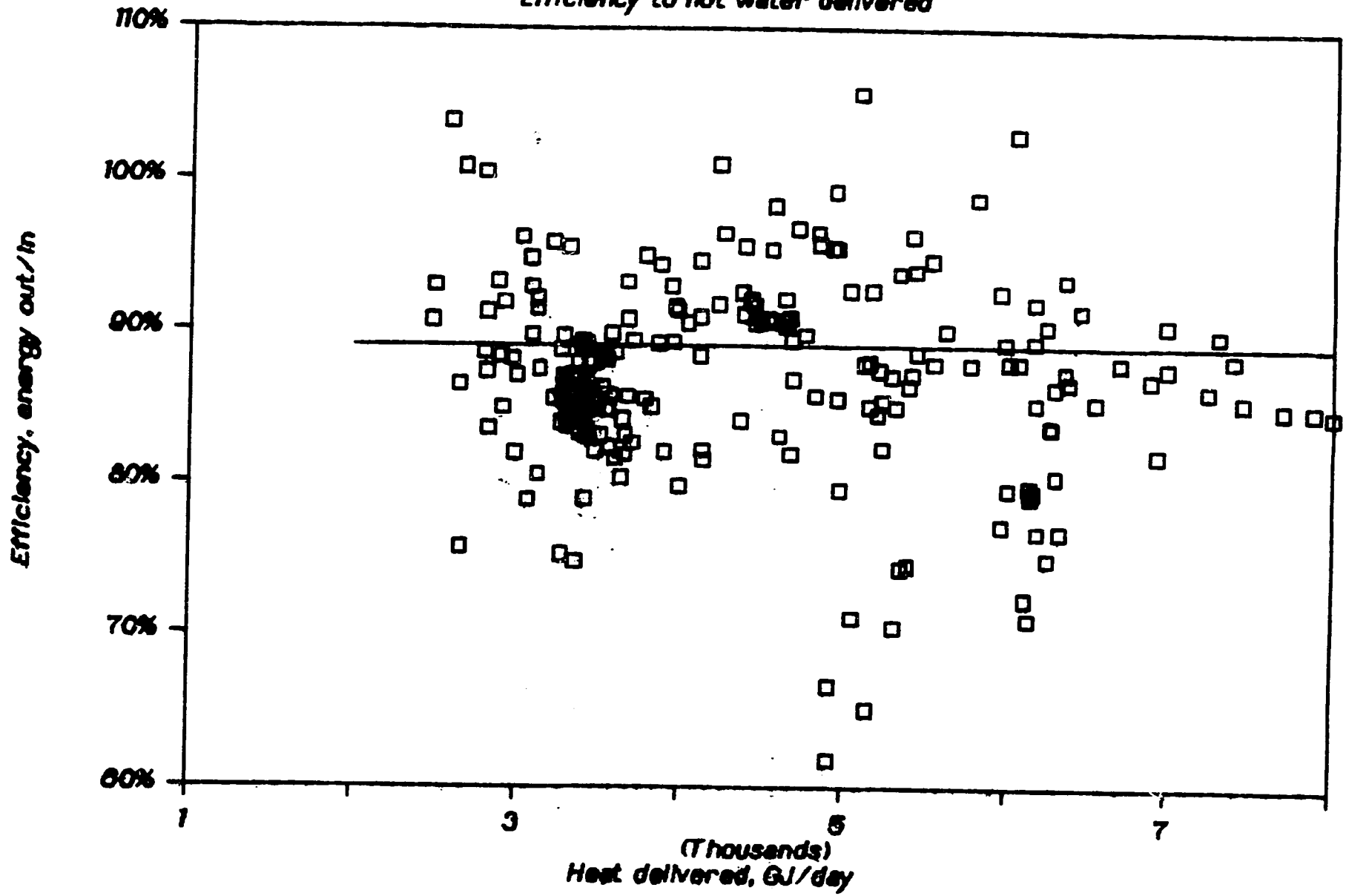
FUREDI 1989/90

Boiler - gas to hot water



FUREDI 1989/90

Efficiency to hot water delivered



FOTAV ESZAK-PESTI

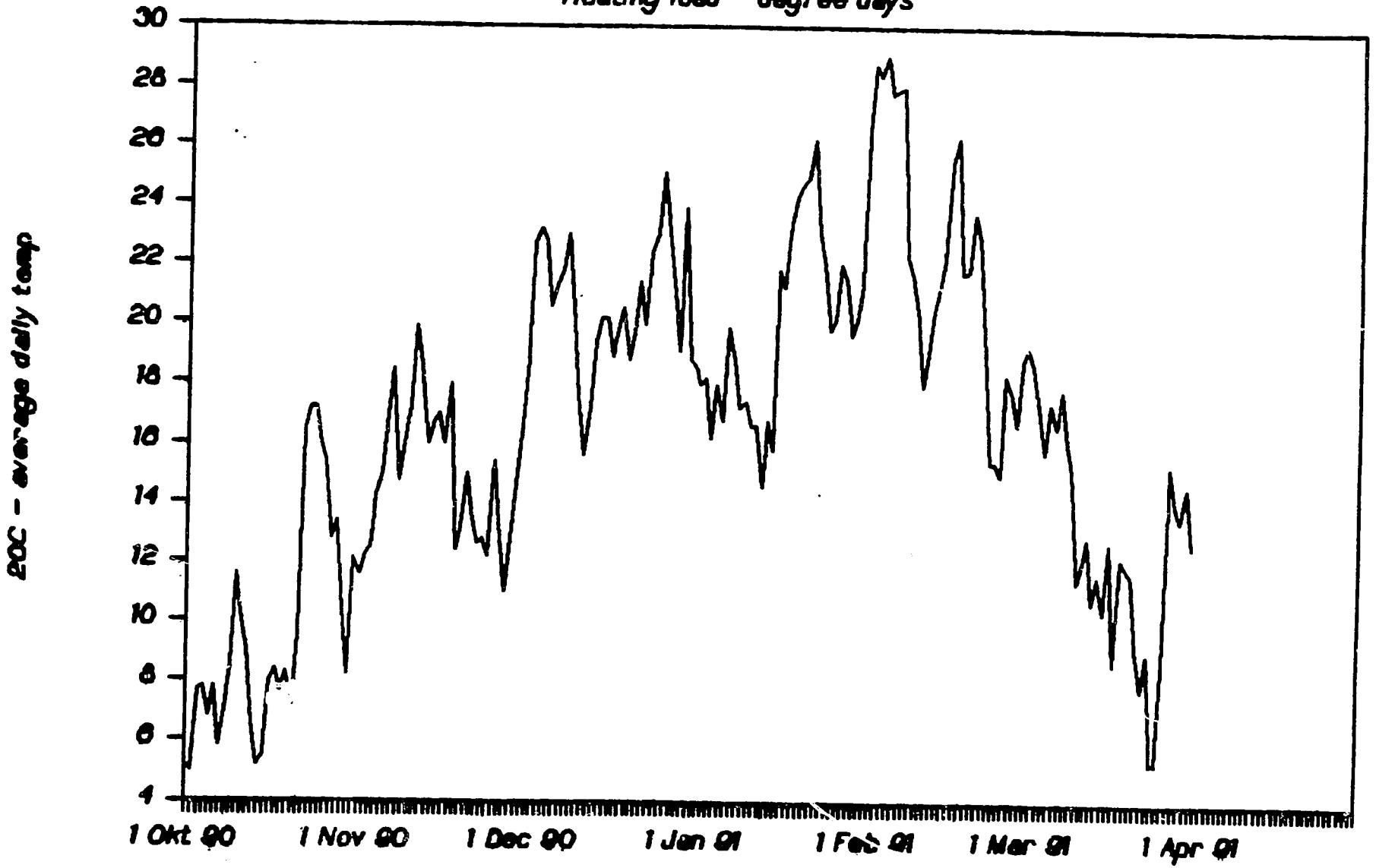
District Heating Works of Budapest, North-East Section

DAILY DATA
FUREDI HEAT GENERATION STATION
1990/91 HEATING SEASON

67

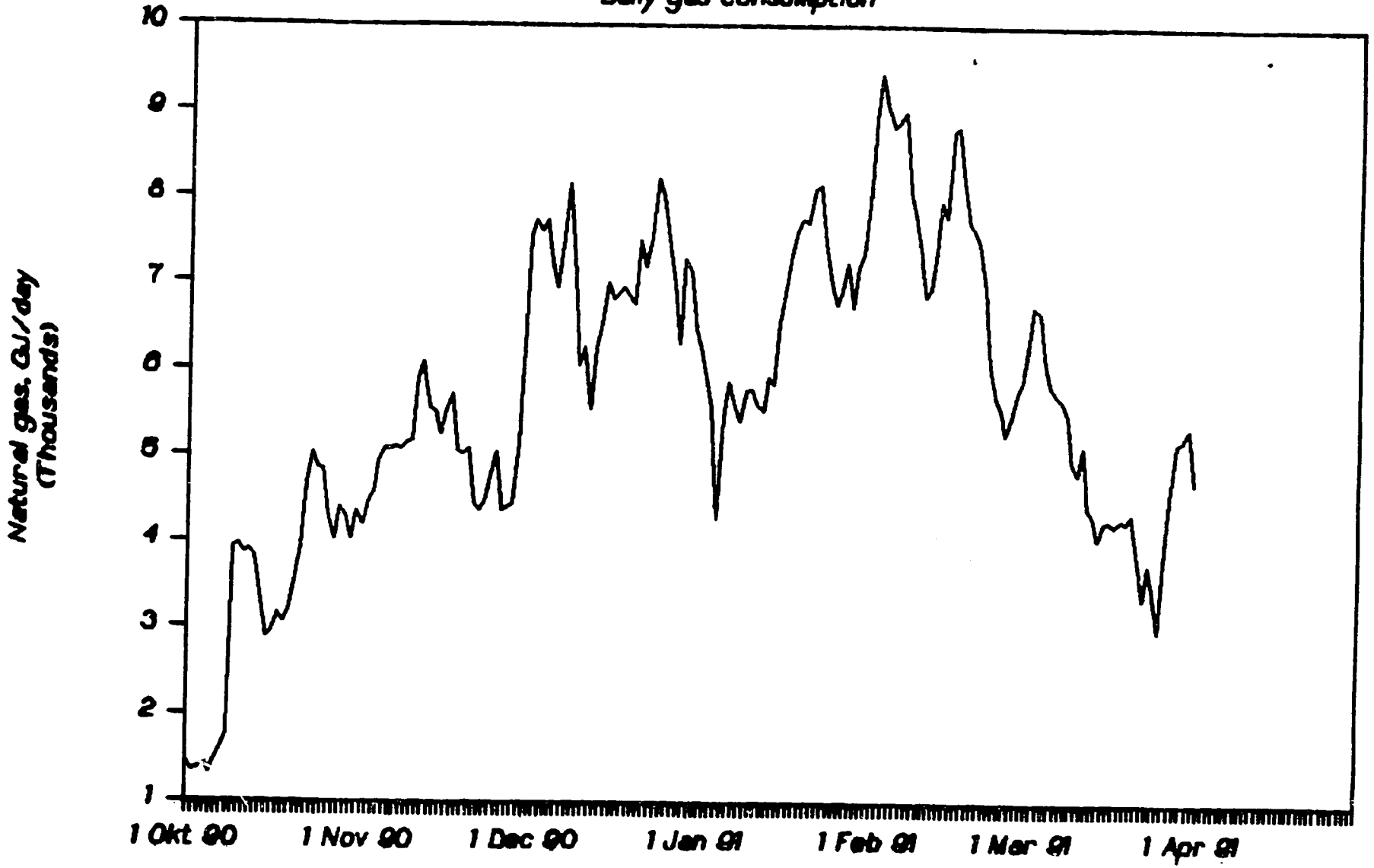
FUREDI 1990/91

Heating load – degree days



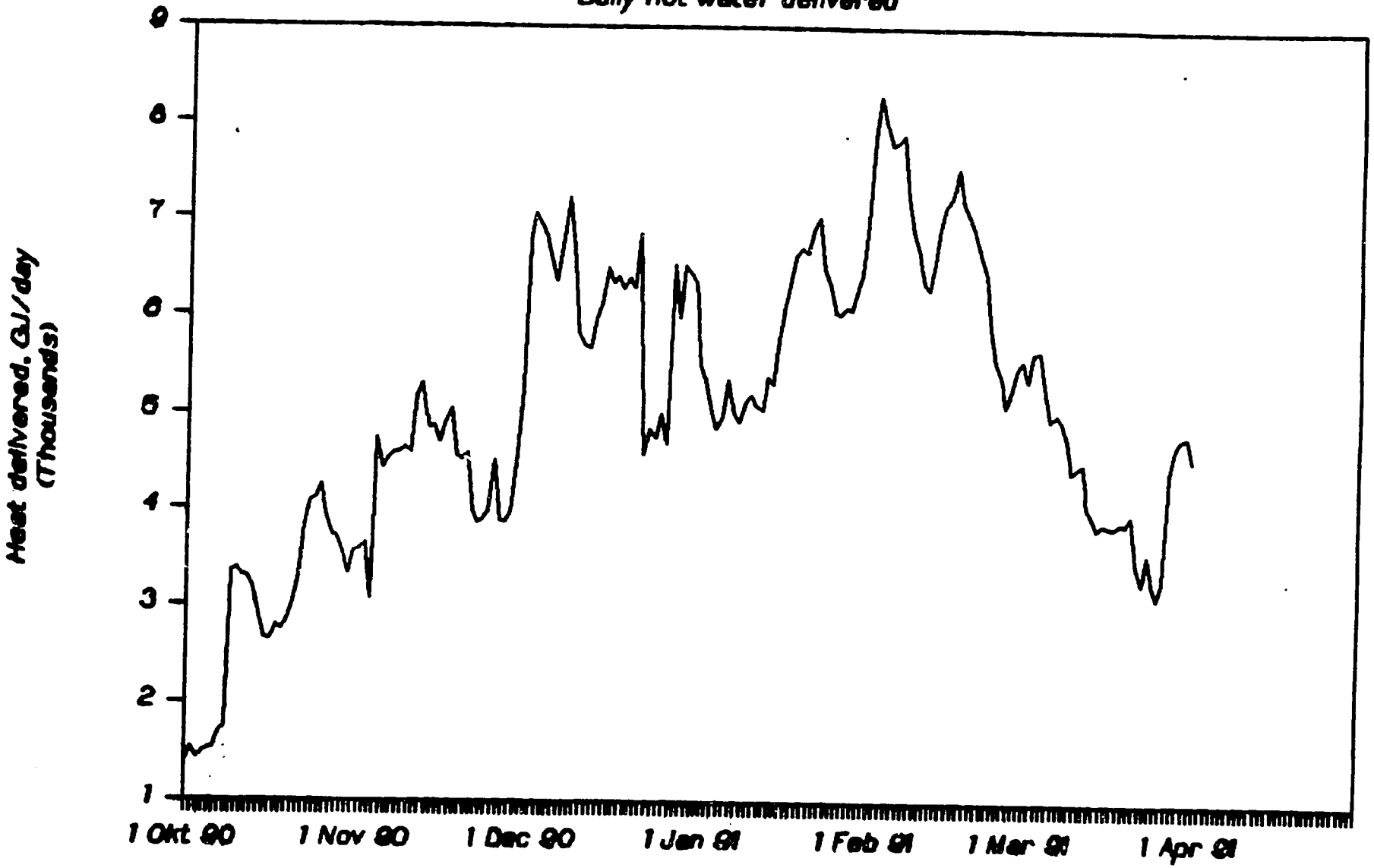
FUREDI 1990/91

Daily gas consumption



FUREDI 1990/91

Daily hot water delivered



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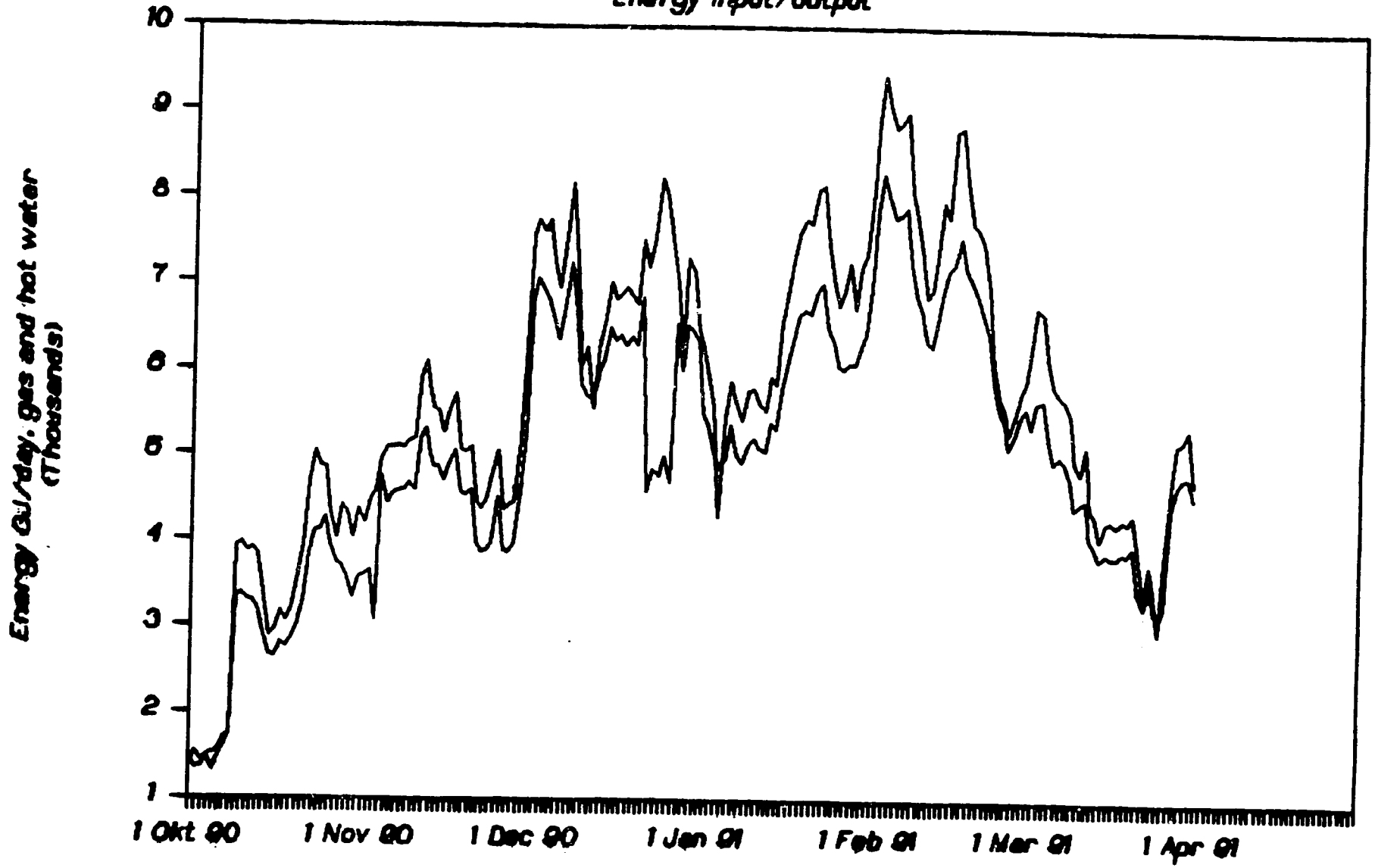
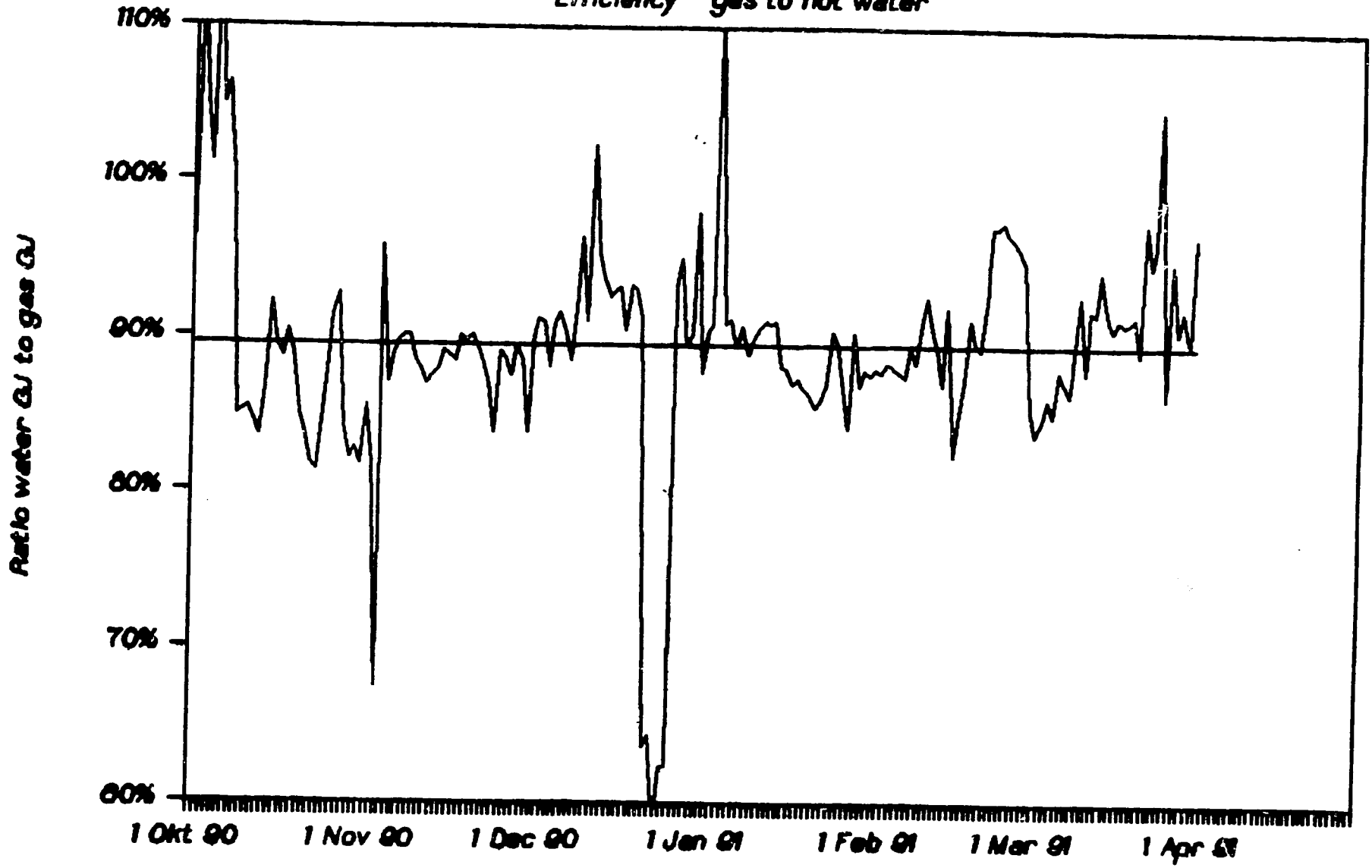
FUREDI 1990/91

Energy input/output



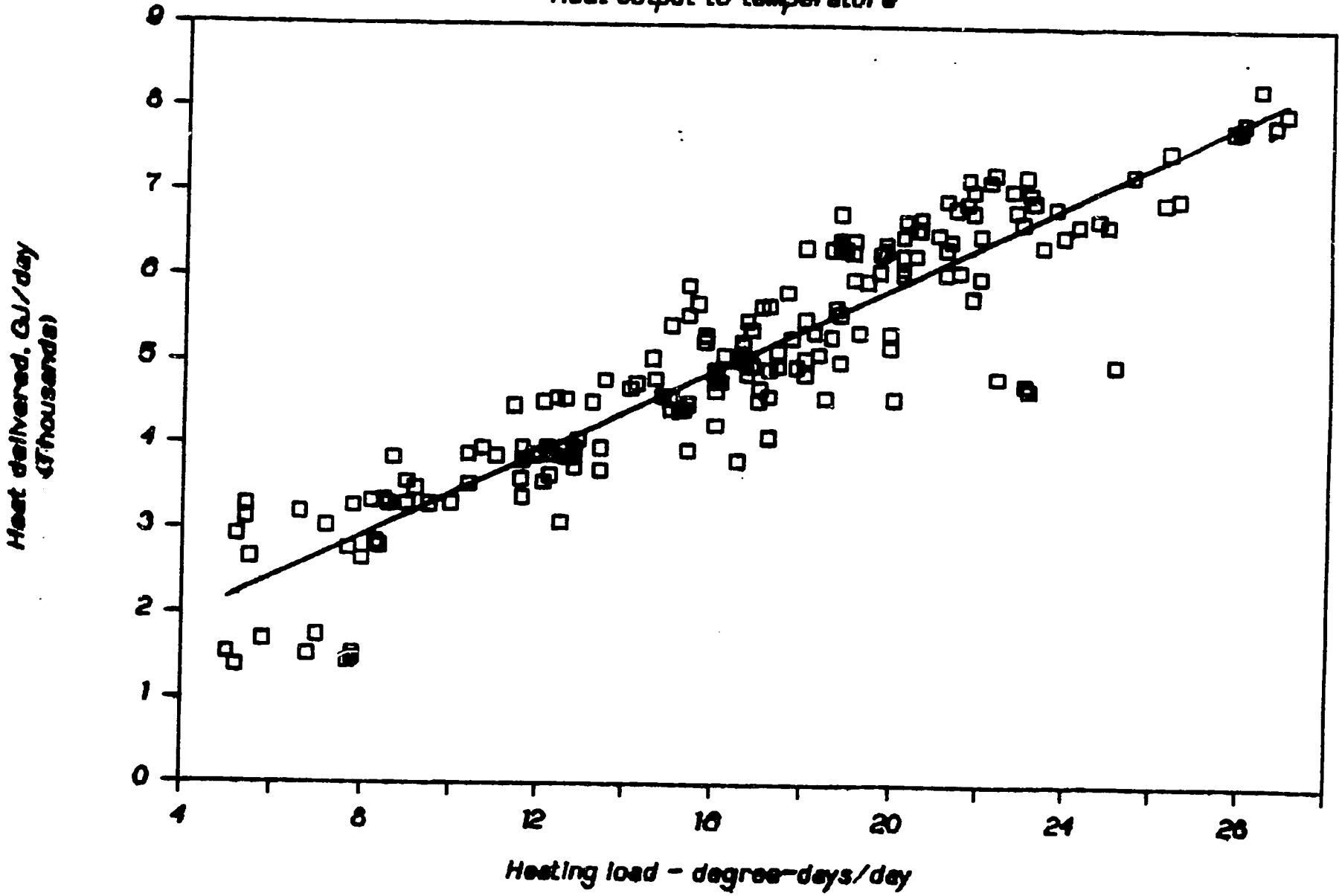
FUREDI 1990/91

Efficiency - gas to hot water



FUREDI 1990/91

Heat output to temperature



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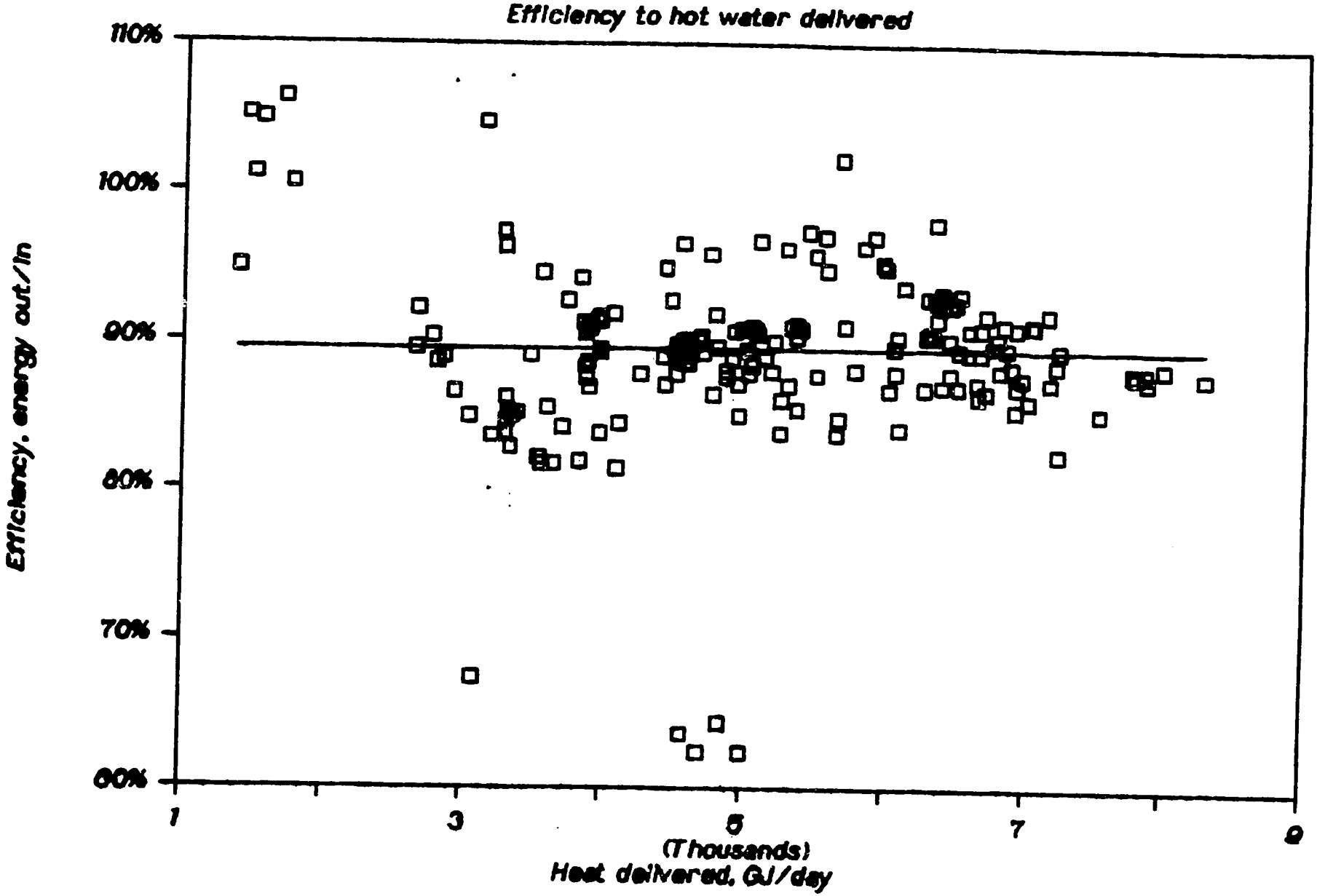
FUREDI 1990/91



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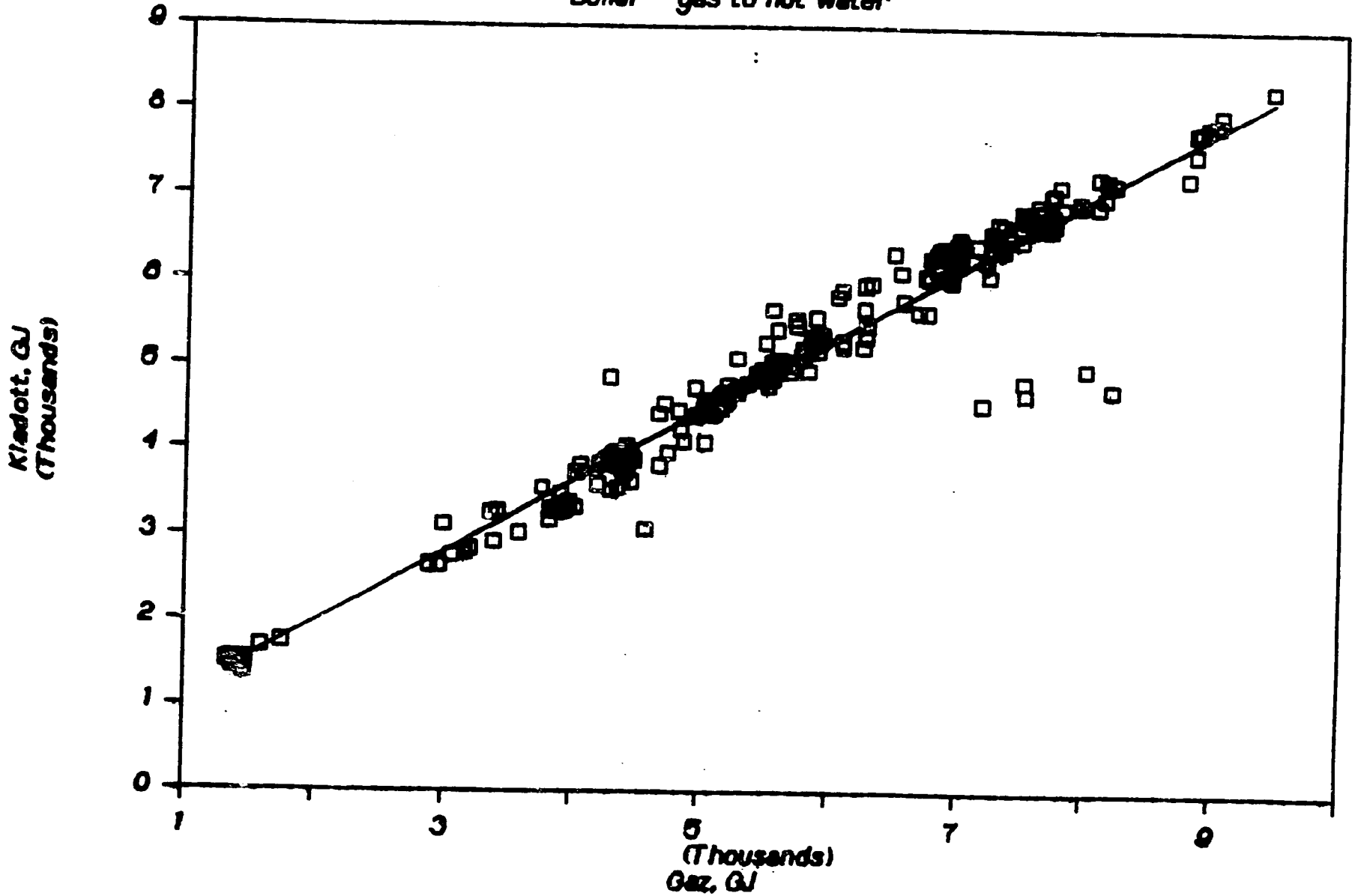
FUREDI 1990/91

Boiler – gas to hot water



25

APPENDIX 2
PROJECT FORMS FOR
DEMAND-SIDE MANAGEMENT DEMONSTRATION PROJECT
U.S. EMERGENCY ENERGY PROGRAM FOR HUNGARY

FOTAV ESZAK-PESTI

District Heating Works of Budapest, North-East Section

1

27 April 1991

Mr. Imre Schiller
Chief Engineer for Development
District Heating Works of Budapest
H-1116 Budapest
Kalotaszeg u. 31

Dear Mr. Schiller:

The purpose of this letter is to express support of the U.S. Agency of International Development's (U.S.A.I.D.) Emergency Energy Program for your development of the Building Heating System Retrofit Program.

Following the meeting of April 26, 1991 with you and Mr. Farkas, I wish to express the U.S.A.I.D. intention to finance the purchase of equipment for one building in the Building Heating System Retrofit Program as described in the attached draft document prepared as a result of the meetings.

Purchase of the equipment must meet the U.S.A.I.D. procurement regulations and the approval by the U.S.A.I.D. contract office in Washington D.C. It is my expectation that the purchase of the U.S. or Hungarian equipment discussed, will meet the U.S.A.I.D. procurement requirements.

The discussions indicated the importance also of the institutional issues in success of the Program. To have the best chance of success, it is understood that the following will be done by the District Heating Works of Budapest: (1) Get the full cooperation of the cooperatives, (2) design and implement a heating tariff that gives residents an incentive to save energy, (3) develop monthly billing that gives residents information on how they saved, (4) promote energy efficiency among the residents and (5) monitor results systematically. It is also understood that the District Heating Works of Budapest will fund the design and installation costs.

RCG/Hagler, Bailly will work to purchase the equipment in cooperation with your organization and E.G.I. They will also provide on a limited basis technical advice or review on the retrofit design and incentive tariff design.

We look forward to the opportunity of working together to make this important project successful.

Sincerely yours,

Robert Archer
Project Officer
U.S.A.I.D.

Attached: draft report of the meetings of April 26, 1991

11

(2) The data sheet of the apartment house:

Address of mother building: Budapest, 1158
Frankovics utca 19-23
Building N°10
(presently the heating center is situated here)

Address of daughter building: Budapest, 1158
Frankovics utca 13, 15, 17
(a separate heating center is to be implemented here to compare the heat consumption of the two buildings)

Object N° 49-4-7070-7071

Number of apartments: 2 x 190 = 380

Energy consumption for space heating: 1 913 kW
Energy consumption for hot water gen.: 280 kW
Sum total: 2 193 kW

Monthly data:

Heated space of:			Lumpsum		Fee
residential facilities	50 001 m³	x	10.20	=	519000 Ft
- common rooms	545 m³	x	6.30	=	3434 Ft
commonly used space	0 501 m³	x	0.90	=	22434 Ft
Hot water consumption	3 440 m³	x	31.50	=	108360 Ft

Monthly heating fee during heating season (15th of October till 15th of April) 653316 Ft

Monthly hot water fee (from 15th of April till 15th of October) 108360 Ft

Total yearly fee for FOTAV 4570056 Ft

Breakdown of heat consumption (heating and hot water) based on actual measurements:

MONTH	CONSUMPTION (GJ)
January	3334
February	1993
March	1661
April	1697
May	910
June	491
July	553
August	579
September	432
October	1108
November	1885
December	2603
Total	17248

Fee paid according to lumpsum contract	4 570 056.00 Ft
Fee which would have been paid based on measurement	4 173 532.00 Ft

Characteristics of the buildings:

One pipe heating system with upper distribution.

Design heat demand 1 878 000 kcal/h

Design water flow 24 m^3/h

Automatic vents with collected vent lines

570 pcs "RADAL" typ. (aluminum) radiator

ACTION

1. PLANT IDENTIFICATION

FOTAV: District Heating Works of Budapest

2. STATEMENT OF RECOMMENDATION

Retrofit Heating Systems in Dristict Heated Apartments

3. DESCRIPTION/RATIONALE

3.1 Existing conditions

FOTAV provides heat to 240,000 homes, 5,000 municipal customers and 430 industrial customers, with a peak load of 2,600 MW (thermal). Of the heat supplied, 2/3 is purchased from MVMT (cogeneration from backpressure turbines) and 1/3 is generated in the company's 15 boiler plants (each has 3 or 4 boilers). The primary water is supplied at up to 150C, the temperature being modulated by ambient conditions. The secondary loop installed in the buildings, each supplying 50 -230 homes, works on supply temperature of up to 90C. There is no storage in either loop. For 1990, FOTAV had energy costs of Ft 7,000 million for heat (from MVMT and for natural gas) and Ft 200 million for electricity from MVMT. The cost of the heat supplied is Ft 140 per cubic meter of living space per year, whereas the 1990/91 heat tariff was only Ft 61.2. The price will be increased to Ft 104 effective 1 June 1991. The basis for the subsidy is that there are different gas prices for industrial (Ft 12 per cubic meter) and residential (Ft 5 per m3) gas customers, and FOTAV buys gas at the industrial rate.

Over the past 15 years, FOTAV has had an organized program to improve efficiency, so as to reduce the subsidy to a minimum. They first reduced the target interior space temperature from 23C to 21C, and more recently have been installing control equipment to improve combustion efficiency in boiler plants, and have achieved improvements of about 5%. They have improved the insulation of distribution systems (even building a manufacturing plant to make styrofoam pipe insulation) and have installed systems to keep insulation dry.

Since 1982, they have had an ongoing program to install energy meters in substations, and expect to begin using these meters for billing purposes beginning with the 1992/93 heating season, if an appropriate tariff can be worked out.

The key energy conservation action is now on the demand side. Potential savings of 15-25% are available through conversion of existing systems to meterable and controllable systems. Some 20% (50,000) of the customers have the uncontrollable 1-pipe system.

3.2 Recommendation

Carry out a demonstration project to show the effect of converting a 1-pipe system to a controllable and meterable system. Install thermostat valves and meters on radiators.

3.3 Application

FOTAV has identified two apartment buildings hooked-up to the district heating system through a substation equiped with a meter. Each apartment building is managed by a different cooperative. Therefore, FOTAV intends to install separate heat meters, one per apartment building.

Specification of one apartments buildings

heated volume 1/	m3/bld	27500		
apartments per buildings	#	190		
average volume per apart.	m3	145		
stories	#	11		
rooms per apartment	#	2	3	3
apartments per level	#	6	8	4
apartment on the ground level	#	4	2	4
heated volume per apartment	m3	115	160	160
radiators per apartment	#	2	3	4
type of radiator		aluminium		
hot water taps per apartment	#	2	2	2

note 1: this volume doesn't include heated common space which are not charged to residents.

4. BENEFITS

4.1 Benefit to the district heating company

Benefit to the district heating company depends on the billing method:

o In the case of a fixed price per m3 of living space, the district heating will get a reduction of operating cost with no reduction of billed revenue.

o In the case of a price structure with a proportional component per GJ of heat, the district heating company will experience a reduction of both operating cost (fuel gas) and billed revenue. If the marginal price per GJ of heat is lower than the marginal cost per GJ, the district heating company will have an increase of its net earnings. The structure of the binomial price function is expected to be 40% constant (demand charge), 60% variable (per GJ price) so that the tariff applied to an uncontrollable one-pipe building yields the same charge as the existing regulated lump-sum tariff per m3.

4.2 Benefit to the customer

o In the case of a fixed price per m3 of living space, the customer doesn't receive any financial benefit. However, he will benefit from an increased comfort as a consequence of the

81

improved technology (thermostatic automatic control). The bill will have only one item: charge per m3 x volume of the apartment.

- In the case of a tariff with a proportional component per GJ and no individual meter, all residents of the building will equally benefit financially from a reduction of heat consumption. Savings might be increased by a modification of consumer attitude of residents. The bill will show 2 items: (1) total cost of heat based on the lump-sum tariff per m3, (2) reduction of heating bill based on the application of binomial tariff to the building and allocated to residents on a m3 basis.

- In the case of a tariff with a proportional component per GJ and individual meters, each resident will benefit from a reduction of heat consumption according to his individual level of effort. Individual interest may generate additional savings by influencing the consumer attitude of residents. The bill will show 3 items: (1) Total cost of heat based on the lump-sum tariff per m3, (2) reduction of heating bill based on the application of binomial tariff to the building and allocated to residents on a m3 basis. (3) individual energy conservation charge which can be positive or negative depending on the level of effort of the resident compared to the average in the building.

4.3 Energy savings per dwelling

Percentage savings on heating	30%
Percentage savings on hot water	30%
Percentage reduction of peak demand	50%
Dwelling volume	145 m3
Current heat consumption	45 GJ/dwelling/yr
Peak demand	5 kW
District heating cost reduction	
cost of natural gas	
per GJ	Ft 264/GJ
demand charge	Ft 1007/kW/year
combustion efficiency of boilers	92 %
annual savings	Ft 6,610
of which GJ charge	Ft 3,874
demand charge 1/	Ft 2,736
annual O&M cost	Ft 700
annual cost reduction	Ft 5,910
Resident reduction of charge	
annual charge	Ft 144/m3/yr
of which space heating	Ft 104/m3/yr
domestic hot water	Ft 40/m3/yr
breakdown of demand charge & GJ charge	40% / 60%
marginal price per GJ of heat	Ft 278
annual savings	Ft 3,758
District heating increase of earnings 2/	Ft 2,152

82

note 1: assuming that the gas utility company is willing to reduce the demand charge according to the actual demand reduction.

note 2: this increase of earnings is most likely a reduction of operation losses, which will translate automatically into reduction of government subsidy of the same amount.

4.4 Energy savings for one building

Heat consumption reduction at building level	2,565 GJ
Natural gas savings	2,788 GJ
equivalent to	66 toe
Natural gas demand reduction	516 kW
Natural gas cost reduction	1,236,000 Ft
Increased maintenance cost	133,000 Ft
Net earnings increase	1,123,000 Ft

Annual gas savings
at international price (@ US$ 20/bbl) US$ 9,300

5. IMPLEMENTATION COST

5.1 Average cost per dwelling

Estimated for a dwelling - 1 pipe system

Thermostatic radiator valves (3 @ Ft3,000)	9,000
Radiator meters (3 @ Ft900)	2,700
Hot water meters (2 @ Ft2000)	4,000
Bypass and installation cost:	
(3+2)devices x 2 hours/device x Ft400	4,000
supply and accessories	2,000
TOTAL COST	21,700

5.2 Total cost for one building

	cost in 000Ft	of which US$
Thermostatic radiator valves (604 @ Ft3,000)	1,812	26,000
Radiator meters (604 @ Ft900)	544	7,800
Hot water meters (380 @ Ft2000)	760	10,800
subtotal equipment	3,116	44,600
shipment (@ 10%)	311	4,460
Installation cost 1/		
labor	790	
supplies and accessories	380	
Total 1/	4,600	49,000
contingencies (@ 5%)	230	2,450
GRAND TOTAL	4,830	51,500

note 1: do not include procurement and installation of a new pump or booster for the space heating hot water loop

6. FINANCIAL AND ECONOMIC ANALYSIS

6.1. Financial analysis

Total cost	Ft 4,830,000
Net annual savings	Ft 1,123,000
Payback	4.3 years
Internal rate of return	23%

Financial hypothesis	
Duration of financial analysis	10 years
Discount rate	15 %

sensitivity analysis

scenario		worst	avg	best
percentage savings	%	20	30	40
probability	%	15	60	25
Payback	year	6.5	4.3	3.2

6.2 Economic analysis

6.3 Hard currency balance

Total cost	US$ 41,500
Annual savings	US$ 9,300
Payback	5.5 years

sensitivity analysis

scenario		worst	avg	best
International price of energy	US$/bl	30	20	18
probability	%	20	75	5
Payback	year	3.7	5.5	6.2

7. SCHEDULE

7.1 Critical path schedule

Task 1 - completion date: May 3

HBI identifies US valves manufacturers, collects catalogues and brochures and ships them to Hungary through EGI for FOTAV review.

Task 2 - completion date: May 10

FOTAV establishes a list of qualified US and Hungarian manufacturers and selected lines of products based on catalogues.

FOTAV reviews and comments specifications of equipment prepared by HBI.

FOTAV - BUILDING HEATING SYSTEM RETROFIT PROGRAM

Task 3 - completion date: May 24

HBI collects quotation, basic performances of proposed equipment, sample of proposed equipment from US manufacturers and has it shipped to Hungary by express mail.

FOTAV collects quotation, basic performances of equipment from Hungarian manufacturers.

Task 4 - completion date: May 27

FOTAV makes an evaluation of proposals based on price, product performance, product quality, delivery time, availability of maintenance support in Europe and other criteria.

FOTAV establishes a final specification of equipment based on technical characteristics of products and inspection of sample.

Task 5 - completion date: May 30

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

Task 6 - completion date: June 1

HBI sends purchase orders for equipment

Task 7 - completion date: June 15

First shipment of equipment arrives in Hungary, installation works starts.

Task 8 - completion date: July 1

Last shipment of equipment arrives in Hungary.

Task 9 - completion date: August 30

End of installation works.

Task 10 - completion date: September 8

End of hydraulic tests.

Task 11 - completion date: September 15

Beginning of heating season.

7.2 Other tasks to be completed

7.2.1 Tasks to be completed by FOTAV

- get the full cooperation of the cooperative
- design and implement a heating tariff that gives residents an incentive to save energy

- promote energy efficiency among the residents
- monitor results systematically
- fund the design and installation costs

7.2.2 Tasks to be completed by RCB/Haqler,Bailly and EGI

- minimize technical risks by reviewing engineering design made by the heating company
- review the incentive tariff design
- identify US equipment suppliers who would have subsidiary or licensee in Europe to maintain procured equipment

8. TECHNICAL RISK AND REFERENCE

8.1 Legal barriers

- Installation works in occupied apartments

In addition of possible nuisances, damages, and risks of robbery, there is an access problem to the apartment to perform installation works.

- Impartiality of heat metering method

Heat meters provide at best a good estimate of heat used in a dwellings. There is no doubt that this estimate is much better and equitable than the allocation of heat use on a m3 basis. However, it requires a fairly sofisticated data processing to insure a relative impartiality of results. In no way, this metering process (hardware and software) can provide an accurate measurement of the quantity of heat used by a customer. To avoid any contestation, this metering process must be reviewed and agreed by an independant agent and/or the cooperative.

In any case a procedure of "most defavourized" customer should be consider to examine plaints or extreme bills (e.g. customer who pay the more and customer who pay the less in the building).

8.2 Psychological barriers

It is clear that this "pay-for-what-you-use" way of billing heat consumption must be introduced carefully, step by step, and must code with the usual irrational (as in any country) attitude of customers.

8.3 Adverse effects - nuisances

- increased noise in valves

Specification of the three way valves must address that issue

8.4 Perverse effects

The hot tap water meters might appear as a luxury at first sight. However, if not installed, there is the risk that residents will find that heat allocation method can be cheated by using hot tap water to heat the apartment instead of radiators...

9. SPECIFICATION OF EQUIPMENT

FOTAV - BUILDING HEATING SYSTEM RETROFIT PROGRAM

9.1 THERMOSTATIC RADIATOR VALVES - ONE PIPE SYSTEM

type of valve	3 way valves
circulating fluid	hot water
total number of valves per building	604

Temperature and pressure ratings

Maximum temperature	°C	95
Normal temperature	°C	50 to 60 °C
Maximum pressure	bg	10
Normal pressure	bg	5
Maximum differential pressure	m WG	0.5

capacities

identification		A1	A2	A3
maximum flow	m3/h	1	0.5	0.3
maximum pressure droc	m WG	0.3	0.3	0.3
percent of valves	%	10	75	15

connections

inlet port	internally threaded
by-pass port	internally threaded
outlet port (to radiator)	externally threaded

dimensions

identification	
size of valve	to be defined, can be different of pipe size

thermostatic control

control	self contained
sensor, setpoint dial, valve actuator	in one unit mounted on valve body
setpoint dial	selectable limit stops
range	8 - 28°C
construction	vandal resistant

mounting information

incoming pipe	horizontal
outgoing pipe	horizontal, same side of radiator
position of control	vertical
location of radiator	under window

no pipe cutting, no welding, radiator shall be moved along the wall by the length of the valve (expected 10 cm).

reference standart

ASHRAE

FOTAV - BUILDING HEATING SYSTEM RETROFIT PROGRAM 10

9.3 HEAT METERS

technology: evaporative tube or electronic digital

function: cost allocation of space heating

number of heat meters: 604

description:

economics:

maximum equipment price	US$/item	10
maximum data processing/maintenance price	US$/item/year	10

9.4 HOT TAP WATER FLOW METERS

number of meters : 2 x 190 = 380