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ENERGY EFFICIENCY AUDIT REPORT
JELGAVA SILTUMS - DISTRICT HEATING ENTERPRISE
JELGAVA, LATVIA

JULY 1992

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The contents of this report include recommendations based on data provided by the client organization, measurements made on site, calculations, and engineering judgement. The conclusions reached were based on a limited engagement in Latvia 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.

TABLE OF CONTENTS

ACKNOWLEDGMENTS

EXECUTIVE SUMMARY 1

I. GENERAL DESCRIPTION 5

1.1 Regional Boilerhouse Description 8
1.2 Description of Boilerhouse No. 3 (26 Matela St.) 10

II. ANALYSIS OF ENERGY CONSUMPTION AND EFFICIENCY 11

2.1 Energy Prices 11
2.2 Energy Consumption Variation with Ambient Temperature 11
2.3 Energy Management 13
2.4 Boiler Efficiency Measurements 14

III. ENERGY CONSERVATION RECOMMENDATIONS 17

A.1 Improve Energy Monitoring/Control 19
A.2 Set Up Thermal Distribution Efficiency Program 21
A.3 Increase Boiler Efficiency Testing and Tune-ups 24
A.4 Increase Electric System Efficiency Testing 26

B.1 Install Measuring Instruments 28
B.2 Install Fire-Tube Boiler Air Preheaters 30
B.3 Convert to market-oriented energy supply system, and implement demand-side management program for energy efficiency improvement 32

C.1 Replace District Heat with Local Heaters 37

APPENDICES

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Mr. Nikolai Sashinov	Director
Mr. Aleksandr Matjeev	Chief Engineer
Mr. Janis Veidemanis	Mayor of Jelgava

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

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c/

FINAL ENERGY AUDIT
DZIVOKLU KOMUNALAS SAIMNIECIBAS RAZOSANAS APVIENIBA
JELGAVA SILTUMTIKLU UZNEMUMS

JELGAVA SILTUMS - DISTRICT HEATING ENTERPRISE
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BY
RCG/HAGLER, BAILLY, INC.
LATVIJAS ENERGI ATTISTIBA (LEA)
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JULY 1992

EXECUTIVE SUMMARY

This report presents the results from a preliminary energy audit carried out by a team of engineers from RCG/Hagler, Bailly, Inc., LEA, and Riga Technical University at the Jelgava Siltums, the district heating enterprise of the municipality of Jelgava, Latvia, during the period December 12-17, 1991. The objectives of the audit were to work with the plant staff to: evaluate energy consumption at the plants; determine the level of energy management practiced; to determine energy conservation actions or opportunities; and identify instrumentation and low-cost equipment needed by the plant to implement the more attractive energy conservation actions.

Jelgava Siltums provides hot water to more than 40,000 residences and steam and hot water to about 90 industries, operating approximately 50 boilers in 20 different boilerhouses. The primary energy form used by Jelgava Siltums is natural gas.

Based on energy consumption in 1991, and January 1992 European market energy prices[1], the total economic cost to the economy of Latvia for the energy used by Jelgava Siltums is estimated as $5.6 million per year. The actual cost may be less, if Latvia succeeds in obtaining fuels and electricity at prices lower that the European market. A summary of the primary energy consumption at the plant based on 1991 data is given below (one terajoule, TJ is 1 x 10^{12} Joules[2]).

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

[2] Joules is the SI standard energy unit. 1 TJ = 0.2388 Tcal

	physical units	Energy Distribution TJ	%	Economic Cost Distribution US $	%
Natural gas	47,619,000 Nm^3	1,657	94	4,971,000	96
Heavy fuel oil	446 tonnes	18	1	30,000	1
Coal	3,623 tonnes	82	5	152,000	3
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SUBTOTALS (Thermal)		1,758	100	5,153,000	100
Electricity	10,000,000 kWh	0	0	500,000	

TOTAL COST				5,653,000	

During the brief preliminary energy audit work at two of the boilerhouses, Jelgava District Heating Enterprise staff worked closely 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 energy consumption and outside temperature data, and measurements of certain process parameters, a list of energy conservation actions have been identified. The recommendations and expected results are summarized in ()Exhibit 1.

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

EXHIBIT 1
JELGAVA SILTUMS District Heating System

Summary of energy efficiency projects

	Fuel[3] TJ/yr	Electric MWh/yr	Cost US$/yr
BASE CASE	1,758	10,000	$5,653,000

RECOMMENDATIONS AND ESTIMATED ECONOMIC SAVINGS:

	Fuel TJ/yr	Electric MWh/yr	Net benefits US$/yr
A. General & Energy Management			
A.1 Energy monitoring	53	300	$156,000
A.2 Steam efficiency team	5		10,000
A.3 Boiler efficiency	18		52,000
A.4 Electric efficiency		100	5,000
B. Short-term, Low-cost Efficiency Improvements			
B.1 Install meters	35		52,000
B.2 Air preheaters	1		3,000
TOTAL SHORT-TERM SAVINGS	112	400	$278,000
Percent of base case	6%	4%	5%
Other Medium-term Efficiency Improvements			
B.3 Market reform & demand-side management program	497		$1,550,000
TOTAL MEDIUM-TERM SAVINGS	609	400	$1,828,000
Percent of base case	35%	4%	32%

[3] Assumed to be 100% natural gas for these calculations

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

FINAL PLANS FOR PROCUREMENT

JELGAVA SILTUMS District Heating System

	Estimated Procurement Budget
(2) Combustion analyzers	7,000
(2) Portable thermocouple sets	1,500
(2) Ultrasonic tester	1,500
(1) Electric power meter (with power factor)	1,200
(1) Infrared pyrometer, laser sighting	1,300
Fixed thermal energy meters: to demonstrate typical installations, for example: outlet of boilerhouses inlet to steam customers at substations at buildings	25,000
Total	$37,500

CHAPTER 1 -- GENERAL DESCRIPTION

Jelgava is a city of approximately 120,000 people located about 60 km south of Riga. The district heating enterprise, run by the municipality, is typical of those in cities and towns all over Latvia, and most likely, the former Soviet Union. The director of the enterprise is responsible directly to the mayor, who is appointed by the elected city council. The existing director has been in his position since 1974.

The enterprise was referred to as "self-financing" by its staff, but more than 10% of its 1991 budget of 12 million rubles was subsidized by the city of Jelgava and the Government of Latvia. All users, except some of the large industries, pay a flat yearly rate for heat; this does not encourage efficient use of the heat, nor does it cover all the expenses of the enterprise. Of the total budget, fuel costs were approximately 7 million rubles, and electricity costs totaled an additional 2 million rubles.

Customers can be summed up as follows:

Industries:	90 total, not all metered
Public housing systems:	4, totaling 32,000 residences
Other public housing:	10,000 residences
Private homes:	30 total

The enterprise operates 20 heating locations throughout the greater Jelgava area, comprising over 50 steam and hot water boilers. There are approximately 300 employees, of which 25 are engineers. The enterprise operations are divided into 5 regions on two sides of the river. Distribution pipelines total about 60 km, much of it old and corroded pipe with significant leaks.

The majority of the small boiler plants have no metering. On the large boiler plants, there is some heat metering installed, but much of it is old, poorly maintained, not considered reliable, and used at best only for perfunctory logging of hourly data. The lack of good heat production information is not only a problem for optimizing and maintaining efficiency, but makes it even more difficult in identifying sources and sizes of leakages, as well as theft.

The 1991 energy consumption from thermal fuels is summarized in the table on the following page. Gas accounts for 94% of the energy consumed; the remainder is primarily coal, with a

small amount of diesel fuel in only one boiler plant.

No detailed data for electricity consumption was obtained. An estimate of 10 million kWh is taken, based on observations at the two boilerhouses visited by the team.

The preliminary energy audit covered only two of the plants listed in the table: the regional boiler house, and the boilerhouse located at No. 26 Matela Street, referred to in this report as boilerhouse No. 3. These are described in more detail below.

Jelgava District Heating Enterprise 1991 Energy Consumption (December data is planned)

(source: data provided by the District Heating Enterprise technical staff)

Plant Location		Jan	Feb	Mar	Apr	Oct	Nov	Dec	Totals
Rupnusibos	1000 Nm3 gas	1130	1200	1225	960	830	1200	1600	8145
Chakaste 9		120	177	162	90	90	170	180	989
Slimnicas 33		90	95	86	130	60	85	130	676
Matela 26*		250	340	227	210	140	300	310	1777
Katolu 15		100	150	108	90	65	120	170	803
Gastelo 11		330	350	305	210	175	380	330	2080
Palidzibas 3		960	1000	790	666	625	900	1100	6041
Filozofu 63		170	179	150	140	120	160	190	1109
Regional Boilerhouse*		3930	4900	3500	3030	2449	3600	4590	25999
Totals	1000 Nm3 gas	7080	8391	6553	5526	4554	6915	8600	47619
	(GJ)	246,384	292,007	228,044	192,305	158,479	240,642	299,280	1,657,141
Panzionats	tonnes diesel	60	55	73	57	54	70	77	446
	(GJ)	2,520	2,310	3,066	2,394	2,268	2,940	3,234	18,732
Panzionats	tonnes coal	49	46						95
Instituta 4		80	72	89	60	34	62	76	473
Filozofu 50		55	54	66	27	24	44	55	325
Stadiona 1		12	11	13	8	5	9	11	69
Eleja Darza 14		140	126	121	85	58	109	135	774
Eleja Darza 5		33	29	28	19	13	24	30	176
Eleja Mezha 8		35	31	30	21	14	25	32	188
Eleja Pad Armija		12	11	10	7	5	9	11	65
Lielplatone		80	76	74	54	39	61	75	459
Blukas 2		111	101	125	66	43	73	89	608
Slimnicas 37		31							31
Totals	tonnes coal	638	557	556	347	235	416	514	3263
	(GJ)	16,141	14,092	14,067	8,779	5,946	10,525	13,004	82,554
GRAND TOTAL	(GJ)	265,045	308,409	245,177	203,478	166,693	254,107	315,518	1,758,427

* visited by the audit team

1.1 Regional Boilerhouse Description

The regional boilerhouse is the largest of the boilerhouses operated by the enterprise. It accounts for approximately 50% of the total thermal energy consumed by the enterprise. A brief description of the main equipment in the plant is provided below.

Boilers K-1,2:	steam, 42 GJ/h (16 t/h; 8 bar saturated); one operating
Boilers K-3,4,5:	hot water, 125 GJ/h (about 500 t/h flow, 60-70C inlet, 90-95 C outlet); two operating
Circulating Pumps:	3 x 800 m3/h, with 300 kW motors; all operating
Hot water/steam: converter	2; each sized for steam boiler capacity; only one operating at partial load

Miscellaneous pumps; boiler air forced and induced draft fans; other miscellaneous equipment

Four of the five boilers have dual fuel capability; however, mazout is not burned due to its higher price and pollution level.

The plant normally operates throughout the whole heating season in the mode described above: one steam boiler and two hot water boilers. Steam is always necessary for deaerators for both the hot water and steam boilers; what steam is not needed within the plant is passed through the converter to generate hot water. According to the plant, the steam boiler operates at only about 30% load; this corresponded to the gas pressure and combustion air pressure measured at the boiler inlet and compared to plant data for maximum load. In the summer, only one steam boiler is operated.

All control of the boilers is manual. Boiler load is varied as little as possible. When load adjustments are made, both the gas and combustion air flows are adjusted according to a nomogram relating their corresponding pressures in order to optimize the fuel-air ratio. These nomograms were confirmed to be reasonably accurate by the audit team.

Water flows through the hot water boilers are measured by orifice flow meters and monitored in the control room. Steam flows are not measured. The majority of parameters measured in the control room, while designed for continuous recording, are not recorded due to inability of the staff to obtain chart paper (apparently due to a combination of lack of chart paper and lack of budget to buy it). Some values are logged hourly, but since they don't change much, little attention is paid to the logging.

Boiler efficiencies are measured once or twice per year, and the nomogram is checked to be still applicable.

Supply water temperature is supposedly varied with outside air temperature according to the table below:

Outside Temperature (°C)	Design Control (°C)	Actual Control (°C)	Alternate Control (°C)
+5	70.0	70	70
0	85.4	80	85
-5	102.0	90	91
-10	118.8	100	99
-15	134.5	110	104
-20	150.0	120	110

According to plant staff, the design control is no longer utilized since the piping and distribution system cannot handle the higher temperatures. As a result, the plant claims to be using the actual control between 70 and 120°C; nevertheless, due to gas limitations, a much more severe control is imposed. (According to plant staff, 5 years ago there was a salary reduction penalty for each degree Celsius deviation from the above relations during inspection; now the only rule is the gas rationing.) The supply temperature is maintained at the maximum permitted by the limited gas supply: during the audit visit the temperature never exceeded 95°C (see Exhibit 3 in the Appendix).

Heating water is circulated throughout the city, and piped to heat exchangers located in the buildings. The secondary heat exchanger water is distributed through the buildings in a one-pipe series circuit from the top of the building to the bottom. While the room radiators at different levels are supposedly designed to compensate for the difference in heating water temperature, the team heard complaints of both too little heat as well as too much heat, even during the colder days. In a number of cases, windows were observed open. No visit was made to any building.

1.2 Description of Boilerhouse No. 3 (26 Matela St.)

This plant is one of the largest of the small boilerhouses, but is apparently typical of most of them. It accounts for about 3.5% of the thermal energy consumption of the whole enterprise. It serves 8 nearby apartment buildings containing over 3,000 flats.

The main equipment consists of 5 three-pass fire-tube hot water boilers of unknown capacity (but estimated at 10 to 15 GJ/hr). Four are typically in operation, with one of the four dedicated to the production of sanitary hot water.

The gas service meter is the only flow measuring device in the boilerhouse; there is no metering within the plant. Hot water supply and return temperatures are measured with mercury thermometers. Boiler instrumentation consists of a stack mercury thermometer on two of the boilers.

Hot water supply temperature is maintained between 45 and 55°C according to plant staff; record show that both for March 1991 and November 1991 the temperature ranged between 50 and 60°C (see Exhibit 6). Water enters directly into the flats in a typical one-pipe system, and returns to the boilerhouse. Sanitary hot water circulation is stopped from 2300 to 0600 hours; heating water supply is maintained 24 hours per day.

CHAPTER 2 -- ANALYSIS OF ENERGY CONSUMPTION AND EFFICIENCY

2.1 Energy Prices

Energy prices in this report are converted to US dollars based on typical European market prices for different energy sources. The bases of the conversions are as follows:

Heavy fuel oil, high sulfur:	$70/tonne ($1.67/GJ)
Natural gas:	$3.00/GJ
Anthracite coal:	$42/tonne ($1.68/GJ)
Electricity:	$0.05/kWh

The average price of thermal energy for the Jelgava district heating enterprise is $2.96/GJ, or a total of approximately $5.2 million annual energy bill for the thermal portion, and $0.5 million annually for electricity.

2.2 Energy Consumption Variation with Ambient Temperature

In both of the plants visited, boilerhouse logbooks were inspected, and sample data related to energy consumption and outside air temperature were copied. A graphical analysis of this data is presented in Exhibits 1 through 12 in the Appendix.

The analysis of the variation of energy consumption with weather data (outside air temperature, wind, precipitation) provides a good indication of the operation of the plants. Non-weather factors are essentially not existent, since there is no local control on the heating (although windows can be opened and closed), and since sanitary hot water use (which would be expected to vary during the day and from weekday to weekend) is a relatively small portion of the total heat load. By taking larger samples (30 to 45 days) most of the side effects can be excluded. Ambient or outside air temperature has by far the greatest effect of the weather parameters, and the analysis is limited to that factor.

2.2.1 Regional Boilerhouse

Exhibits 1 and 2 point out the extremely strong effect of the gas flow limitation to the plant. During a week in which ambient temperatures ranged from -20 to +6°C, the gas consumption varied only from 4000 to 6250 m^3/h. The same point is underscored in Exhibit 3: regardless of the outside air temperature, the supply water temperature never exceeds 95 or 96°C. Exhibit

3 also shows that the temperature difference across the boilerhouse (supply water temperature less return water temperature) varies very little with outside temperature. Assuming the water flow is constant, the exhibit implies very little effect of outside air temperature.

In the same way, Exhibit 4 shows that regardless of outside temperature, it takes about the same amount of gas to raise the water at (assumed) constant flow one degree Celsius. At the same time, however, for any outside temperature (0°C, for example) there is a significant variation in gas consumption per degree temperature raised. A similar variation is observed in supply water temperature in Exhibit 3: at 0°C the plant has operated (supposedly successfully) with supply temperatures as high as 94°C and as low as 77°C.

Electricity consumption was not analyzed in detail. No reliable electricity consumption data was obtained. Exhibit 13 provides a comparison of electric consumption over several days, noting less than a 10% variation from day to day.

In conclusion, the following points can be made:

- outside air temperature seems to have little effect on the energy consumption; this is due to a large degree to the gas limitation imposed on the plant

- nevertheless, even not considering gas rationing, there is not a strong effect of air temperature: from +5 to 0°C there does not appear to be much variation in gas consumption, but from 0 to -2°C, the gas consumption suddenly increases 20 to 30%

- at higher outside air temperatures, there are wide bands or ranges of gas consumption and supply temperature: this is most likely due to the manual control and the reluctance of plant staff to change operating conditions often; with a closer control, the bands can be narrowed, and gas consumption reduced

- the fact that the plant can operate successfully at gas rationing conditions may imply that gas consumption can be further reduced at higher outside air temperatures (for example, above 0°C); this would have to be supported with a survey of temperatures in consumers' flats.

2.2.2 Boilerhouse No. 3

A similar set of graphs are presented in the Appendix for Boilerhouse No. 3. Exhibit 5 shows wide hourly variations of gas consumption, pointing to the possible difficulty of providing precise control with manually operated valves. The fact that the dates of this Exhibit covered

a weekend may partially explain this wide variation. Meanwhile, Exhibit 6 shows that the supply water temperature is maintained essentially constant at about 50°C.

The lack of precise control, however, is strongly suggested by Exhibit 7, which implies that outside air temperature has no effect at all on gas consumption. Unlike the Regional Boilerhouse, the gas limitation does not directly affect Station No. 3. But the wide ranges of gas consumption at given outside temperatures are cause for concern: if, for example, at +5°C the load can be maintained with 1000 m^3/quarter-day, why should the consumption be 3 times as high during other quarter-days?

In order to attempt to determine if there might be an indirect effect of gas rationing, data from March and April 1991 (before the rationing) were compared to the November and December data. This leads to an interesting conclusion. For example, comparing Exhibits 7 and 9, it is evident that there is a much wider variation of consumption, at the same outside temperatures, in November than in March. Comparing Exhibits 8 and 10, it is clear that gas consumption in November is higher than in March, even when the outside temperature ranges are the same.

In an attempt to correlate the energy consumption with outside temperature, Exhibit 11 was plotted. Degree days with a basis of 20°C were arbitrarily defined; this means if the average temperature over 24 hours of a day is 0°C, that day is worth 20 degree days; at an average temperature of 10°C, 10 degree days would be used. This analysis again shows little or no correlation, implying that energy consumption is independent of outside temperature.

In conclusion, the following points can be made:

- energy consumption seems to be higher in November than in March, despite similar outside air temperatures

- energy consumption varies significantly, but is essentially independent of outside air temperature during both March and November: this is counterintuitive, and leads to the conclusion that energy savings should be possible with better control and monitoring.

2.3 Energy Management

In both of the plants visited, there is awareness of energy efficiency; this awareness is more than just that imposed by the forced conservation of natural gas. The enterprise has undertaken a variety of measures to improve energy efficiency throughout its system:

- boiler efficiency is tested and adjusted once or twice per heating season; a nomogram showing relative valve positions or relative fuel and gas pressures at different loads in order to optimize the air-fuel ratio is used in all the boilers

- temperature regulators have been installed on many of the building heat exchangers to maintain minimum but adequate temperatures of the secondary heating water within the buildings

- distribution piping is being repaired and upgraded as much as allowed by the meager repair budget

- steam and hot water piping insulation in the boilerhouses is well insulated and shows no leaks

- a direct contact heat recovery system was installed on one of the hot water boilers at the Regional Boilerhouse to preheat make-up water with exhaust gases (the system did not work successfully, and has been disconnected)

- a simple air preheater has been installed on one of the hot water boilers at Station No. 3, and has been working successfully for two years.

Despite these advances in efficiency, three critical conditions must be met to continue improvements:

(1) reliable measuring equipment must be installed; some of the installed measuring equipment can be repaired, but it should be complemented with better equipment

(2) better data recording and analysis must be performed in order to develop the right control procedures to optimize performance of the equipment; for example, analysis such as begun in the exhibits of the Appendix can provide the basis for a stricter water supply temperature control

(2) management and organization must be improved in order to improve work habits to achieve a better level of manual control of the systems; this includes the possibility of incentives to staff for better performance.

2.4 Boiler Efficiency Measurements

Instantaneous combustion efficiencies of a majority of the operating boilers were measured with

an electronic combustion analyzer during the audit. In most cases, comparison and confirmation of the analysis was obtained with the Russian GHP (Orsat-type) analyzer. In addition, adjustments were made to the fuel-air mixture to improve and optimize the combustion efficiency. The results of the measurements are given below.

Regional Boilerhouse

Boiler 4 (hot water) As found		**Corrected**
Oxygen (O_2)	1.1 %	2.9 %
Carbon Dioxide (CO_2)	11.4 %	10.4 %
Carbon Monoxide (CO)	>3000 ppm	7 ppm
Stack Temperature	135 °C	132 °C
Ambient Temperature	22 °C	22 °C
Excess Air	5 %	14 %
Combustion Efficiency	92-94 %	94.9 %

Boiler 5 (hot water) As found		**Corrected**
Oxygen (O_2)	4.7 %	2.6 %
Carbon Dioxide (CO_2)	9.4 %	10.6 %
Carbon Monoxide (CO)	0 ppm	10 ppm
Stack Temperature	140 °C	140 °C
Ambient Temperature	24 °C	24 °C
Excess Air	26 %	13 %
Combustion Efficiency	94.1 %	94.7 %

Boiler 1 (steam) As found		**Corrected**
Oxygen (O_2)	10.4 %	3.5 %
Carbon Dioxide (CO_2)	6.1 %	10.1 %
Carbon Monoxide (CO)	0 ppm	10 ppm
Stack Temperature	247 °C	220 °C
Ambient Temperature	27 °C	27 °C
Excess Air	88 %	18 %
Combustion Efficiency	84.0 %	90.7 %

Boilerhouse No. 3

Boiler 2 (hot water; air preheat))

	As found	Corrected
Oxygen (O_2)	1.2 %	2.3 %
Carbon Dioxide (CO_2)	11.4 %	10.7 %
Carbon Monoxide (CO)	>3000 ppm	4 ppm
Stack Temperature	125 °C	125 °C
Ambient Temperature (preheated)	45 °C	45 °C
Excess Air	15 %	15 %
Combustion Efficiency	93-95 %	96.4 %

Boiler 3 (hot water)	**As found**	**Corrected**
Oxygen (O_2)	5.6 %	4.2 %
Carbon Dioxide (CO_2)	8.8 %	9.6 %
Carbon Monoxide (CO)	0 ppm	4 ppm
Stack Temperature	130 °C	130 °C
Ambient Temperature	24 °C	24 °C
Excess Air	32 %	23 %
Combustion Efficiency	94.4 %	94.8 %

CHAPTER 3 -- ENERGY CONSERVATION RECOMMENDATIONS

There are a number of actions that the Jelgava District Heating Enterprise 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 hot water, 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. Jelgava District Heating Enterprise 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 installation of improved metering systems, or automated control of combustion efficiency. 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. These projects may require significant investment, but will eventually be necessary to ensure the long-term efficiency and viability of the enterprise. 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
- Simple payback analysis
- Scheduling
- Technical risk and reference

Action A.1 -- Improve Energy Monitoring/Control

1. STATEMENT OF RECOMMENDATION

Set up an energy management program in each of the heating stations throughout the enterprise to reduce fuel consumption. This program should include the following components:

- -- historical analysis of hourly or quarter-daily fuel consumption over the past two heating seasons, and comparison of corresponding outside temperatures
- -- development of a revised schedule for supply water temperature versus outside air temperature, for each station, given its specific load characteristics
- -- corroboration of the revised temperature schedules with a pilot test period, during which spot checks of end users should be included
- -- development of procedures and instructions for boiler load control in each boilerhouse, depending on the particular operating characteristics and equipment
- -- instruction to the operating staff of the goals of this program; improving of operating and maintenance procedures.

3. DESCRIPTION/RATIONALE

The data in the Exhibits of the Appendix show significant variation in fuel consumption, as high as a factor of 2 or 3, for the same outside temperature conditions and similar heat loads, as discussed in Section 2.1. These exhibits show that for a given ambient temperature and operating mode, one hour or quarter-day can utilize significantly less energy 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 for the overall enterprise, even small percent improvements can translate into significant cost savings. The key to such a program is a management commitment, proper organization, and staff motivation. It would make sense to centralize the data analysis in the main office, but the local operating staff must see and understand the results.

Furthermore, such an undertaking in all of the boilerhouses can provide the basis for a more

careful and rigorous logging of data by the staff, which in turn can lead to a better identification of unreliable instrumentation which should be improved or replaced. Eventually, the savings could be as high as 10 to 15%; initially, however a 3% savings should be the target.

4. BENEFITS

Potential energy savings are estimated at 3%, based on the discussion above. The savings for the enterprise as a whole can be calculated as follows:

$5.2 million/y x 0.03 = $156,000

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, as well as to confirm comfort levels at the end users. 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. It will take several months to implement fully, but the results should be immediately noticeable.

8. TECHNICAL RISK AND REFERENCE

This project presents no risk in its implementation.

Action A.2 -- Set Up Thermal Distribution Efficiency Program

1. STATEMENT OF RECOMMENDATION

Assign a qualified technician the responsibility of ensuring the minimization of steam, water, and heat leaks at all the boilerhouses. Supply this person with the necessary instrumentation and provide approximately one week of on-the-job training by a local consulting group, or by Riga Technical University staff.

Once trained, this person should make the rounds of all the boilerhouses on a regular basis, checking all pipe insulation for adequacy, identifying valves and flanges needing insulation, reviewing steam traps, and identifying steam and other leakages. A simple form can be developed for reporting. The technician must work closely with the boilerhouse supervisors and their staff.

1.1 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.

1.2 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.

1.3 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.

1.4 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.

1.5 Support for Testing of Distribution Piping

Support the teams carrying out regular maintenance and leak identification on the distribution piping throughout the city.

2. DESCRIPTION/RATIONALE

In general, the thermal fluid distribution systems at the two boilerhouses visited appeared 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.

Based on the successful model of a roving boiler inspector that visits all the boilerhouses, a thermal distribution system inspector could readily be accepted by boilerhouse staff. In addition, once trained and having obtained experience, this technician could also support the maintenance teams for the distribution piping systems.

3. BENEFITS

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 hot water, steam and condensate distribution systems. In the case of Jelgava, 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 thermal energy basis:

$5.2 million/y x 0.0025 = $13,000

This savings will be reduced by additional annual maintenance and spare parts costs, estimated at approximately $2,500. Net savings is therefore $10,500.

4. IMPLEMENTATION COSTS

Implementation costs include handheld thermometer ($350), an ultrasonic tester ($1400), and an infrared pyrometer ($1000). The cost of training is estimated at $150. Duties and installation is estimated at about $300. Total cost is estimated at about $3,200.

5. PAYBACK

The payback period for this project is 0.3 years, or 3.7 months.

6. SCHEDULE

USAID can assist in the procurement of the equipment. It should arrive in time for the fall 1992 heating system. The selection of staff and the training session should be completed before the heating season begins.

7. TECHNICAL RISK AND REFERENCE

This project presents no risk in its implementation.

Action A.3 -- Increase Boiler Efficiency Testing and Tune-Ups

1. STATEMENT OF RECOMMENDATION

Purchase at least two electronic combustion analyzers to complement the existing Orsat-type gas analysis instrument. Hire an additional boiler tune-up technician, and have him work as an apprentice to the existing boiler tune-up technician. Eventually, have both technicians work independently, and increase the frequency of tune-ups for each boiler.

2. DESCRIPTION/RATIONALE

While the existing boiler technician is extremely qualified and capable, he is able to visit each boiler in the system twice in a year at the most. By purchasing electronic combustion analyzers, his rate of boiler testing will be greatly increased, thus enabling him to visit more boilers. The purchase of a second analyzer will allow the training of an additional technician, who can ensure an even more frequent testing of each boiler.

Increasing the frequency of testing is paramount to improving the average boiler efficiency. Because all boiler control is manual, the boilers tend to go out of adjustment even more readily. In addition, staff at the boilerhouses do not always pay attention to ensuring careful adjustment of the optimal fuel-air ratio.

Finally, use of the electronic analyzers offers an important advantage over the Russian Orsat analyzer and the Draeger (CO) tubes currently used. Since the major fuel is gas, CO is the parameter which defines optimum combustion. With the Draeger tubes, only an approximate idea of the presence of CO can be determined. During the audit measurements, as shown in Section 2.4, two of the five boilers tested showed significant deficiencies of air, with CO levels higher than 3000 ppm; this is both inefficient and dangerous. An electronic combustion analyzer which includes accurate CO measurement provides a simple solution to this problem.

3. BENEFITS

Energy savings are estimated on the basis of an average 1% improvement in overall fuel efficiency. Based on the boilers measured and adjusted during the audit visit, improvements ranged from 0.4 to over 2% (see Section 2.4).

- at a savings of 1.0% on an equivalent thermal energy basis:

$5.2 million/y x 0.01 = $52,000

4. IMPLEMENTATION COSTS

Implementation costs are estimated at $10,000, which includes two electronic combustion analyzers with CO measurement, stack temperature probe, and efficiency calculation.

5. PAYBACK

The payback period for this project is 0.2 years, or 2.3 months.

6. SCHEDULE

USAID can assist in the procurement of the equipment. It should arrive in time for the fall 1992 heating system. The selection of staff should be completed before the heating season begins.

7. TECHNICAL RISK AND REFERENCE

This project presents no risk in its implementation.

Action A.4 -- Increase Electric System Efficiency Testing

1. STATEMENT OF RECOMMENDATION

Purchase at least one clamp-on industrial electrical power meter with power factor measurement capability. Assign them to plant electrical engineers on a rotating basis to carry out regular checks and log motor loading and power factor.

Based on the surveys, carry out actions such as replacing underloaded motors, balancing three-phase voltages, cleaning connections, and installing power factor correction capacitors.

2. DESCRIPTION/RATIONALE

The Jelgava boilerhouses contain hundreds of motors of a wide variety of sizes. Currently, no measurements or tests are performed on these motors on a regular basis. Little is known about motor efficiency and power factor.

A proper maintenance program should include regular testing of motors, and comparing historical data to determine changes in load, operating conditions, or temperature. This can identify needs for preventive maintenance of the motor itself, but can also help identify mechanical problems in pumps and other driven equipment. Finally, such a regular testing program will inevitably lead to energy savings, both from the improved performance of motors, as well as from the increased awareness and care of plant operating staff.

3. BENEFITS

Energy savings are estimated at 1% of the existing electricity consumption.

$500,000/y x 0.01 = $5000

4. IMPLEMENTATION COSTS

Implementation costs are estimated at $2,200, which includes two clamp-on voltmeter/ammeter/power factor meters, and $200 in duties and installation.

5. PAYBACK

The payback period for this project is 0.44 years, or 5 months.

6. SCHEDULE

USAID can assist in the procurement of the equipment. It should arrive in time for the fall 1992 heating system.

7. TECHNICAL RISK AND REFERENCE

This project presents no risk in its implementation.

Action B.1 -- Install Measuring Instruments

1. STATEMENT OF RECOMMENDATION

Install fixed energy meters at several locations in the district heating system to demonstrate measuring systems and provide a basis to evaluate the necessary future investments in metering. As a beginning, install total energy meters at the following locations:

- at the hot water supply outlet of two boilerhouses
- at the inlet to 5 steam customers
- at 2 buildings.

2. DESCRIPTION/RATIONALE

The Jelgava District Heating Enterprise needs to begin operating as a modern utility in a market economy. This will require the conversion to a meterable, controllable system. Conversion to such a system will provide the necessary incentive to individual customers to improve energy efficiency. At the same time, metering will enable the enterprise to measure efficiency of various components of the system, by comparing input to output. During the audit, it was observed that there is insufficient metering, in general, for an adequate and consistent determination of system efficiency.

3. BENEFITS

The benefits are estimated based on the ability to bill more accurately for the heat energy and steam supplied. Assuming that the 9 meters are placed in boilerhouses and customers that account for approximately 2% of the total district heating system energy, and that the billing will allow recovery of 50% additional cost, the total savings can be estimated as approximately 1% of the value of the current annual consumption.

$5.2 million/y x 0.02 x 0.05 = $52,000

4. IMPLEMENTATION COSTS

Implementation costs are estimated as follows:

2 energy meters for boilerhouses @ $5,000:	$10,000
5 steam meters for industries @ 6,000:	$30,000
2 energy meters for buildings @ 4,000:	$ 8,000
local duties and installation costs	$ 5,000
Total Costs	$53,000

5. PAYBACK

The payback period for this project is approximately 1 year.

6. SCHEDULE

USAID can assist in the procurement of part of the equipment, however unfortunately the budget is not sufficient for all of it. It should arrive in time for the fall 1992 heating system.

7. TECHNICAL RISK AND REFERENCE

This project presents no risk in its implementation.

Action B.2 -- Install Fire-Tube Boiler Air Preheaters

1. STATEMENT OF RECOMMENDATION

Install simple locally made air preheaters on 5 fire-tube boilers of the type located in the boilerhouse of Station No. 3. The boilers should be chosen among all gas-fired boilers in the system, by looking for the following characteristics: high energy consumption, long operating hours, and ease of installation. Care should be taken to also evaluate the increased power requirements of the forced draft blower for combustion air, and include a larger blower motor as part of the retrofit.

2. DESCRIPTION/RATIONALE

One boiler in Station No. 3 has been retrofitted with a Latvian-made air preheater, and operates at an efficiency of 1.0 to 1.5% higher than other similar boilers. While there have been no problems with reliability, there is some concern that the boiler capacity has been slightly reduced due to the increased fan power required for combustion air. Nevertheless, the potential savings, and the low cost of locally made equipment can make this an attractive investment for the district heating system.

3. BENEFITS

A typical boiler of this size would consume approximately 400,000 Nm^3 or 13,600 GJ of natural gas per year, with a value of approximately $40,000/year. A savings of 1.5% would result in:

$$\$40{,}000/y \times 0.015 = \$600/y$$

For 5 boilers, the annual savings would be $3000.

4. IMPLEMENTATION COSTS

Implementation costs are estimated at approximately the equivalent in rubles of $1000 per boiler, or $5000.

5. PAYBACK

The payback period for this project is 1.7 years.

6. SCHEDULE

Project should be implemented as funds are available.

7. TECHNICAL RISK AND REFERENCE

This project presents no risk in its implementation, provided that the best boilers are chosen, and that fan power increase is evaluated..

Action B.3 -- Convert to market-oriented energy supply system, and implement demand-side management program for energy efficiency improvement

BACKGROUND

In its transfer to a market economy, the Jelgava District Heating Enterprise will have to meet its operating costs from its billing. In order to provide adequate and fair billing to the consumers, two conditions must be met: control must be provided to the customer, and a method of measurement of consumption must be developed.

It is unfortunate that district heating systems developed in the former Soviet Union which treated energy as "too cheap to meter" and did not offer individual customers control over their energy consumption. The infrastructure changes required to change to a market-oriented system require a large investment, and will take years to implement. Nevertheless, in large buildings with many users, it may be attractive and cost-effective to undertake such an installation.

The first step in such a project would be to characterize the different consumers to determine the possible application of a control and measurement system.

1. STATEMENT OF RECOMMENDATION

Jelgava Siltums 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 Latvia is based on the volume (cubic meters) of heated space, not on actual energy consumption. This tariff design has been used because it has lower capital costs than a meterable system, and because of prevailing social views toward energy supply in the past. Such a system offers no incentive for energy efficiency, because the billpayer receives no benefit, should he or she take control actions to save energy.

As a further cost-reduction in the initial design, many of the homes in the Jelgava system were built with heating elements connected in the so-called one-pipe system. This system 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 a fixed quantity.

RCG/Hagler, Bailly recommends that Jelgava Siltums should take the lead in organizing a demand-side management (DSM) program. This program should be seen as a partnership between Jelgava Siltums 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 Jelgava Siltums, 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:

- Pricing - establish a tariff that offers an incentive for the customer to limit energy consumption

- Information - educate the consumer regarding the new tariff and at the same time provide information on ways to conserve energy

- Metering -

  Step 1 - install a method of metering energy consumption on an individual building basis

  Step 2 - instal a method of metering for the allocation of energy consumption to the individual flats

- 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 Latvia by reducing the demand for natural gas, all of which is imported. Our calculations are based on the following assumptions:

Annual economic cost of heat supply = $5.6 million

Residential homes heated = 40,000
Residential homes with ONE-PIPE SYSTEMS
(we assume 80% = 32,000)
Annual residential heat = 80% of total supplied
Annual energy cost of heat supply to residential customers =
$4.4 million

3.1 For flats connected to ONE-PIPE SYSTEMS, the cost of heat supply is estimated as $3.5 million per year. RCG/Hagler, Bailly estimates the total energy conservation potential as 35%, as follows:

1. Conversion to a meterable system with a tariff based on the cost of residential service, together with conversion to a controllable system based on a radiator bypass and thermostats can reduce energy consumption by 25% (benefits of $875,000 per year).

2. Implementation of cost-effective load reduction investments (insulation, weatherstripping, window treatments) can reduce energy consumption by 10% (benefits of $440,000 per year).

3.2 For flats connected to TWO-PIPE SYSTEMS, the cost of heat supply is estimated as $900,000 per year. RCG/Hagler, Bailly estimates the total energy conservation potential as 25%, as follows:

1. Conversion to a meterable system with a tariff based on the cost of residential service, together with conversion to a controllable system based on thermostats can reduce energy consumption by 15% (benefits of $135,000 per year).

2. Implementation of cost-effective load reduction investments (insulation, weatherstripping, window treatments) can reduce energy consumption by 10% (benefits of $90,000 per year).

4. IMPLEMENTATION COSTS

4.1 For apartments connected to ONE-PIPE SYSTEMS (32,000 homes), RCG/Hagler, Bailly estimates the following costs:

1. Conversion to a controllable system based on a radiator bypass and thermostats

would cost $100 per customer. Conversion to a meterable heat and hot water system with a tariff based on the cost of residential service would cost $50 per customer, with an annual servicing/meter reading cost of $20 per customer. Total investment cost for 32,000 customers = $4.8 million.

2. Implementation of cost-effective load reduction programs would cost $100 per customer. Total cost for 32,000 customers = $3.2 million.

4.2 For apartments connected to TWO-PIPE SYSTEMS (8,000 homes), RCG/Hagler, Bailly estimates the following costs:

1. Conversion to a controllable system based on thermostats would cost $50 per customer. Conversion to a meterable heat and hot water system with a tariff based on the cost of residential service would cost $50 per customer, with an annual servicing/reading cost of $20 per customer. Total cost for 8,000 customers = $800,000.

2. Implementation of cost-effective load reduction programs would cost $100 per customer. Total cost for 8,000 customers = $800,000.

4.3 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 $1 million. Annual costs are expected to be distributed as follows:

Year 1 (92/93) = $0.1 million
Year 2 (93/94) = $1.0 million
Year 3 (94/95) = $2.0 million
Year 4 (96/97) = $4.0 million
Year 5 (97/98) = $3.5 million

5. ECONOMIC ANALYSIS

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

	US$M COST	US$M/YR BENEFIT	YEARS PAYBACK
ONE-PIPE SYSTEMS			
1. Controls/meters	4.8	0.88	5.5
2. Load reduction	3.2	0.44	7.3
TWO-PIPE SYSTEMS			
1. Controls/meters	0.8	0.14	5.7
2. Load reduction	0.8	0.09	8.9
PROGRAM FIXED COSTS	1.0		
	---	---	---
TOTAL	10.6	1.55	6.8

The payback for retrofit applications (6.8 years) is fairly long, especially compared to other "energy conservation" projects. However, such returns are not uncommon for infrastructure projects, such as energy supply systems.

6. IMPLEMENTATION SCHEDULE

A five-year program is recommended, beginning in 1993. During the 1992/93 heating season, a pilot demonstration is recommended in a sample building.

Action C.1 -- Replace District Heat with Local Heaters

1. STATEMENT OF RECOMMENDATION

Evaluate the district heating system from a long-term ECONOMIC financial viewpoint. Concentrate on the requirements in the distant parts of the system, and in portions with low loads but long distribution lines. Consider the oldest lines in the system which will soon need outright replacement. Analyze the possible costs of eliminating certain lines, and purchasing local heating units for the buildings served by these lines.

2. DESCRIPTION/RATIONALE

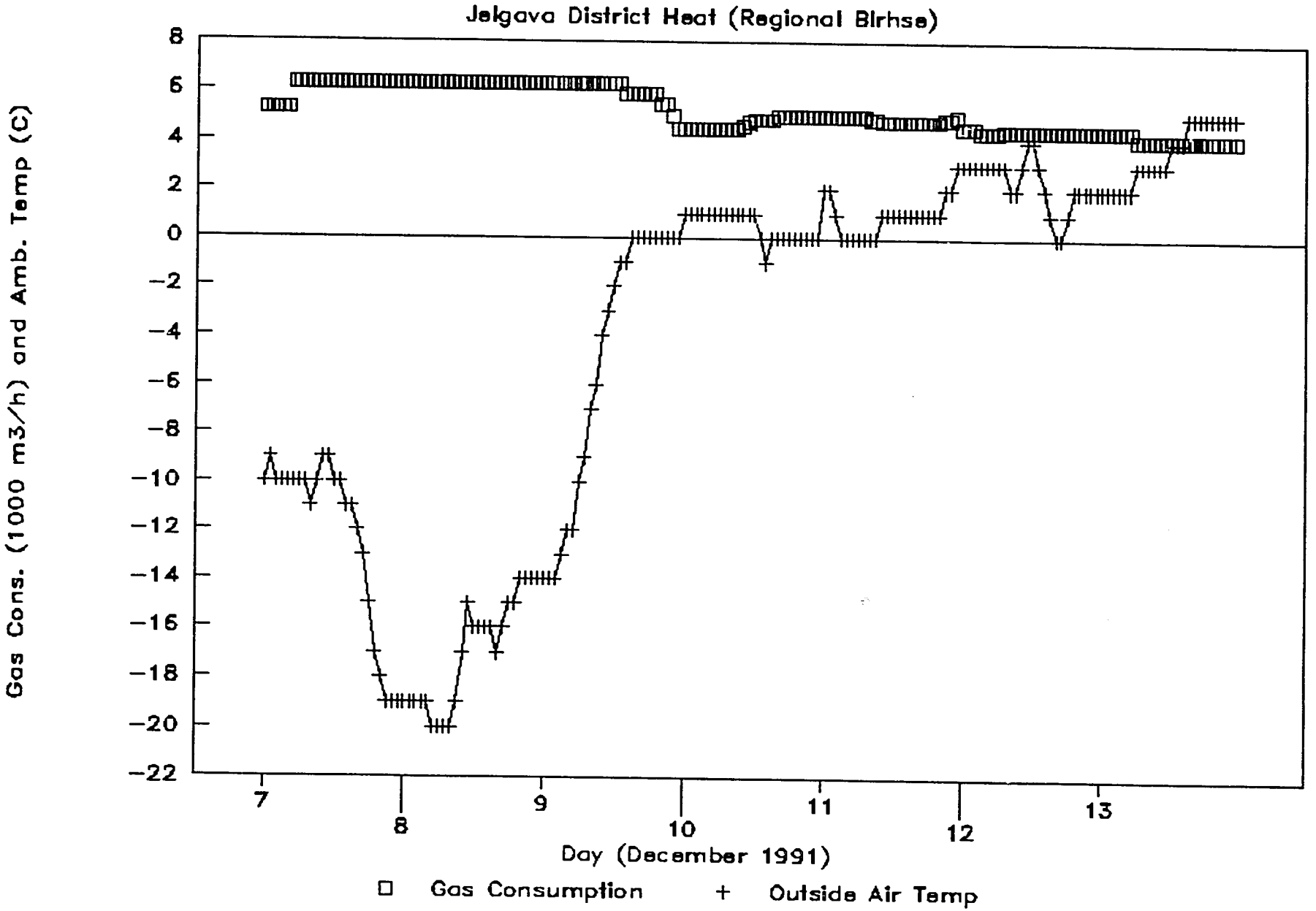
Local units have a high first cost, but in areas where distribution costs are high, they may include the following advantages: efficient heat generation with the latest technology equipment, especially at lower loads; possible local control; reduced maintenance costs; and potential ability to bill on a heat used basis.

Local heating units may have limited but attractive applications, and their analysis should be part of a long-term plan for an efficient district heating system.

APPENDICES

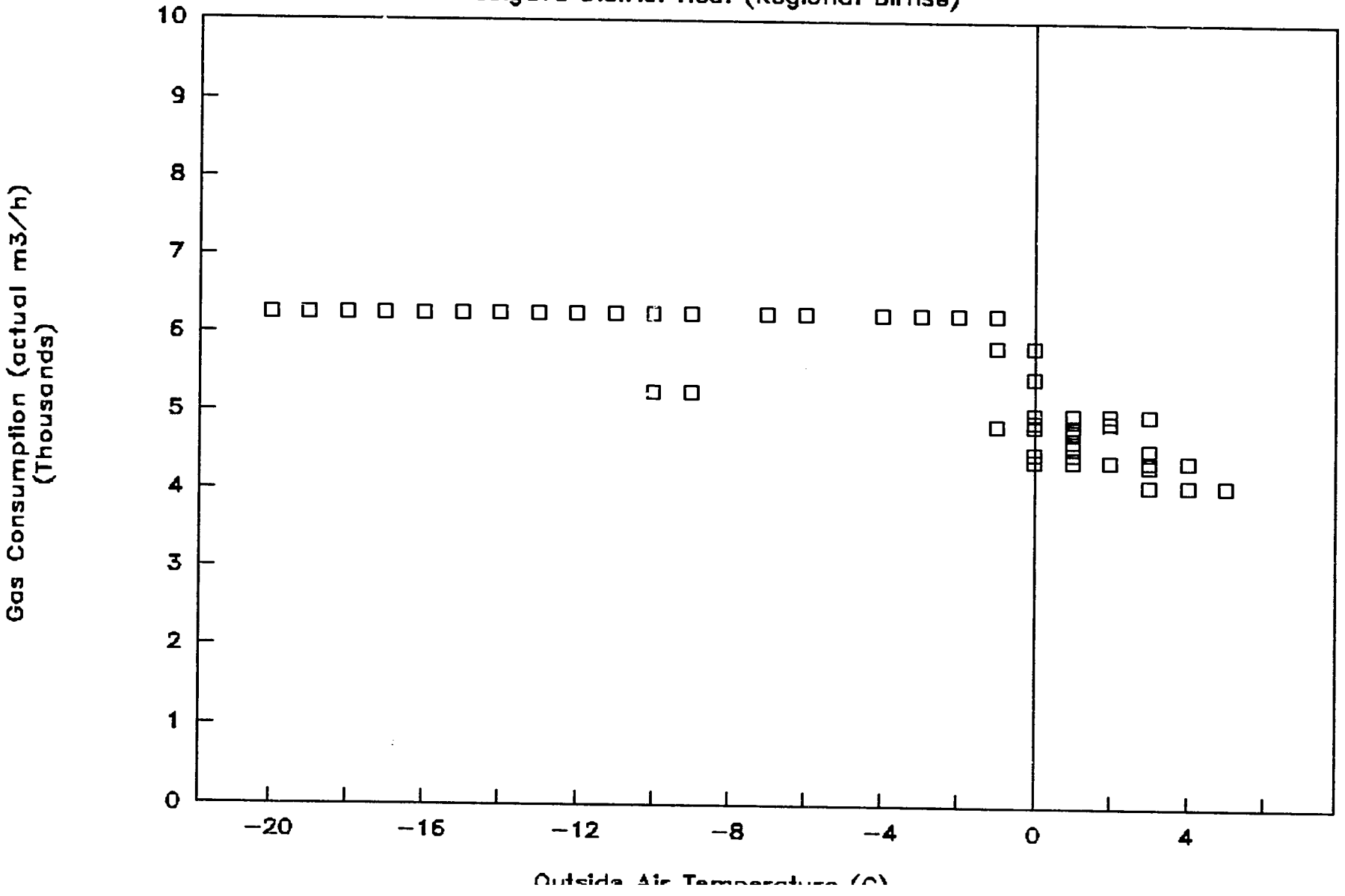
SPREADSHEET AND GRAPHICAL PRESENTATION OF ENERGY DATA
JELGAVA SILTUMS - DISTRICT HEATING ENTERPRISE

1. Ambient Temps and Gas Consumption



2. Gas Cons. vs Outside Temp (Dec 1991)

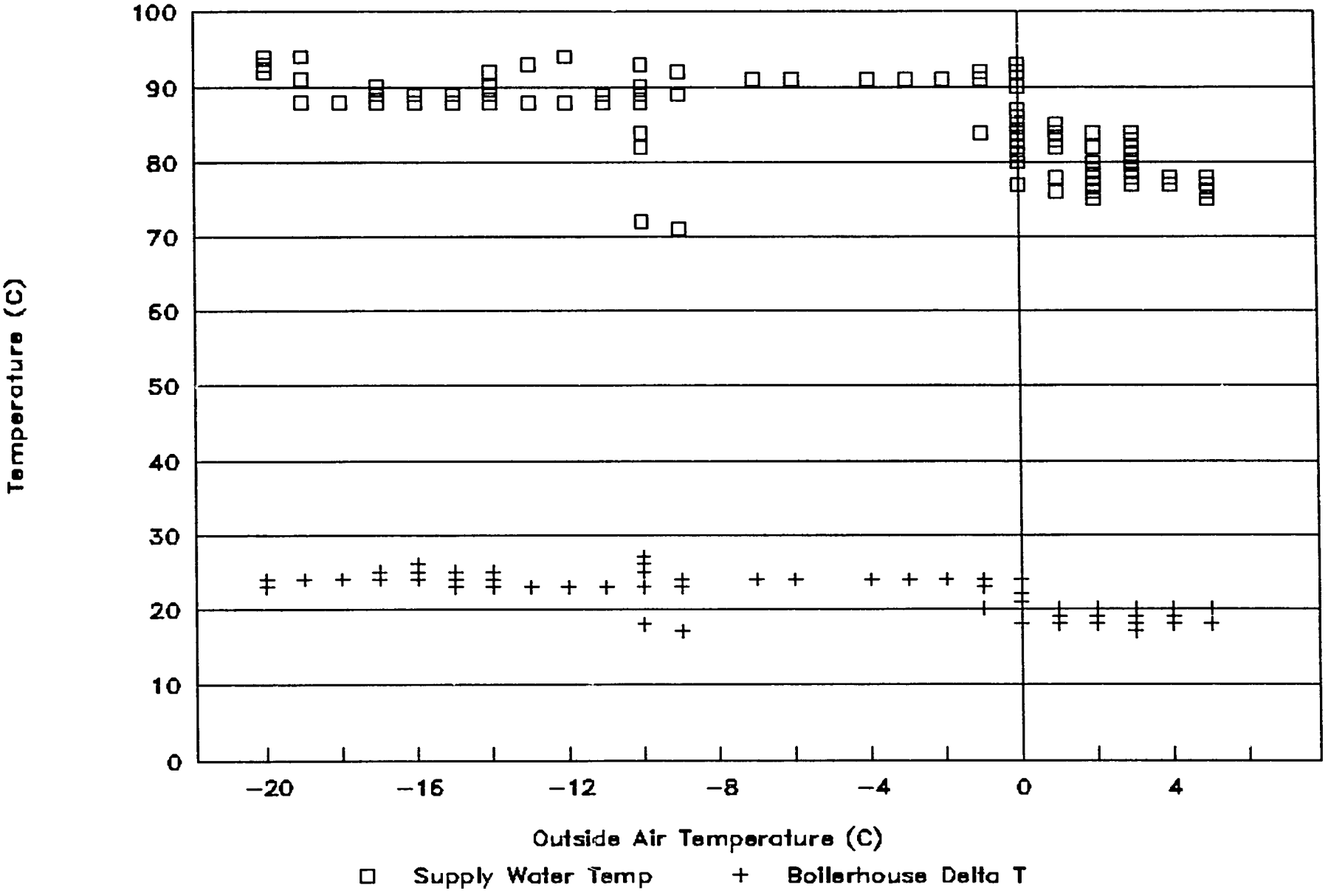
Jelgava District Heat (Regional Birhse)



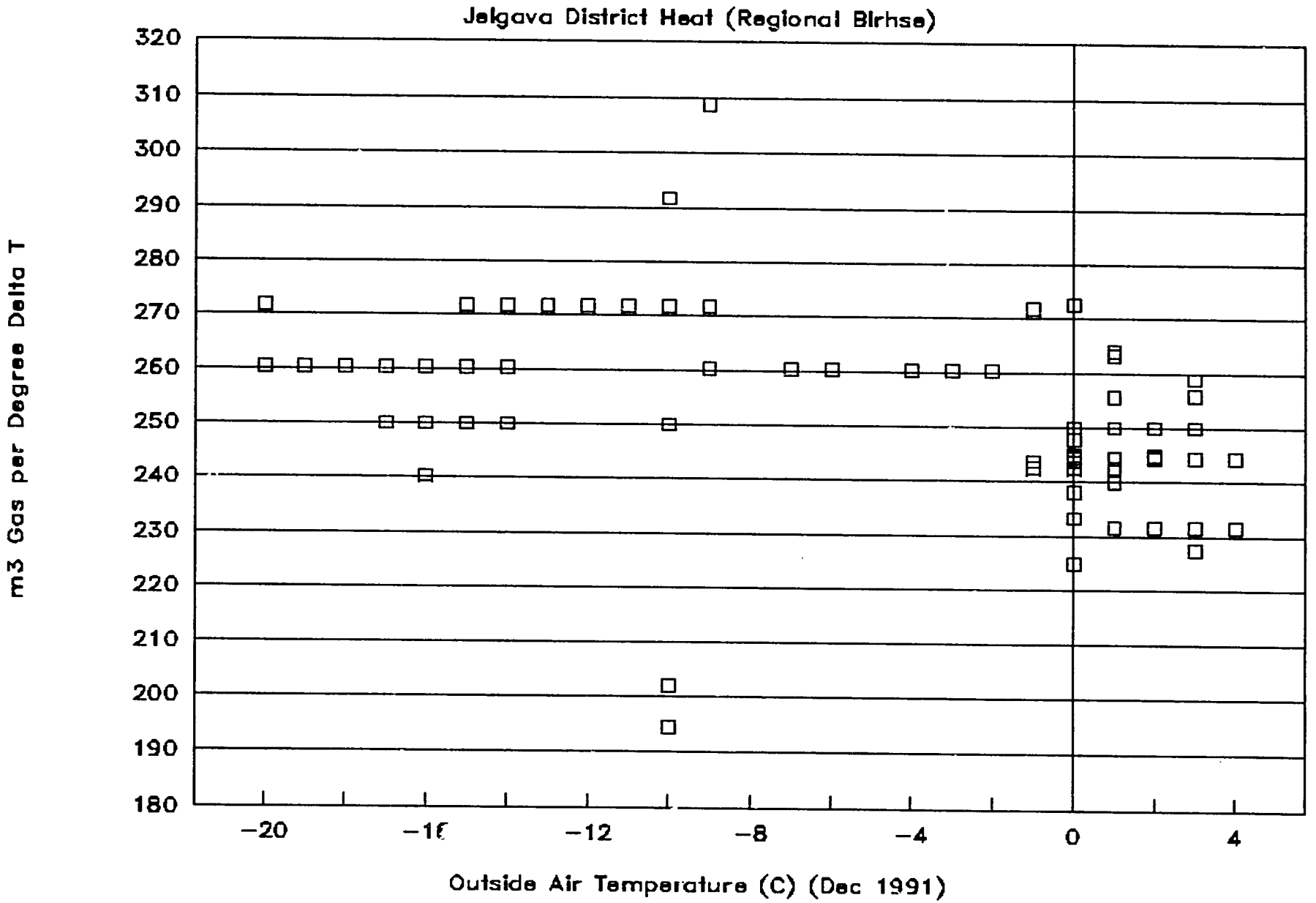
40

3. Water Temp, Delta T vs. Ambient Temp

Jelgava District Heat (Regional Birhse)

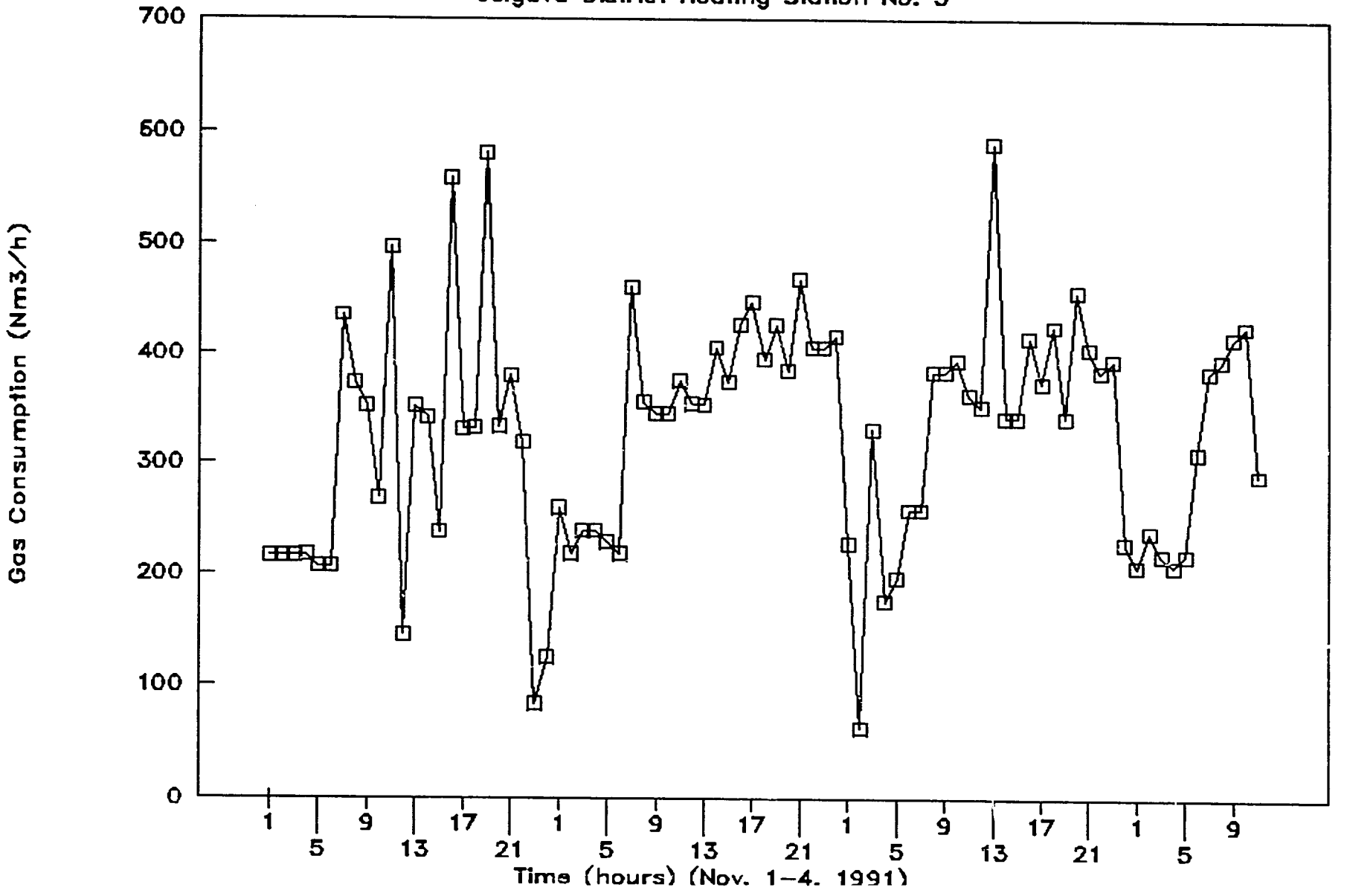


4. Specific Heat Cons. vs. Ambient Temp



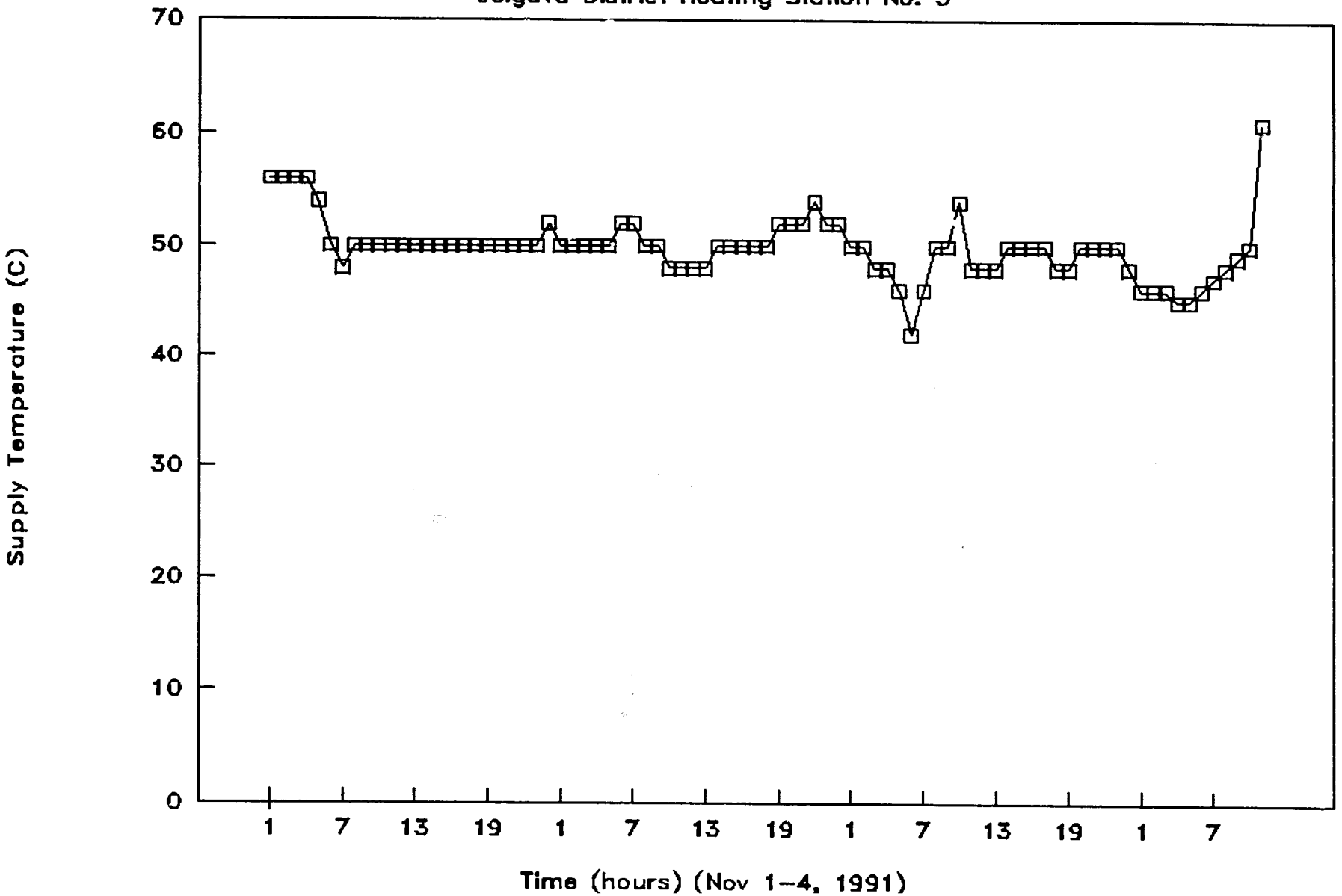
5. Hourly Gas Consumption

Jelgava District Heating Station No. 3



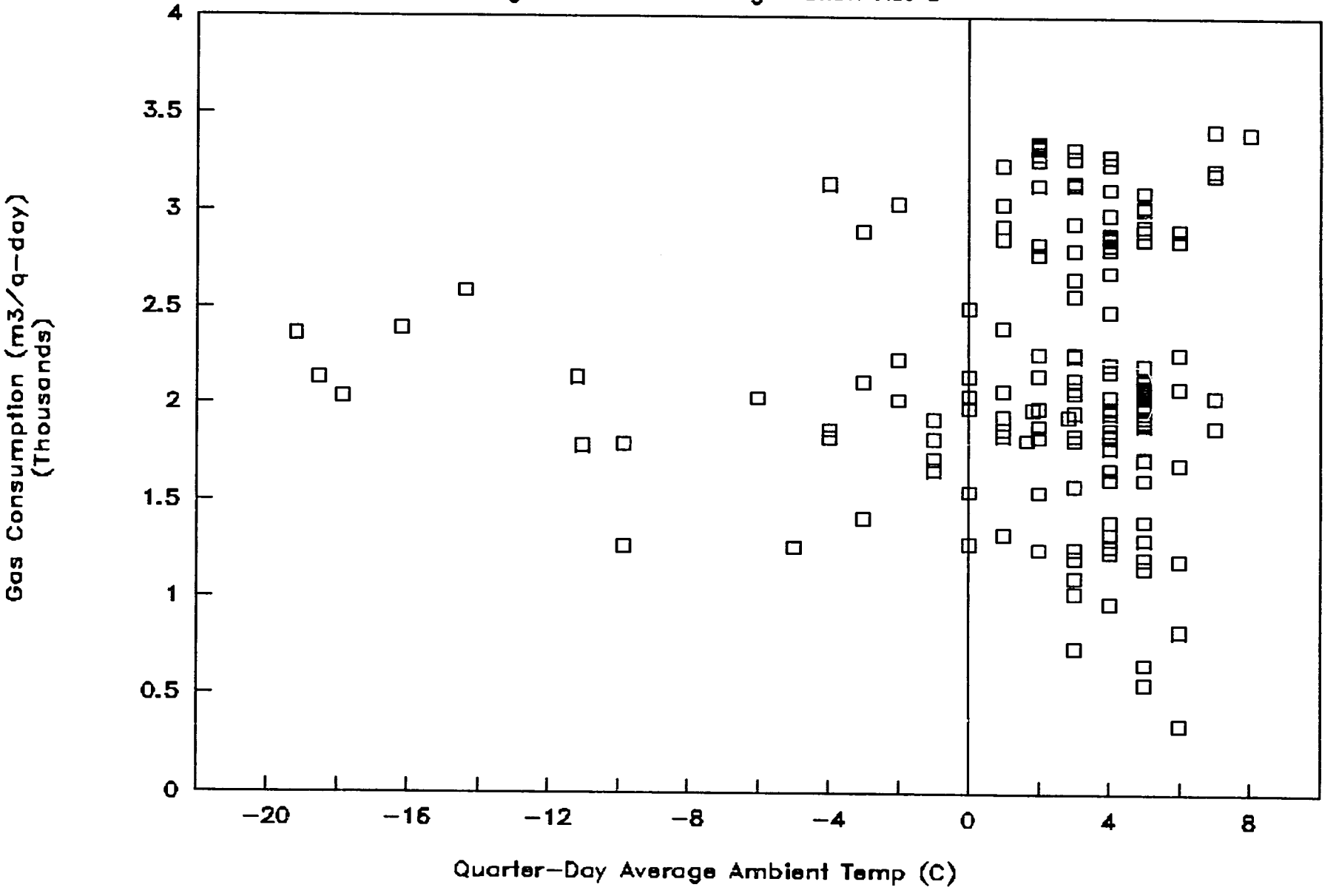
6. Hourly Supply Water Temperature

Jelgava District Heating Station No. 3



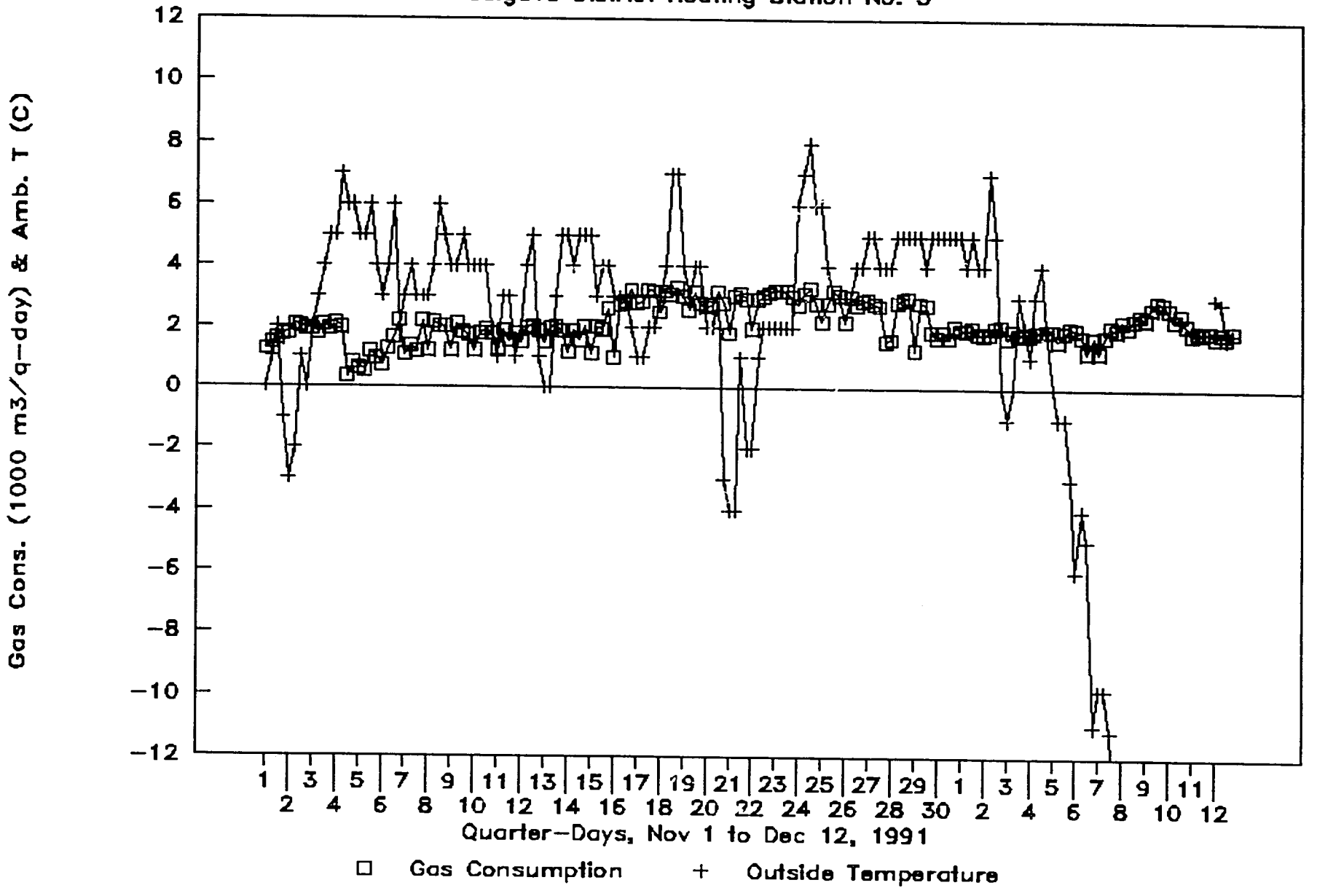
7. Quarter-Day Gas Consump.(Nov-Dec 91)

Jelgava District Heating Station No. 3



8. Gas Cons. and Amb. Temp (Nov-Dec 91)

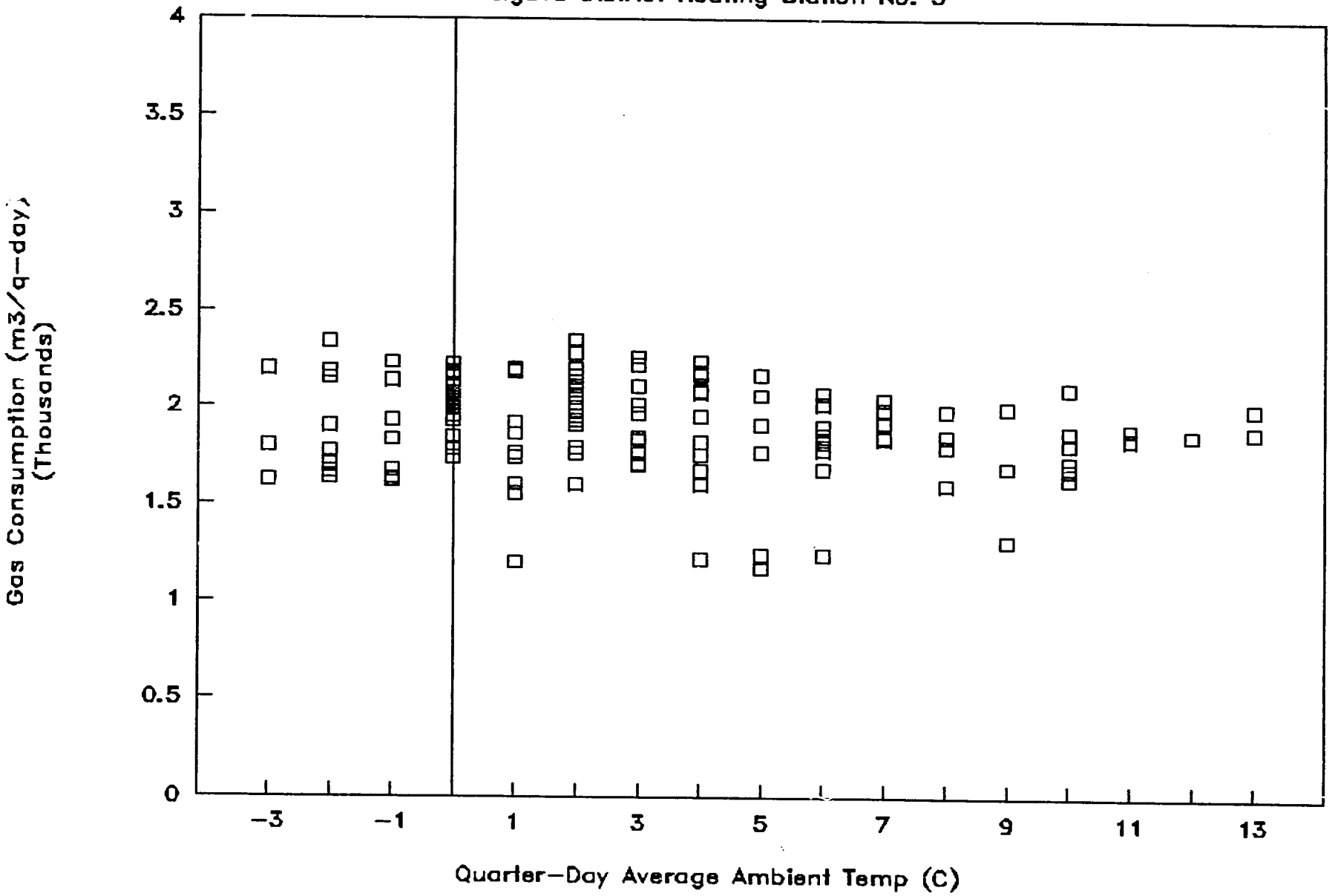
Jelgava District Heating Station No. 3



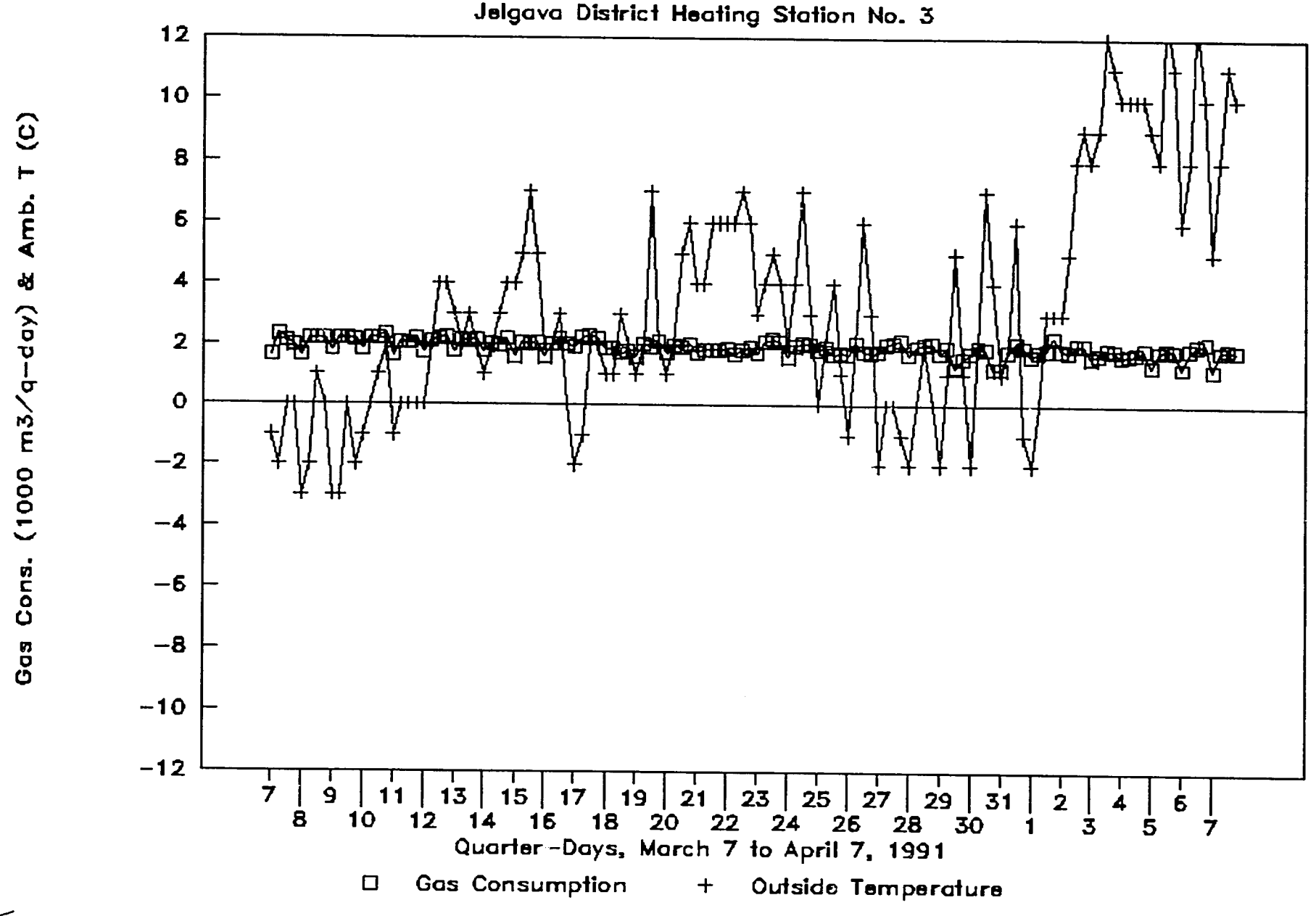
46.

9. Quarter-Day Gas Consump.(Mar-Apr 91)

Jelgava District Heating Station No. 3

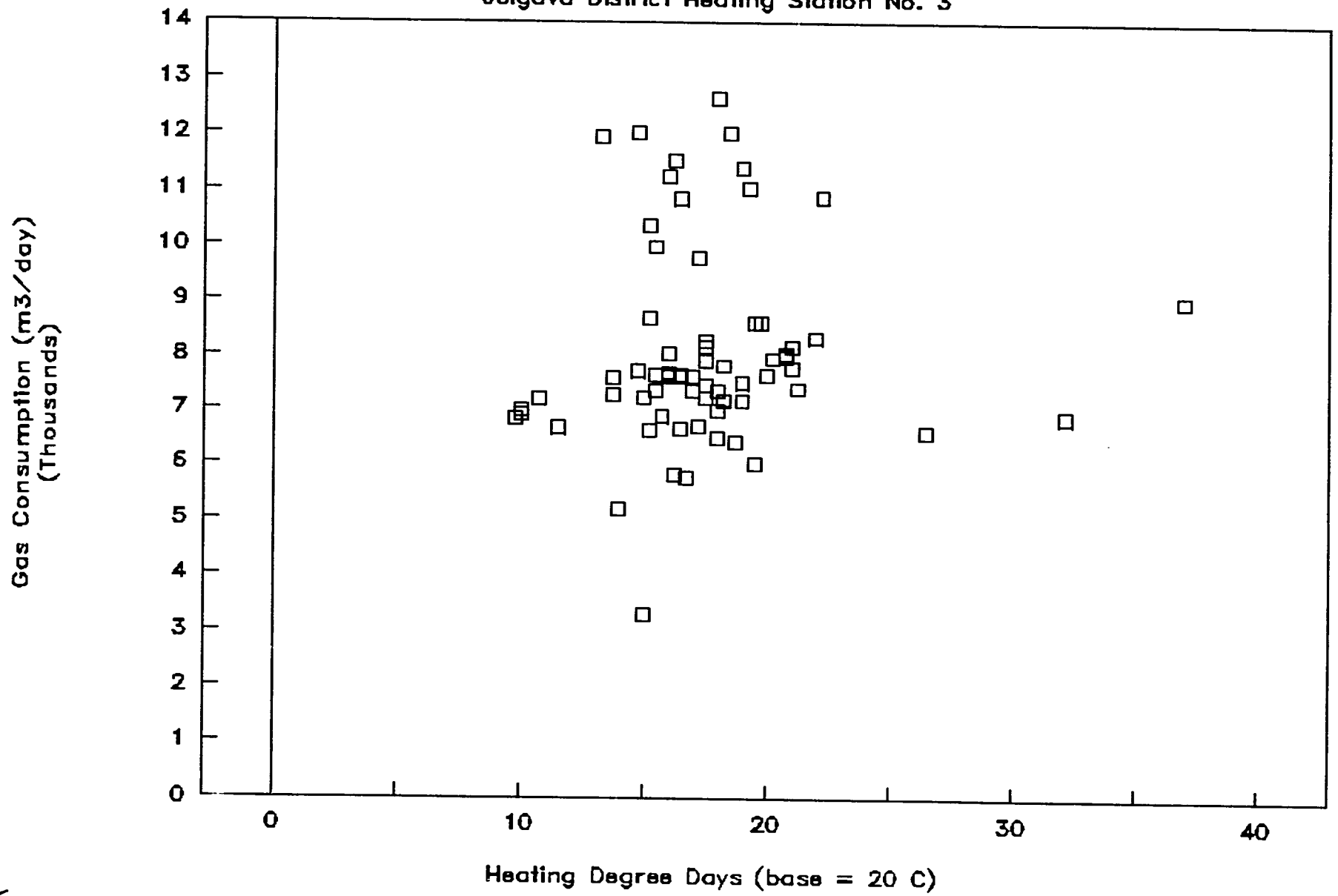


10. Gas Cons. & Amb. Temp (Mar-Apr 91)

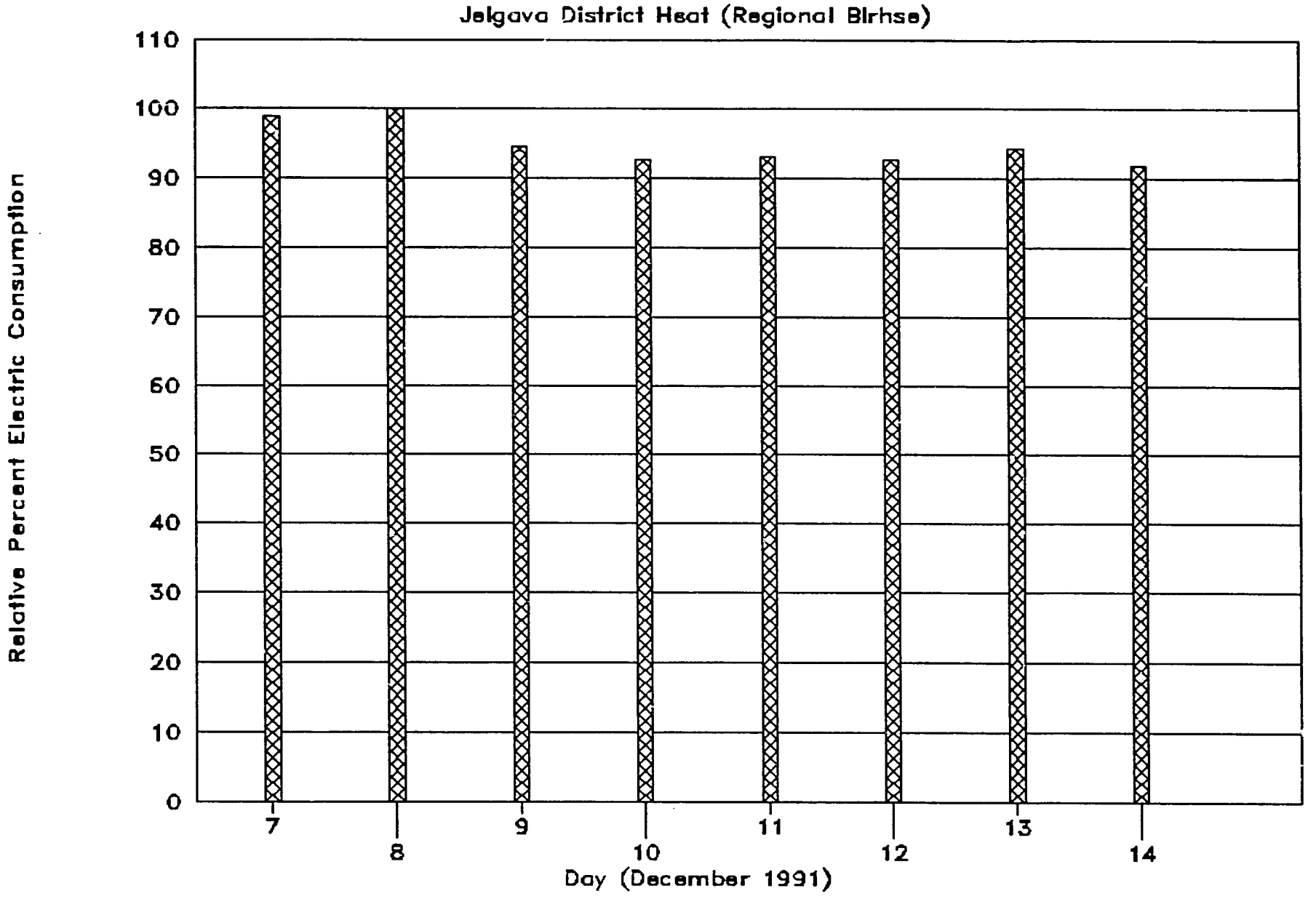


11. Daily Gas Consump. vs Degree Days

Jelgava District Heating Station No. 3



12. Relative Electricity Consumption



13. Heat balance calculations for Jelgava District Heating Enterprise (based on measurements on December 12, 1991; 2 C outside air temp)

M measured value
A assumed value
C calculated value

			Col. 1		Col. 2
0	Hourly average gas consumption	M	4250	m3/hr	4250
1	Hourly average gas consumption	C	4887.5	Nm3/hr	4887.5
2	Gas lower heating value	A	0.00803	Gcal/Nm3	0.0080
3	Average hourly input energy (2/1)	C	39.25	Gcal/hr	39.25
4	Boiler 1 (steam) maximum output	A	10	Gcal/hr	10
5	Boiler 4 (h.w.) maximum output	A	30	Gcal/hr	30
6	Boiler 5 (h.w.) maximum output	A	30	Gcal/hr	30
7	Total maximum output (4+5+6)	C	70	Gcal/hr	70
8	Total maximum input (@ 85% eff)	C	82	Gcal/hr	82
9	Avg loading of all 3 boilers (3/8)	C	47.7	%	47.7
10	Return water temperature	M	59	C	59
11	Boiler 4 outlet temperature	M	94	C	94
12	Boiler 5 outlet temperature	M	96	C	96
13	Boiler 4 water flow	M	495	t/hr	471
14	Boiler 5 water flow	M	495	t/hr	471
15	Boiler 4 heat addition (13*(11-10))	C	17.325	Gcal/hr	16.485
16	Boiler 5 heat addition (14*(12-10))	C	18.315	Gcal/hr	17.427
17	Total heat addition (15+16)	C	35.64	Gcal/hr	33.912
18	Assume 3 Gcal/hr for boiler 1	A	3.00	Gcal/hr	3.00
19	Total heat added by boilers (17+18)	C	38.64	Gcal/hr	36.912
20	Calculated overall boiler eff	C	98.5	%	94.1
21	Actual measured boiler efficiency	M	93	%	93
22	Heating water pump voltage	M	6000	V	6000
23	Heating water pump current amperes	M	28.8	A	28.8
24	Pump power factor	A	0.9		0.9
25	Pump power cons. (22*23*24)*1.73	C	269.0	kW	269.0
26	Pump motor efficiency	A	92	%	92
27	Pump energy consumption	C	247.5	kW	247.5
28	Pump average suction pressure	M	1.4	bar	1.4
29	Pump average outlet pressure	M	12.5	bar	12.5
30	Pump average head provided	C	11.1	bar	11.1
31	Pump average head provided	C	113.2	m H2O	113.2
32	Pump flow from curves	C	680	m3/h	680
33	Total flow for 3 pumps	C	2040	m3/h	2040
34	Measured supply water temperature	M	78	C	78
35	Estimated total hot water flow	C	2040	t/hr	1795
36	Heat addition by boilers	C	38.76	Gcal/hr	34.105
37	Make-up water flow, measured	M	34	t/h	34
38	Make-up water inlet temperature	A	8	C	8
39	Supply hot water temperature	M	78	C	78
40	Heating of make-up water	C	2.38	Gcal/hr	2.38
41	Calc. overall boiler eff (36+40)/3	C	104.8	%	93.0
42	Actual measured boiler efficiency	M	93	%	93

Note: Column 1 represents actual data taken during the measurements. In Column 2, the water flows across the hot water boilers are estimated to make the boiler efficiency balance at 93%. Similarly, the total hot water supply flow is estimated to provide a 93% boiler efficiency. The results show that the flows in either case are slightly less than measured (hot water boilers) and calculated from the pump curve for the overall flow.