PN-ABL-625

RESOURCE MANAGEMENT ASSOCIATES
of Madison, Inc.

ENERGY EFFICIENCY AUDIT REPORT

ALYTUS WOOD PRODUCTS PLANT
Alytus, Lithuania

JUNE 1992

PREPARED BY: RESOURCE MANAGEMENT ASSOCIATES OF MADISON, INC.
Madison, WI

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-1006-00

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i. Industrial Energy Efficiency Program

The countries of Eastern Europe face unprecedented changes both in their political and economic systems. To aid in the transition to market economies, the U.S. Agency for International Development (USAID) designed the Eastern Europe Emergency Energy Program. Resource Management Associates of Madison, Inc. (RMA) is the technical assistance contractor for the Industrial Energy Efficiency Component (IEEC) of the program in Lithuania.

The Industrial Energy Efficiency Component was designed to address the problems of industrial energy efficiency with a short-term program aimed at the immediate needs of industry. The program involves three main activities:

1. To identify and implement cost-effective low-cost/no-cost energy improvements, with an emphasis on oil savings.

2. To conduct energy audits and transfer energy auditing and management techniques, including financial and economic analysis.

3. To provide energy auditing and/or energy efficiency equipment to implement the program objectives, improve energy management, and identify additional energy efficiency opportunities.

The IEEC program deliverables consist of plant audit reports, a policy and institutional analysis report and the in-country audits, training, and equipment delivery and installations. The tasks are being carried out by a team of energy specialists and policy analysis experts in four different phases:

- Phase One: Screening - During this phase the plants to be audited will be identified, and a specific plan to implement the following phases developed and put in place.

- Phase Two: Industrial Plant Energy Audit/Training - A team of energy specialists will arrive in-country and perform a detailed energy audit at the eight selected industrial sites. They will identify short-term energy efficiency measures, develop recommendations to implement these measures, demonstrate and train plant personnel on auditing techniques, and demonstrate financial and economic methodologies for justifying energy improvement projects. Additional equipment will be ordered for Phase Three.

- Phase Three: Implementation - The recommendations identified in Phase Two will be implemented, evaluated, and modified as necessary. Additional training will be provided and the final energy efficiency equipment turned over to the host country.

- Phase Four: Analysis of Factors - This phase will analyze the factors that make up energy efficiency management and investment decision making. Recommendations for policy reform and options for enhanced energy management will be identified and a program for implementation suggested.

Energy monitoring and testing equipment will be turned over to the Lithuania industrial sector and the Government of Lithuania (GOL). The GOL will be provided with analysis and recommendations for further energy efficiency measures.

ii. Executive Summary

This report describes the energy audit that was performed at the Alytus Wood Products plant. The audit was performed from January 14 to January 18, 1992. A pre-audit visit was performed by the Energy Efficiency Component Team Leader to obtain preliminary facility information. The Alytus plant produces houses and other wood products that are sold within Lithuania and Russia. It has been producing houses since 1973. Part of the facility's production is exported to Bulgaria, Germany, Mongolia, Yemen, and the USA.

Steam is delivered to the facility from a utility at two pressures, 14 and 33 atm. Most of the steam is reduced to 7 and 12 atm for plant use. Annual average steam consumption is 180,000 Gcal for the entire facility. Treated cooling water is brought from the local thermal and electric power plant to cool the condensate returned to the central thermal area before it is sent to the utility.

The cost of steam is based on the difference in the energy content of the steam received and the energy content of the condensate returned. The largest steam users are the frame area wood dryers, the wood plate presses, and "kameros" in the wood plate area. The base cost for steam at the time of the audit was 50R/Gcal ($.181 MMBTU).

Thermal water is provided by the utility and is used primarily for space heating. It is also used for the heating of potable water. Annual thermal water consumption is 52,721 Gcal at an average cost of 77.1R/Gcal ($.281 MMBTU).

Annual electric energy consumption is about 60,000 MWh; maximum demand is 15 MW. The majority of electrical use is by motors, with the 500 kW chip grinder being the largest. The wood plate and framing area consume the greatest proportion of electricity. Electric costs at the time of the audit were 0.051R/kWh ($.0007/kWh), and an average demand charge of 10R/peak kW per month ($.143/kW).

Natural gas is used primarily in the mineral wool area for the operation of kilns and a furnace. Annual gas consumption is 8.4 million cubic meters per year at a cost of 1.054R/m^3 ($.00043/$ft^3$).

The energy costs for gas and electricity have increased drastically in the last year and are scheduled to take another significant jump in the beginning of 1992. Because of the extreme volatility of the energy prices and because world energy prices are the most likely outcome, world energy prices were used in the economic analysis of energy conservation opportunities (ECOs).

The main focus for the audit was on the wood plates, framing and house construction areas due to their high energy use. The central thermal area and the air compressors were also investigated. During the audit the use of a power analyzer and combustion efficiency analyzer were demonstrated.

The short-term ECOs recommended for the plant are:

1. Computer energy management
2. Demand control for lacquer dryers
3. Increase furnace combustion efficiency
4. Pipe insulation upgrade
5. Filter and return dust collection air
6. New steam traps
7. Makeup air coil maintenance
8. Repair compressed air leaks
9. Repair dryer steam leaks.

Table 1 is a summary of the estimated annual energy savings after the implementation of the above mentioned measures. USAID specified equipment is to be used in measures one through five.

Table 1. Energy Conservation Measures' Energy Savings

No.	ECO	Energy Saved	Cost Savings	Project Cost	Payback (Months)
1	Computer Energy Management	600 MWh 2,322 Gcal 89,000 m^3	$70,000	$4,500	1
2	Demand Control	150kW	$18,000	$6,000	4
3	Combustion Analysis	267,000 m^3	$28,000	$8,500	4
4 *	Piping Insulation	1,160 Gcal	$7,000	$2,100	4
5	Filter & Return Dust Collection Air	85.8 Gcal 20,600 kWh	$2,750	$5,896	25
6 *	Steam Trap	1,200 Gcal	$7,200	$800	1.3
7 *	Coil Maintenance	-	-	-	-
8 *	Repair Compressed Air Leaks	100,000 kWh	$5,000	-	-
9 *	Repair Dryer Steam Leaks	3,062 Gcal	$18,000	-	-

* Indicates ECO's recommended by the auditors but not funded by USAID.

The equipment that is recommended for purchase by USAID for the computer energy management ECO includes a portable computer, printer and appropriate software for tracking energy information and performing energy analysis of future ECOs. A power analyzer is recommended for purchase to facilitate the demand control of the electric lacquer dryer elements. A portable combustion analyzer is recommended to increase the combustion efficiency in the mineral wool area furnace and kiln. A low temperature infrared sensor is recommended for purchase to increase the ability of the facility staff to identify and justify increases in insulation levels.

The long-term projects recommended for the facility are shown in *Table 2*:

Table 2. Long-Term ECO's Recommended by Auditors but not Funded by USAID

No.	ECO
1	Air Compressor Heat Recovery
2	Log Bath Steam Control
3	Reduce Cooling Water
4	Time of Use Rates/Demand Charger

The ECO with potentially the greatest impact is the reduction in the removal of air from the facility during dust collection. This can be accomplished by returning the air through a baghouse or filter system and back into the building space. This not only reduces the heating requirements for the space, but can reduce the electric fan energy for the makeup air. The ECO analyzes one such system while the plant has many.

1.0 Plant Description

The Alytus Wood Products plant was started in 1969 with the participation of a West German firm, Austrian Zuckerman, and a Polish firm, Zemak. The first product was distributed in Lithuania in 1973. Presently, the plant produces seven types of houses of 71 to 121 m^2. The factory is comprised of six plants with 4,600 employees for the various tasks required in the house production.

At the wood working plant about 106,837 m^2 of boards are sawn daily. The plant of "joinery articles" is the largest of the six plants. It produces window and door blocks, parquet planks, and floor and window sill boards. The wood fiberboard or wood plate plant uses mechanical-thermal-chemical treatment to produce the boards. A mineral wool plant uses a mixture of dried clay and limestone to make the wool insulation. The "Jure Building Structures Plant" was added to the facility in 1986. Its main production is glue-laminated structural components.

The products from the above plants go to the "house structures" plant where 7 to 8 houses are assembled daily. The annual production of the facility is 200,000 m^2 of sectional one family houses, 250,000 m^2 of windows, 260,000 m^2 of door blocks, 10,000,000 m^2 of conventional wood fiberboard, 200,000 m^3 of mineral wool and 3,500 m^3 of sawed lumber. The facility maintains some foreign contacts. Companies from Finland purchase fiberboards and wood waste. These Finnish companies also make it possible for the plant to obtain small mechanization machinery. The facility also exports fiberboard and mineral wool to Poland. Part of the facility's production is exported to Bulgaria, Germany, Russia, Mongolia, Yemen, and the USA. The majority of the houses are used in Lithuania.

1.1 General Energy Utilization

The Alytus plant has an electric demand of about 15 MW at full production capacity. The electric equipment includes large 500 kW motors for cutting wood, large dust and pneumatic wood transport fans, air compressor motors, and electric lacquer dryers. Their power factor is generally low, but the penalty costs they pay are insignificant compared to the overall electric bill. The cost of the electricity purchased in 1991 has been 13% of their production costs. Their cost for gas consumption was 1.5% of their production costs in 1991. The steam costs were the largest of the costs at 24% of production costs and thermal water accounted for 10%.

The cost of energy as percentage of production costs is illustrated as follows:

Steam	24%
Power	13%
Thermal Water	10%
Natural Gas	1.5%
Total	48.5%

Thus, almost 50% of production cost at this facility is consumed by energy needs.

1.2 Organization

The general organization of the plant is shown in *Figure 1*. There are six directors that report to the general director. They head the wood supply, construction, technical, economic, production and commercial departments. These departments are under the direction of the general director, Mr. Bronius Janonis. The figure only shows the sections that relate to decisions on energy projects. These sections are under the direction of the technical director, Mr. Mindaugas Digaga. The primary section under the technical department that directly relates to energy projects is the Energy Maintenance section. This is the section where the energy manager is placed. The chief energy manager is Mr. Valentinas Anuzis. This organizational chart is complex and should be refined to allow energy related concerns to be more clearly addressed. The company is planning on breaking into smaller companies and has delayed any significant reorganization. Once this breakup occurs, it is strongly suggested that the energy manager be given more direct lines of communication to the final decision makers.

1.3 Electrical System

The electrical system is comprised of a higher ratio of large motors to small motors than the typical industrial facility. The electrical distribution is provided by 10 kV and some 6 kV lines. Most of the common motors run on 380 V lines. Each major area or plant within the facility has an electric meter that allows them to allocate electric costs for a specific area's function. *Table 3* lists the main electric motors used in the factory.

Table 3. Electric Motors

Power (kW)	Number	Area	End-Use
500	10	Wood Plates	Wood Chip Grinding
250	2	Mineral Wool	Vent. Fans
200 200 200	5 7 8	House Const. Frames Compressors	Dust Collect. Dust Collect. Compressors
175	6	Wood Plates	Lacquer Dryer
160 160 160	5 5 2	House Const. Frames Compressors	Dust Collect. Dust Collect. Compressors
132	2	Wood Plates	Grinding
110	7	General	Fans/Saws
100	3	General	Dust Collect.
75	1	House Const.	Dust Collect.

The largest motors are on the wood chipping and grinding machines which operate from 7 am to 5 pm each day. The next largest motors are on the mineral wool ventilation fans which operate almost continually throughout the year. Most electric motors are found in the dust collection and ventilation fans. The only non-motor, large electrical user is the six 175 kW electric dryers used to dry lacquer on the fiberboard.

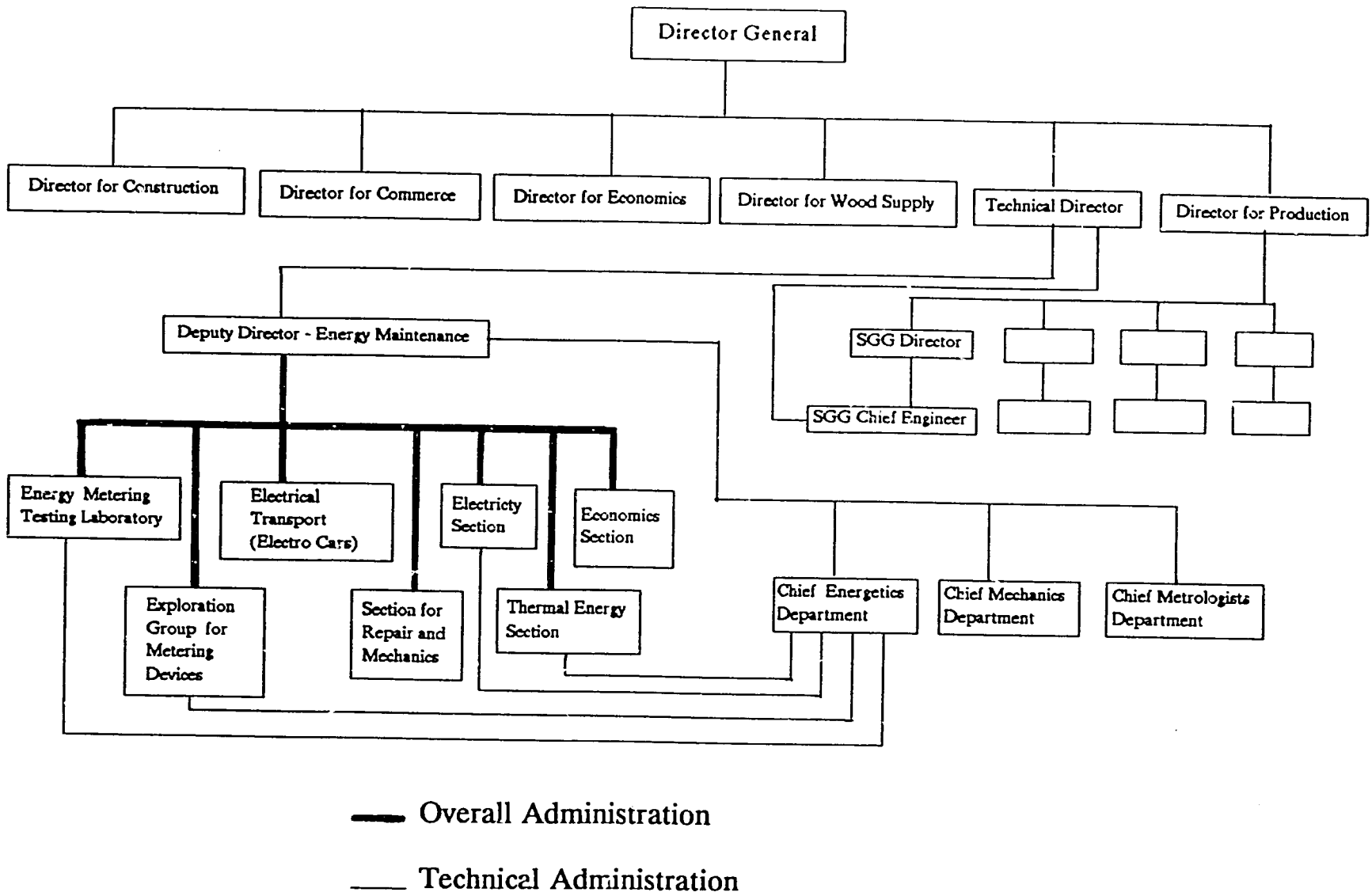


Figure 1. Plant Organization

1.4 Thermal System

Steam and thermal water are provided to the plant from the local power station. The steam comes into the plant at two different pressures, 33 atm and 14 atm. *Figure 2* shows the basic piping system layout for the steam and thermal water distribution. The system allows the 33 atm steam to be reduced to 12 atm as needed, with some of the steam used at 33 atm. The only direct use for this 33 atm steam is in the pressing of the boards for the plywood panel production (MPPG). The 14 atm steam is reduced to 7 atm. The processes in the facility require either 7, 12 or 33 atm steam. The corresponding condensate return pressures are 5, 9 and 30 atm respectively. *Table 4* lists the major steam users in the facility.

The condensate returns to two condensate tanks and is mixed with treated cooling water, provided by the local power plant. This reduces the temperature of the condensate below 100 °C before it is pumped back to the power plant. About 40 to 60 metric ton/hour of the special cooling water is added. The facility is billed for the steam use based on the net energy use, which is the difference between the energy content of the steam flowing in and the condensate flowing out. This part of the system is metered to measure the flow rate and temperature of the condensate and cooling water. Although cooler water is added, the net energy content remains constant because the lower return temperature is compensated by the increased flow rate. The addition of the cooling water is, in practice, providing the power plant with preheated makeup water. Because the Alytus facility is not charged for the amount of cooling water used, there is less of an incentive to fully condense the steam.

Six pumps are used to pump the condensate from the tank, once the required temperature is obtained, to the power station. The system also has two separators for the 30 atm condensate, so the flash steam in the 7 atm line can be reused. This system is presently not in use and the 30 atm steam flows directly into the condensate tanks.

The thermal water from the power station provides space heating and heating of potable water. The piping system allows for the recirculation of the water through the facility and additional thermal water is added as the energy is consumed from the water. Average consumption is approximately 50 metric ton/hour.

As mentioned earlier, the 33 atm steam at 270 °C is used only in the plywood panel production. *Figure 3* is a schematic of the "Ruttsa" hot water production from the steam. The steam is injected at the top of the tank directly into the water, maintaining a 200 °C water temperature The water is used in the press for the boards and for the "kameros" that are used to dry and cure the boards. The water is returned to the tank and some is pumped back to the condensate tanks.

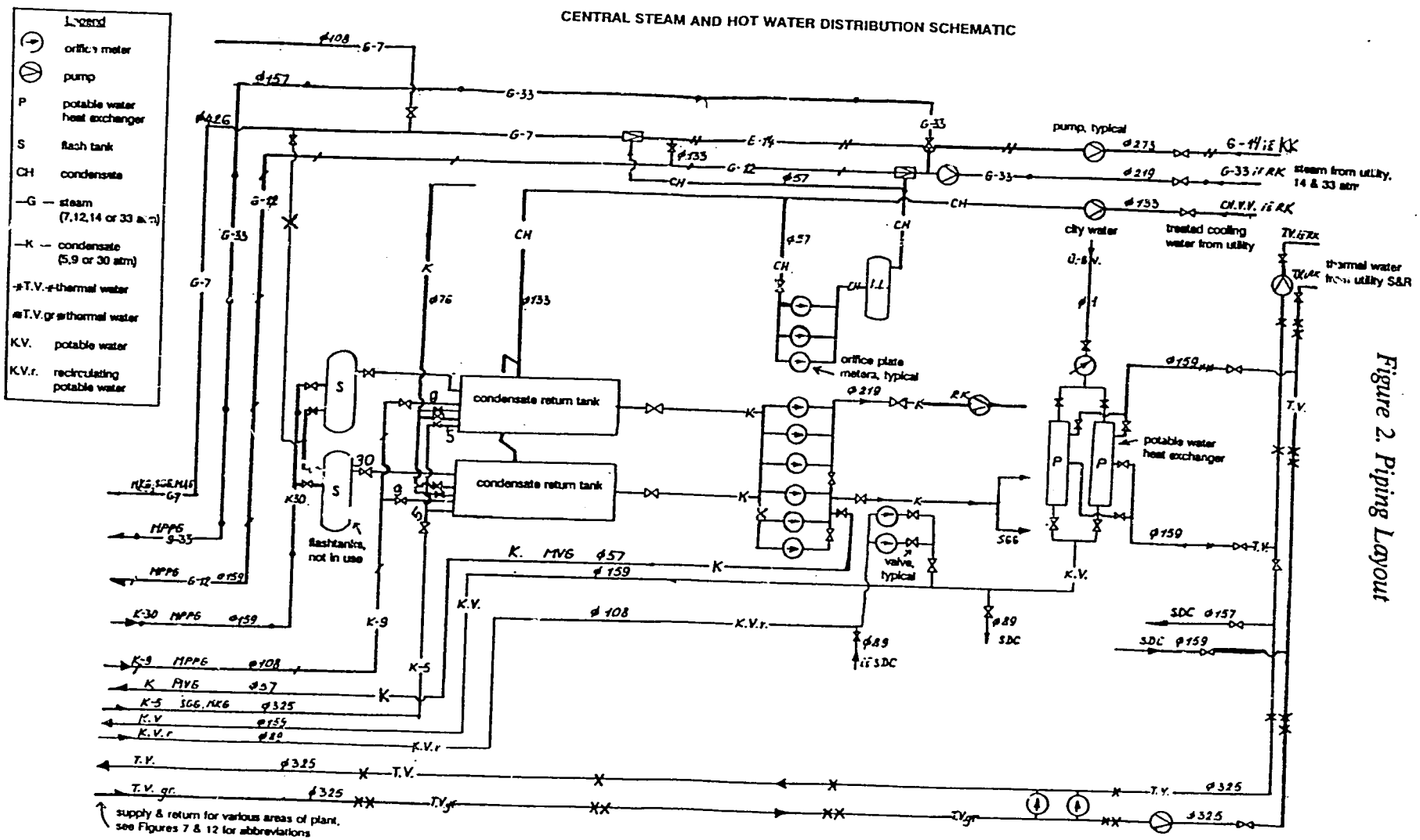


Figure 2. Piping Layout

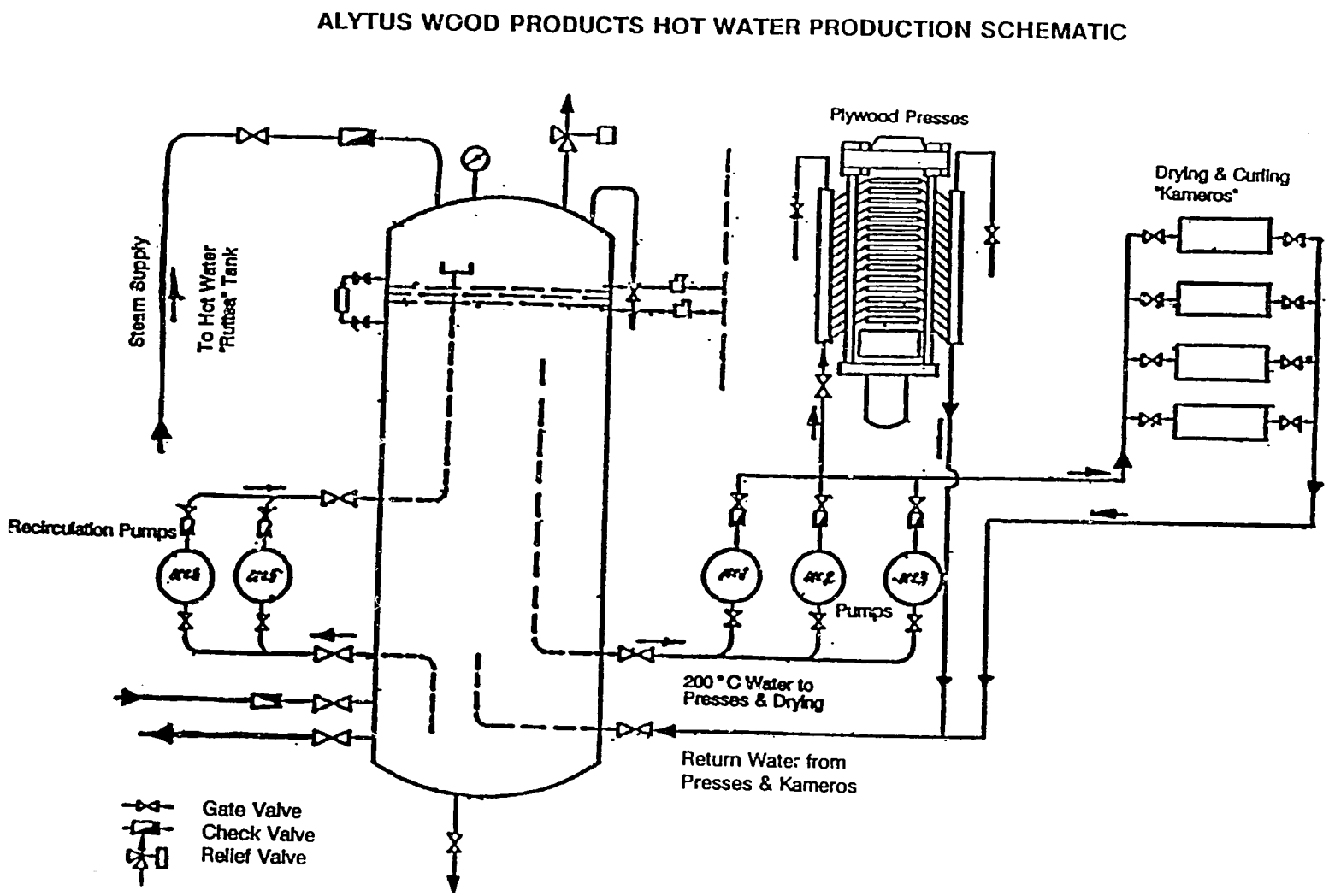


Figure 3. "Ruttsa" Hot Water Production

Table 4. Steam Users

Capacity	Number	Area	End-Use
14.1 Gcal/hr	3	Frames	Soft Dryers
6.0 Gcal/hr	1	Wood Plates	"Ruttsa"
5.3 Gcal/hr	3	Wood Plates	Chip Melters
4.7 Gcal/hr	1	House Const.	Dryer
3.1 Gcal/hr	2	Lumber	Log Bath
2.6 Gcal/hr	4	Wood Plates	Cameras
2.3 Gcal/hr	2	Frames	Hard Dryers
1.4 Gcal/hr	8	Wood Plates	Cameras

1.5 Process Description

In the past, 80% of the raw materials for the wood products were obtained from Russia. Presently, only about 30% of the raw materials are from Russia and 70% are from Lithuania. In plywood panel production the wood chips are pumped through large circular cutting machines that grind the chips into a slurry. The slurry is spread onto a mesh where the excess water is pressed out. The press uses seven 55 kW motors to turn the rollers. The wood cake on the mesh conveyor is cut and loaded onto panel-size press sheets. After the total number of press sheets are filled (approximately 20), the press is activated, the water is pressed out and the boards are dried. The boards are further processed in the hardening "kameros" to dry at 150 °C for 4 to 6 hours. Steam is injected to control the drying process. The process uses 2,500 m^3/day of water.

The frame plant has eight steam dryers for wood. Six are softwood and two are hardwood dryers. Four of the softwood dryers are the older "Hildebrand" dryers. The other two are "Bauman" dryers. The dryers use 6 atm steam for the heating of the dryers and 1 atm steam for injection of steam to maintain proper humidity. For one inch thick wood, the drying time is 36 to 48 hours. The end of the cycle is determined by a "resistance meter" that measures moisture content of the wood at the end of each cycle. The hardwood dryers have eight stages that require a total of two weeks to cycle through.

The control of temperature and humidity is through central automatic cycling equipment, with sensors for dry and wet bulb temperatures. The Baumans have new actuators that allow better control. The steam traps used are from Russia and some are not functioning properly. An average of .8 Gcal/m^3 and 1.2 Gcal/m^3 are required for drying soft and hard woods respectfully. About 5,000 Gcal per month of steam is used in the dryers which is about 35% of the overall facility steam use.

The other area within the framing plant is for cutting the wood. This area has a lot of dust collection equipment and ducts. There are 40 makeup air units serving this area with an average power consumption of 11 kW. Another area is the steam heated paint dryers. Presently, they are using olive oil to coat the wood instead of paint because of the lack of paint.

The plant adjacent to the framing plant is the house construction plant. The main steam use is the "Hildebrand" dryer. There is a steam press to dry the glue in laminating the boards. The process also requires dryers for treated lumber and pressurized treatment tanks to treat the wood. The tanks use compressed air and steam.

2.0 Plant Energy Profile

The plant's relative energy costs in percent are shown in *Figure 4*. Almost half of the energy costs are from steam use. Electricity accounts for about one-third, while thermal water accounts for one-fifth. Although the gas use is only 3% of the total energy costs, the potential for savings and cost reduction should not be ignored.

2.1 Gas Consumption

The total consumption of gas for 1991 is shown in *Figure 5*. During the year the gas consumption stayed relatively constant. As was mentioned earlier, most of the gas consumed was in the making of mineral wool. Therefore, for the year 1991 it appeared the production of mineral wool was constant. Even with the low gas costs relative to the other energy costs, the average gas consumption per month was 750,000 m^3.

2.2 Electric Consumption

The electric consumption for the Alytus plant for 1991 is shown in *Figure 6*. The electric consumption for 1991 is not as constant throughout the year as the gas, because it is dependent on the use of many production areas. The average electrical consumption is 5,000 MWh per month. There appears to be little variance in the electrical consumption due to seasonal changes.

Figure 7 shows the electrical use breakdown by percent for the whole plant. The largest user is the wood plates area at 34%, with the frame area using about 23%. This is due to the largest motors being in these areas. It should be noted that air compressors use 10% of the facility electricity.

The breakdown of electricity by end-use is shown in *Figure 8*. The largest consumption is by the process motors at 69%, which includes the large chip grinders. The other large users are the pneumatic transport and ventilation fans. Between these two, they account for 25% of the electric use and are necessary for the transport and removal of dust.

Twice a year the demand of the facility is tracked on an hourly basis. *Figure 9* shows this tracking for the winter, and *Figure 10* shows this tracking for the summer. It is of particular interest that the peak kW during the day is for only 3 to 4 hours. This is a very sharp demand curve and is not typical of most industries. The peak also falls exactly in the morning "on-peak" period, which is in-between the hours 9 to 11 in the winter and 8 to 10 in the summer. This occurrence seems somewhat artificial and may be due to the need to establish the peak to secure the allocation of power for next year. Without these peaks, the average peak power consumption for these days is about two megawatts less.

The use of demand projections for the bill and the concern over allocations of power for the next year reduces the ability to effectively use demand controls. Certainly, if actual demand was billed, the peak demand of the profiles shown could be reduced 2,000 to 4,000 kW. The figures also indicate that some of the daytime energy use could be shifted to nighttime to flatten the demand profile further.

2.3 Steam Consumption

Figure 11 shows the monthly consumption of steam for the facility. The warmer weather lowers the consumption during the summer months. The average consumption of steam per month is about 15,000 Gcal. The breakdown of steam use by area is shown in *Figure 12*. The wood plates section uses about 50% of the steam. The frame and house construction sections consume almost all of the other 50%. The largest use of steam in the wood plates section is in heating process water directly with steam. The largest consumers of steam throughout the entire plant are the various drying processes.

2.4 Thermal Water Consumption

As seen in *Figure 13*, the thermal water consumption is based on the time of year. This is due to the thermal water being used primarily for space heating. *Figure 14* shows that most of this heat is required in the frame and house construction areas. Both of these areas use a large amount of makeup air. The frame area has a lot of dust collection requirements that draw air out of the space. In *Figure 15*, the ventilation or makeup air use 84% of the hot water consumed. Other heating uses another 10% of the hot water consumption.

2.5 Energy Costs

The energy costs for the plant have increased enormously in the last year. Natural gas prices have increased recently from .072 R/m^3 to the current price of 1.054 R/m^3, an increase of 1,360%. The electric costs are presently 0.051 R/kWh with a demand charge of 10 R/kW each month. The prices will soon change to 0.30 R/kWh, with a demand charge of 50 R/kW each month. This would result in the plant's electric bill increasing five fold. The plant has no direct penalty for power factor, but pays 0.035 R/kVAr. Even though the plant does not have a very high power factor, the cost is very minimal for the reactive power.

For steam, 10% of the energy bill is a capacity charge. This is based on a charge of 2,000R/Gal per hour, billed monthly. The cost of the steam consumption is 50 R/Gcal. The condensate not returned is 2 R/metric ton, but the plant is not presently paying for the cooling water into the system. Thermal water costs also have a capacity charge. The thermal water capacity charge is also 2,000 R/Gcal per hour billed monthly, with a consumption charge of 50 R/Gcal. The new thermal water and steam cost will be 200 R/Gcal.

2.6 History of Energy Efficiency Measures

As is true of the other facilities visited, energy conservation measures have been very limited during the life of the plant. An example of one of the adopted measures is the use of fluorescent instead of incandescent lighting in the administration building. Other measures that were mentioned by the staff include replacing the steam drying system for the lacquer dryers with electric elements, and the addition of recirculation pumps in the thermal water system.

Figure 4. Energy Costs

Figure 4. Energy Costs

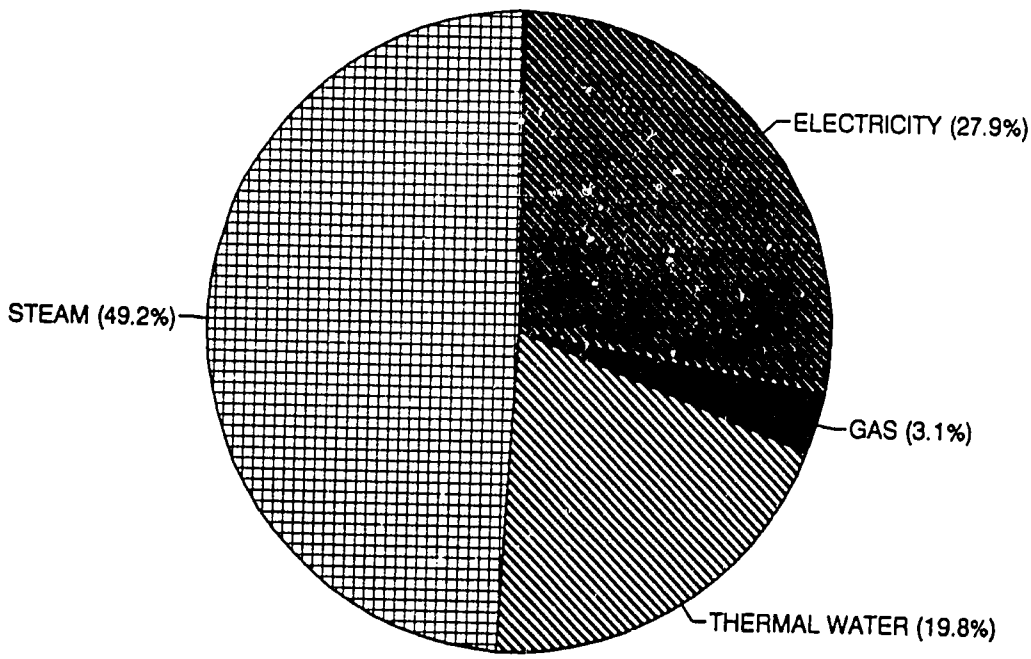


Figure 5. 1991 Gas Consumption

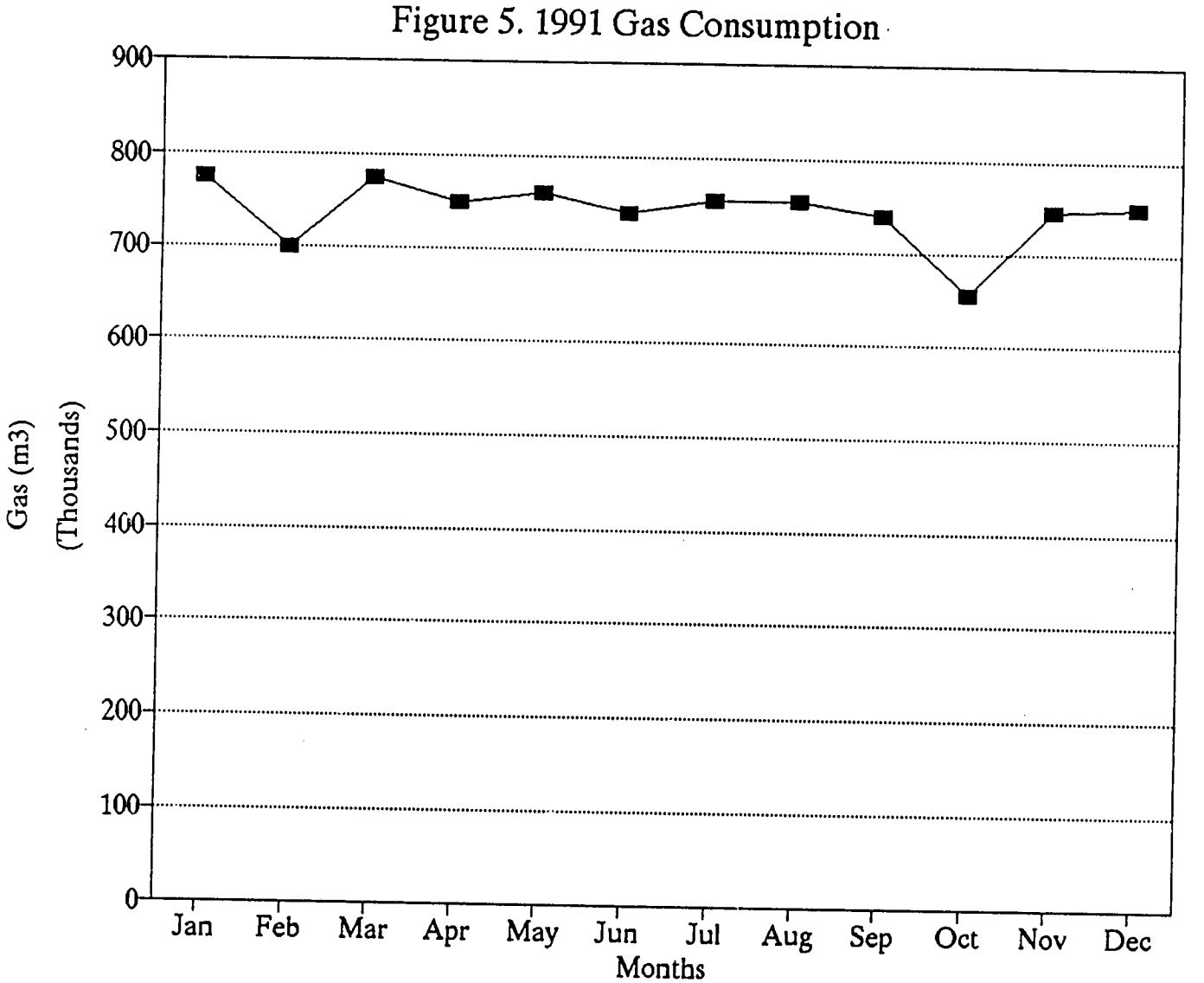


Figure 6. 1991 Electricity Consumption

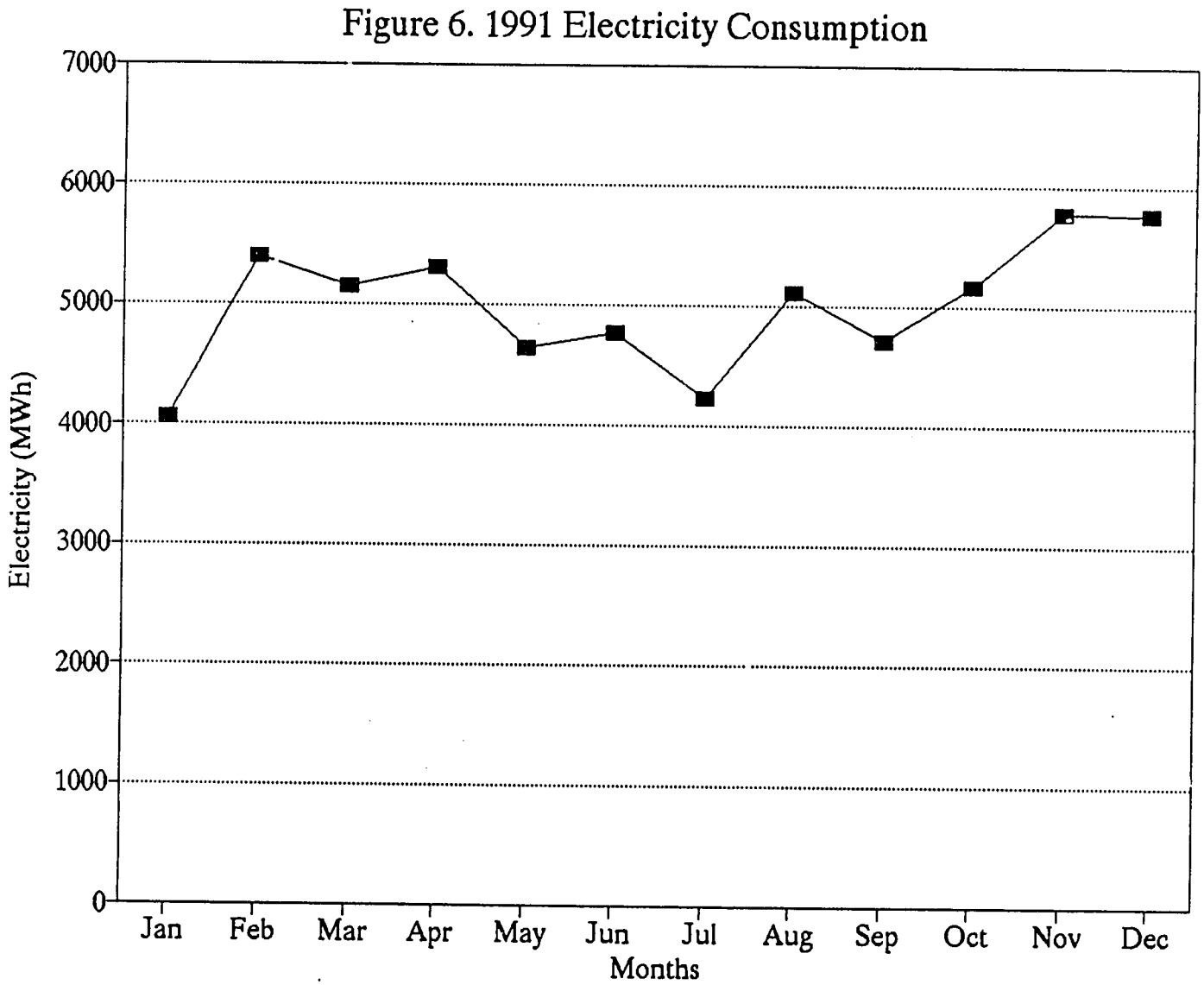


Figure 7. Electricity Use by Section

Figure 7. 1991 Electricity Use By Section

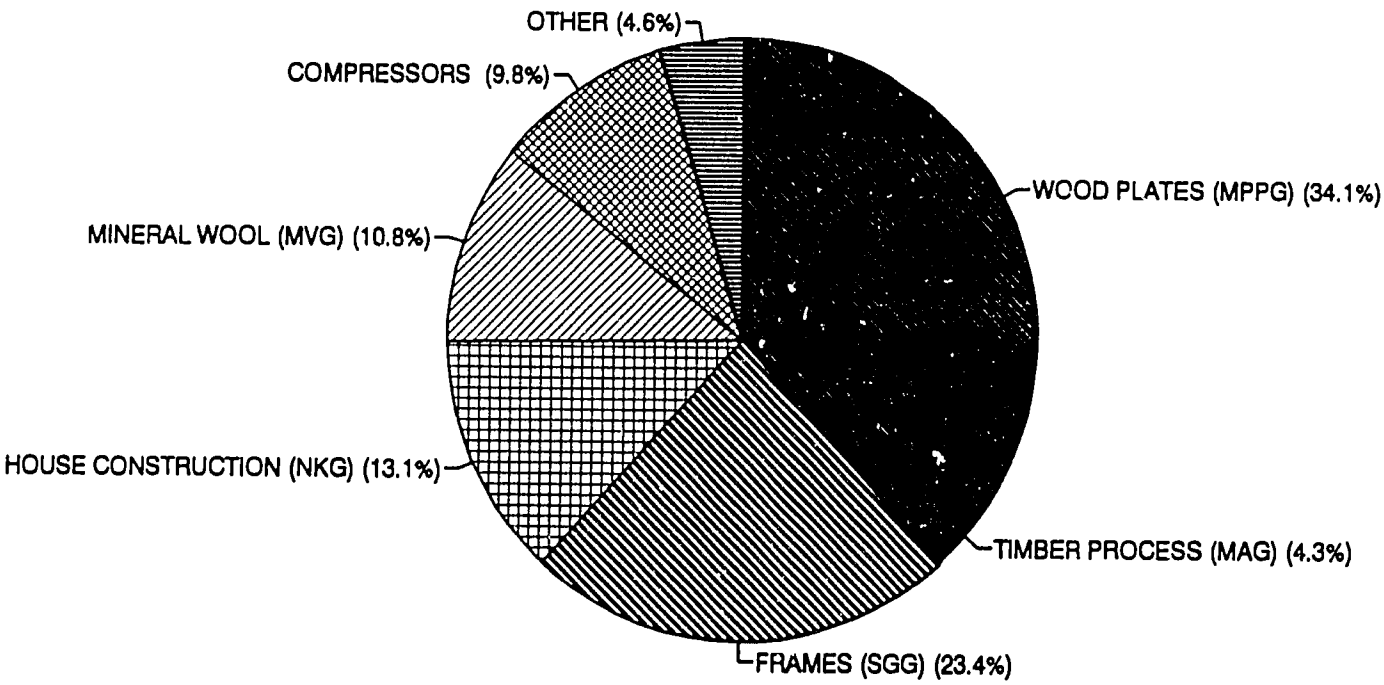


Figure 8. Electricity Use

Figure 8. 1991 Electricity Use

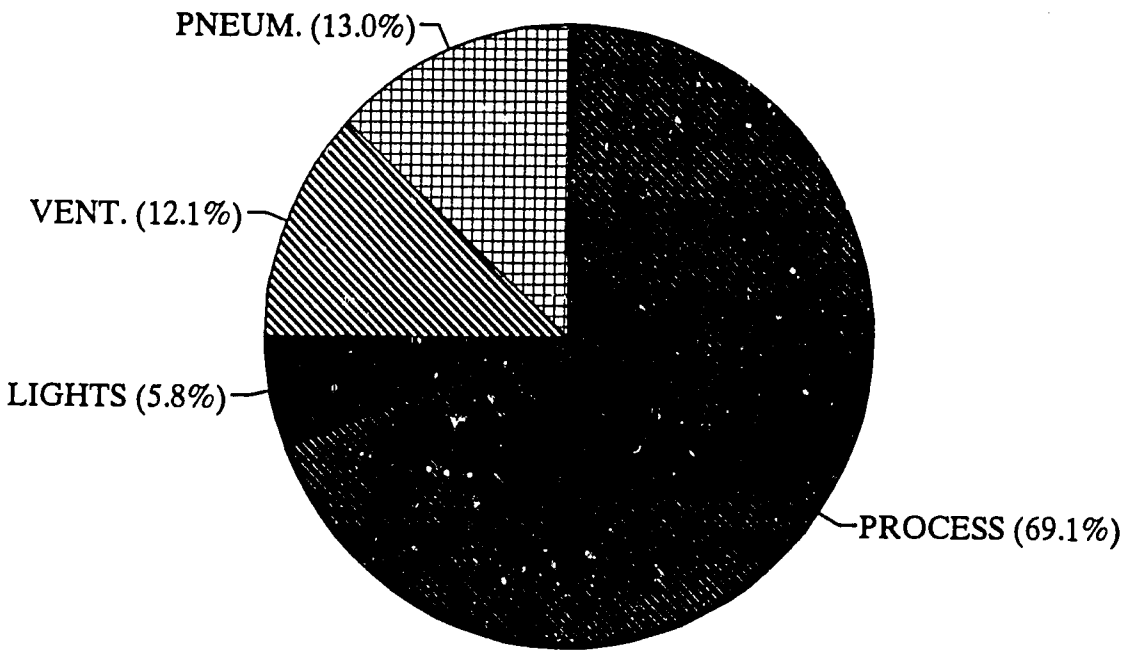


Figure 9. 1990 Winter Daily Demand Profile

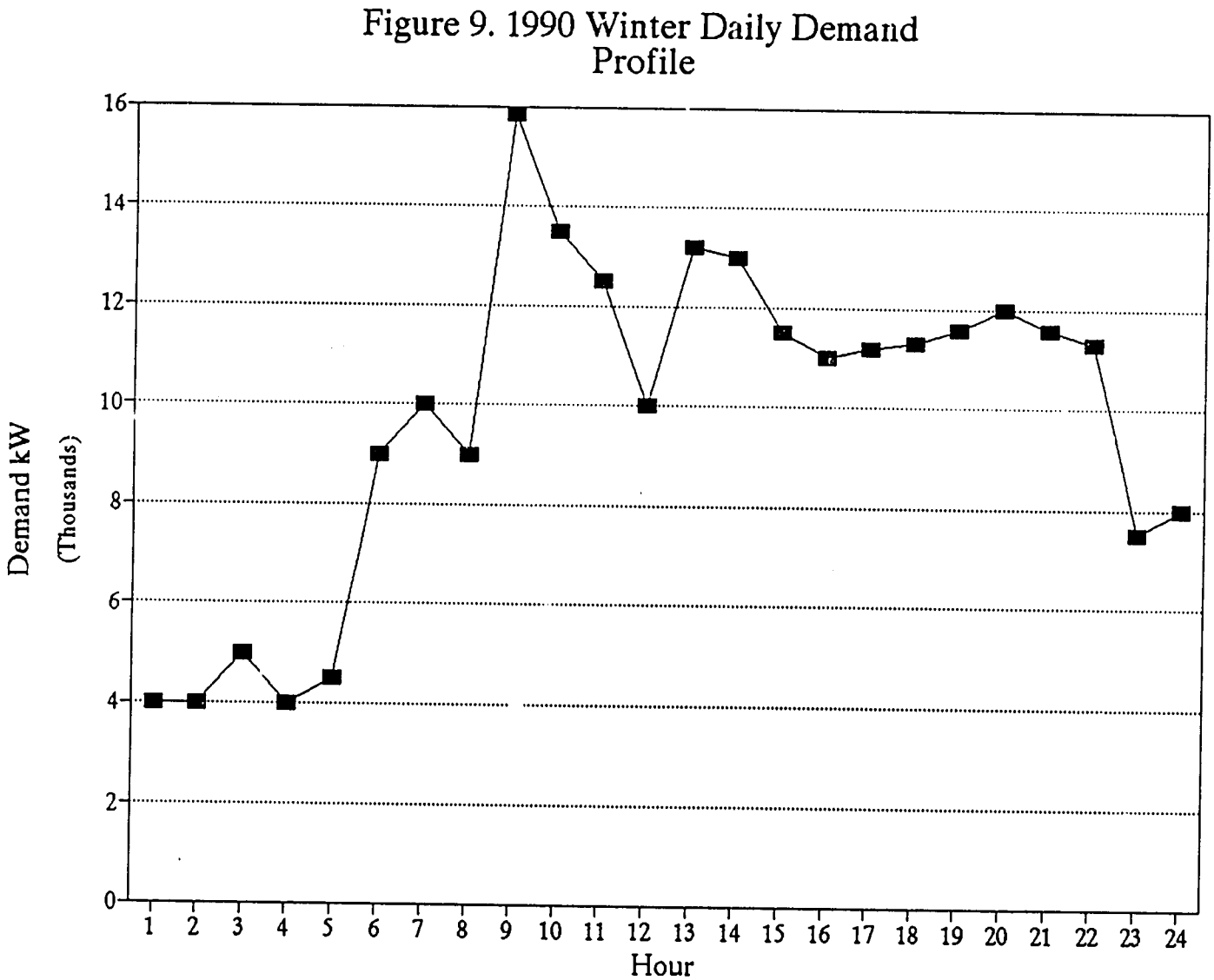


Figure 10. 1991 Summer Daily Demand Profile

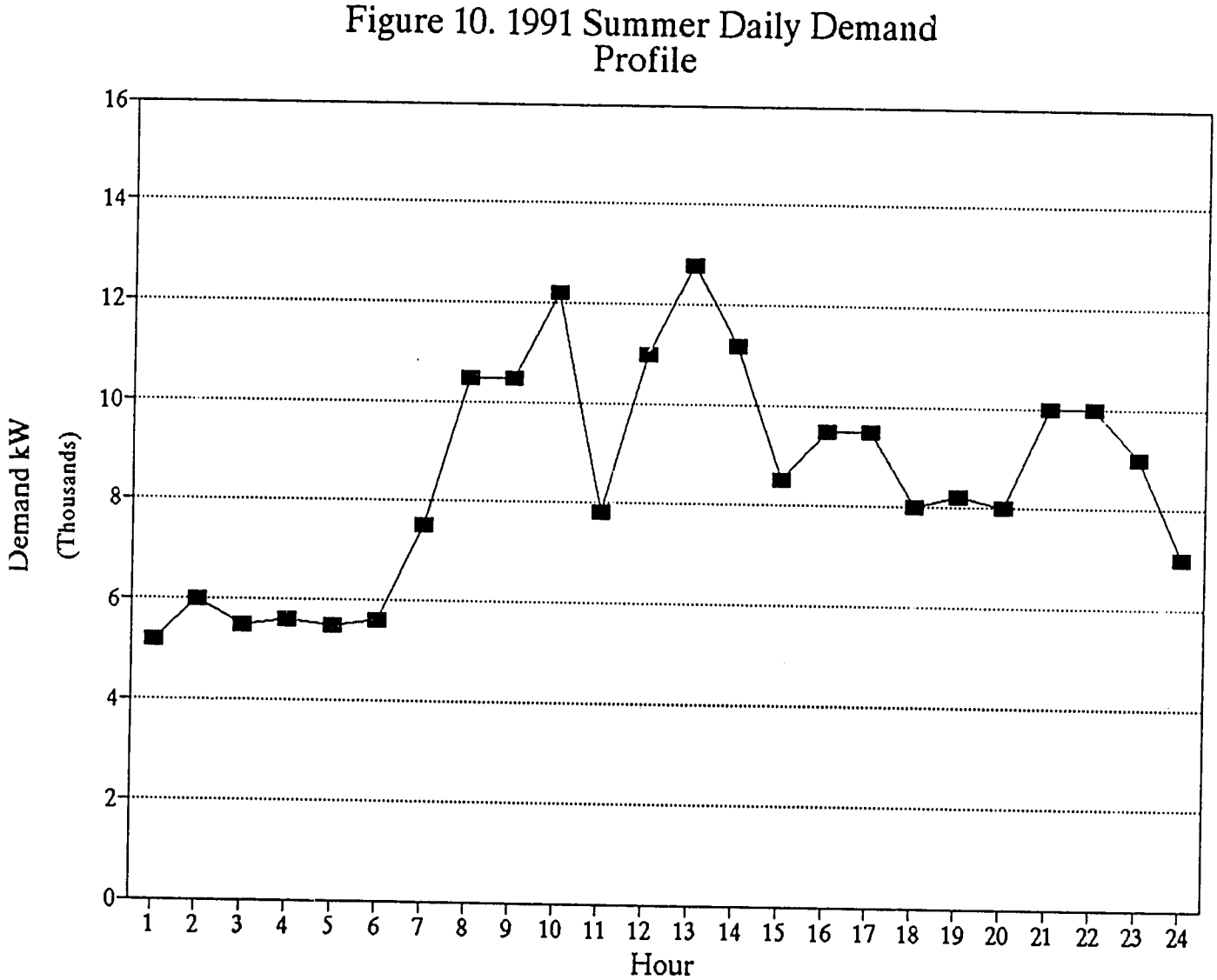


Figure 11. 1991 Steam Consumption

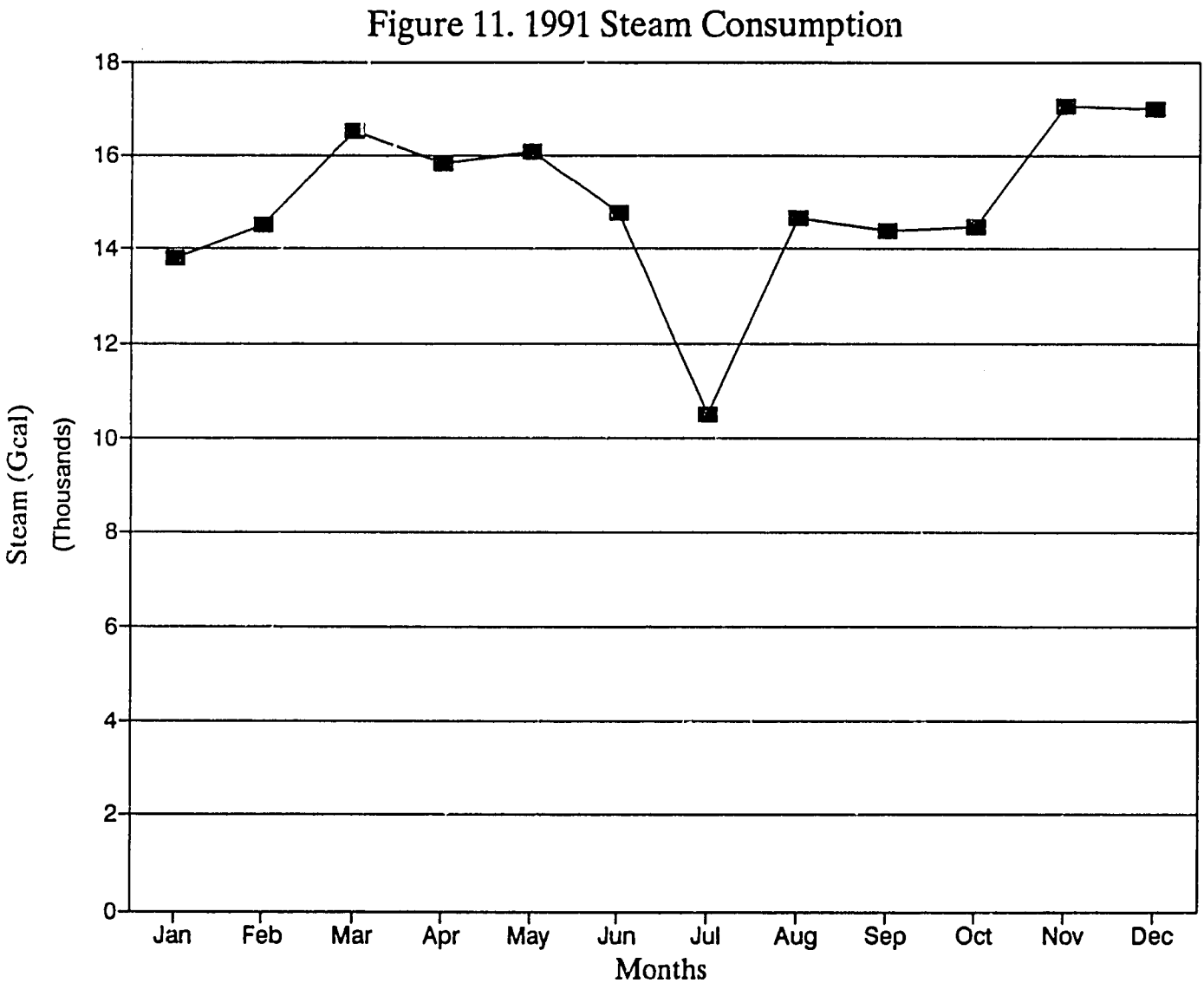


Figure 12. Steam Use By Section

Figure 12. 1991 Steam Use By Section

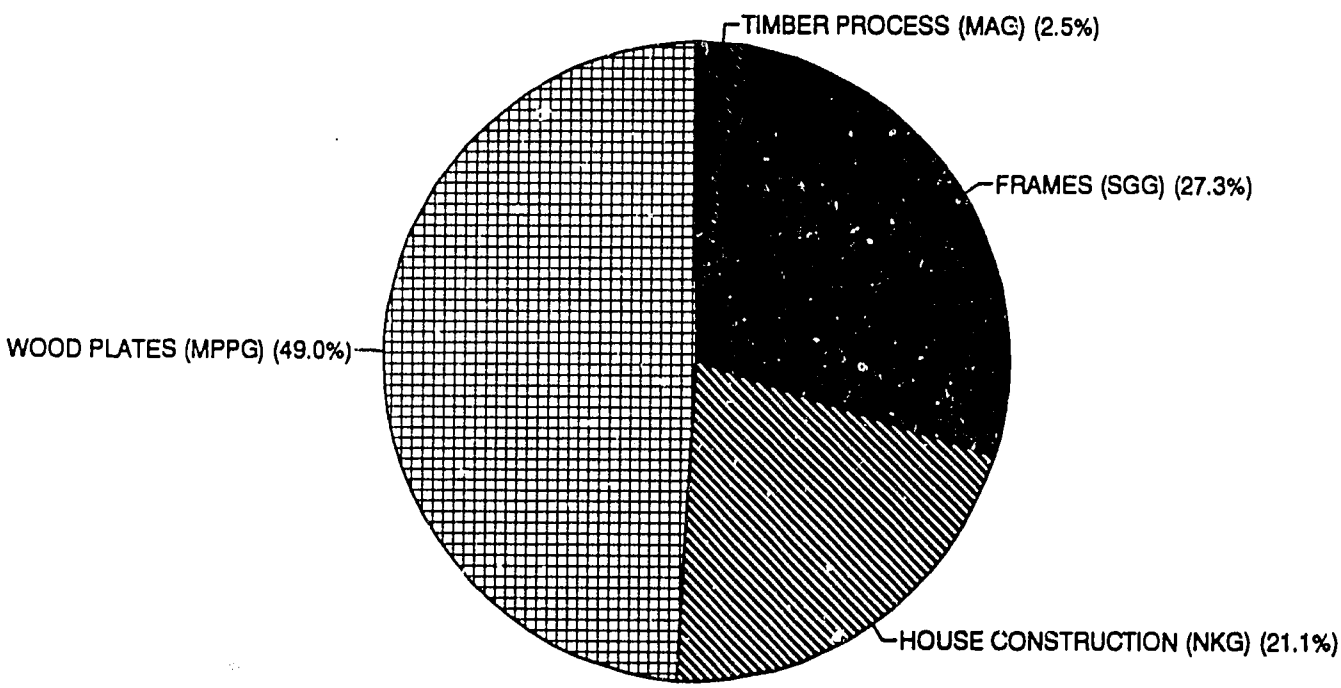


Figure 13. 1991 Thermal Water Consumption

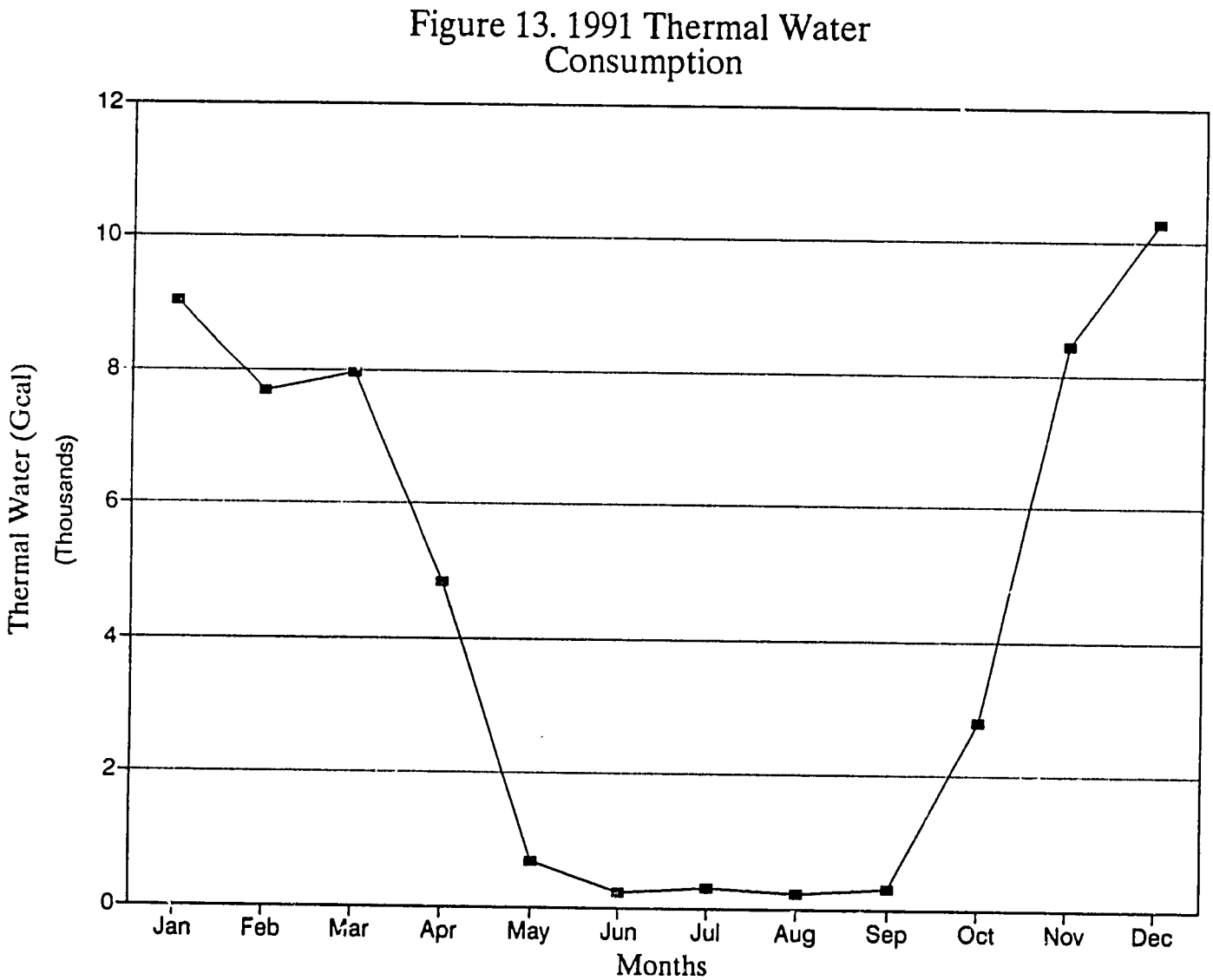


Figure 14. 1991 Hot Water Use by Section

Figure 14. 1991 Hot Water Use by Section

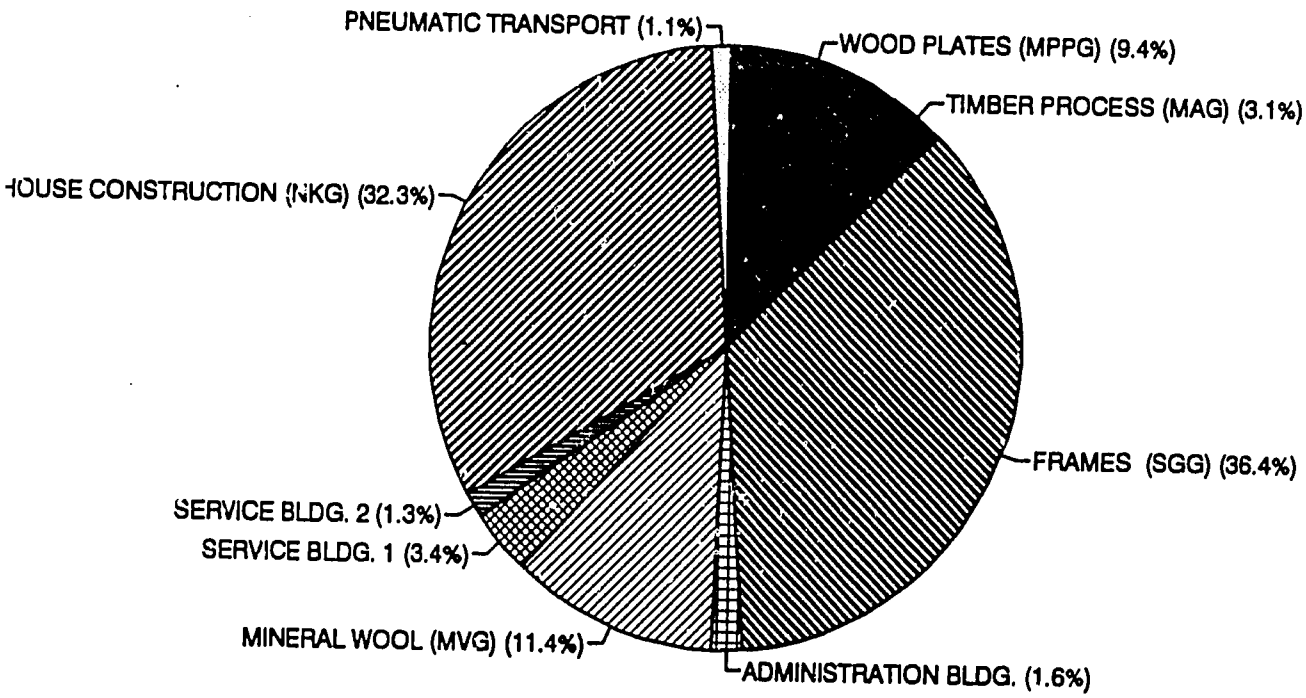
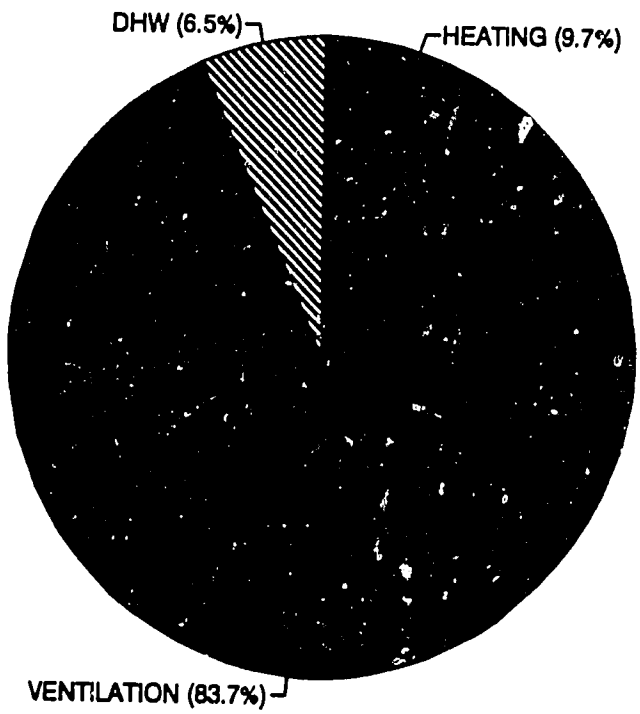


Figure 15. 1991 Hot Water Use



3.0 Energy Audit Description

The audit was conducted over a five day period from January 14 to January 18, 1992. A pre-audit trip was made to the facility in late November by the Energy Efficiency Component Team Leader. Discussions were held with key personnel to determine the major energy issues, to describe the purpose of the project's work, and to make initial requests for basic information about the facility. The main contacts at the facility for the auditing team were Mr. Valentinas Anuzis, Mr. Kazimieras Alksnys and Mr. Mindaugas Pigaga, who are responsible for the energy use of the plant. Also met with was the General Director, Mr. Bronius Janonis. Additionally, specific issues for each audited area was discussed with key plant personnel. The representatives of the Ministry of Energy that were met with were Mr. Edvardas Vazgela and Mr. Antanas Varpukevicius. Virginijus Buciunas of NEGA. W., a private contractor, assisted with the equipment selection during the audit and will continue to assist with the auditors as necessary regarding further equipment selection and compatibility.

In the first part of the audit the key issues were discussed and a short tour of each area within the facility was performed. The second part included using various auditing instruments to collect energy efficiency information and in-depth discussions with various plant personnel. After the information was analyzed, the short and long-term recommendations were formulated and presented to the facility staff.

3.1 Summary

From the discussions held with the plant personnel, the key energy areas within the plant were identified and the main problems related to energy efficiency were presented. The areas identified were as follows:

- Reduction in dust collection air quantity
- Management of energy use and information
- Control of steam and thermal water use
- Piping insulation levels.

The facility personnel are aware of the primary inefficiencies in their plant and are technically capable of determining the energy losses given the right instrumentation. They are also in the best position to determine the proper projects to undertake, given the factors of production such as labor costs, material costs and their long-term business plan. Therefore, the audit focused on determining the most appropriate instrumentation to obtain accurate measurements that an in-depth energy evaluation would require, and the type of technical information they may require to make long-term energy efficiency decisions such as the retrofitting of their wood panel area. The main areas that the audit addressed were:

- Mineral wool area
- Wood panel area
- Framing area
- House construction area
- Air compressor room
- Central thermal area

3.2 Mineral Wool Area

As was already mentioned, the mineral wool area uses most of the total gas consumption. Therefore, the audit was focused on this area to identify energy efficiency opportunities for gas. The majority of the gas is consumed in the area by the kiln for the clay and limestone mixture, and the furnace for the mineral wool. During the audit of the area, the combustion analyzer was used to measure the efficiency of the furnace. See Appendix B for a photograph of the drying kiln and vents.

The furnace has two different sides and stacks to recover some heat from the combustion air. The stacks are alternatively switched every half-hour. One stack is used to provide outdoor air for combustion to the furnace while the other exhausts the hot combustion gasses from the furnace. The main stack is the "header" that connects the furnace to the left and right stacks. Because the stacks are made of thick brick material they capture some of the heat from the exhausted air and preheat the incoming combustion air when the switch is made. Therefore, there is some basic heat recovery occurring. The combustion air was sampled on the two sides and at the stacks of the furnace when the side was acting as the exhaust stack. The raw data for these combustion readings are in Appendix A. The results of these tests are summarized in *Table 5*.

Table 5. Combustion Analysis Results

LOCATION	FUEL	T(stack)	O2%	CO(PPM)	EX. AIR	EFF.
RIGHT STK.	GAS	390 °C	13.9	70	179%	49%
LEFT STK.	GAS	383 °C	2.1	2,532	10%	68%
MAIN STK.	GAS	449 °C	12.4	7	133%	50%

The combustion analysis readings indicate that although there is significant recovery of heat from the exhaust gases, which are at about 800 °C, there is still some heat that is available for recovery. There was also a marked difference between the oxygen concentration in the two stacks. The right stack had a high percentage of oxygen, but still had some unburned carbon monoxide. This indicates an inefficient burning zone. The left stack had a low percentage of oxygen, but high carbon monoxide concentration. Measurements at the main stack outlet showed much higher temperatures and again high excess air for the furnace combustion.

These measurements indicate a significant potential for improvement of combustion efficiency and recovery of more heat. Also measured with the infrared temperature sensor was the exterior furnace temperatures. The area staff was particularly interested in measuring the temperature of the exterior of the refractory on the roof of the furnace. The roof is overdue for replacement but because of the shortage and expense of material it has not been replaced.

3.3 Wood Panel, Framing and House Construction Areas

The wood panel, framing and house construction sections' main production areas of the plant were investigated for energy conservation opportunities. To determine areas of poor insulation, the infrared temperature sensor was used to take pipe temperature measurements. Observations of the areas revealed several large steam leaks. In the house construction area the dryer was leaking steam from the edge of the dryer roof. This was pointed out and the audit team was informed that the plant planned to reconstruct the roof, but because of other priorities in the construction department, reconstruction of the roof had not been performed. There was also some leakage occurring on the dampers of the Hildebrand dryers at the framing area.

While walking through the wood cutting part of the framing area several large compressed air leaks were observed. It is not uncommon for air leaks to go unnoticed for years, thus wasting considerable energy. Many times plant personnel will view compressed air as a free utility. The temperature measurements indicated that there were many areas that could benefit from increased insulation levels and repair of insulation especially around the steam valves.

The makeup air dampers were investigated in these areas. The outdoor air dampers for the makeup air units are set manually and left in the open position. It was also observed that some of the heating coils were dirty. Cleaning the coils would reduce the pressure drop across the coils, increase the heat transfer, and reduce fan requirements. The temperature of the piping at the steam traps for the dryers was observed. The measurements indicated that some of the traps were not performing correctly.

The dust collection for the framing area has many branches. There were many ducts that were drawing air even though the cutting machine was not operating. These may be able to be closed without disturbing the air balance. In the wood panel area, the slurry of the wood chips had considerable water content. It may be possible, through better control, to reduce the water requirement and reduce the energy required to remove the water from the wood.

The audit team also toured the area where the drying of the lacquer occurs. The panels are dried with resistant electric heat. There are 2,500 electric heating elements at a power consumption of .8 kW/element. If all the elements are working at once, this area draws about 13% of the total plant power requirements. Because of the high use of electric power there is a high potential to control energy demand in this area and to decrease energy costs.

3.4 Air Compressor Room

Compressed air is used throughout the plant in many processes. The plant has two main areas for the reciprocating compressors. The compressors are two stage, water cooled, and provide air at about 20 m^3/hr. The cooling water is sent to a cooling pond and recirculated. Temperatures for the cooling water were observed to be between 30 °C and 38 °C. The compressors provide both 8.5 and 12 atm air. Most of the air use is at 8.5 atm. For the compressor room the operation of the compressors continually runs all week to provide 12 atm air, while one to two compressors are continually loaded for the 8.5 atm requirements. This provides an average of 70 m^3/hr of air to the plant.

During the audit the power consumption of two of the air compressors was measured with the Dranetz power analyzer. Because of time constraints, the measurement was meant to train the facility personnel and not to evaluate the compressor performance.

3.5 Central Thermal Area

As previously mentioned, the condensate for the various steam pressures returns to the central thermal area and is mixed with treated cooling water in the condensate tanks. This is done to reduce the condensate temperature to the proper temperature. During the audit, a discussion of alternative operations were discussed at length with the chief of the area. One idea that was discussed in particular was to use the excess heat from the steam condensate to heat water for the thermal water requirements. But at present, this idea was deemed not economical because there would be no energy cost savings due to the payment of steam costs based on the net energy used by the plant. By using cooling water to reduce the condensate temperature, the mass flow of the condensate returning is increased proportionately and the net energy difference remains the same. But if the plant is charged for the cooling water consumed, which will probably occur soon according to the plant staff, the use of a heat exchanger to recover condensate heat may become economical.

4.0 Summary of Results

As a result of the energy audit, several short and long-term energy conservation opportunities (ECOs) were identified. Short-term projects are characterized with low or no-cost implementation and short payback periods. These projects could be implemented in two months. Long-term projects are characterized by larger costs in implementation and with longer payback periods. Short-term energy conservation opportunities identified at the Alytus factory include:

- Computer energy management
- Demand control for lacquer dryers
- Increase furnace combustion efficiency
- Pipe insulation upgrade
- New steam traps
- Makeup air coil maintenance
- Repair compressed air leaks
- Repair dryer steam leaks

In the long-term, it will be very effective to: 1) recover heat from air compressors; 2) to provide better control of the steam to the log baths; 3) to add a turbine for reducing steam pressure; and 4) to reduce the cooling water requirements for the condensate tanks.

The costs of natural gas, steam, thermal water, electricity and the exchange rate are changing so rapidly that it is not possible to predict the cost of fuel savings in rubles. Therefore, the energy savings are calculated based on nominal world energy prices. Lithuania is in the process of trying to bring fuel prices in line with world prices. For the purpose of this analysis a cost of natural gas is assumed to be $3.00 per million BTU or $105.00 per 1,000 Nm^3, the cost of electricity is assumed to be $0.05/kWh and $10/kW/month, and the cost of steam and thermal water is assumed to be $6/Gcal.

4.1 Short-Term Energy Conservation Opportunities

1. Energy Information Management

The facility is very large and has many different types of energy use. The management of the energy consumption for different uses and areas is essential to identify opportunities for energy conservation and to justify projects. For a facility of this size the use of a computer and software will make this management of energy information more effective. Not only can initial opportunities be more clearly identified, but tracking energy use trends can bring out areas of energy waste and a need for maintenance. The benefits of projects and a maintenance program can be justified and verified through the use of the appropriate computer software.

The computer can also be used with other energy metering equipment, such as a power analyzer, to more efficiently process information during energy analysis and the justification for projects. By using a computer to manage energy use in these ways it is estimated that 1% of the overall energy use can be easily conserved through the more effective management that it would afford. This 1% reduction in energy would result in an annual cost savings of about $70,000. The cost of the computer, accessories and software is estimated to be $4,500. This would result in a payback of about one month. The purchase of a computer and software by USAID is recommended for this facility and the specifications are listed in Section 4.3.

2. Demand Control for Lacquer Dryers

The lacquer dryers account for about 5 to 10% of the demand on the facility. The dryers are only used for three days per week for a continuous drying operation. A number of approaches to reduce the demand in this area can be considered. The operating period of the dryers can be extended or shifted to reduce the demand during on-peak periods. This method may not require any capitol outlay. Or a demand controller can be integrated with the elements to reduce the demand by duty cycling the elements as the facility demand reaches the maximum during on-peak periods. The annual cost savings for reducing the demand in this area by 10% or 150 kW, which is realistic with these strategies, is $18,000 at world energy prices. The method chosen will depend on other factors of production such as labor and quality, but a justification for the project can be determined with the assistance of a power analyzer. The power analyzer is recommended for purchase by USAID for this facility and the specifications are listed in Section 4.3. At an estimated cost of $6,000, this would result in a payback of 4 months.

3. Increase Furnace Combustion Efficiency

The cost of gas at .072 R/m^3 is much lower than the world energy price and is reflected in the large increase to 1.054 R/m^3 that is now charged. However, 1.054R/m^3 is still lower than world prices. At the old rates the cost of the gas consumed was only about 3% of the overall energy costs, but at world prices for the energy the percentage of gas costs jumps to 13%. The combustion efficiency of the mineral wool furnace was measured at an average of about 60%. This efficiency can be greatly increased by better monitoring of the oxygen and carbon monoxide in the stack gases. Also, by using an infrared high temperature sensor, the temperature of the mineral wool can more closely be maintained and eliminate some over heating.

With a portable combustion analyzer and the infrared temperature sensor, the efficiency of the furnace could easily be increased by an average of 3%. This would result in a cost savings of $28,000. At a cost of about $6,500 for the combustion analyzer and $2,000 for the temperature sensor, a 4 month payback would result. The combustion analyzer could also be used to justify larger projects to increase the combustion efficiency much further. Therefore, it is recommended that USAID purchase a combustion analyzer and a high temperature sensor for the facility. The specification for this equipment is in Section 4.3.

4. Piping Insulation Upgrade

A number of uninsulated pipes containing thermal water, steam, and condensate were observed. The majority of the plant piping is adequately insulated. Ventilation air is required during part of the year to maintain worker comfort. This compounds an inefficient situation by using energy to mitigate the impacts of energy loss. Using an infrared temperature sensor the pipe surface temperatures can be easily measured and increased insulation quickly justified.

Piping, such as hot water distribution to space heaters and hot water control valves, should all be insulated to reduce heat loss. Reinstallation of insulation after piping repairs should be part of maintenance activities. Heat loss from hot water distribution space heating lines contribute to the overheating of rooms. When this occurs, plant personnel open windows to provide control. This results in an additional source for heat loss. The observed plant pipe insulation, which consists of mineral wool wrapped with aluminum foil and chicken wire, would be an acceptable insulation system. It is recommended that the factory make a determination of the necessary line insulation lengths and obtain a bid from a local supplier for the insulation improvements to project the actual payback.

It is recommended that USAID purchase a low temperature infrared sensor to facilitate the identification of their insulation needs. The use of this sensor should conservatively reduce heat losses in their steam and thermal water lines by an additional 10% over their present identification methods. Assuming that 5% of their energy use for steam and thermal water is heat loss, the cost savings from the use of this instrument is about $7,000 per year. The payback on the equipment, at an estimated cost of $2,100, would be about 3.6 months. Therefore, it is recommended that this type of sensor be purchased by USAID. Thus, the facility should use it's personnel to identify areas of insulation requirements and justify the purchase of the insulation. Specifications for the sensor are in Section 4.3.

5. Filter and Return Dust Collection Air

One of the largest consumers of electricity and thermal water for heating is the dust collection system and subsequent makeup air system. A very good energy conservation opportunity exists in reusing the dust collection air, by bringing it back into the building. This would not only save thermal energy, but would also reduce the electric fan energy required for makeup air. The present dust collection system uses cyclones to precipitate the dust out of the air. (See Appendix B for a photograph of the dust collection system cyclones.) The air is then exhausted to the atmosphere. This air could be brought through a baghouse filter system to sufficiently clean the air and reintroduce it to the building.

The air temperature lost in moving the air through the proposed system is calculated at about 6 °C. At this recovery rate, the thermal energy saved on 18,500 m^3/hr is about .035 Gcal/hr. For 1,000 hours per year this results in a savings of about $1,720 per year. Including the electric savings for the reduction in makeup air fan use adds $1,030 for a total of $2,750.

It is recommended that a pulse-jet baghouse be installed next to one of the existing cyclone units, to be used as an after-filter. The air which has passed through the cyclone and has had most of the dust removed will be ducted through the baghouse to remove the rest of the dust and then into the building. In order to reduce shipping costs and permit the system to be air-freighted, only the inner workings of the baghouse will be supplied from the U.S.A. The housing, hopper, ducting, and support structure for the unit will all be constructed by the plant personnel. The U.S. supplier has agreed to supply the complete shop drawings for this work, because they will be in an optimal position to bid on the supply of baghouses to be used as after-filters for all the other cyclones at the plant. This follow-on work will be strongly recommended to the plant, provided the demonstration system functions as well as expected.

The baghouse that is to be installed will be attached to a cyclone with a capacity of 18,500 m^3/hr. Thermal energy will be saved through return of the air to the plant, and electrical energy will be saved through reduction of the make-up air required. During the audit of plants, the Dranetz AC Power Analyzer was used to measure the electric power used by the fans. It was found that the fans consume an additional 1 kW for an airflow of 1,800 m^3/hr. The electric and thermal energy savings can be calculated as follows:

Assume:

One shift operation for area served by this system or 2,000 hr/yr. The heating system is approximately 6 months/yr. Therefore, the thermal savings are based on 1,000 hours during the heating system. The electrical energy for the make-up fans will be saved year round.

Energy content of air	= .24 kcal/(kg °C)
Density of air	= 1.2 kg/m^3
Therefore: 1.2 * .24	= .29 kcal/(m^3 °C)

Assume that the average difference in temperature is 22 °C during the heating season. Air passing through the filter system could be expected to drop in temperature by approximately 6 °C before being returned to the building. Calculations are based on one baghouse.

Electric energy saved	= (1 kW/1,800 m^3/hr) * 2,000 hr
	= 20,600 kWh
Thermal energy saved	= 0.29 kcal * (22 °C - 6 °C) * 18,500 m^3/hr * 1,000 hr
	= 85,800,000 kcal
	= 85.8 Gcal

Annual energy cost savings are based on the following assumed costs:

Thermal energy costs	= $20/Gcal
Electric energy costs	= $0.05/kWh

The cost of the dust collection system will be $4,496, plus some additional materials purchased locally for ducting, housing, and support structure. The latter materials are estimated at $1,400. Note that approval is being sought only for the U.S. materials in this request.

Estimated annual energy savings (steam):	85.8 Gcal/yr
Estimated annual energy savings (electricity):	20,600 kWh
Estimated annual cost savings:	$2,750/yr
Estimated payback:	2.1 yrs

6. Steam Trap Replacement

The present steam traps that are used in the dryers at the facility were not all functioning properly. Because the factory pays for the net energy used in the steam, and the condensate energy is subtracted, there is not as large an incentive to maintain the steam traps. The incentive to have properly functioning steam traps comes from the wasted heat in the condensate lines due to increased temperature if steam is present. Because the facility may be separating into sub-plants, it may require steam metering with a gross measurement system to prevent wasting this steam. The facility may also be required to pay for treated cooling water in the condensate tank that cools the steam as it comes back into the condensate lines.

If the facility is broken up into separate plants, these sub-plants may be required to pay for the steam based on the measurement of steam into the plant. If this occurs, the frame area should consider replacing their steam traps. Each softwood dryer uses 7.3 Gcal/hr of steam at 6 atm that is returned as condensate. Assuming that 5% of this steam is lost due to faulty traps, this would result in .4 Gcal/hr of wasted steam. Using 3,000 hours of operation a year at this steam consumption for the dryer would result in 1,200 Gcal of wasted steam or a cost of $7,200. With the price of the steam trap at about $800, the payback would be under 2 months.

7. Makeup Air Coil Maintenance

During the audit it was observed that the outlet temperature of the thermal heating water in the makeup air coils was much different from one coil to another. It was determined that the primary reason for this is the dirty coils which reduces the heat transfer. It is recommended that the coils be maintained and cleaned, and after maintenance is performed, an air balance be made on the area to determine if the makeup air fans can be shut off.

8. Repair Compressed Air Leaks

In many industrial facilities the use of compressed air is considered a free utility. During the audit, many air leaks were observed. A quarter inch hole with air pressure at 100 psi will waste about 100 cfm. A typical reciprocating compressor produces 5.3 cfm per horsepower. Therefore, the 100 cfm requires 19 horsepower or 16.5 kW of energy. For 6,000 hours of compressed air use, this comes to about 100,000 kWh wasted, or a cost of $5,000 dollars annually. Therefore, it is strongly recommended that a strict maintenance schedule be used to identify existing air leaks and plan for immediate repairs.

9. Repair Dryer Steam Leaks

There were a number of steam leaks in the wood dryers in the framing area. Most of the leaks involved dampers for ducting that were not sealing properly. Allowing these leaks to continue can be very costly. Also, in the house construction area the main dryer was leaking steam due to the roof being in disrepair. It is difficult to estimate the leakage of the steam, but the dryer itself is rated for 4.71 Gcal/hr of steam. If it is assumed that 10% is being wasted, at an annual operation of 6,500 hours the annual steam wasted is 3,062 Gcal. This results in a annual cost of $18,000. Therefore, it is recommended that this problem be addressed soon.

4.2 Long-term Energy Conservation Opportunities

The long-term measures discussed in this section are more complex, typically more costly, and involve a more in-depth engineering and economic analysis with the inclusion of production factors other than energy. The long-term measures recommended are:

- Heat recovery for air compressors
- Steam control for log bath
- Reduce cooling water required
- Time of use rates/demand charges

1. Heat Recovery For Air Compressors

There is the potential at the facility to use the heat from the air compressor's cooling water to heat the portable hot water in the plant. The average temperature of the cooling water is 35 °C. Assuming an average city water temperature of 10 °C, 150 m^3/day of hot portable water, and 70 m^3/day of compressor cooling water required, heat recovery could save about 510 Gcal/year. This is a cost savings of $3,000. An economic analysis should be performed based on the cost of this project.

2. Steam Control For Log Bath

The log bath is used to heat and soak the logs to make cutting them easier. The soaking of the logs is the main objective so the baths just need to remain unfrozen. The baths are heated by steam injection and during the audit the temperature of one bath was 20 °C. Therefore, it is recommended that a better control scheme be developed to more closely meet the thermal needs of the bath, thus reducing steam use. It may also be possible to use the hot waste water from the press in the wood plate section to heat the bath water. This project should be investigated further.

3. Reduce Cooling Water Required

In the thermal area, treated cooling water is brought from the power station to cool the condensate water returning. Presently there is no charge for this water, but the plant staff said that soon there may be a substantial charge for the water. Once this charge occurs, the use of heat exchangers to reduce the condensate temperatures and the cooling water requirements should be investigated. A good opportunity would be to use the condensate heat for the heating of the thermal water used in the facility.

4. Time Use Rates/Demand Charges

Western type time of use rates or demand charges are not used. The government of Lithuania should consider implementing time of use rates or demand charges for electric consumption. Higher electric rates at coincident or non-coincident peaks will provide the market with pricing signals to encourage conservation, minimize new plant construction, and make more efficient use of existing resources.

4.3 USAID Equipment Specification For Selected ECOs

This section describes the specifications for the equipment recommended for purchase and implementation by USAID. Calculations for the energy savings expected by the implementation of this equipment and the economic justification is in Section 4.1. The energy conservation opportunities that the equipment addresses are:

1. Computer Energy Management

Portable PC Computer with Printer ($4,500)

- Epson 386 or similar
- Bubble jet printer
- Compatible software including:
  - Spreadsheet
  - Word processing
  - Energy management programs
- 220 volt/50 Hz

2. Demand Control For Lacquer Dryers

Portable Power Analyzer ($6,000)

- DRANETZ
- Max. Voltage 600 volts
- Max. Current 1,000 amps
- Memory (one week at 15 min readings)
- Measure: volts, amps, vars, power factor, kW
- Ability to download to computer
- Hard copy printout
- 220 volt/50 Hz

3. Increase Furnace Combustion Efficiency

Combustion Analyzer ($6,500)

- ENERAC 2000
- RS-232 Port
- 220 volt/50 Hz
- Four foot probe
- Extra desiccant
- Extra paper

High Temperature Infrared Sensor ($2,000)

- Heat Spy (WAHL DHS-52C)
- Temperature range: 600 °C to 3,000 °C

4. Pipe Insulation Upgrade

Low Temperature Infrared Sensor ($2,100)

- Digital Heat Spy
- Temperature range: 0 °C to 1,000 °C

5.0 Plant Management Organization/Recommendation

Our discussions with plant management indicate that energy conservation measures do not have a high priority. This appears to be due to a lack of finances and a lack of materials. There also appears to be a problem with prioritizing projects and available resources. Major improvement projects are attractive, while potentially cost saving low-cost/no-cost projects go unattended. The current organization does not lend itself to promoting energy efficiency projects.

It is recommended that the organizational structure be altered to focus efforts on developing justifiable priorities for energy conservation projects. The Chief of the Energetics Department should have an energy engineer directly responsible for investigating and justifying energy cost cutting projects. And as importantly, the Chief of Energetics should have a more direct link with the Director of Construction. With this link, long-term plans can be developed and projects economically justified for consideration by the Technical and the General Director.

LEFT SIDE
ZONE 1, FRONT

SERIAL # 11100046
ENERAC MODEL 2000
COMBUSTION TEST RECORD

FOR: R.M.A.

TIME: 09:56:01
DATE: 01/18/92

FUEL NATURAL GAS:21870 BTU/LB

COMBUSTION EFFICIENCY:	67.8	%
AMBIENT TEMPERATURE:	11	°C
STACK TEMPERATURE:	383	°C
OXYGEN:	02.1	%
CARBON MONOXIDE:	2532	PPM
CARBON DIOXIDE:	10.6	%
COMBUSTIBLE GASES:	0.32	%
STACK DRAFT (INCHES H20):	+ 00.0	
EXCESS AIR:	10	%
CARBON MONOXIDE ALARM:	50	PPM

MODE:PPM OXY_REF=TRUE%

MAIN STACK
RIGHT SIDE
SOON AFTER SWITCH

SERIAL # 11100046
ENERAC MODEL 2000
COMBUSTION TEST RECORD

FOR: R.M.A.

TIME: 10:36:39
DATE: 01/18/92

FUEL NATURAL GAS:21870 BTU/LB

COMBUSTION EFFICIENCY:	49.3	%
AMBIENT TEMPERATURE:	11	°C
STACK TEMPERATURE:	390	°C
OXYGEN:	13.9	%
CARBON MONOXIDE:	70	PPM
CARBON DIOXIDE:	04.0	%
COMBUSTIBLE GASES:	0.00	%
STACK DRAFT (INCHES H20):	+ 00.0	
EXCESS AIR:	179	%
CARBON MONOXIDE ALARM:	50	PPM

MODE:PPM OXY_REF=TRUE%

MAIN STACK
(COMBINED, LEFT SIDE)

SERIAL # 11100046
ENERAC MODEL 2000
COMBUSTION TEST RECORD

FOR: R.M.A.

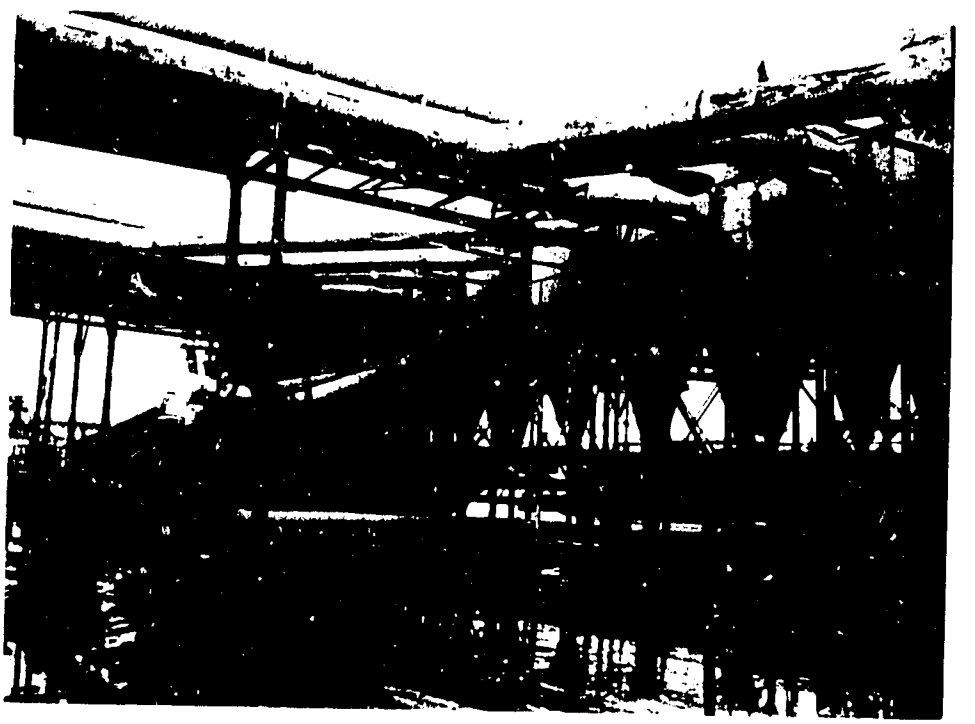
TIME: 10:32:36
DATE: 01/18/92

FUEL NATURAL GAS:21870 BTU/LB

COMBUSTION EFFICIENCY:	49.7	%
AMBIENT TEMPERATURE:	11	°C
STACK TEMPERATURE:	449	°C
OXYGEN:	12.4	%
CARBON MONOXIDE:	7	PPM
CARBON DIOXIDE:	04.8	%
COMBUSTIBLE GASES:	0.00	%
STACK DRAFT (INCHES H20):	+ 00.0	
EXCESS AIR:	133	%
CARBON MONOXIDE ALARM:	50	PPM

MODE:PPM OXY_REF=TRUE%

1. Plant drying kiln and vents. A plant worker (front), Valentinas Anuzis, a representative from the plant (middle), and Virginijus Buciunas from NEGA. W. (back) are all pictured.



2. The plant dust collection system cyclones.

[redacted]

AC	= alternating current
amps	= amperes
atm	= atmosphere = 14.696 pounds per square inch
bar	= 100,000 pascals = 14.504 pounds per square inch
BTU	= British thermal unit
cfm	= cubic feet per minute
cm	= centimeter = 0.3937 inches
cm^2	= square centimeter = 0.155 square inches
CO	= carbon monoxide
CO_2	= carbon dioxide
DC	= direct current
°C	= degree Celsius T[°C] = 5/9*(T[°F] - 32)
°F	= degree Fahrenheit
°R	= degrees Rankine T[°R] = T[°F] + 460
ECO	= Energy Conservation Opportunity
eff	= efficiency
ex air	= excess air
ft^2	= square feet
ft^3	= cubic feet
Gcal	= gigacalorie = 1 billion calories = 3.968 million BTU
GJ	= gigajoules = 1 billion joules
gph	= U.S. gallons per hour
gpm	= U.S. gallons per minute
GWh	= gigawatt hours = 1 billion watt hours
H_2	= hydrogen
H_2O	= water
H_2SO_4	= sulfuric acid
hectare	= 10,000 square meters = 2.471 acres
hectoliter	= 100 liters = 26.42 U.S. gallons
Hg	= mercury
hr	= hour
Hz	= hertz = cycles per second
J	= joules
kcal	= kilocalories = 1 thousand calories = 3.968 BTU
kg	= kilogram = 2.2046 pounds
Kgcc	= 7,000 Kcal = 27,776 BTU
kJ	= kilojoules = 1 thousand joules = 0.947813 BTU
km	= kilometer = 0.621 miles
kN	= kilonewton = 1 thousand newtons
kp	= kopeck = 1/100 ruble
kPa	= kilo pascals = 1 thousand pascals = 0.14504 pounds per square inch
kV	= kilovolts = 1 thousand volts
kVA	= kilovolt-amperes
kVAr	= kilovars = 1 thousand volt-amperes (reactive)
kW	= kilowatt = 1 thousand watts
kWh	= kilowatt hour = 1 thousand watt hours
lbs	= pounds

liter	= 0.2642 U.S. gallons = 0.03531 cubic feet
m	= meter = 39.37 inches
m^2	= square meter = 10.76 square feet
m^3	= cubic meter = 35.31 cubic feet
mA	= milliampere = 0.001 amperes
MCal	= megacalorie = 1 million calories
metric ton	= 1 thousand kilograms = 1.1023 U.S. tons
mg	= milligrams
min	= minute
MJ	= megajoules
MM	= million
mm	= millimeter = 0.03937 inches
MPa	= 1 million pascals = 145.04 pounds per square inch
MVA	= megavolt-amperes
MW	= megawatt = 1 million watts
MWh	= megawatt hours = 1 million watt hours
NG	= natural gas
nm	= nanometer
Nm^3	= cubic meters at standard conditions of temperature and pressure (20°C and 1 atmosphere)
NO_X	= nitrogen oxide
O_2	= oxygen
P	= pressure
PC	= personal computer
ppm	= parts per million
psi	= pounds per square inch
psig	= pounds per square inch (gauge)
R	= ruble = 70R/US$1
s	= second
SO_2	= sulfur dioxide
sq ft	= square feet
Tcal	= teracalorie = 1 trillion calories = 3.968 billion BTU
T	= temperature
V	= volts
VArs	= volt-amps (reactive)
VSD	= variable speed drive
yr	= year