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RESOURCE MANAGEMENT ASSOCIATES
of Madison, Inc.

ENERGY EFFICIENCY AUDIT REPORT

KAUNAS CERAMICS FACTORY
Kaunas, 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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ENERGY & INFRASTRUCTURE DIVISION
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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 four 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. The GOL will be provided with analysis and recommendations for further energy efficiency measures.

ii. Executive Summary

An industrial energy efficiency audit was conducted at the Kaunas Ceramics Factory located in Kaunas, Lithuania. The Kaunas Ceramics Factory utilizes energy in the form of natural gas, heavy oil, and electricity for the production of bricks and ceramic building material. Three primary building materials are produced at the factory including: bricks, roofing tiles, and a ceramic pellet material that is used for insulation. The primary application for the pellet insulation is in the construction of concrete walls for buildings. 41 million bricks and 3 million tiles per year are produced. 400,000 cubic meters of ceramic insulation are also produced in two different processes. The dry process area is identified as Ceramics #1 and the wet process area is identified as Ceramics #2. Each process produces a different material with specific properties. A small amount of specialty tile and bricks for building restoration are also produced. Raw materials are locally derived and the dominant market for the finished products is the domestic market. This is a highly energy intensive business with energy costs representing approximately 41 percent of their operating costs and that cost is expected to rise rapidly with the depreciation of the Ruble.

The steam and thermal water systems are in generally good repair. There are some areas where steam and thermal water piping insulation has deteriorated or is non-existent (discussed under recommended improvements). A few minor steam leaks were apparent. Direct steam is used only in the heavy oil handling process which uses approximately 10 percent of the steam directly with no condensate return. The major fuel consumption is used for process heat requirements in the production of ceramic pellets, building bricks, and ceramic tile roofing material.

During the audit, it was clearly apparent that the personnel operating the plant were very aware of their greatest energy efficiency problems. With the right instrumentation and information on equipment available outside of Lithuania, plant personnel are in the best position to justify energy efficiency measures within the other constraints of the operation. Therefore, for short-term measures, the audit focussed on identifying information and control needs in terms of instrumentation and foreign equipment not available to the plant. Both short-term measures and long-term measures were recommended for the plant.

Short-Term Energy Management Equipment Recommendations

There are 14 major fuel-burning systems operating at the Kaunas Ceramics Factory with minimal control of fuel and air and no monitoring of combustion products to measure combustion efficiency. Utilizing the portable equipment will improve energy efficiency of the boilers, kilns and dryers by providing data on efficiency measures, oxygen concentration measurements in the exhaust gases, and temperature measurements within the kilns.

The lack of an effective metering system for steam also contributes to the boilers working at low efficiency except when fully loaded. There is no steam metering for the production of the thermal water which is sold to the local residential users or to the factory. Users are satisfied with the estimated energy sold to them by the plant.

Boiler, Kiln, and Dryer Combustion Efficiency Metering

Boiler flue gas energy losses due to high levels of excess air can be reduced by routine monitoring with a combustion analyzer and manual adjustment of the boiler combustion controls. Kiln and dryer flue gas energy losses due to high levels of excess air can also be reduced by routine monitoring with a combustion analyzer and manual adjustment of the combustion controls. As part of the inspection and training aspect of this project, boiler combustion analyses were conducted using a portable combustion analyzer.

Estimated savings for all applications is a two percent increase in overall efficiency of the boilers, kilns, and dryers resulting in a savings of 1.06 million cubic meters of gas saving $113,000 for an 18 day payback period.

Infrared Temperature Measurement

Currently kiln operators sit at the end of the kiln and watch the flame and flow of pellet material along the wall of the rotating kiln. They take random samples of the pellet density after the pellets have cooled. From these quantitative data, they modulate the fuel and air flows. Temperature data using a non-contact infrared high temperature device along with a portable combustion analyzer will provide quantitative data to the operators that could result in at least a one percent improvement in fuel utilization efficiency. This would save 490,000 cubic meters of natural gas per year or a savings of $51,450 annually. The cost of a Wahl Heat Spy with a temperature range of 600 to 1,000 °C is $2,350 for a total cost of $4,728. The resultant payback period is 33 days.

Orifice Steam Meters

Boiler steam output is currently measured with a non-pressure compensated steam flow meter. This results in the boiler operators having to correct flow meter readings which is usually done for record keeping purposes. With the current operating procedure of allowing the boiler pressure to float between 4 and 7 bar to accommodate regulation of the thermal water production, the boiler operators do not have current data on the steam production from the boilers. This, along with the lack of combustion efficiency measurements results in the boilers being operated at low efficiency. Providing accurate steam metering and combustion efficiency test equipment will allow operators to correct the operating deficiencies and should result in an increase in the boiler efficiency from 72% to 84%, saving 750,000 cubic meters per year of natural gas at the boiler house.

Total cost for five pressure cells and a single monitoring device is approximately $3518. The incremental increase in efficiency form operating the boilers at a constant know pressure is a two percent increase in overall operational efficiency. This will result in a savings of 90,100 cubic meters of natural gas. At a value of 10.5 cents per cubic meter, the annual savings is estimated to be $9460 annually for a payback period of 4.5 months.

Thermal Water Temperature Control

Steam is produced at the boiler house to provide direct steam for handling mazut (heavy fuel oil) and to produce thermal water for distribution to the factory and to residential users for space heating purposes. Approximately 90 percent of the steam is used at the boiler house in steam to water heat exchangers with the remaining 10 percent used as direct steam in mazut handling with no condensate return. 1991 data in *Figure 8* shows a maximum thermal water production of 4,176 Gcal in February and 1,250 Gcal in August. Total thermal water production in 1991 was 31,150 sent to the thermal water end-users. The only mechanism for controlling heat is to control steam production from the boilers by varying the fuel input and steam pressure level. The steam pressure level varies between 4 bar and 7 bar to accommodate steam production levels. Utilization of steam flow control valves at the steam to water heat exchangers will provide control of the out-going water temperature and allow operation of the boiler at a constant pressure providing for more effective operation of the boiler.

Cost for a 150 mm, 125 psi rates valve with a capacity of 7 metric tons per hour with all actuators is $3,100. Three valves will cost $9,300. The resultant payback period is 4.3 months.

The table below summarizes the short-term savings from implementing the recommendations.

Measure	Energy Saved (Gcal)	Annual Savings (1000s Ruble)	Annual Savings (1000s $)
1. Combustion analyzer	8080	12420	103.5
2. Infrared temp. meter	3920	6180	51.5
3. Steam meter	720	1140	9.5
4. Water temp. control	1760	3084	25.7

Long-Term Recommendations - Power Plant

The long-term ECO's require larger capital investments than the short-term ECO's and have longer payback periods. Therefore, these measures should be performed after the short-term ECO's and should be investigated further by the plant staff. These items are recommended by the auditors but not funded by USAID. These items are recommended by the auditors but not funded by USAID.

Replacement of Tile Material Dryer Chains

The cost of replacing the chains was estimated by plant staff at 100,000 rubles. The air flow through the dryer was estimated by the staff to be about 25,000 M^3/H.

Replace Incandescent with Fluorescent Lights

There are a number of areas that use incandescent lighting. Many of these areas could use fluorescent lighting and reduce the electric energy consumed considerably.

Repair Windows to Reduce Leakage

After the ventilation system is brought into balance, and the make-up air is sufficient to meet the exhaust air, tightening up the windows will reduce infiltration and reduce heating energy. Reparation of the windows could include complete replacement or maintenance of the window to ensure a snug fit with the frame.

Uninsulated Piping

A number of uninsulated pipes containing thermal water, steam, and condensate were observed. The majority of the plant piping is adequately insulated. However, several areas experience over-heating due to large lengths of uninsulated piping. Ventilation air is required during parts of the year to maintain worker minimum comfort. This compounds an inefficient situation by using energy to mitigate the impacts of energy loss.

In summary, plant management has not had the luxury to maintain their equipment properly due to the continual demand on the plant. They have been much more concerned with maintaining the operation of the equipment than improving the efficiency. They are just now in a position to use economic justification to request authorization to purchase energy efficient equipment. Besides being inadequately maintained and of inadequate capacity, the system is very old. Therefore, in the long-term, management will need to be making decisions about large investments in new equipment. The equipment recommended in this report will allow them to make informed decisions optimizing short and long-term investments.

1.0 Plant Description

1.1 General

The Kaunas Ceramics Factory is located in the city of Kaunas, Lithuania. The plant has a staff of 600 working three shifts per day seven days a week. The telephone number and address are:

Kaunas Ceramics Factory
Palemono Valstybines, Keramikos Gamyklos
Pamario 1
Kaunas 233023 Lithuania
Telephone: 73-73-63

Three building materials are produced at the factory: bricks, roofing riles, and ceramic pellet insulation. The primary application for the pellet insulation is in the construction of concrete walls for buildings. Raw clay is brought in by truck for the tile and brick products. The company owns the clay deposit and transports the clay to the factory using their own narrow gauge railway. Forty-one million bricks and 3 million tiles per year are produced. Four-hundred thousand cubic meters of ceramic insulation are also produced in two different processes. The dry process area is identified as Ceramics #1 and the wet process area is identified as Ceramics #2. Each process produces a different material with specific properties. For example, a small amount of specialty tile and bricks for building restoration are produced. Raw materials are locally derived and the dominant market for the finished products is the domestic market. This is a highly energy intensive business with energy costs representing approximately 41% of their operating costs. The energy cost is expected to rise rapidly with the depreciation of the ruble.

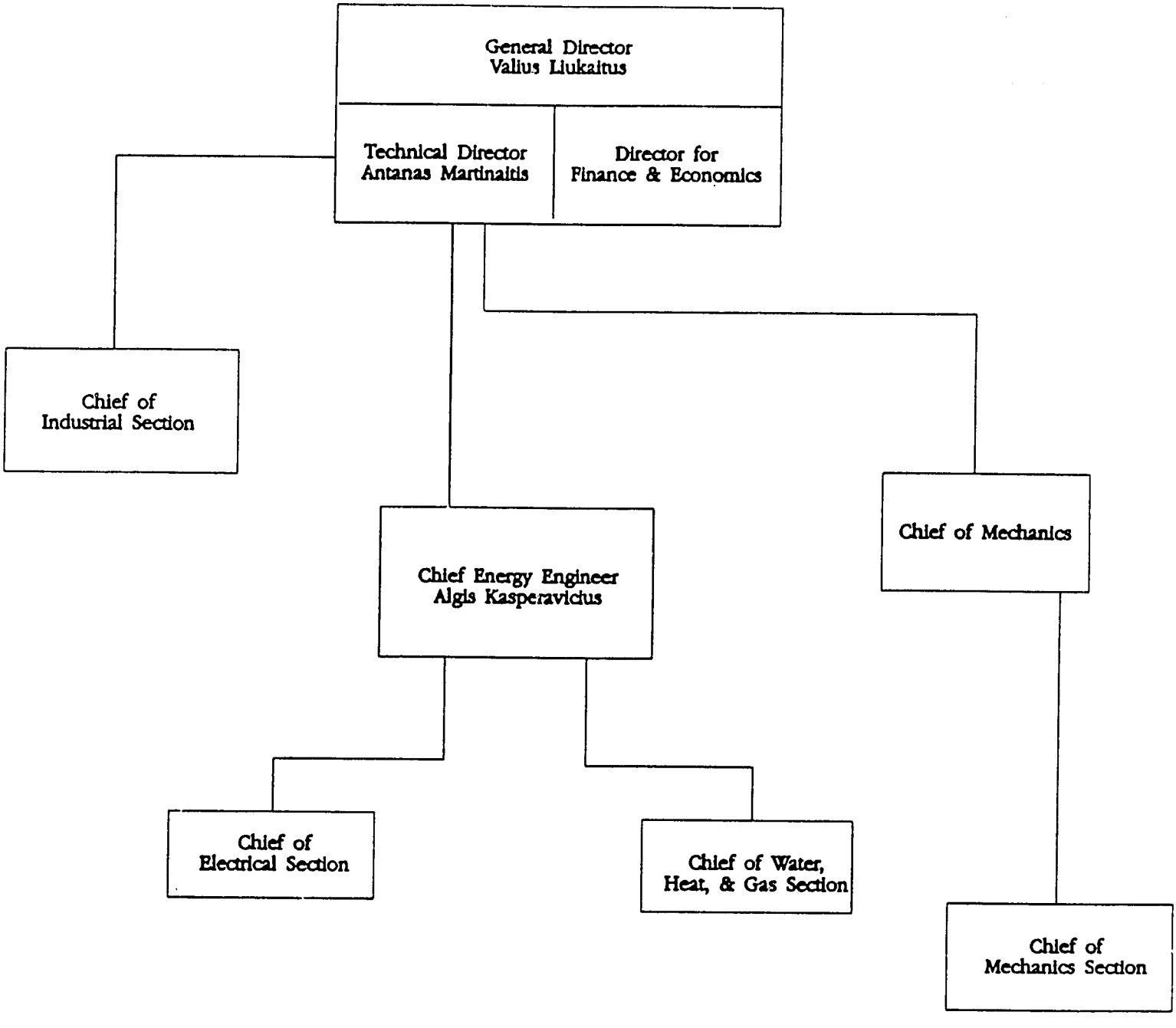
1.2 Organization

The key plant staff with whom the U.S. audit team met are the following individuals:

Mr. Valius Liukaitus, General Director
Mr. Antanas Martinaitis, Technical Director
Mr. Algis Kasperavicius, Chief Energy Engineer.

The plant organizational chart is provided in *Figure 1*. Production of the products is directly related to the energy systems. Energy costs are a major portion of their production costs. As a result, the Technical Director and Chief Energy Engineer are responsible for the production related issues as well as maintenance, repair, and up-grade of the plant production and energy systems. The Chief Energy Engineer has been at the plant for over forty years and has had direct working experience in all segments of plant operations. Both the Technical Director and Chief Energy Engineer were active participants in conducting the energy audit.

Figure 1. Plant Organizational Chart



1.3 Electrical Description

The facility is directly connected to the power grid via four transformers. These transformers feed the 380V/220V plant electrical distribution system. Key electrical parameters are the following:

Peak Load:	3,000 kW
Installed Capacity:	7,000 kW Transformers, 8,000 kW motors
Annual Cost:	1.22 million R/yr, 19.5 MM kWh
% of Operating Cost:	12-15 %
Power Factor:	0.3 Reactive Load, due to a lack of capacitors and auto-switch capacitors.
Metering:	Major buss and sub-metering installed; 80% of consumers are metered.
Equipment:	Motors (100-200 kW), Asynchronous type, one electric furnace (30 kW)
Distribution:	Motors 93% Lighting 7%
Electricity Cost:	.067 R/kWh

Electric energy use is distributed between process and its use and is measured during the process by electrical sub-metering. Electricity consumption is about 17,000 MWh/yr and represents 15% of operating costs.

1.4 Thermal Description

The factory produces steam for in-plant processes, its own heating needs, and supplies a small residential district heating system with thermal water. Plant space heating and district heating is done with thermal water through a steam-to-water heat exchanger. District heat users are charged a separate fee. Steam is also used directly for the handling of heavy fuel oil and the cleaning of oil rail cars. Direct consumption steam accounts for 10-15% of the annual boiler output depending on space heating requirements. Details of steam production and consumption are as follows:

Boilers - Three Russian-made (installed 1968) boilers supply steam to a common header for distribution:

Capacity:	6.6 metric tons per hour each
Pressure:	13 bar saturated steam (nominally operated at 7 bar)
Temperature:	191 °C (nominally operated a 167 °C)
Fuel:	Pipeline natural gas from the Soviet Union
Operations:	2 on-line, one not operational
Type:	Water tube with economizer, no combustion air preheater (other than drawing combustion air from inside the boiler house)
Controls:	Strictly manual, no stack gas monitoring
Instrumentation:	Pressure/Temperature/Water Level only

The boilers are operated in a range of pressure from 4 - 7 bar to control the steam required for the thermal water heat exchangers. Steam is distributed to the heavy oil handling area and the thermal water heat exchangers located in the boiler house via a header operating at 4 - 7 bar. A schematic of the steam system is presented in *Figure 2*. Approximately 10% of the steam is consumed in the plant for heavy fuel oil handling with the remainder used for the production of thermal water. Thermal water is used in the factory for direct radiator space heating and to heat ventilation make-up air. It is also exported to a small group of residential users that use approximately 30% of the thermal water production. Thermal water billing is done (and accepted by the customers) using estimates calculated by the factory staff. There is no separate metering for district heat customers.

Each boiler has a steam flow meter that is not pressure compensated. The steam meters are calibrated for operation at 7 bar. A scaling coefficient is used to adjust the steam meter readings when the boilers are not operating at 7 bar. Data from these meters along with estimates of use by other end users of steam and thermal water are the basis for the steam balance data shown in *Figure 2*. Also note that flow quantities are for one specific day Jan 20, 1992 and do not indicate equipment capacity ratings. Energy from the steam produced exceeds the incoming energy of the natural gas indicating that in addition to the lack of meters for steam and thermal water customers, the meters that are present are largely inaccurate. Condensate is not recovered from the heavy oil handling area because of the potential for contamination.

Boiler fuel consumption represents approximately 8.4% of the natural gas used at the factory. There are an additional 12 fuel burning systems that represent the process equipment of the ceramics product. Process thermal loads for natural gas-fueled systems include:

6 - Rotary kilns for insulation material
2 - Tunnel kilns for bricks
1 - "Zigzag" kiln for tiles
1 - Dryer for tiles
2 - Rotary dryers for tile materials.

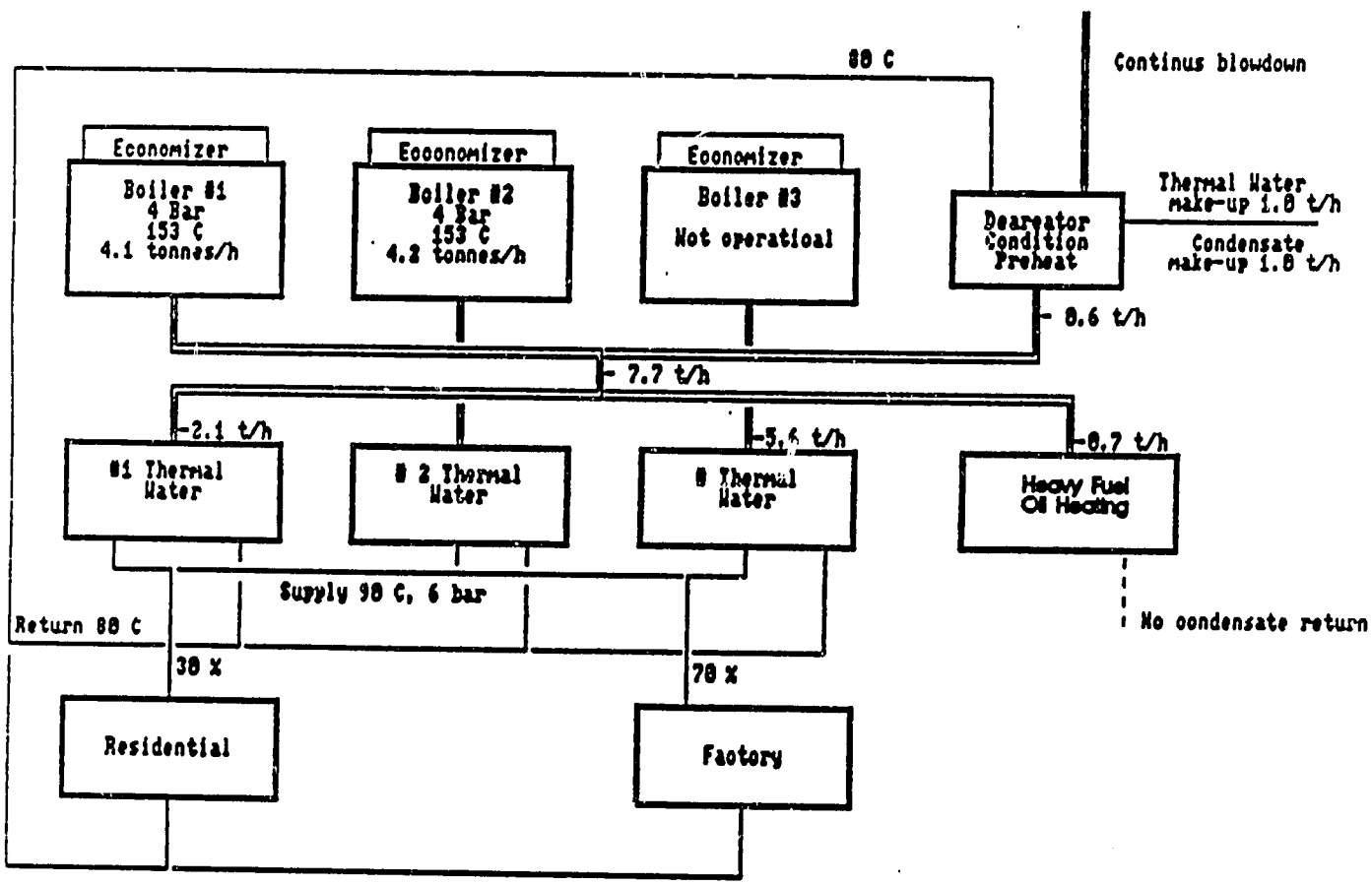
Typical operating temperatures are 1,000 °C, with little or no air preheat and no O_2 control. Typical burner operating rates are 700 - 1,000 Nm^3 per hour with limited fuel controls and no air/fuel ratio control. Flue gas temperatures average between 300-350 °C and provide little opportunity for waste heat recovery. Each furnace is rebuilt every year. Total gas consumption is 53 million m^3/yr.

Fuel is about 28% of production costs, all energy is therefore approximately 41% of the operating cost. All units listed as tons are metric tons.

Figure 2. Schematic of Steam System

Figure 2 Kaunas Ceramics Boiler Steam Flow Diagram

(January 20, 1992)



1.5 Process Description

Raw materials come into the plant in the form of virtually dry clay from several sources. This clay is processed in one of two methods, wet or dry, to form the moist clay. The moist clay is shaped into a specific product and then fired in one of the kilns to finalize its production process. In the firing process, the clay changes state becoming a hard brittle material highly resistant to absorbing water.

The wet process is used to produce tiles and ceramic pellets in the Ceramics #2 area. Water is mixed with clay to form a fluid mixture that is strained to remove rock and other large particles. It is then dried to form tiles and pellets, depending on the process.

The material for tiles is dried from the fluid state in one of two rotary dryers fueled by natural gas. The material, dried to about 55% moisture, is aged for 7 days in a holding room and then formed into tiles. The moist tiles are dried to a leather hard state in an Italian manufactured dryer. Dry tiles are then transferred to the "Zigzag" kiln where they are fired to their finished state.

Wet material for production of pellets has heavy fuel oil and other materials added. This is done to expand the ceramic material during its firing process which reduces its density and improves its insulation value. The wet material is introduced directly into the dryer section of the kiln.

In the dry process, much less water is used and therefore the energy intensity of producing bricks and pellets in the Ceramics #1 area is much less than for tiles and pellets produced in the Ceramics #2 area. While in the plastic state, the clay is formed into bricks or pellets. The bricks are dried in chambers using waste heat from the two tunnel kilns that fire the bricks. After the bricks are dried to a leather hard stage, they are sent through the tunnel kiln. The tunnel kiln is a continuously operating kiln through which carts of bricks move from pre-heating to firing to cool-down portions of the kiln.

The drying of the pellets in the Ceramics #1 area is accomplished in a rotary dryer that uses waste heat from the kiln to dry the material before it is introduced into the kiln.

2.0 Plant Energy Profile

Kaunas Ceramics Factory utilizes energy in the form of natural gas and electricity for the production of ceramics. There are some areas where steam and thermal water piping insulation has deteriorated or is non-existent (discussed under recommended improvements). A few minor steam leaks were apparent. With only a few apparent small leaks and a known amount of steam used directly in drying, the remaining steam loss could not be accounted for. Plant personnel suspect that the commercial metering equipment is faulty.

Table 1 contains the annual natural gas, thermal water, and electrical profiles for 1991. *Figure 3* shows the 1991 Electric energy use by area. *Figure 4* shows the annual use profile of electricity for 1991 by month. Energy requirements vary slightly through the year. However, the cost increased by a factor of 3 from December 1990 to November 1991. This is due to the Lithuanian shift toward world energy prices. A typical hourly electric demand profile for a summer and winter day is shown in *Figure 5*. 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.

Figure 6 shows the 1991 natural gas use by area. *Figure 7* shows the annual use profile of natural gas for 1991 by month. Energy requirements vary somewhat with season through the year.

Figure 8 shows graphically the annual production of thermal water by month in 1991. Energy requirements vary seasonally throughout the year. This thermal water is delivered to the factory areas and the a residential district heating system. Steam from the boilers is used to produce the thermal water which is supplied at an apparently constant temperature of 90 °C.

Table 1. Annual Profiles for 1991

TABLE 1
Kaunas Ceramics Factory 1991

Month	Thermal Water Gcal	Electricity MWh	Nat. Gas 1000 Nm(3)
Jan	3500	1650	6500
Feb	4050	1610	5100
Mar	4250	1550	4700
Apr	3700	1650	5100
May	2750	1350	3350
Jun	1600	1500	4250
Jul	1400	1450	4100
Aug	1250	1430	4250
Sep	1400	1440	4300
Oct	2150	1390	3250
Nov	2550	1360	4000
Dec	2550	1500	5000
Total	31150	17880	53900

Thermal Water produced in on-site boiler house
Annual heavy oil consumption 3838 metric tons

Figure 3. Annual Use Profile for Electricity in 1991

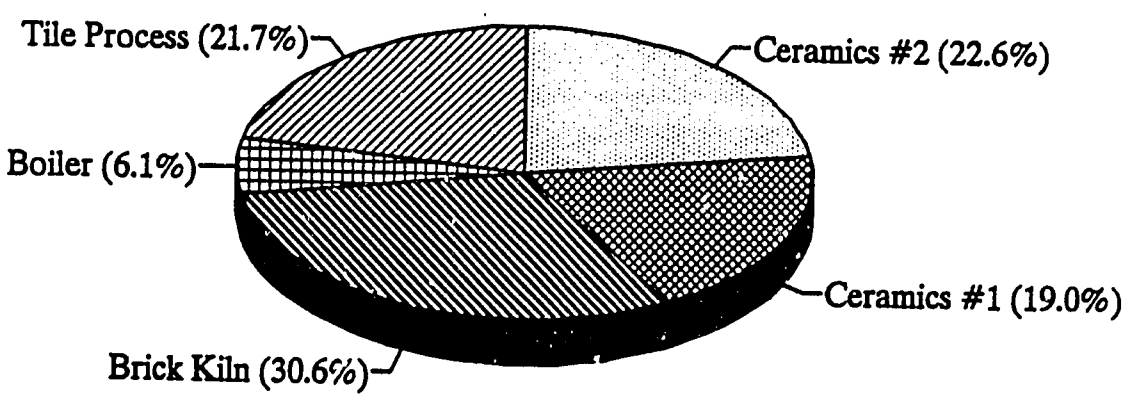


Figure 4. Annual Use Profile for Electric Energy by Month in 1991

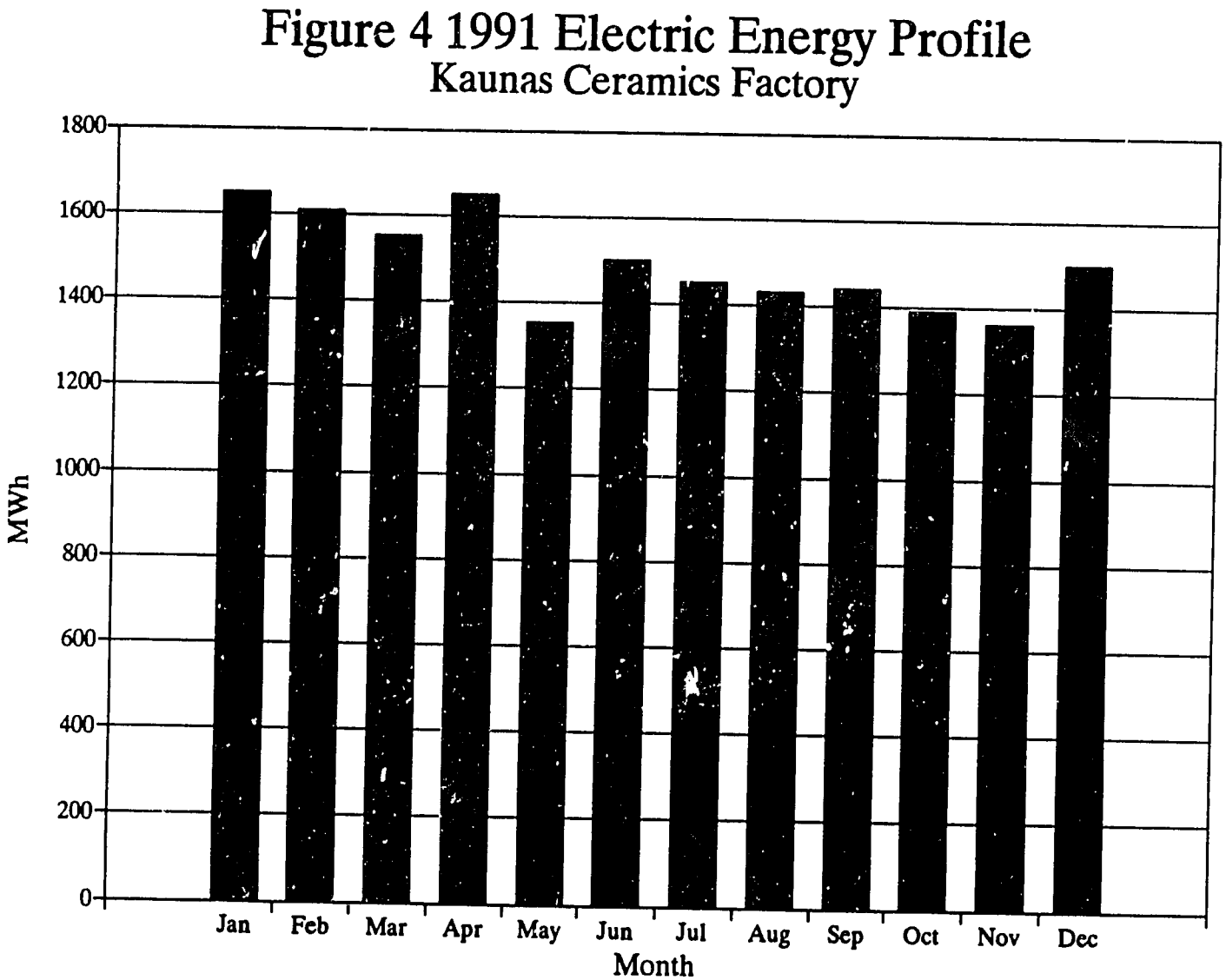


Figure 5. Average Hourly Load Profiles

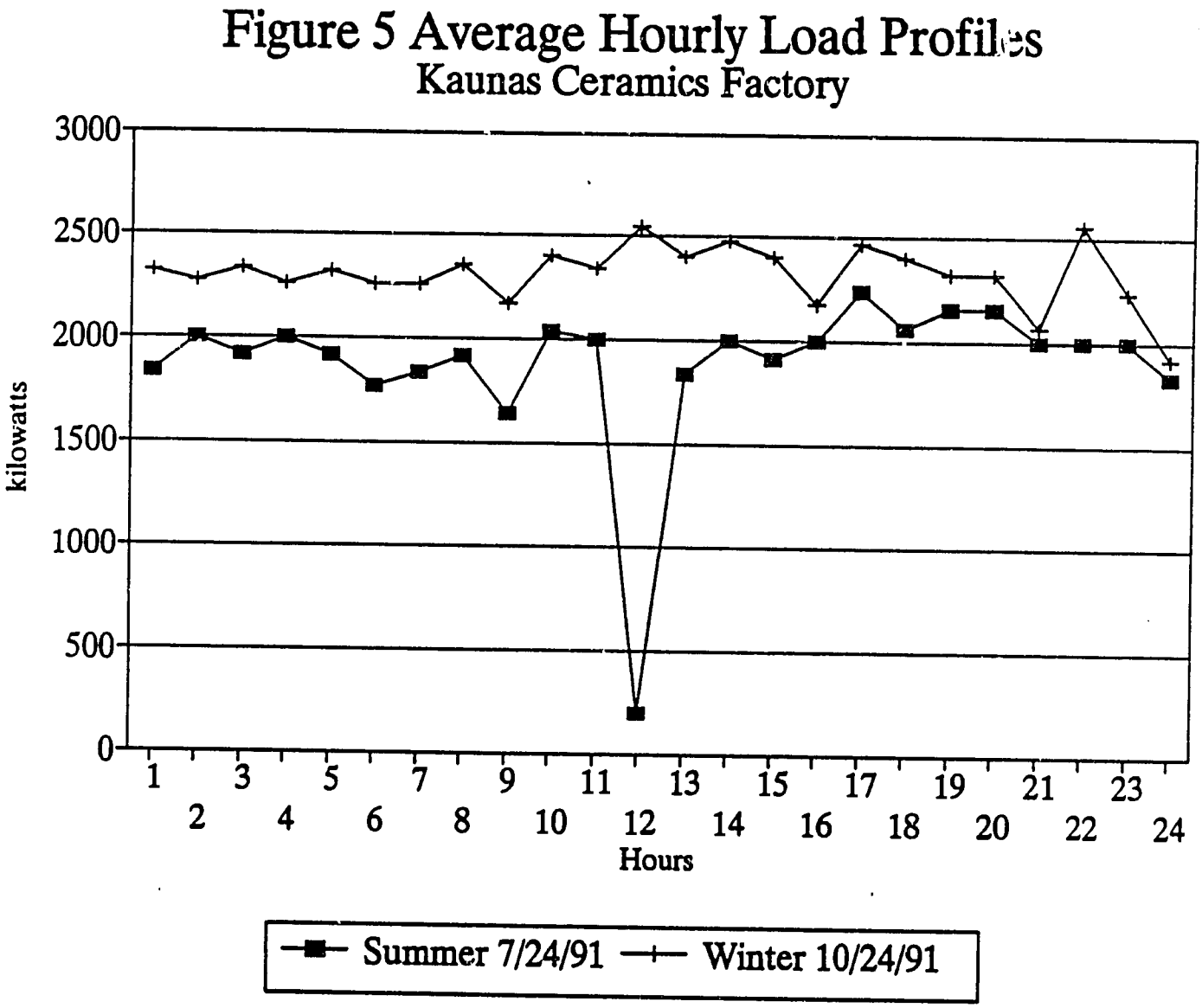


Figure 6 1991 Natural Gas Use
53,900,000 cubic meters

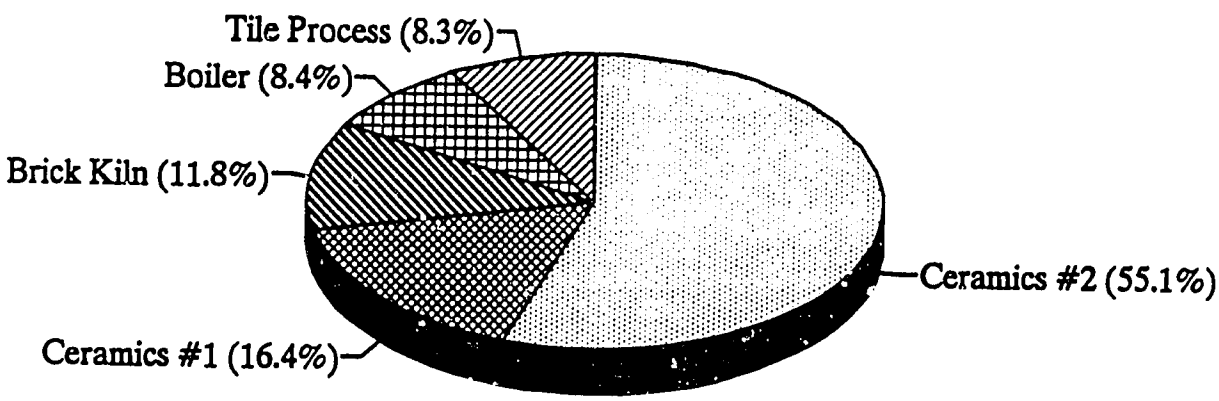


Figure 7. Annual Use Profile for Natural Gas by Month in 1991

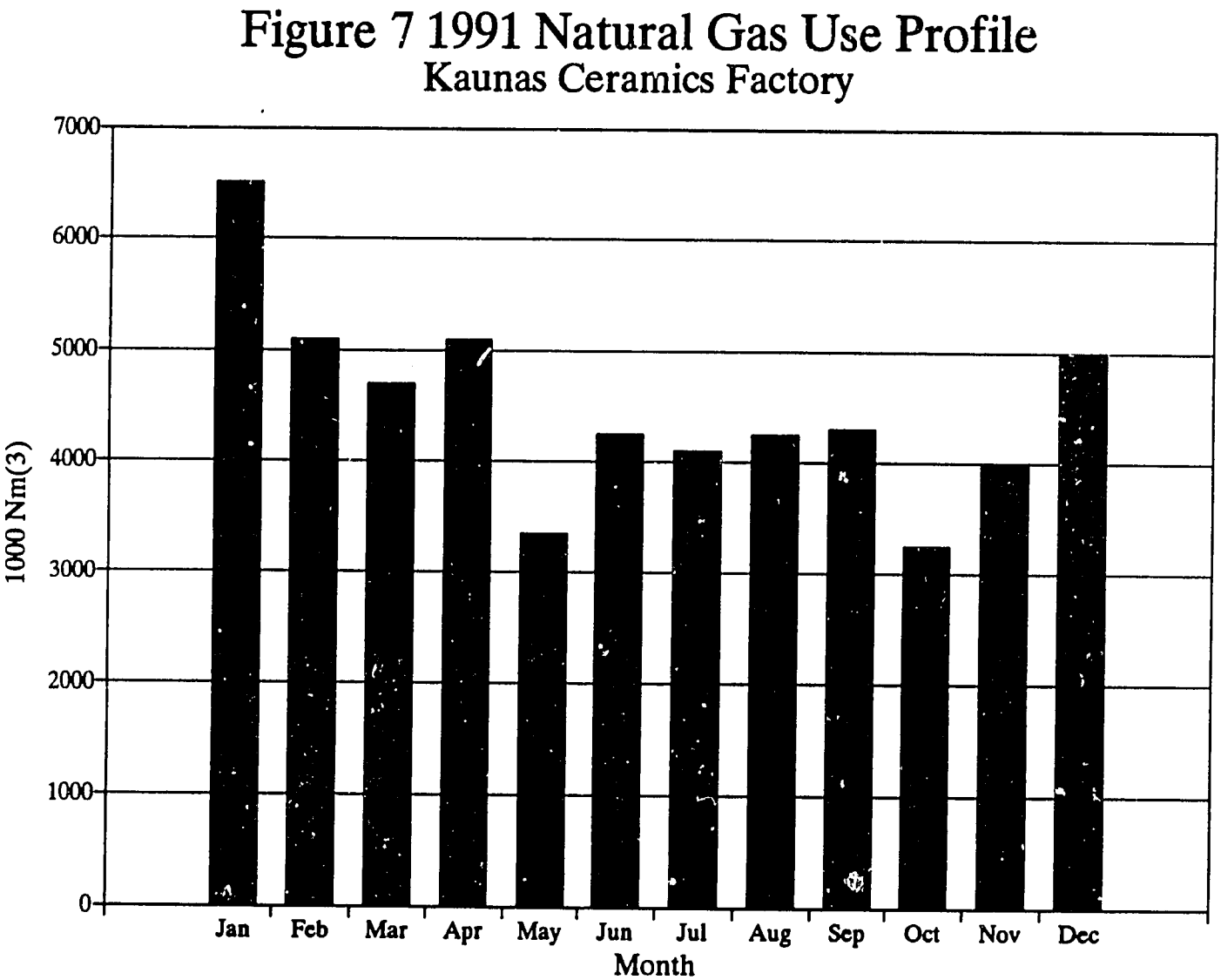
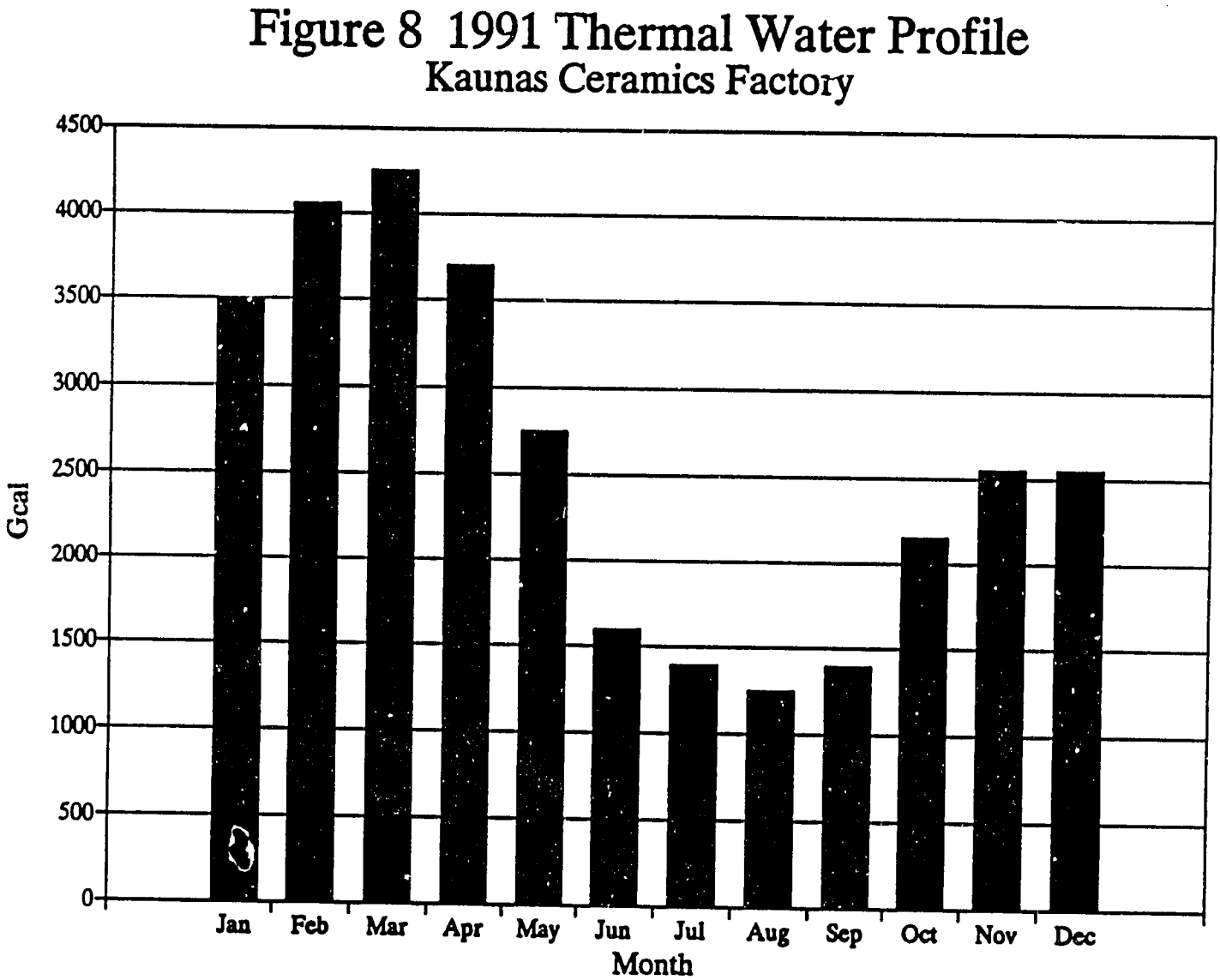


Figure 8. Annual Production of Thermal Water by Month in 1991



3.0 Audit Description

The audit began with a meeting at the plant on January 20, 1992 attended by Mr. Liukaitus, plant General Director; Mr. Martinaitis, Technical Director, Mr. Kasperavicius, Chief Energy Engineer; and the audit team. Specific areas of the plant to be audited in detail were selected. These areas/items included: piping insulation; uncontrolled building heating (see Photograph 1 in **Appendix A**); temperature and flow measurements of steam and thermal water; and combustion analysis measurements of the large number of fuel-burning systems that are used to produce steam and process heat for production of the ceramic products. Methods and procedures for controlling the kilns, dryers, and boilers were reviewed. Audit data collection and measurement were started on Tuesday and completed on Thursday. Virginijus Buciunas of NEGA W., a private contractor, assisted with equipment selection during the audit and will continue to assist the auditors as necessary regarding further equipment selection and compatibility.

The plant technical director and chief energy engineer also were present to answer questions and support our data requirements throughout the week. Mr. Martinaitis and his staff furnished information on the energy usage of various process sections. Additional people in the plant furnished information as requested by the audit team.

- The pipe surface temperature was measured with an infrared digital non-contact pyrometer and pipe dimensions were recorded.

- Power consumption measurements were made at one of the wet process clay mixing devices in order to determine the power used by the mixer motor under varying loads due to change in the loading level of the mixing tank (see *Figure 9* and Photographs 3 and 4 in **Appendix A**).

- The high temperature infrared instrument was used to measure temperatures within the kiln to obtain data relative to process control.

- Combustion efficiency measurements were made at the boilers before and after the economizer to evaluate performance of the boilers (see Photographs 2 and 5 in **Appendix A**).

- Exhaust gas temperatures and oxygen concentration measurements were made at the exhaust section of the kilns and dryers to obtain data relative to improving operation of the kilns.

On Friday, the Audit Team presented the recommendations at a meeting attended by Mr. Liukaitus, plant General Director; Mr. Kasperavicius, Chief Energy Engineer; Mr. Martinaitis, Technical Director, and chiefs from all major sections. The Energy Audit presentation was well received and included an explanation of the funds available to implement the recommendations. The recommendations were discussed at the meeting and included the details of the time schedule for implementation.

The plant management personnel concurred with the recommendations and agreed that improved instrumentation would enable them to have better control over the energy system.

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 by low or no-cost to implement and short payback periods. These projects could be implemented within two months. Long-term projects are characterized by a larger cost to implement and longer payback periods. Short-term energy conservation opportunities identified at the ceramics factory include: boiler combustion control and steam metering, monitoring of combustion gasses from ceramic pellet kilns to improve firing efficiency, and utilization of recoverable heat from the cooling section of the brick kiln. In the long-term, it will be effective for the boiler operations to evolve to a fully automated combustion control system, improve thermal water piping insulation, improve the general thermal integrity of the buildings, and develop a computerized energy management system. The review of the data from the audit and working with the staff of the ceramics factory resulted in the following equipment being recommended for purchase.

Portable Equipment

1. Enerac combustion analyzer. The Kaunas plant has 14 major natural gas burning systems that all need combustion or oxygen monitoring to optimize fuel utilization.

2. Low temperature Wahl Heat Spy - an infrared temperature sensor, that detects temperature inconsistencies in the -20 - 1000 °C temperature range.

3. High temperature Wahl Heat Spy - same as number two accept that the high temperature spy detects temperature in the 600 - 3000 °C range.

4. On a lower priority, Dranetz 808A Power Analyzer - detects electrical system inefficiencies by monitoring power use.

Fixed Equipment

1. Five steam flow meters.

2. Three steam flow control valves that will control temperature on a continuous process of sending hot water to the factory and to a residential area for space heating purposes. The temperature will be controlled manually as a function of outdoor temperature.

3. Heat will be recovered from the cooling section of the brick kiln and used as pre-heated combustion air for the two brick kilns. The factory agreed to do all the work necessary to accomplish this recommendation.

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 normal cubic meters, 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 Efficiency Opportunities

There are 14 major fuel-burning systems operating at the Kaunas Ceramics Factory with minimal control of fuel and air and no monitoring of combustion products to measure combustion efficiency. Use of the portable equipment will provide combustion efficiency measurements and oxygen concentration in the exhaust gasses of the kilns. Temperature measurements will provide data to the operators that will allow them to improve the energy efficiency of the boilers, kilns, and dryers.

Boiler, Kiln, and Dryer Combustion Efficiency Metering

The plant has three natural gas-fueled steam boilers as shown in *Figure 2*. Each boiler is rated at 6.6 metric tons and 12 bar, but operates at between 4 - 7 bar at about 4.2 metric tons/hr. Typically two boilers are operated at less than rated pressure and capacity, although one boiler would be sufficient. The boilers supply saturated steam to the heavy fuel oil handling facility and to the thermal water heat exchangers. Heavy oil is delivered on an irregular schedule and must be handled immediately upon delivery to satisfy the rail systems' requirements on turn-around of tank cars. Failure to do so could effect the availability of tank cars for delivery of oil to the handling site. This is the main reason given for operating two boilers rather than one.

The lack of an effective metering system for steam also contributes to the situation of the boilers working at low efficiency except when fully loaded. There is no steam metering for the production of the thermal water sold to the local residential users or to the factory. Users accept the bills estimated by the plant.

Boiler flue gas energy losses due to high levels of excess air can be reduced by routine monitoring with a combustion analyzer and manual adjustment of the boiler combustion controls. As part of the inspection and training aspect of this project, boiler combustion analyses were conducted using the Enerac 2000 combustion analyzer. These analyses showed a wide variation in results, with the high excess air of 378%, oxygen content of 16,7%, temperature of the boiler stack gases at 294 °C and temperature of the gases from the economizer at about 154 °C.

It is estimated that the average typical boiler efficiency of the two boilers is 72% (based on the higher heating value of the fuel). A well maintained boiler should have boiler efficiency over 80%. This corresponds to excess air of 50% and economizer heat recovery of about 14%. With monitoring of excess air resulting in improved combustion control and improved control of boiler loads with better steam metering, it is estimated that the operating efficiency could be improved to 84%. This would represent a boiler efficiency improvement of about 12%. It is estimated that this would save 750,000 m^3 of natural gas/yr - $78,750 at $.105/$m^3$ of natural gas.

Kiln and dryer flue gas energy losses due to high levels of excess air can also be reduced by routine monitoring with a combustion analyzer and manual adjustment of the combustion controls. As part of the inspection and training aspect of this project, boiler, dryer and kiln combustion analyses were conducted using the Enerac 2000 combustion analyzer. Results of the analyses are contained in *Table 2* for boilers, *Table 3* for kilns and *Table 4* for dryers. The testing was done at the exhaust of the units. These units operate at very high excess air as a result of cooling air that is introduced where the pellets exit the kiln.

Currently kiln operators sit at the end of the kiln and watch the flame and flow of pellet material along the wall of the rotating kiln. They take random samples of the pellet density after the pellets have cooled. From this quantitative data, the operators modulate the fuel and air flows. Temperature data using a non-contact infrared high temperature device along with a portable combustion analyzer will provide quantitative data to the operators that could result in at least a 1% improvement in fuel utilization efficiency. This would save 490,000 cubic meters of natural gas per year. The cost of natural gas is $.105/$m^3$; thus, the monetary savings would be $51,450.00.

In addition to the gas conservation measures that are appropriate for this process, there are electric saving measures that are also applicable. During the audit the electric power analyzer was used to measure electric energy consumption of motors associated with the "wet process" method of making the insulation pellets. The process uses four large rotating kilns to both dry and fire the clay to form the pellets. The power analyzer was used to measure the power required by each of the four induced draft fans. The analyzer was also used to measure the load on the motor driving the mixing of the clay.

The general results of the power analysis on the fans indicated that there was a considerable difference in power requirements between the four fans. Two fans were at full load while one fan was drawing current for only about 20% of full load. The fans are on almost identical systems, except that the 20% loaded fan is on a newer kiln. The difference in energy consumption was further investigated using the Enerac combustion analyzer to determine if there was significant difference in the exhaust stream of oxygen (excess air) or pressure.

Table 2. Boiler Combustion Analysis Results

BOILER COMBUSTION ANALYZER RESULTS BEFORE AND AFTER ECONOMIZER

Boiler #2 Before Economizer

SERIAL # 11100046
ENERAC MODEL 2000
COMBUSTION TEST RECORD

FOR: R.M.A.

TIME: 11:24:40
DATE: 01/22/92

FUEL NATURAL GAS:21870 BTU/LB

COMBUSTION EFFICIENCY:	74.7	%
AMBIENT TEMPERATURE:	24	°C
STACK TEMPERATURE:	265	°C
OXYGEN:	06.9	%
CARBON MONOXIDE:	9	PPM
CARBON DIOXIDE:	07.9	%
COMBUSTIBLE GASES:	0.00	%
STACK DRAFT (INCHES H20):	+ 00.0	
EXCESS AIR:	44	%
CARBON MONOXIDE ALARM:	50	PPM

MODE:PPM OXY_REF=TRUE%

Boiler #1 Before Economizer

SERIAL # 11100046
ENERAC MODEL 2000
COMBUSTION TEST RECORD

FOR: R.M.A.

TIME: 09:56:19
DATE: 01/22/92

FUEL NATURAL GAS:21870 BTU/LB

COMBUSTION EFFICIENCY:	59.6	%
AMBIENT TEMPERATURE:	18	°C
STACK TEMPERATURE:	324	°C
OXYGEN:	13.3	%
CARBON MONOXIDE:	12	PPM
CARBON DIOXIDE:	04.3	%
COMBUSTIBLE GASES:	0.00	%
STACK DRAFT (INCHES H20):	+ 00.0	
EXCESS AIR:	154	%
CARBON MONOXIDE ALARM:	50	PPM

MODE:PPM OXY_REF=TRUE%

Boiler #2 After Economizer

SERIAL # 11100046
ENERAC MODEL 2000
COMBUSTION TEST RECORD

FOR: R.M.A.

TIME: 11:10:18
DATE: 01/22/92

FUEL NATURAL GAS:21870 BTU/LB

COMBUSTION EFFICIENCY:	85.7	%
AMBIENT TEMPERATURE:	24	°C
STACK TEMPERATURE:	76	°C
OXYGEN:	11.7	%
CARBON MONOXIDE:	0	PPM
CARBON DIOXIDE:	05.2	%
COMBUSTIBLE GASES:	0.00	%
STACK DRAFT (INCHES H20):	+ 00.0	
EXCESS AIR:	114	%
CARBON MONOXIDE ALARM:	50	PPM

MODE:PPM OXY_REF=TRUE%

Boiler #1 After Economizer

SERIAL # 11100046
ENERAC MODEL 2000
COMBUSTION TEST RECORD

FOR: R.M.A.

TIME: 09:47:04
DATE: 01/22/92

FUEL NATURAL GAS:21870 BTU/LB

COMBUSTION EFFICIENCY:	67.5	%
AMBIENT TEMPERATURE:	16	°C
STACK TEMPERATURE:	154	°C
OXYGEN:	16.7	%
CARBON MONOXIDE:	3	PPM
CARBON DIOXIDE:	02.5	%
COMBUSTIBLE GASES:	0.00	%
STACK DRAFT (INCHES H20):	+ 00.0	
EXCESS AIR:	378	%
CARBON MONOXIDE ALARM:	50	PPM

MODE:PPM OXY_REF=TRUE%

Table 3. Kiln Analysis Results

PELLET KILN COMBUSTION ANALYZER RESULTS AT KILN EXIT (WITH COOLING AIR)

WET PROCESS

Kiln #2 Right/Close Before I.D. Fan

SERIAL # 11100046

SERIAL # 11:00046
ENERAC MODEL 2000
COMBUSTION TEST RECORD

FOR: R.M.A.

TIME: 15:15:40
DATE: 01/23/92

FUEL NATURAL GAS:21870 BTU/LB

COMBUSTION EFFICIENCY:	54.7	%
AMBIENT TEMPERATURE:	24	•C
STACK TEMPERATURE:	259	•C
OXYGEN:	16.3	%
CARBON MONOXIDE:	0	PPM
CARBON DIOXIDE:	02.7	%
COMBUSTIBLE GASES:	0.00	%
STACK DRAFT (INCHES H20):	- 04.6	
EXCESS AIR:	313	%
CARBON MONOXIDE ALARM:	50	PPM

MODE:PPM OXY_REF=TRUE%

DRY PROCESS

Kiln #1 Exit from Kiln

SERIAL # 11100046
ENERAC MODEL 2000
COMBUSTION TEST RECORD

FOR: R.M.A.

TIME: 12:05:37
DATE: 01/22/92

FUEL NATURAL GAS:21870 BTU/LB

COMBUSTION EFFICIENCY:	35.2	%
AMBIENT TEMPERATURE:	16	•C
STACK TEMPERATURE:	433	•C
OXYGEN:	15.4	%
CARBON MONOXIDE:	404	PPM
CARBON DIOXIDE:	03.2	%
COMBUSTIBLE GASES:	0.00	%
STACK DRAFT (INCHES H20):	+ 00.0	
EXCESS AIR:	246	%
CARBON MONOXIDE ALARM:	50	PPM

MODE:PPM OXY_REF=TRUE%

Table 4. Dryer Test Results

TILE CLAY DRYER COMBUSTION ANALYZER RESULTS AT DRYER EXIT (WITH COOLING AIR)

Kiln Exhaust Before Fan

```
SERIAL # 11100046
  ENERAC MODEL 2000
      COMBUSTION TEST RECORD

 FOR: R.M.A.

TIME: 15:51:57
DATE: 01/22/92

FUEL  NATURAL GAS:21870 BTU/LB

COMBUSTION EFFICIENCY:        35.5   %
AMBIENT TEMPERATURE:            15  °C
STACK TEMPERATURE:             113  °C
OXYGEN:                       19.8   %
CARBON MONOXIDE:                48 PPM
CARBON DIOXIDE:               00.7   %
COMBUSTIBLE GASES:            0.00   %
STACK DRAFT (INCHES H2O): + 00.0
EXCESS AIR:                   OVER   %

CARBON MONOXIDE ALARM:          50 PPM

MODE:PPM OXY_REF=TRUE%
```

TILES

DRYER (Rotating)

```
SERIAL # 11100046
```

```
SERIAL # 11100046
  ENERAC MODEL 2000
      COMBUSTION TEST RECORD

 FOR: R.M.A.

TIME: 16:26:39
DATE: 01/23/92

FUEL  NATURAL GAS:21870 BTU/LB

COMBUSTION EFFICIENCY:        54.5   %
AMBIENT TEMPERATURE:            18  °C
STACK TEMPERATURE:             168  °C
OXYGEN:                       18.1   %
CARBON MONOXIDE:                 0 PPM
CARBON DIOXIDE:               01.6   %
COMBUSTIBLE GASES:            0.00   %
STACK DRAFT (INCHES H2O): - 00.8
EXCESS AIR:                    606   %
CARBON MONOXIDE ALARM:          50 PPM

MODE:PPM OXY_REF=TRUE%
```

Plant personnel felt that it may be possible to increase the flow of processing clay by increasing the filling of the initial mixing tanks in the wet process pellet line. The power analyzer was used to monitor the mixing motor power demand through the cycles of filling, Results from this test are shown in *Figure 9*. The mixer motor is rated at 130 kW. As can be seen from this figure, the load was maximized in its first loading. The second loading resulted in exceeding the demand rating of the motor.

The draft fan and ducting system number two had a fully loaded fan. The negative pressure was at 4.6" of water, while system four (20% loaded) had a negative pressure of 3.7" of water. Also, system number two's exhaust air stream had a percent oxygen of 16.3%, while system number four had a lower concentration of oxygen at 14.4%. Both these measurements indicate that the there is more air flowing through system number two than number four, which would account, at least in part, for the higher power requirements for system two.

After further investigation of the inlet to the kiln it was observed that the pellets leaving the kiln were piled higher in kiln four than in kiln two. Because most of the air coming into the kiln must flow through this "pile" of pellets, it would follow that system number four had a larger pressure drop across its pile. This is equivalent to closing the inlet to a fan, as in inlet vane fan systems, thus resulting in lower air flow and power consumption. This result seems to indicate that kiln number two (and number one) are drawing more air than required, and that some of the air from cooling the pellets should be diverted until the kiln(s) operates similar to kiln four.

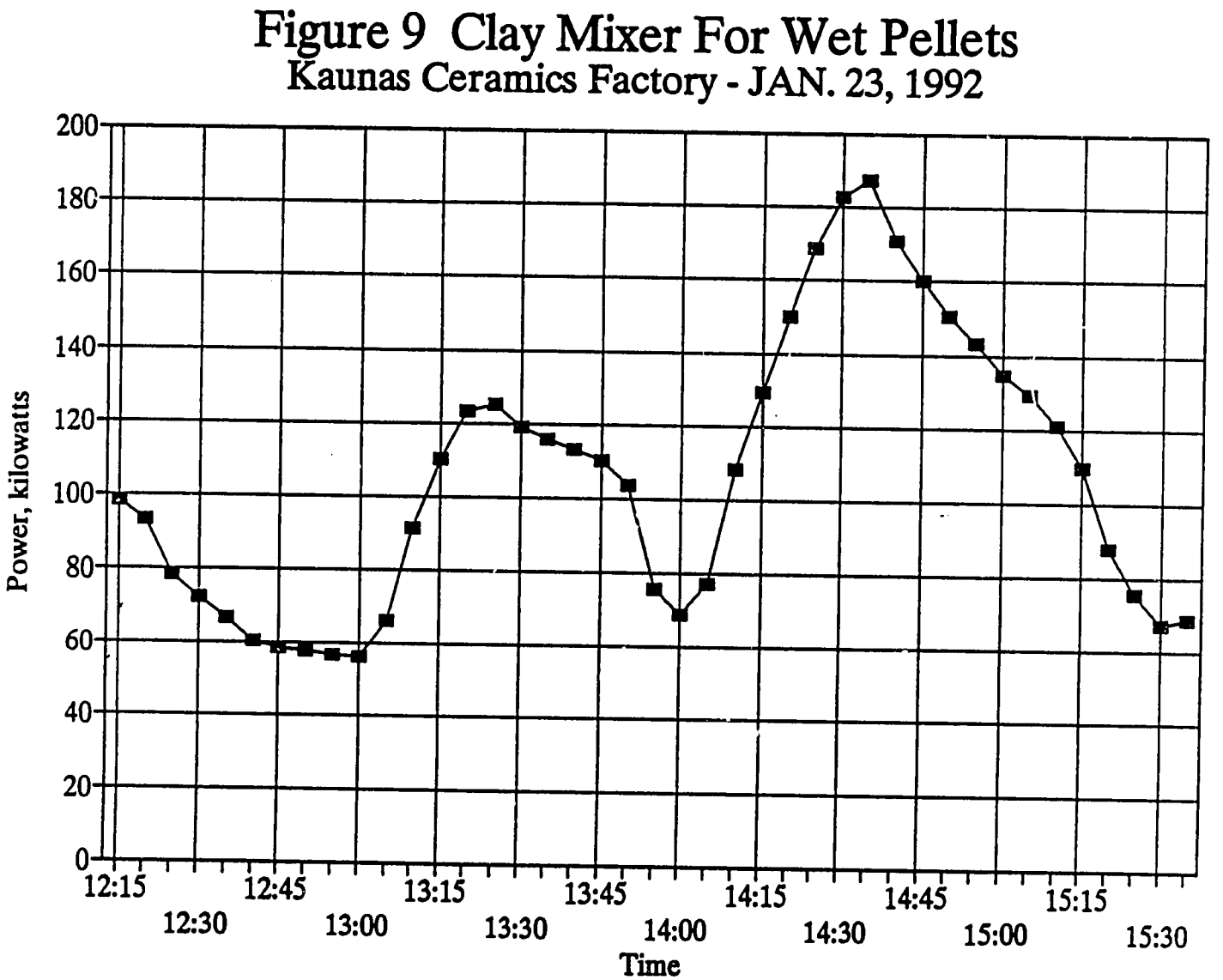
One way to divert this air is to bring the cooling air into the kiln as combustion air. This would not only reduce the air flow, saving electric energy, but also save on gas energy.

Tile Clay Dryers

The clay for the tiles is dried and stored before it is shaped into the tiles. The dryers used are two rotating kiln dryers with a burner capacity of about 2000 m^3/hr of natural gas. They can also be fired on oil. During the audit the gas meters for the dryers were reading 560 and 700 m^3/hr. For the last year the dryers consumed 4.4 million cubic meters of natural gas. The operation of the dryers is scheduled every other week. Therefore, the annual hours of operation is about 4400 hours.

The combustion analyzer was used during the audit to measure the combustion of efficiency of the dryers. One dryer had an exhaust temperature of 242 °C and the temperature of the exhausted air for the other dryer was 168 °C. This temperature difference is significant and results in a large difference in combustion efficiency. This temperature difference was discussed with factory personnel and they were confident in concluding that the major cause of the difference was in the newer "chains" in one of the dryers.

Figure 9. Clay Mixing Motor Power Demand



There are large chains hung on the walls of the dryer that mix the clay to increase the heat transfer between the clay and the heated air. As the chains age their effectiveness in facilitating this heat transfer greatly diminishes. The chains in the dryer with the lower exhaust temperature were relatively new compared to the other dryer's chains. Therefore, significant energy savings could occur with the replacement of the older chains in the other dryer.

Orifice Steam Meters

Boiler steam output is currently measured with a non-pressure compensated steam flow meter. This results in the boiler operators having to correct flow meter readings which is usually done for record keeping purposes. With the current operating procedure of allowing the boiler pressure to float between 4 and 7 bar to accommodate regulation of the thermal water production, the boiler operators do not have current data on the steam production from the boilers. This, along with the lack of combustion efficiency measurements results in low efficiency boiler operation. Providing accurate steam metering and combustion efficiency test equipment will allow operators to correct the operating deficiencies and should result in increased boiler efficiency from 72% to 84%, saving 750,000 cubic meters per year of natural gas at the boiler house. A monetary savings of $78,750 is achieved at $.105/m^3 of natural gas.

Thermal Water Temperature Control

Steam is produced at the boiler house to provide direct steam for handling heavy fuel oil. The steam also produces thermal water for distribution to the factory and a residential area providing space heating purposes. Approximately 90% of the steam is used at the boiler house in steam to water heat exchangers with the remaining 10% used as direct steam in heavy fuel oil handling with no condensate return. Data from 1991, shown in *Figure 8*, depicts a maximum thermal water production of 4,176 Gcal in February and 1,250 Gcal in August. Total thermal water production in 1991 was 31,150 Gcal. The factory has no way of controlling the temperature of the water sent to the thermal water end-users. The only mechanism for controlling heat is to control steam production from the boilers by varying the fuel input and steam pressure level. The steam pressure level varies between 4 and 7 bar to accommodate steam production levels. Utilization of steam flow control valves at the steam-to-water heat exchangers will allow for the control of out-going water temperature and allow operation of the boiler at a constant pressure providing for more effective operation of the boiler. Out-going water temperature from the heat exchangers was 90 °C. Planned distribution temperature was 75 °C. Proper control of thermal water temperature by manipulating steam flow will reduce thermal losses and allow the boilers to be operated at stable pressures. These valves will allow the temperature of the thermal water to be lowered with rising outdoor air temperature. This will reduce overheating in the spaces and reduce distribution and standby losses.

4.2 Long-Term Energy Conservation Opportunities

The long-term ECO's require larger capital investments than the short term investments and have longer payback periods. Therefore, these measure should be performed after the short term ECO's and should be investigated further by the plant staff.

1. Replacement of tile material dryer chains

The cost of replacing the chains was estimated by plant staff at 100,000 rubles. The air flow through the dryer was estimated by the staff to be about 25,000 m^3/hr. The following parameters and data were used in determining the payback of this measure. This ECO is calculated using only local energy and equipment prices. This is due to the equipment being readily available locally.

- New chains would increase the heat transfer between the furnace air and the clay. The furnace exhaust temperature would therefore be reduced.
- Specific heat of air = .24 kcal/kg °C
- Air density = 1.2 kg/m^3
- Energy content for gas = 9000 kcal/m^3
- Annual hours = 4400 hours
- Gas price = 1.054 rubles/m^3

* <u>Calculation:</u>

(242 - 168 °C) * .24 * 1.2 * 25,000 = 533,000 kcal/hr

<u>Equivalent gas consumption:</u>

533,000/9000 = 59 m^3/hr

<u>Annual gas savings:</u>

59 * 4,400 = 260,000 m^3 of gas (or about 12% of the gas for one dryer)

<u>Annual cost savings:</u>

260,000 * 1.054 = 274,000 rubles

Payback period for chain replacement:

100,000/274,000 = .36 years or 4.4 months

Therefore, this measure is recommended and should be implemented by the staff as chains age. An optimal age for chain replacement depends greatly on chain prices and gas costs, so will change as these prices change.

2. Replace Incandescent with Fluorescent Lights

There are a number of areas that use incandescent lighting. Many of these areas could use fluorescent lighting and reduce the electric energy consumed.

3. Repair Windows to Reduce Leakage

After the ventilation system is brought into balance, and the make-up air is sufficient to meet the exhaust air, repairing the windows to reduce leakage will reduce infiltration and reduce heating energy. Reparation of the windows could include complete replacement or maintenance of the windows to ensure a snug fit with frame.

4. Uninsulated Piping

A number of uninsulated pipes containing thermal water, steam, and condensate were observed. The majority of the plant piping is adequately insulated. However, several areas experience over-heating due to large lengths of uninsulated piping. Ventilation air is required during parts of the years to maintain worker minimum comfort. This compounds an inefficient situation by using energy to mitigate the impacts of energy loss. Using pipe surface temperature measurements and unit pipe surface area, the heat loss from the uninsulated pipe was estimated. *Tables 5 and 6* present the results of a heat loss analysis for steam supply, condensate return, thermal water supply, and thermal water return respectively. As can be seen from these Tables, thermal supply line insulation of 1.5 inches of mineral wool insulation is paid back in 9 months for uninsulated areas. Insulation of all types of lines has a pay-back period of less than 12 months for thermal water return for 1.5 inches of insulation versus no insulation. 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 and is therefore considered a long-term improvement.

Table 5. Steam Supply & Condensate Return

INSULATION ECONOMIC EVALUATION FOR THERMAL WATER SUPPLY LINES, KAUNAS CERAMICS FACTORY

..INSULATION ECONOMIC THICKNESS.. DATE 03-21-1992 TIME 14:33:52

*** INPUTS ***

1. PROJECT NAME		CERAMICS
2. RUN IDENTIFICATION		TH WT SUPP
3. AMBIENT TEMP,	F	70
4. FLUID TEMP,	F	185
5. FUEL COST,	$/MILLION BTU	3.75
6. ANNUAL INFLATION, FUEL COST,	%	5
7. BOOK VALUE OF STEAM PLANT,	$	0
8. INTEREST RATE,	%	5
9. AVG HEAT TO PROCESS,	MMBTU/HR	7
10. SCHEDULE,	HOURS PER YEAR	5200
11. REMAINING LIFE,	YEARS	10
12. INSULATION TYPE		MINERAL WOOL
13. CITY COST MULTIPLIER		1
14. SYSTEM COMPLEXITY		SIMPLE
15. 2''MTRL (2'' PIPE,$/FT) OR (FLAT,$/FT2)		3
16. INSTALLATION LABOR RATE,	$/HR	15
17. PIPE SIZE,	IN	3
18. BOILER EFFICIENCY,	%	80

....RESULTS.....

AVERAGE FUEL COST, $/MMBTU: HEAT @ 6.35 + COST PLANT @ 0

CONDUCTIVITY, BTU-IN/HR-SF-F: .275 AT AVG INSUL TEMP, F: 127.5F

CAPITAL RECOVERY FACTOR AND INFLATION AVERAGING FACTOR: 0.130 AND 1.233

NO OF LAYER	THCKNSS INCHES	MTRL $/FT	LABOR $/FT	TIC $/FT	TIC $/FTYR	HEATLOSS BTU/HR-FT	HEATLOSS $/FTYR	TOTAL $/FTYR	SURF TMP,F
0	0	0	0	0.0	0.0	228	7.5	7.5	
1	1	2	3	4.7	0.7	28	0.9	1.6	85
1	1.5	3	3	5.8	0.8	22	0.7	1.5	80
1	2	4	3	7.0	1.0	18	0.6	1.6	77
1	2.5	5	3	8.5	1.2	16	0.5	1.7	75
1	3	7	4	10.1	1.4	15	0.5	1.9	74
1	4	8	4	12.1	1.7	12	0.4	2.1	73
2	3	7	5	11.2	1.6	15	0.5	2.1	74
2	4	9	6	14.2	2.0	12	0.4	2.4	73
2	5	12	7	18.8	2.7	11	0.4	3.0	72
2	6	15	8	23.1	3.3	10	0.3	3.6	72

Table 6. Thermal Water Supply & Thermal Water Return

INSULATION ECONOMIC EVALUATION FOR THERMAL WATER RETURN LINES, KAUNAS CERAMICS FACTORY

..INSULATION ECONOMIC THICKNESS.. DATE 03-21-1992 TIME 14:36:56

*** INPUTS ***

1.	PROJECT NAME		CERAMICS
2.	RUN IDENTIFICATION		TH WT RETU
3.	AMBIENT TEMP,	F	70
4.	FLUID TEMP,	F	165
5.	FUEL COST,	$/MILLION BTU	3.75
6.	ANNUAL INFLATION, FUEL COST,	%	5
7.	BOOK VALUE OF STEAM PLANT,	$	0
8.	INTEREST RATE,	%	5
9.	AVG HEAT TO PROCESS,	MMBTU/HR	7
10.	SCHEDULE,	HOURS PER YEAR	5200
11.	REMAINING LIFE,	YEARS	10
12.	INSULATION TYPE		MINERAL WOOL
13.	CITY COST MULTIPLIER		1
14.	SYSTEM COMPLEXITY		SIMPLE
15.	2''MTRL (2'' PIPE,$/FT) OR (FLAT,$/FT2)		3
16.	INSTALLATION LABOR RATE,	$/HR	15
17.	PIPE SIZE,	IN	3
18.	BOILER EFFICIENCY,	%	80

....RESULTS.....

AVERAGE FUEL COST, $/MMBTU: HEAT @ 6.35 + COST PLANT @ 0
CONDUCTIVITY, BTU-IN/HR-SF-F: .268 AT AVG INSUL TEMP, F: 117.5F
CAPITAL RECOVERY FACTOR AND INFLATION AVERAGING FACTOR: 0.130 AND 1.233

NO OF LAYER	THCKNSS INCHES	MTRL $/FT	LABOR $/FT	TIC $/FT	TIC $/FTYR	HEATLOSS BTU/HR-FT	HEATLOSS $/FTYR	TOTAL $/FTYR	SURF TMP,F
0	0	0	0	0.0	0.0	179	5.9	5.9	
1	1	2	3	4.7	0.7	23	0.8	1.4	82
1	1.5	3	3	5.8	0.8	18	0.6	1.4	78
1	2	4	3	7.0	1.0	15	0.5	1.5	76
1	2.5	5	3	8.5	1.2	13	0.4	1.6	74
1	3	7	4	10.1	1.4	12	0.4	1.8	73
1	4	8	4	12.1	1.7	10	0.3	2.1	72
2	3	7	5	11.2	1.6	12	0.4	2.0	73
2	4	9	6	14.2	2.0	10	0.3	2.4	72
2	5	12	7	18.8	2.7	9	0.3	3.0	72
2	6	15	8	23.1	3.3	8	0.3	3.6	71

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 fiberglass wrapped with aluminum foil and chicken wire, would be an acceptable insulation system. Additional measurements of exposed lines will be needed to determine the total annual cost and savings to the plant.

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 be covered by this project.

4.3 Preliminary Equipment Specification and Justification

Combustion Analyzer Specification

The combustion analyzer will provide the means to monitor the boiler flue gas excess air levels and enable a boiler technician to adjust the combustion air controls to reduce the excess air level. The analyzer must have the capability to measure oxygen, carbon dioxide, and carbon monoxide within the flue gases.

Measured Parameters:	Flue Gas Concentrations for Oxygen, Carbon Dioxide, Carbon Monoxide (ENERAC only), and Temperature
Calculated Parameter:	Flue Gas Excess Air Combustion Efficiency
Analyzer Performance:	
Oxygen:	0 to 25% volume +/- 0.1% volume resolution +/- 0.2% volume accuracy
Carbon Dioxide:	0 to 20% volume +/- 0.1% volume resolution +/- 0.2% volume accuracy
Carbon Monoxide:	0 to 2,000 parts per million volume (ppmv) +/- 2 ppmv resolution +/- 5% of reading accuracy
Flue Gas Temperature:	0 to 1,100 °C (ENERAC), 493 °C +/- 1 °C resolution +/- 2 °C accuracy

Flue Gas Excess Air: 0 to 1,000%
+/- 1% resolution
+/- 10% accuracy

Portable combustion monitoring equipment will provide the most effective short-term use with the 14 fuel-burning systems at the factory. It is recommended that one ENERAC 2000 unit without NOX and SOX capabilities be purchased and two Bacharach Fyrite II units be purchased for use throughout the factory. All of these instruments should have extended probes. Estimated cost for this equipment is $5,655.00. Estimated savings for all applications is a 2% increase in overall efficiency of the boilers, kilns, and dryers. At a value or 10.5 cents/m^3 for natural gas, this will result in a savings of 1.08 million cubic meters of gas saving $113,000 resulting in a 18 day payback period.

Steam Metering

An orifice type steam meter is recommended for installation at each boiler and steam supply lines to the factory and for sale of steam. The meter will be used in five steam lines intermittently for economic reasons and will require only one microprocessor read-out device. The temperature of the steam ranges from 140 to 190 °C. The pressure of the steam ranges form 6 to 15 bar. The flow rate of the steam ranges from 5 to 30 metric tons/h. The pipe line's inside diameter varies from 65 to 150 mm.

The supplier shall provide the correction factor when the meter is installed to five steam lines having different operating conditions (mentioned above).

The meter should provide output indicating temperature in °C, pressure in bar, and flow rate in metric ton/hr with the flow totalizer. The standard condition is 20 °C and atmospheric pressure. Local power in Lithuania is 220/380 volt and 50 hertz.

Total cost is approximately $3518 for five pressure cells and a single monitoring device. The increase in efficiency from operating the boilers at a constant known pressure is 2% in overall operational efficiency. This will result in a savings of 90,100 cubic meters of natural gas. At a value of $.105 per cubic meter, the annual savings is estimated to be $9,460 annually for a payback period of 4.5 months.

Infrared Temperature Measurement

Currently kiln operators sit at the end of the kiln and watch the flame and flow of pellet material along the wall of the rotating kiln. They have random samples of the pellet density after the pellets have cooled. From this quantitative data, the kiln operators modulate the fuel and air flows. Temperature data using a non-contact infrared high temperature device along with a portable combustion analyzer will provide quantitative data to the operators that could result in at least a 1% improvement in fuel utilization efficiency. This would save 490,000 cubic meters of natural gas per year - a savings of $51,450 annually. The cost of a

Wahl Heat Spy with a temperature range 600 to 1,000 °C is $2,378 and the cost of a Wahl Heat Spy with a -20 to 1,000 °C temperature range is $2,350 for a total cost of $4,728. The resultant payback period is 33 days.

Steam Flow Control Valves

Total thermal water production in 1991 was 31,150 Gcal. The factory has no way of controlling the temperature of the water sent to the thermal water end-users. The only mechanism for controlling heat is to control steam production from the boilers by varying the fuel input and steam pressure level. Steam pressure level varies between 4 bar and 7 bar to accommodate steam production levels. Utilization of steam flow control valves at the steam to water heat exchangers will allow for the control of out-going water temperature and allow operation of the boiler at a constant pressure providing for more effective operation of the boiler. Out-going water temperature from the heat exchangers was 90 °C. Planned distribution temperature was 75 °C. *Table 7* below is an estimate of the energy and cost savings related to the use of steam control valves.

Table 7. Estimated Energy Savings for Steam Flow Control Valves

Heat Saved from Thermal Water Losses

Estimated water loss 5%. By not heating water to 90 °C saving:	290 Gcal
Estimated thermal distribution losses 20 percent. Energy saving by reducing temperature to 75 °C:	1,180 Gcal
Estimated improvement of 1% in boiler operations:	290 Gcal
TOTAL	1,760 Gcal

Assume reduction of thermal water temperature from 90 °C TO 75 °C.

Using world fuel prices of $.105/m^3 for natural gas, an energy content of natural gas of 9000 Kcal/m^3, and an improved boiler efficiency of 80% give the following savings:

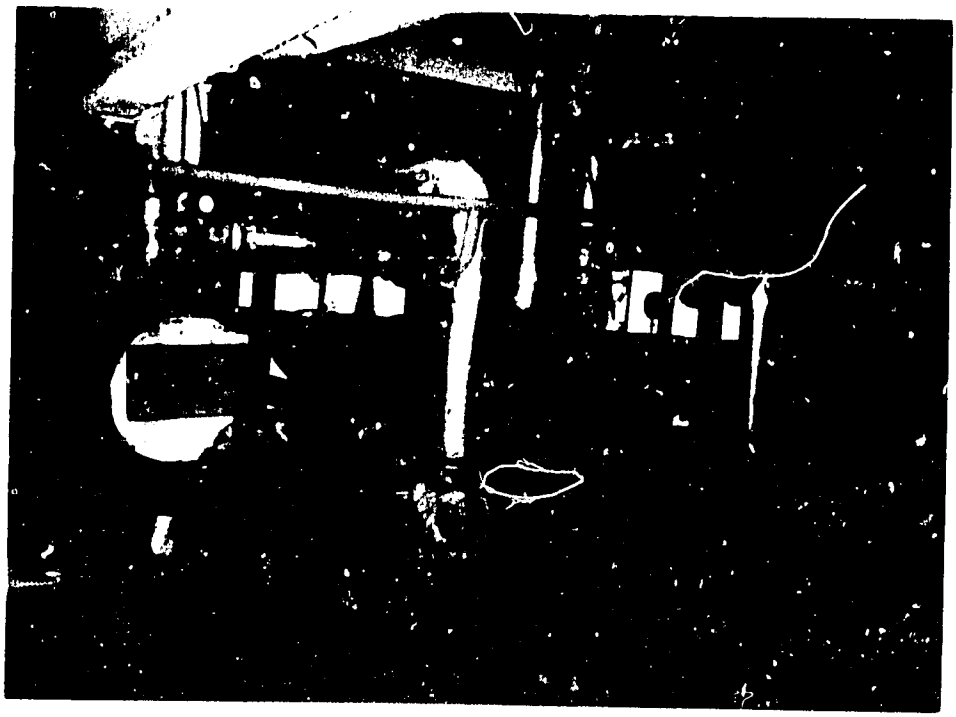
$$\text{TOTAL ENERGY SAVED} = H = 1{,}760 \text{ Gcal} \times 10^6 \frac{\text{Kcal}}{\text{Gcal}} / 80 = 2.2 \times 10^9 \text{Kcal}$$

$$\text{TOTAL COST SAVINGS} = M = 2.2 \times 10^9 \text{ Kcal d } 9{,}000 \frac{\text{Kcal}}{\text{m}^3} \times \$\frac{.105}{\text{m}^3} = \$25{,}670$$

Cost for a 150 mm, 125 psi rated valve that with a capacity of 7 metric tons per hour with all actuators is $3,100. Three valves will cost $9,300. The resultant payback period is 4 months.

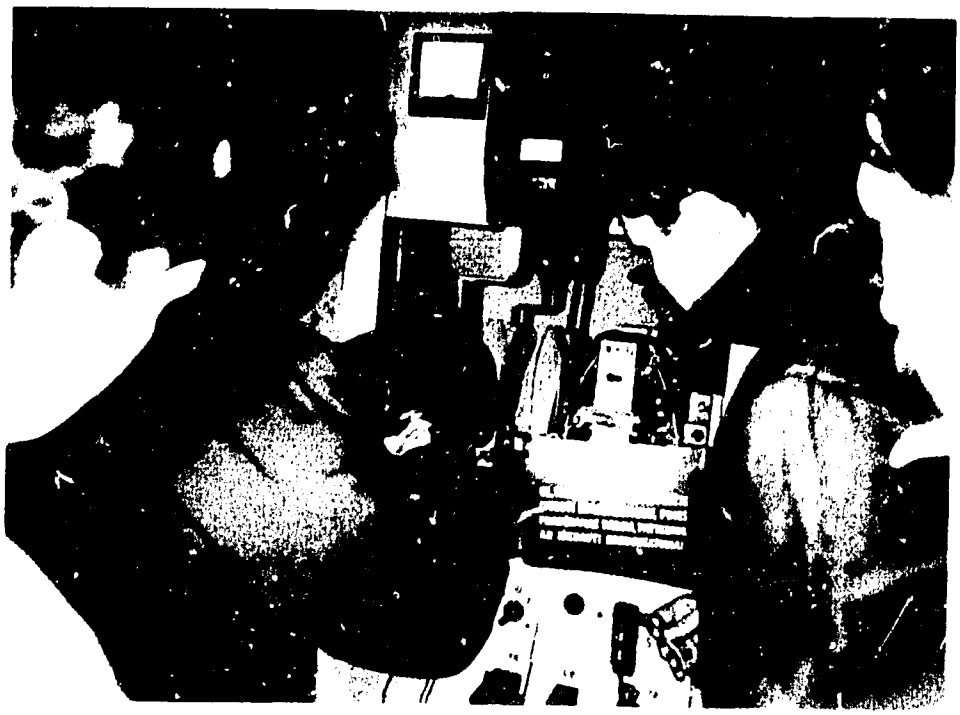
$$\text{Simple payback} = \frac{\text{COST}}{\text{SAVINGS}} = \frac{9{,}300}{25{,}670} = .36 \text{ year} = 4.3 \text{ months}$$

APPENDIX A
Photographs



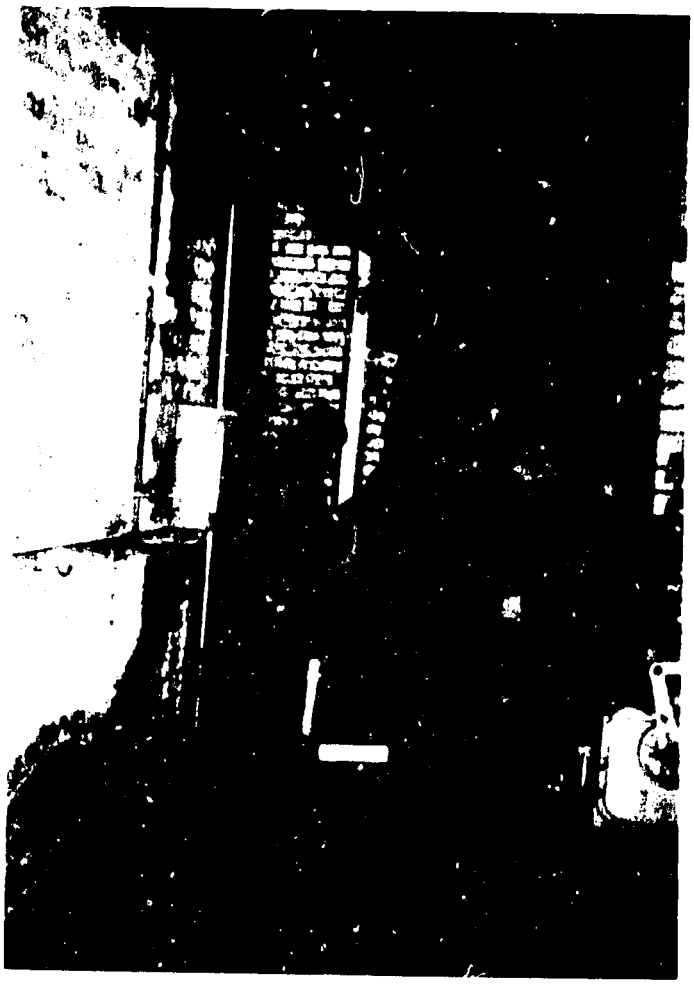
1. Plant heat exchangers.

2. ENERAC testing. The participants are Algis Kasperavicius, the plant's Chief Energy Engineer (right), Virginijus Buciunas, of NEGA. W. (middle), and a plant worker.



3. Monitoring of power to the plant's fans. Algis Kasperavicius, Plant Chief Energy Engineer (left), and Virginijus Buciunas of NEGA W. (right) are doing the monitoring.

4. Observing the power meter. Participants include: (right to left) John Nicol of RMA, Virginius Buciunas of NEGA. W., Plant General Director, Valius Liukaitus, Antanas Martinaitis, Plant Technical Director, Algis Kasperavicius, Plant Chief Energy Engineer, and a plant electrical engineer.



5. Boiler Testing. Participating are Virginijus Buciunas from NEGA. W., a plant boiler engineer, the Technical Director Antanas Martinaitis, and the Chief Energy Engineer, Algis Kasperavicius. (Left to right).

APPENDIX B
List of Abbreviations

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
eff	= efficiency
ex air	= excess air
ft^2	= square foot
ft^3	= cubic foot
Gcal	= 1 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. gailons
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	= millimeter = 0.03937 inches
MM	= million
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