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INDUSTRIAL ENERGY EFFICIENCY AUDIT REPORT

GRIRO S.A. PLANT
Bucharest, Romania

JANUARY 1992

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

and

INSTAPART
Bucharest, Romania

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

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
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U.S. EMERGENCY ENERGY PROGRAM FOR EASTERN AND CENTRAL EUROPE

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
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OFFICE OF DEVELOPMENT RESOURCES
ENERGY & INFRASTRUCTURE DIVISION
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i. Eastern Europe 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 Romania.

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, an industry profile 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 will be 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 Romania industrial sector and the Government of Romania (GOR). The GOR will be provided with analysis and recommendations for further energy efficiency measures.

ii. Executive Summary

An energy audit of the GRIRO S.A. manufacturing plant was conducted from March 25 to March 29, 1991. A pre-audit visit was performed by the Energy Efficiency Component Team Leader to obtain preliminary facility information. The key contact at the facility was the energy engineer, Mr. Dan Ionitza. GRIRO S.A. is one of Europe's largest specialty manufacturers of pressure vessels and process equipment, and has been producing pressure vessels for over thirty years for use in Romanian and foreign plants. It is the only plant in Eastern Europe to have authorization to use the ASME U and U2 manufacturing stamps.

In addition to the manufacturing operation, Griro operates a cogeneration thermal and electric power plant within the facility. The power plant supplies electricity to the facility and sells excess production to the national electric system. The plant is required by the government to supply thermal energy to the district heating system for Bucharest. The thermal supply provides heat to approximately 10,000 apartments.

The total electricity produced in 1990 was 23.6 million kWh and the total consumed was 25.1 million kWh, but because the power plant operation is tied to the thermal demand, the plant had to buy at least 25% of the electrical energy used in the month of August. A total of 48.8 million cubic meters of natural gas was consumed in 1990. In the winter the available gas pressure is low, requiring the plant to use oil. Oil is consumed exclusively in the winter months with a total of 398 metric tons of oil used. The total thermal energy produced in 1990 by the plant was 296,000 Gcal and the total consumed was 75,000 Gcal, or about 25% of the total production. The rest of the thermal energy was used by the district heating system.

The government-established selling price of electric and thermal energy is lower than the actual costs associated with production. Therefore, there is no incentive at this time to produce more energy than is required by the plant, or than is required by the district heating system.

Most of the oil and gas is consumed by the central power station, where there are seven steam boilers. Six are 13 metric tons/hr Babcock and Wilcox boilers built in 1929, and the seventh boiler is a 50 metric tons/hr Romanian boiler built in 1965. The steam produced is directed to two turbines rated at 1.6 and 6.0 MW. The 1.6 MW turbine is a Brown Boveri turbine built in 1929, and the 6.0 MW unit is a Soviet model. The maximum total fuel used by these boilers is 20 metric tons/day of oil or 12,000 cubic meters per hour of gas.

Most of the electricity consumed by the plant is used in the foundry area. The foundry has two electric arc furnaces built in 1951 and one electric induction furnace. The maximum power demand of the arc furnaces and the induction furnace is 1 MW for each furnace. Other major electrical equipment includes four high pressure air compressors with a maximum power consumption of 300 kW per compressor. The compressed air is used for

the testing of pressure vessels, pneumatic controls and pneumatic tools. The other electricity-using equipment, such as fans and pumps, consume an additional 1 MW total.

The facility personnel are aware of the primary inefficiencies in the 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 other factors of production, such as how the long-term business plan relates to the replacement of aging equipment. Therefore, the audit focused on determining the most appropriate instrumentation for obtaining accurate measurements that an in-depth energy evaluation would require, and the type of technical information required to make long-term energy efficiency decisions. The main areas that the audit addressed were:

- Central Steam Boiler Area
- Turbine/Control Room Area
- Air Compressor Room
- Forging/Heat Treatment Area
- Foundry Area.

The results emphasize the inefficiency of the old boilers and the electricity use of the electric furnaces. It was found that the combustion efficiency of the boilers could be significantly increased. One of the largest energy problems at this point is the availability of natural gas. The use of oil creates residue that reduces the capacity and efficiency of the boiler.

Short-Term Energy Management Equipment Recommendations

In general, the plant's management is facing many short and long- term decisions that will directly affect their energy consumption. Much of the equipment needs to be replaced or overhauled in the near future. At present, staff do not have the proper tools and instruments to obtain the information needed to make sound economic decisions regarding energy efficiency projects. The short term recommendations for this plant are to provide these tools as well as to provide information to immediately increase operational efficiency. The recommended short-term measures are combustion analysis, gas flow measurement, monitoring of heating, fluid flow measurement and electric load reduction.

While performing the combustion analysis during the audit, an efficiency problem caused by the open blast doors was identified. Once the blast doors were closed, the excess air was reduced by 25%, and with proper air preheating the efficiency would have increased by 8%. A portable combustion analyzer and a hand held combustion air analyzer are recommended to increase boiler combustion efficiency. The total cost of this equipment is estimated at $6,100.

The gas flow meters at the facility are broken or inaccurate. The total boiler efficiency cannot be determined if the fuel flow rates are not provided. The measurement of overall

boiler efficiency can indicate problems and justify energy conservation measures. It can also increase the system efficiency by choosing the most efficient boiler to operate. Two gas meters for .05 and .6 atm gas flow are recommended, with a total cost of $11,000.

The areas where accurate temperature measurements could improve the efficiency of fuel use include the heat treatment furnaces, the preheating for welding, and the electric furnaces. By heating the material to a higher temperature than necessary, or for a longer time, the fuel used is wasted. The instruments recommended are high and low temperature infrared thermometers, and a digital thermometer with a total cost of $5,200.

There is no accurate measurement of oil or water flow in the plant. With accurate measurement of oil flow to the boilers, the most efficient boilers can be selected to operate. The recommendation is for one portable ultrasonic flow meter that will cost $7,900 and can also be used to measure water flows for thermal energy balance calculations.

The energy profiles of air compressors are not presently known by the plant personnel because they do not have the instruments required to determine this profile. A power analyzer is recommended to determine the air compressor energy use to optimize the system with a cost of $5,700. The system changes that can be justified with an energy profile of these compressors include using separate compressors to supply the low pressure air required in the plant instead of using reducing valves and using electric motors instead of pneumatic equipment.

Energy analysis was performed to calculate energy savings for the recommended measures. In addition, an economic justification was presented on each recommended equipment purchase. The annual energy savings for the short-term measures are as follows:

	Measure	Energy Saved (Gcal)	Gas Saved (million m^3)	Oil Saved (metric tons)	Cost Saved $
1.	Combustion Analysis:	53,000	6.00	63	482,000
2.	Gas Flow Measurement:	8,800	1.00	-	80,000
3.	Monitoring of Heating:	7,200	.81	-	9,000
4.	Fluid Flow Measurement:	745	-	81	9,000
5.	Electric Load Reduction:	174	-	-	11,000
TOTAL SAVINGS		69,919	7.81	144	591,000

The payback periods for these measures would all be less than one and a half years. Some are almost immediate.

Long-Term Recommendations

The main consideration for long-term measures for the plant is the age of the equipment involved. The recommended long term energy efficiency measures must be considered in conjunction with GRIRO's other long-term objectives and economic prospects. The recommended long term measures are: repair or replacement of air preheaters; automatic combustion control; upgrading of arc furnaces; condensate return; replacement of weld preheat burners; and optimization of the air compressor system.

In summary, with the new organization and its export business, the plant seems to have greater opportunities than other facilities audited to increase overall energy efficiency. It is very important to GRIRO's business that they maintain the ability to produce their own power and to maximize the output of the fuel purchased. Many economic decisions will have to be made soon regarding the replacement or overhauling of older equipment. The equipment recommendations from this audit will allow GRIRO to make informed decisions that optimize both short and long-term energy related investments.

Implementation Phase

The implementation phase conducted at GRIRO from August 12 to 16, 1991 involved a return trip to the facility to expedite the installation and use of the supplied equipment. Training on portable equipment was provided for the plant staff. Installation of the fixed gas flow meters was planned with the plant staff and a representative of Instapart, the company that will install the meters. The draft audit report was reviewed with the plant staff, and a plan for using the equipment was developed.

1.0 Plant Description

The GRIRO plant is one of Europe's largest specialty manufacturer of pressure vessels and process equipment. They have made equipment and pressure vessels for use in plants in Romania and abroad for over 30 years. GRIRO is the only plant in Eastern Europe to have certificates of authorization from the American Society of Mechanical Engineers (ASME) for ASME U and U2 stamps, and can meet code requirements for Section VIII Divisions I and II for pressure vessels. GRIRO has had the ASME stamp authorization since 1986. This is a major advantage because it verifies the quality of their products to businesses that may buy from them.

The plant was originally built in 1897 to repair locomotives. It occupies 97,500 square meters with 85,000 square meters of floor space. Production capacity is 16,000 metric tons per year; at present the plant operates at full production capacity with 40% of the product exported. The product line includes towers, heat exchangers, air coolers, reboilers, LPG tanks, debarkers for the pulp industry, and tanks for railway cars. The production equipment is generally very old, but includes many newer numerically-controlled machines.

The plant also produces its own steam and electricity. With the steam some thermal energy is provided to the central district heating system for Bucharest. At times, electricity is also sold to the national system. The production of power has been very important in maintaining GRIRO's operation as other industries were forced by the government to shut down during energy shortages.

1.1 Organization

Much of the plant's organization has been changed within the last year. At the time of the audit, the company had been operating as a private enterprise for only about one month and was still in a transition state. The new organizational structure was not yet approved, but was due to be approved by the General Director in the following month. This new structure is shown in *Figure 1*. There are seven functional areas reporting to the plant director. They are:

- Quality
- Economics
- Engineering
- Sales
- Purchasing
- Production
- Personnel.

As shown in *Figure 1*, the director reports to a board of directors that is responsible to the shareholders. The company is still state-owned, but in the next year plans to issue stocks to the 4000 employees and to sell stock to the general public.

The Director of Production, Mr. Ivanescu Lucian, reports to the general director. The Energy Engineer, Mr. Dan Ionitza, reports directly to the Director of Production on energy problems and conservation measures. The Director of Production is then responsible for deciding on the final course of action after reviewing other factors of production.

1.2 Electrical and Thermal Production Capacity

The plant produces both steam and electricity from the boiler/turbine system. The thermal capacity of the system is 33 Gcal/hour to the district heating system. GRIRO supplies heat for 10,000 apartments in northwest Bucharest. Electric capacity is a maximum of 7.6 MW from the two turbines.

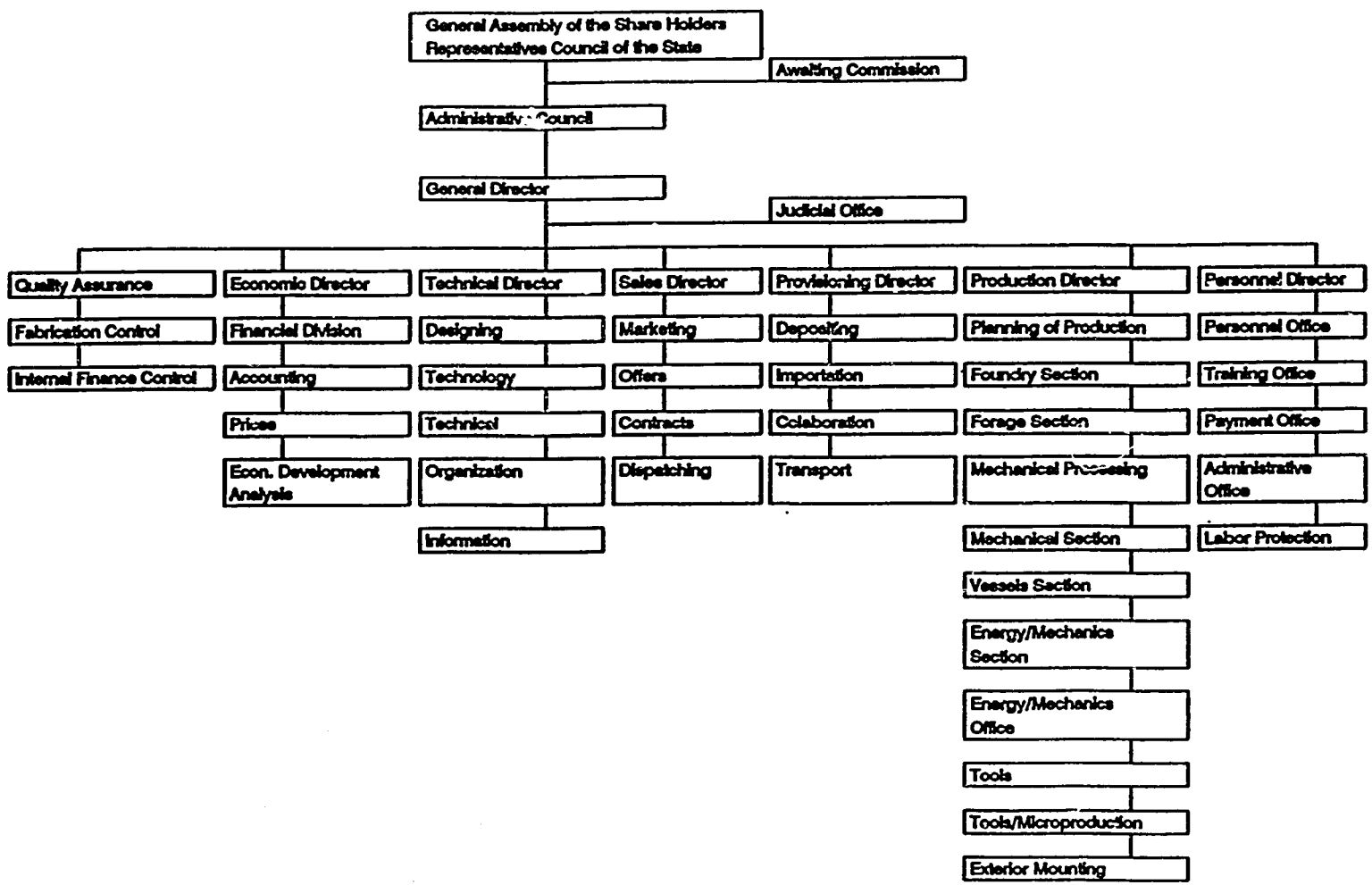
1.3 Operation and Equipment

The plant operates 24 hours per day, 7 days per week. The main areas of energy use include the central power station, the forging area, and the foundry area. The equipment in these areas with the highest energy use is generally very old with few direct controls.

The equipment in the central power station is shown in *Figure 2*. Most of the oil and gas is consumed in this area of the plant. There are seven boilers located in the boiler area. Six of the seven are 13 metric tons/hr Babcock and Wilcox boilers built in 1929. The seventh boiler is a 50 metric tons/hr Romanian boiler built in 1965. They all feed a common steam header with steam at 450 °C and 30 atm. The steam is directed to two turbines rated at 1.6 and 6.0 MW. The 1.6 MW turbine is a Brown Boveri turbine, built in 1929, and provides extraction steam for process use. The 6.0 MW turbine is a Soviet built turbine. The maximum total fuel used by these boilers is 20 metric tons/day of oil or 12,000 cubic meters per hour of gas.

In addition to the turbines, there are two paths of steam pressure reduction for low pressure process steam used in pressure vessel testing and oil heating. The steam pressure is reduced from the 30 atmospheres to either 14 atm or 7 atm. These reduction valves also provide thermal energy for the district heating system if the turbines are not able to operate. The typical consumption of low pressure steam through this system path is 3 to 4 metric tons/hr.

Figure 1. Organizational Chart



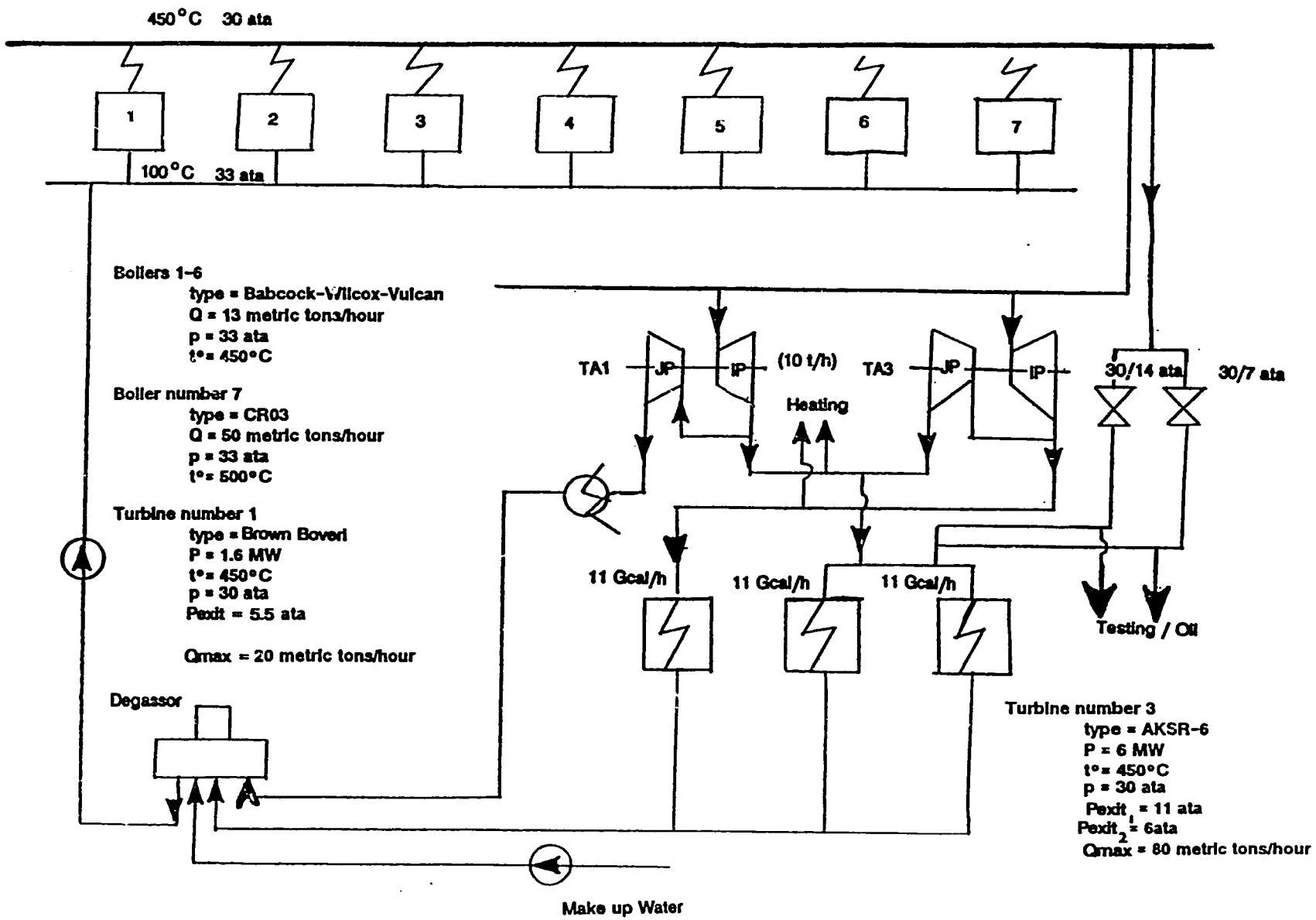


Figure 2. Central Power Station Equipment

Other low pressure steam is available at 3 to 5 atmospheres from the turbines. This steam is used for heating the plant and to heat a nearby hospital. The normal consumption in the winter for this steam is 10 metric tons/hr.

The plant has three 11 metric tons/hr heat exchangers that use the steam extracted from the 6 MW turbine to heat water for use in the district heating system. The condensate from these exchangers is returned to the degasser before returning to the boiler feed water flow.

A simplified schematic of the electrical connection between the plant's system and the national electrical system is shown in *Figure 3*. The two turbines produce power at 5 kV and the national system that they are connected to uses 10 kV. Therefore, there are two 4 MVA transformers to make the connection. The system allows the plant to run on its own electrical power, the national system or both. It also permits the electric power produced to be sold to the national system.

Most of the electricity consumed by the plant is used in the foundry area. The foundry has two electric arc furnaces and one electric induction furnace. The capacity of each arc furnace is 1.5 metric tons/hr of steel and they consume a maximum of 1 MW of electricity each. The induction furnace has a capacity of 1 metric ton per hour, also with a maximum demand of 1 MW.

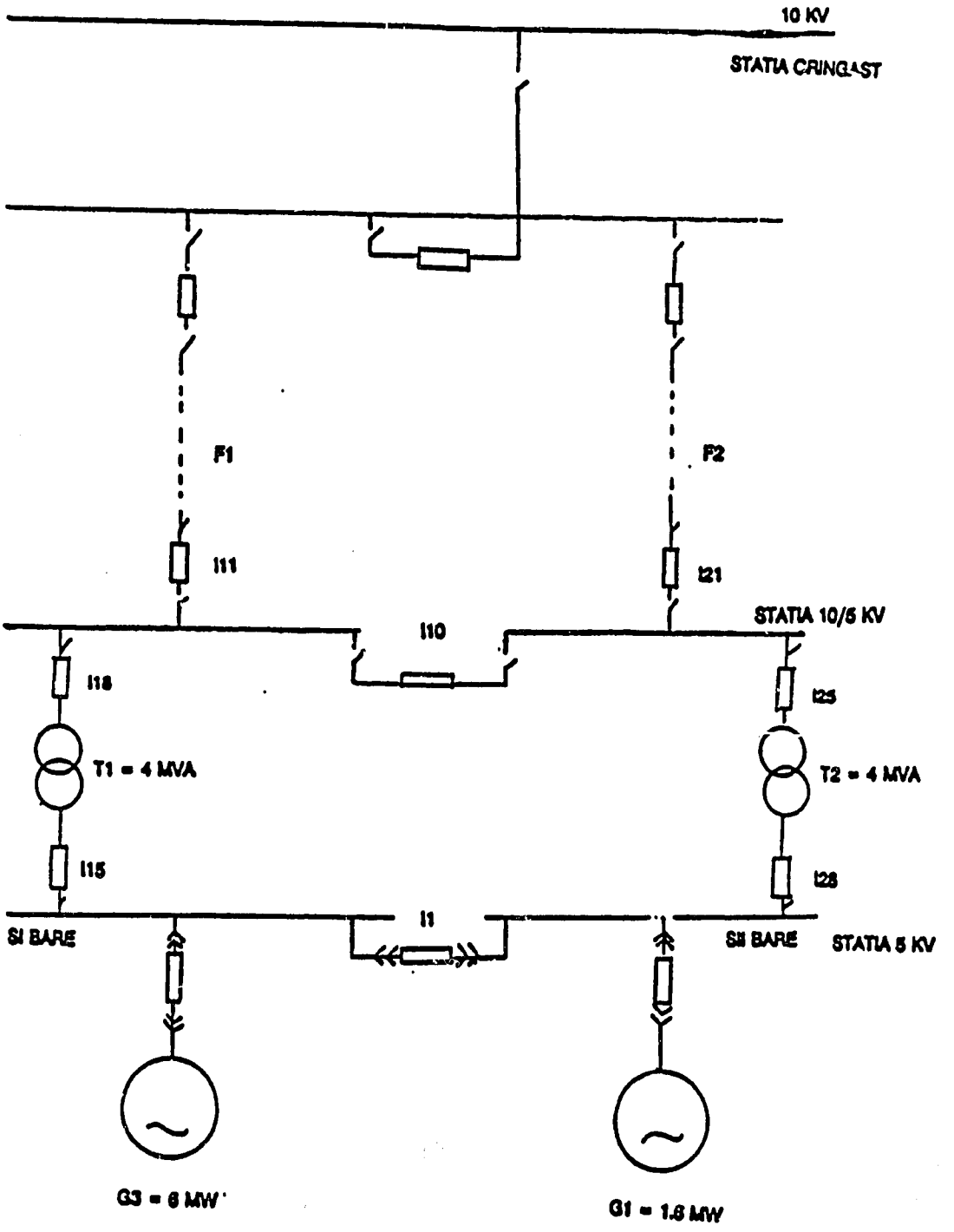
The other major electrical equipment includes four high pressure air compressors with a maximum power consumption of 300 kW each. The air compressors are three stage and three cylinder reciprocating compressors that can deliver 45 m^3/hr. There is also a 40 year old Ingersol-Rand air compressor that is rated for 30 m^3/hr at 150 kW. The air delivered by these compressors is at 7 atm of pressure and is used for the testing of pressure vessels, pneumatic controls and pneumatic tools. The other electricity-using equipment such as fans and pumps consume an additional 1 MW total.

Equipment in the forging area includes heat treatment ovens and ovens to heat billets for forging. The forging hammer formerly operated on steam, but is presently operated by compressed air. All of the ovens in this area use natural gas. The plant has ten gas fired ovens with gas consumption from 25 to 40 m^3/hr.

1.4 History of Energy Efficiency Measures

There have been no new projects implemented in the last 10 years to improve energy efficiency. Because of budget constraints and the lack of incentives for reduced energy use, conservation projects were not performed. The main energy system projects performed in the last ten years include a new pump for the heating system and the interconnection of the electrical system with the 10 kV system. Due to the age of much of the equipment, decisions must be made in the near future on whether to replace some of the equipment or to completely overhaul the equipment.

Figure 3. Electrical System Schematic



2.0 Plant Energy Profile

As mentioned earlier, the plant has the facilities to produce steam and electricity. The electricity can be used for the plant or sold to the national system at a very low rate. The plant also provides thermal energy to the district heating system for Bucharest. (For more information on the district heating system see the Audit Report on South Bucharest Combined Heat and Power Station.

The cost to the plant of producing both the electricity and the hot water is more than the selling price established by the government. Therefore, there is no economic reason to produce more electricity or thermal energy than is required. But both the electric power and district heating system dispatchers can require the plant to increase production to meet the demand, regardless of the cost to the plant. This should change once privatization is completed this year. The thermal demand of the district heating system is the primary demand that the plant is required to meet.

2.1 Annual Electric/Thermal Energy Production and Fuel Consumption

Figure 4 shows the annual energy production profile for 1990. The thermal and electric production follow similar trends throughout the year. The thermal production is the primary concern for the central power station in the winter. The plant is required by the government to provide heating as required (or possible) to the district heating system. Therefore, as more thermal energy is required, more steam is produced, passing through the turbine to produce more electricity.

The production of electrical energy is highest in the winter at 2,900,000 kWh per month and lowest in the summer at 1,300,000 kWh. As can be seen in *Figure 5*, the consumption of electricity is fairly constant at 2,200,000 kWh each month. The total electricity produced in 1990 was 23.6 million kWh and the total consumed was 25.1 million kWh. This appears to indicate that the plant produced almost as much as it consumed and therefore did not have to purchase very much electricity. However, a closer examination of *Figures 4 and 5* shows that GRIRO was required to buy at least 25% of the electrical energy used in the month of August.

The consumption profiles in *Figure 5* show that gas consumption ranged between 3.4 and 4.9 million cubic meters per month with a total consumption of 48.8 million cubic meters for the year. In the winter the available gas pressure is low, requiring the plant to use oil. The oil consumption occurs exclusively in the winter months with a total of 398 metric tons of oil used in 1990. The total thermal energy produced in 1990 by the plant was 296,000 Gcal and the total consumed was 75,000 Gcal, or about 25% of the total produced. About one third of this thermal energy consumption can be attributed to process loads, with another third going to winter heating requirements.

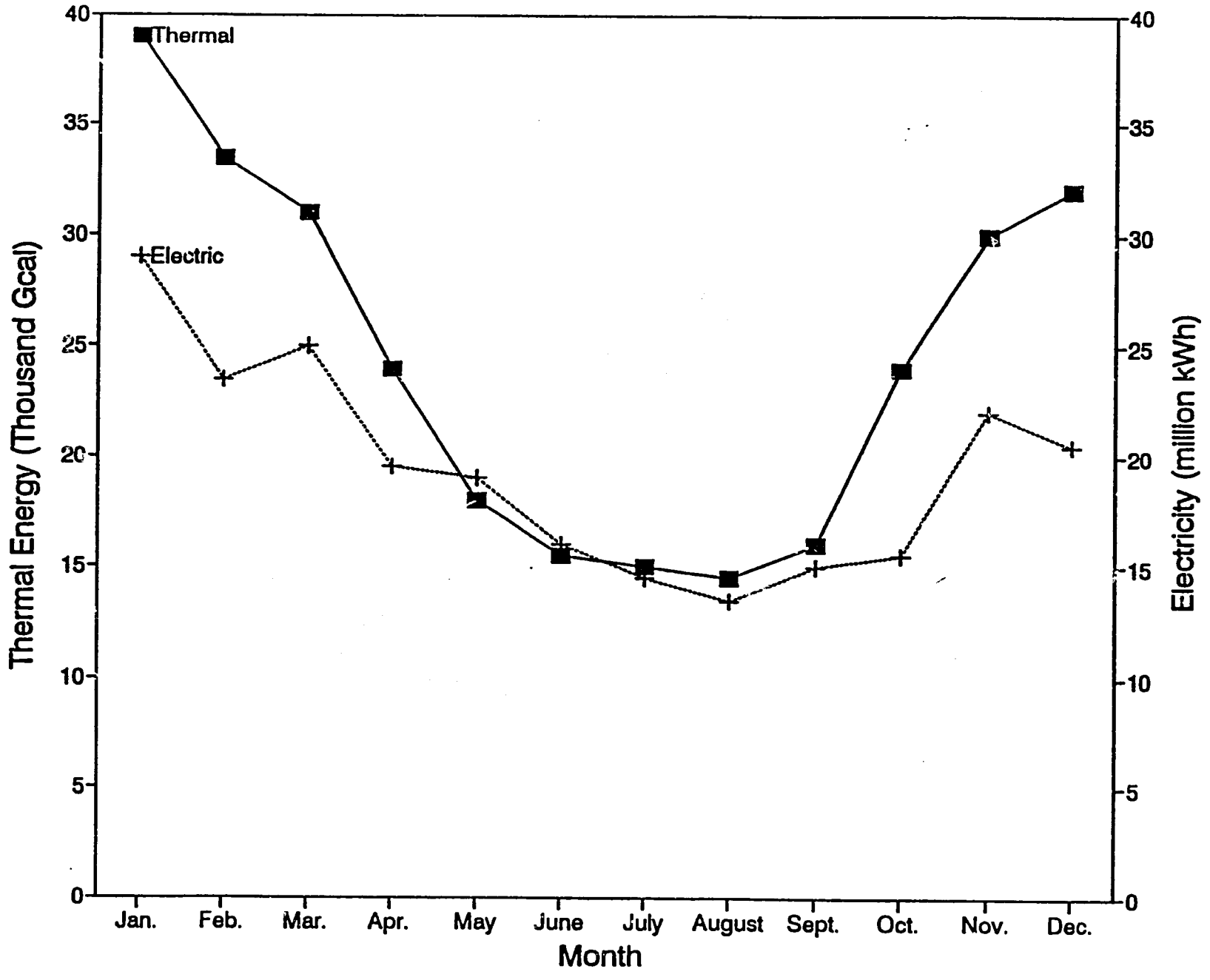


Figure 4. Energy Production in 1990

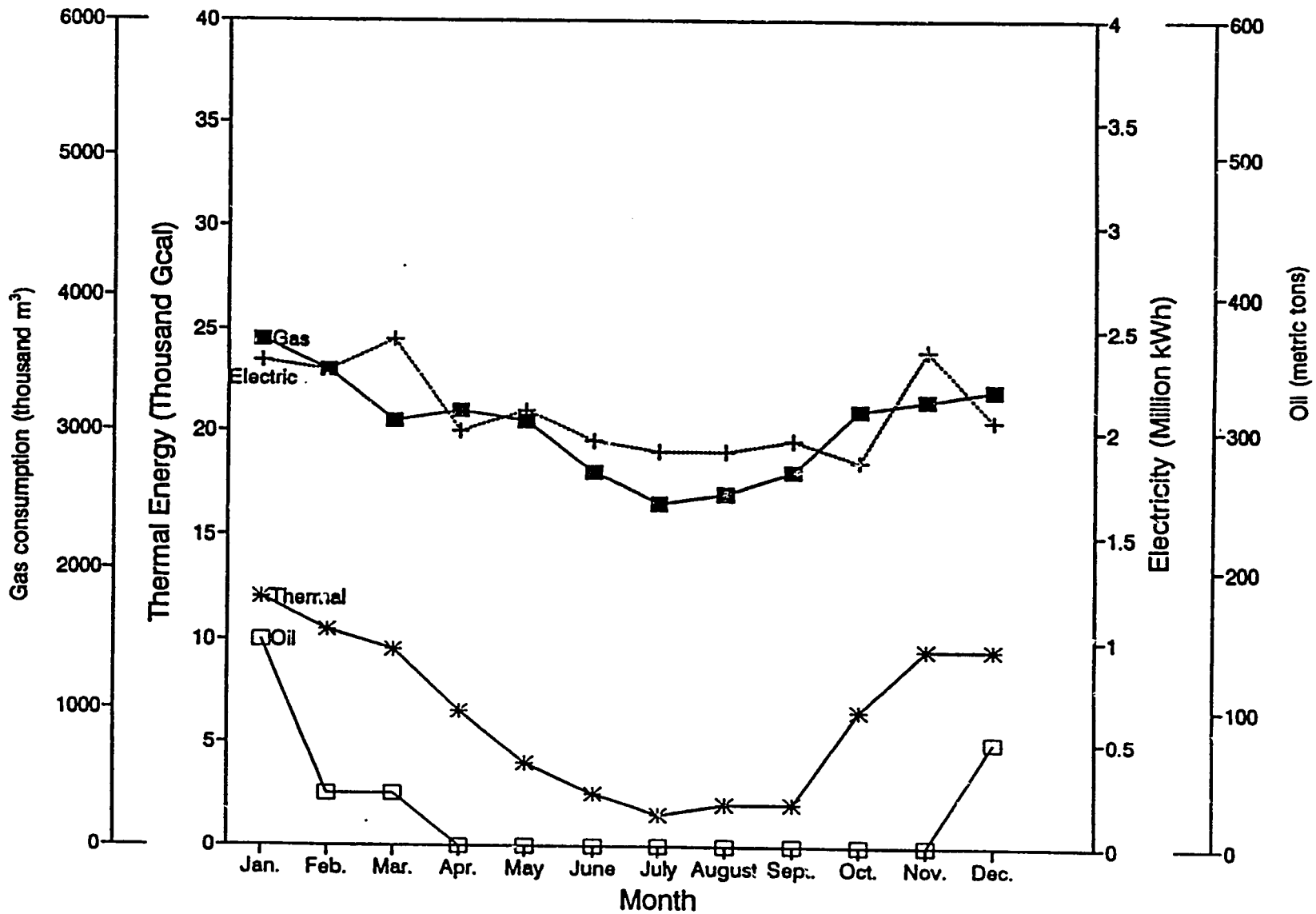


Figure 5. Energy Consumption in 1990

2.2 Weekly Electric/Thermal Energy Production and Fuel Consumption

The production of energy for a typical week in the winter and summer are shown in *Figures 6 and 7*, respectively. Both the thermal and electric production are fairly constant throughout the week, including the weekends, for the summer and winter. Summer production of thermal energy is about half of that in the winter. In contrast, as shown in *Figures 8 and 9*, the consumption of electricity for the two weeks falls during the weekend to 40 to 50% of the consumption during the week. There are no significant changes for oil, gas and thermal consumption during the weekend.

Comparing the summer consumption, *Figure 9*, and the summer production, *Figure 7*, shows that during the week the production was only about 70% of the electricity consumed. On the weekend the electric energy consumed was easily provided by the production of electricity. A similar situation exists for the winter consumption and production of electricity.

Figure 8 shows that oil consumption for the week given was 106 metric tons. Assuming this was the average for the month of February in 1991, the total oil consumption for the month would be 424 metric tons, which is 850% higher than in February 1990. The total oil used for all of 1990 was 398 metric tons. This shows the increased dependence on oil with the reduction in the gas supply from the Soviet Union.

2.3 Daily Electric/Thermal Energy Production and Fuel Consumption

Typical winter and summer day energy production profiles are shown in *Figures 10 and 11* respectively. Due to the limited metering ability of the plant, the thermal production for each hour is the average over the day. The electricity produced for the summer day was constant, but for the winter day the production of electricity peaked at 3.75 MW at 2:00 p.m. and dropped to about 1.5 MW for the rest of the day.

The consumption of electricity, gas and thermal energy is shown for each day in *Figures 12 and 13* respectively. Gas and thermal energy used for each hour are averages due to metering equipment limitations. The consumption peak of electricity on the winter day corresponds to the production peak on the winter day, although most of the rest of the profiles do not match. This indicates that the power station on this day is operating based on the thermal load of the district heating system.

For the summer day profiles it is even clearer that there is no interrelation for operation between the electrical demand of the plant and electrical production.

Figure 6. Typical Week-Winter Energy Production

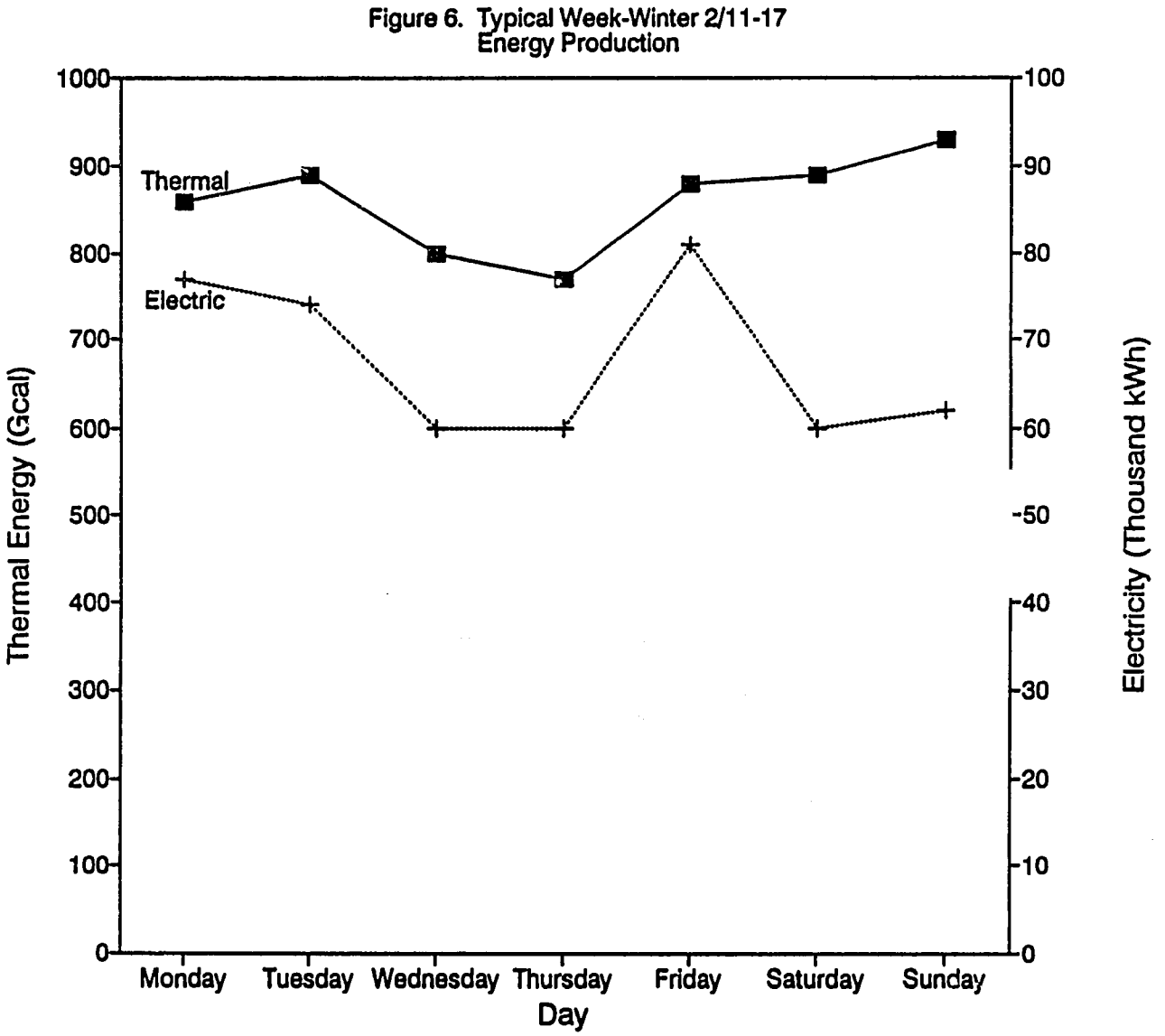
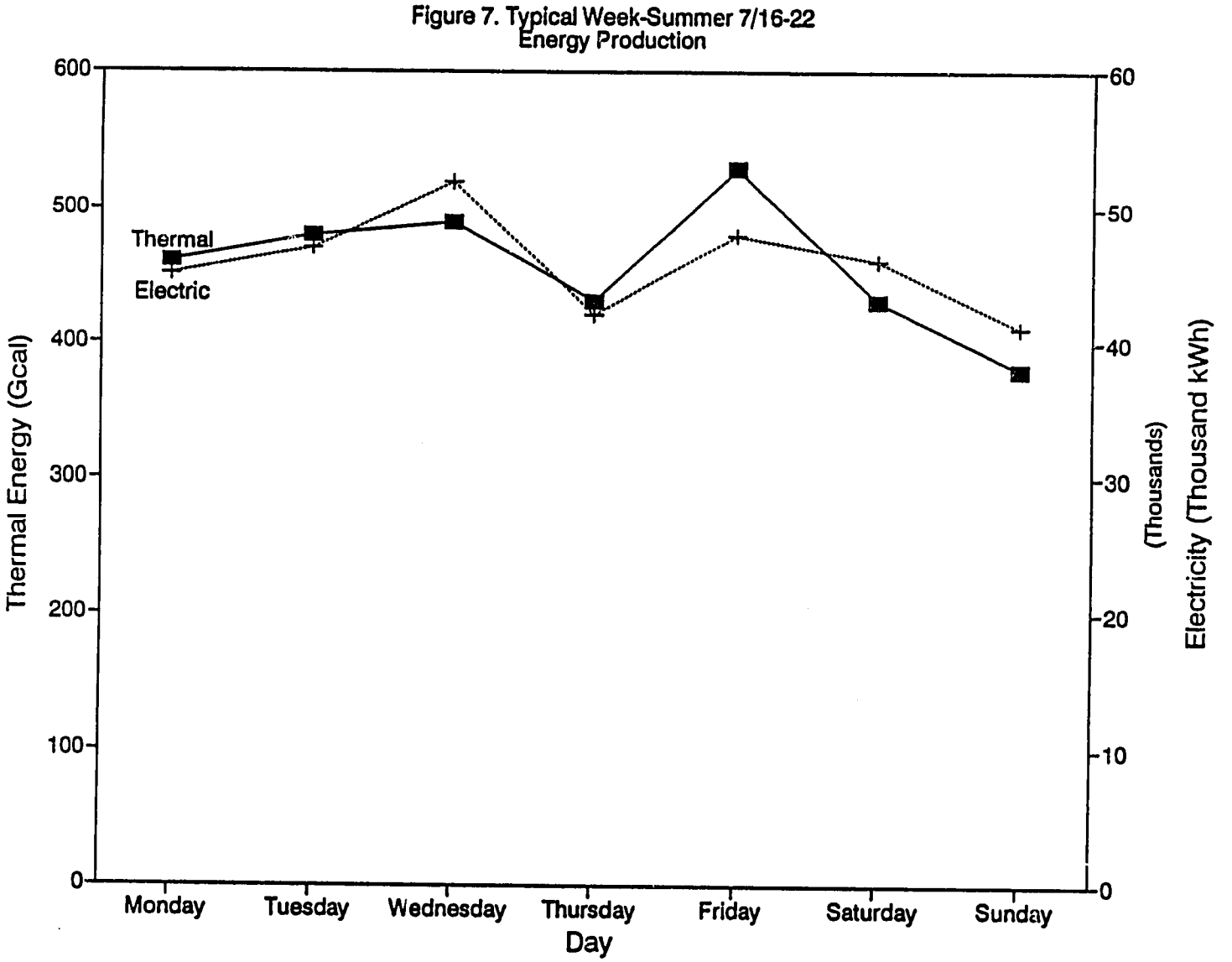


Figure 7. Typical Week-Summer Energy Production



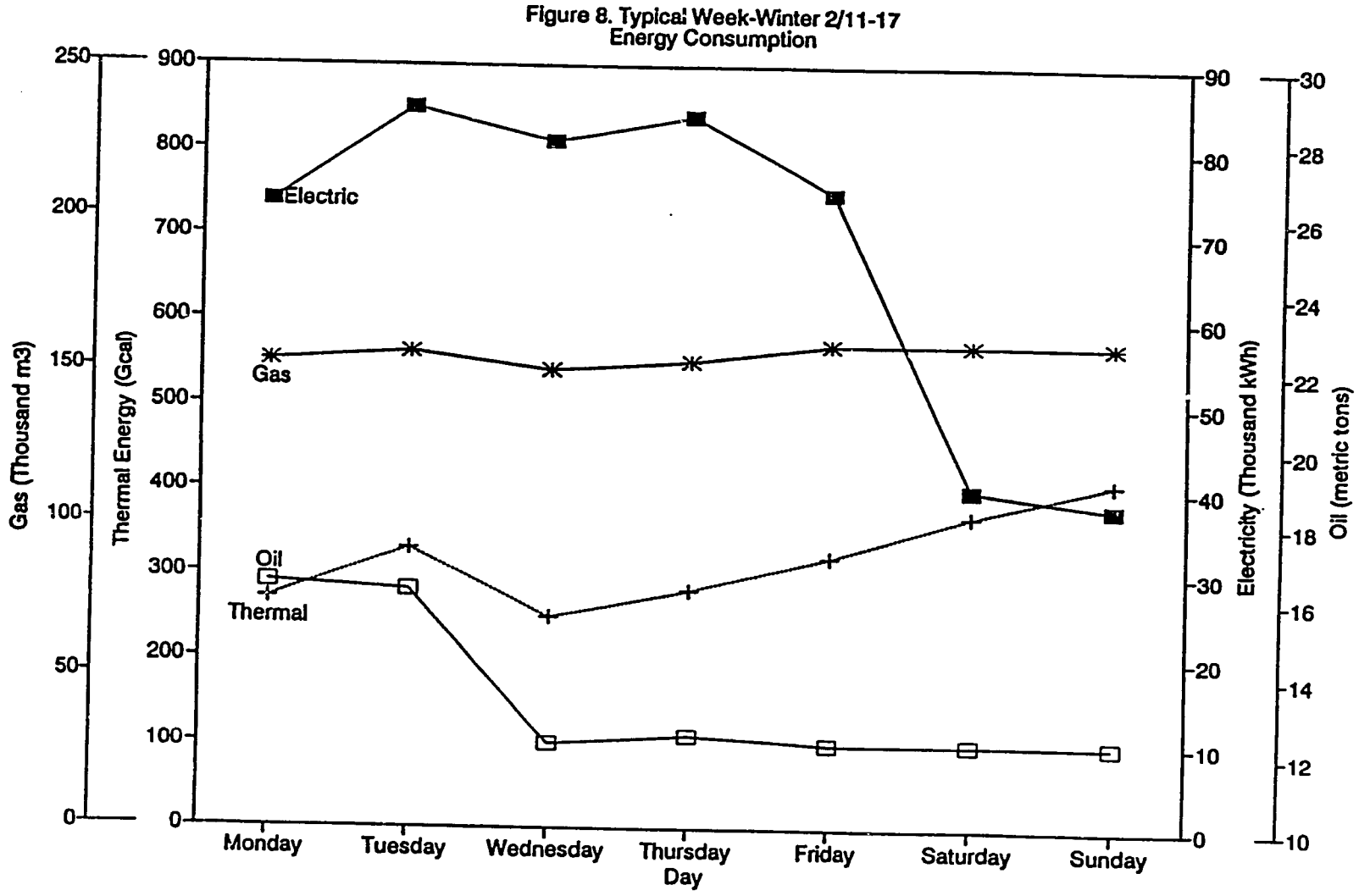


Figure 8. Typical Week-Winter Energy Consumption

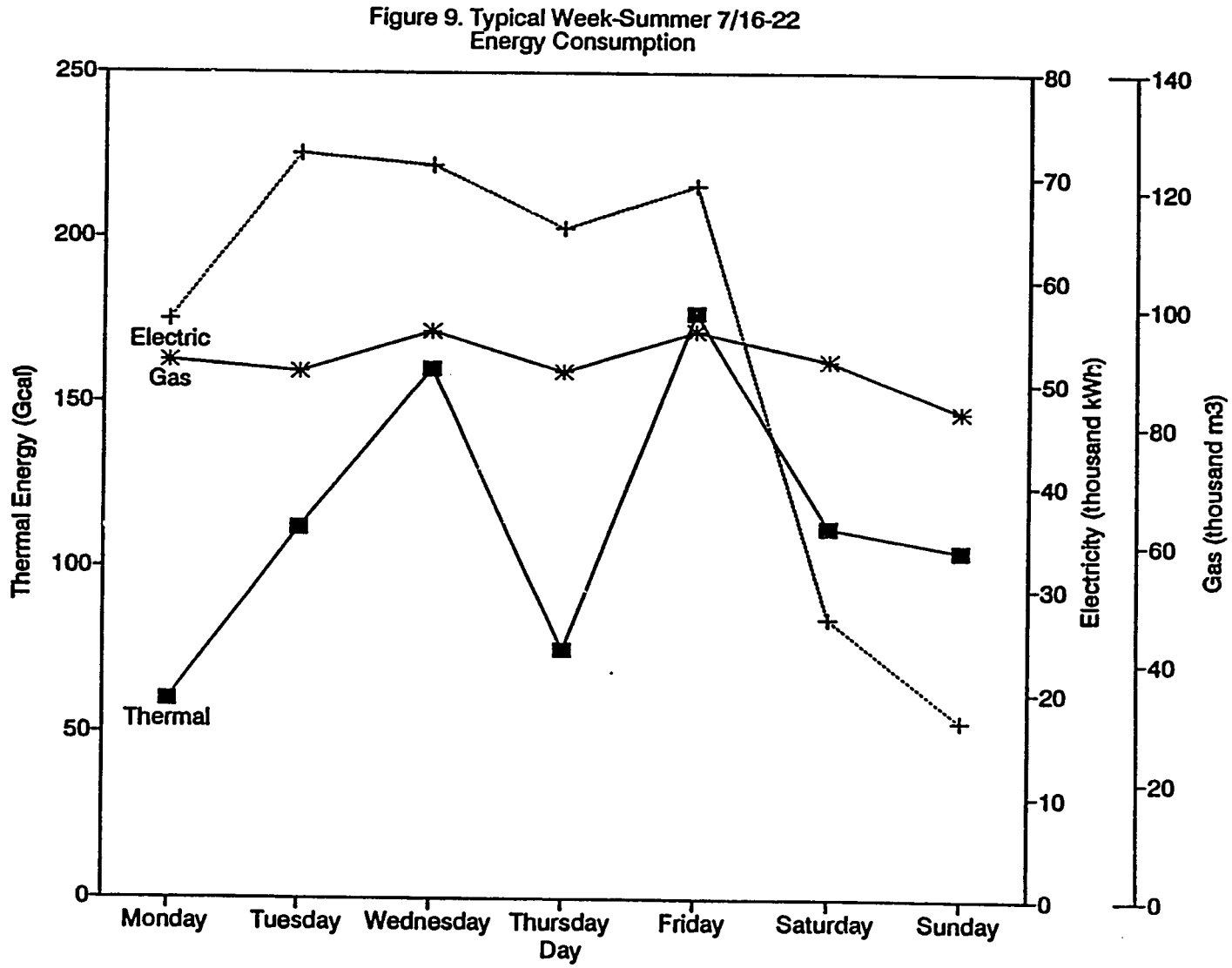


Figure 9. Typical Week-Summer Energy Consumption

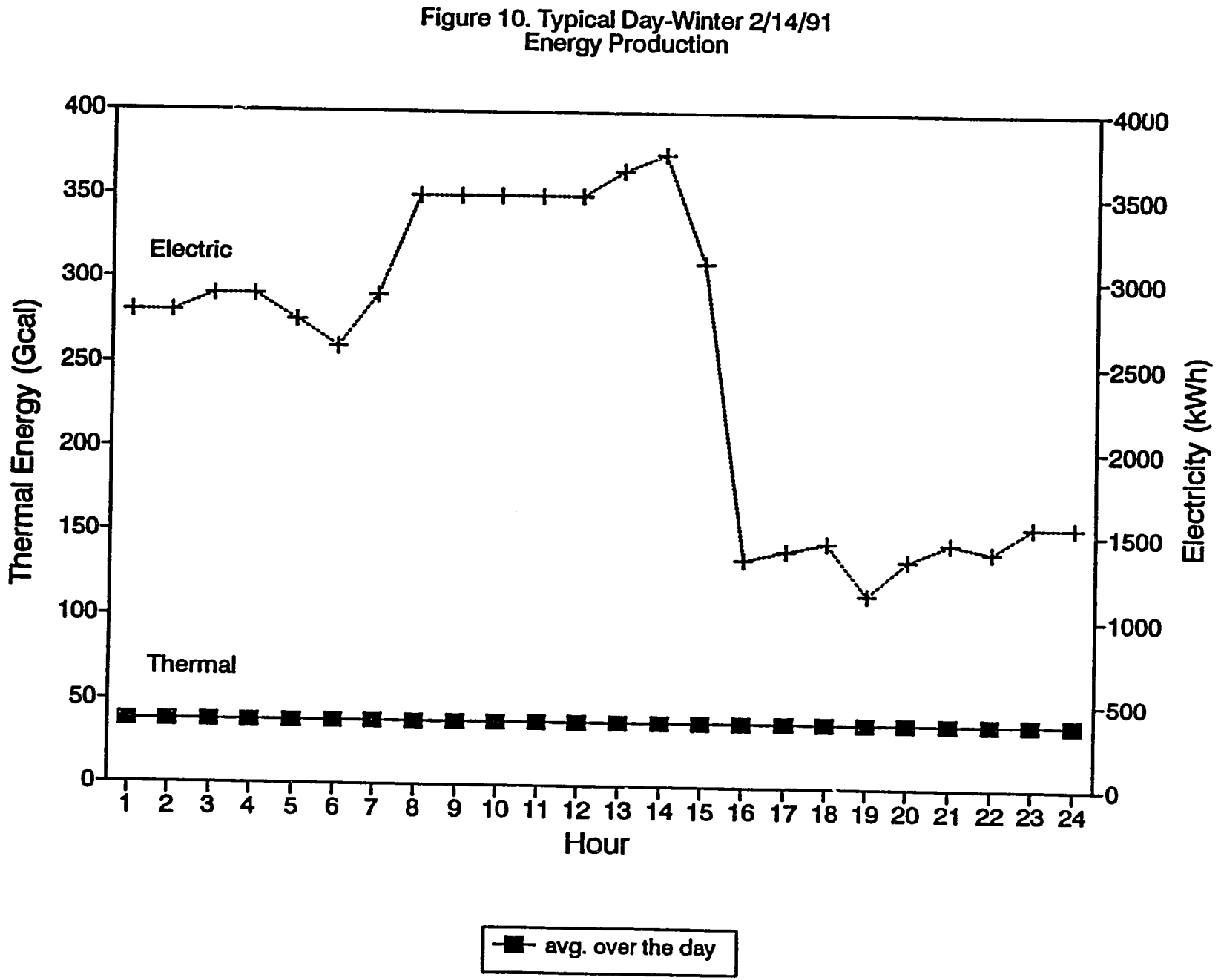


Figure 10. Typical Day-Winter Energy Production

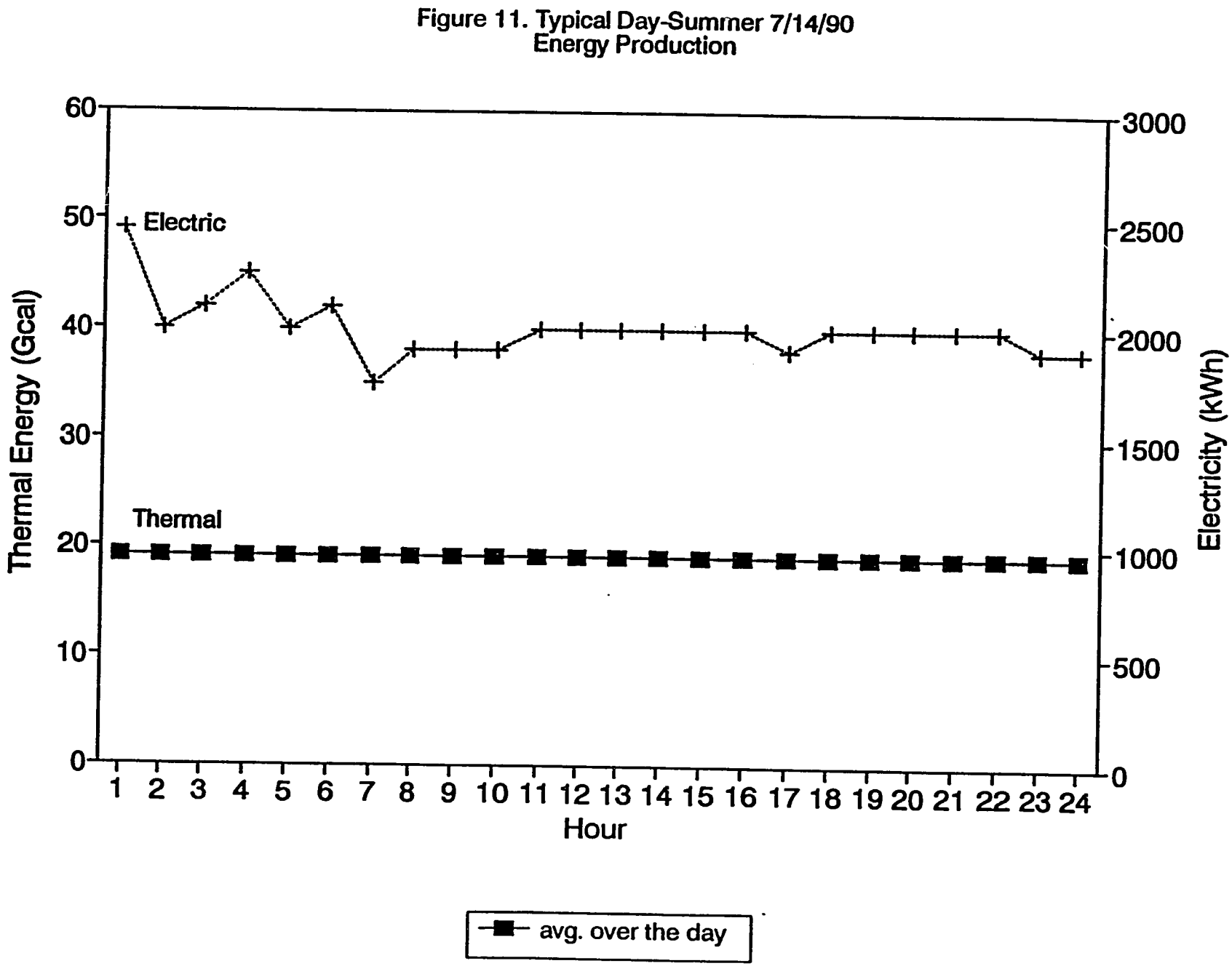


Figure 11. Typical Day-Summer Energy Production

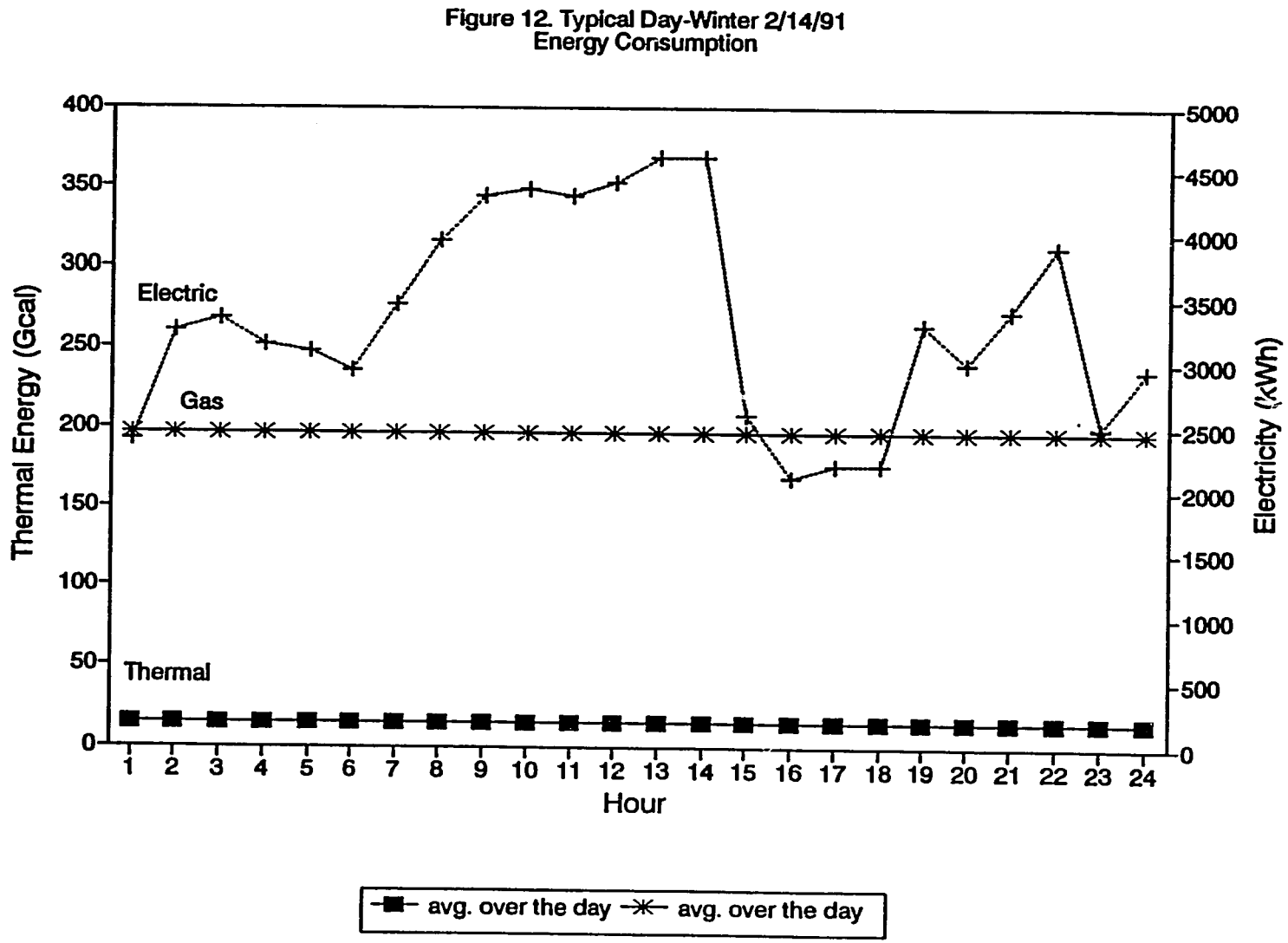


Figure 12. Typical Day-Winter Energy Consumption

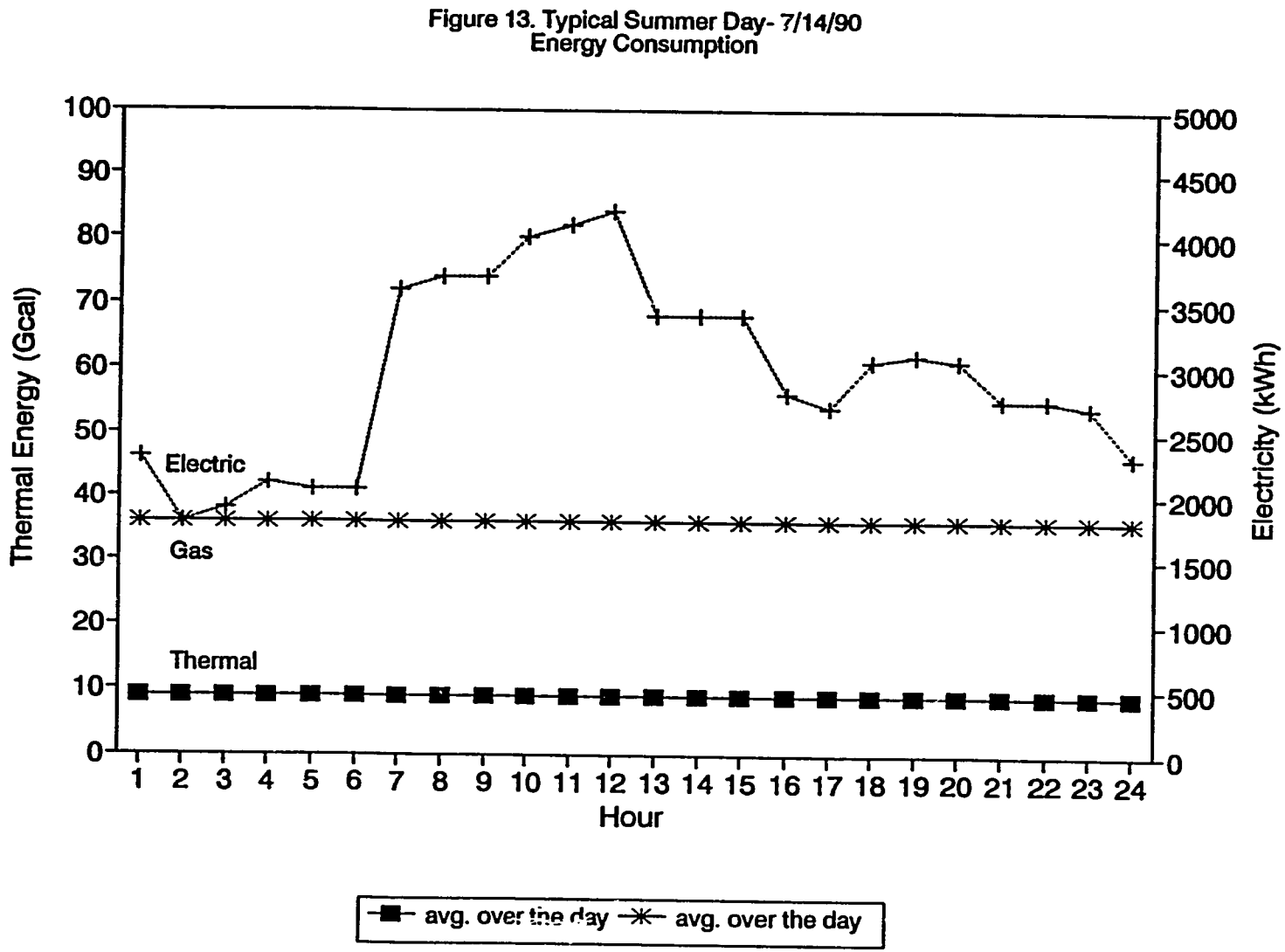


Figure 13. Typical Day-Summer Energy Consumption

2.4 Energy Costs

The prices of gas, oil, electricity and thermal energy are set by the government. The price of oil for the plant is 1400 lei/metric ton which is about one third the cost to other users. The price of gas is 2.8 lei/m^3. The price of electricity purchased by the plant from the national system is 2.0 lei/kWh, while the selling price back to the national system is only 18% of this or .35 lei/kWh. The selling price of the electricity established is so low that it does not cover the costs to produce the electricity. Therefore there is no incentive to produce electricity to sell.

The prices established for thermal energy also place the plant in a difficult situation. GRIRO is required to produce thermal energy for the district heating system, which is sold at 371 lei/Gcal, while the estimated cost of production is about 500 lei/Gcal. In addition, the selling price of steam to industrial users is only 200 lei/Gcal. These prices and costs obviously have a negative effect on the revenue generated. If the selling rate becomes attractive, the plant management is very interested in upgrading the power plant for full operation.

2.5 Power Factor

The power factor for the facility is generally between 84% and 90%. The structure of the electric rate specifies a penalty to be paid to the electric agency when the power factor is below 94%. The staff do not consider this a problem. Because GRIRO is a producer of power they do not always have to pay this penalty and can regulate the power factor with the generators. They do have reactive capacitors for transformer stations and for some larger equipment such as the air compressors. There is opportunity to further improve power factor throughout the plant.

3.0 Audit Description

3.1 Summary

The audit was conducted over a five day period from March 25 to March 29, 1991. A pre-audit trip was made to the facility in late February 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 work, and to make initial requests for basic information about the facility. The main contact at the facility for the auditing team was Mr. Dan Ionitza who is responsible for the energy use of the plant. The Audit Team also met with the Export Manager, Mr. George Alexe, the Sales Director, Mr. Eugen Atanasiu, and the Director of Production, Mr. Ivanescu Lucian. In addition, specific audit issues were discussed with the key plant personnel for each area audited. The representatives of the Ministry of Resources and Industry the team met with at the plant were Mr. Stefan Dumitrescu and Mr. Lucian Stanescu.

In the first part of the audit the key issues were discussed and a short tour of the facility was conducted. The second part included using various auditing instrumentation to collect important energy efficiency information and focused discussions with various plant personnel. After the information collected was analyzed, the short and long-term recommendations were formulated and presented to the facility staff and to Mr. David Salazar, Second Secretary of the U.S. Embassy in Romania.

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 from the plant's perspective were presented. The areas identified were as follows:

- Low gas and oil availability
- General age of equipment
- Feedwater treatment
- Combustion control of Boilers
- Electric arc furnaces.

The facility personnel are aware of the primary inefficiencies in the 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 other factors of production such as labor costs, material costs and the 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 on the type of technical information that may be required to make long-term energy efficiency decisions such as the replacement of boilers. The main areas that the audit addressed were:

- Central Steam Boiler Area
- Turbine/Control Room Area

- Air Compressor Room
- Forging/Heat Treatment Area
- Foundry Area.

3.2 Central Steam Boiler Area

The central steam boiler area provides steam for the turbines for electrical production and for thermal energy required. The age of the boilers is a major concern. The Babcock and Wilcox boilers average about 100,000 hours of operation while they are only rated for 35,000 hours. Therefore, replacement of these boilers should be seriously considered. Like the South Bucharest Plant also audited, GRIRO has problems with oil residuals collecting on the piping of the steam boilers. Once a year the staff chemically clean the pipes to reduce the oil residuals.

Water treatment for the boilers is also a problem. City water is demineralized by a system that uses sulfuric acid (H_2SO_4). The system is limited because there is a shortage of supply of H_2SO_4. Tests are performed every hour to determine if the system needs to be flushed. Many times water is bypassed around the treatment system. Scaling is caused by this bypass of water in the piping system. Five pipes have burst in the boiler piping in the last year due to high deposits.

The control of the boilers is based primarily on flame color, although the staff have tried to use orsat analysis in the past. The operator needs to provide steam to the turbines at 33 atm and 450 °C. The combustion is controlled by manually varying the amount of fuel and the supply of combustion air. Each of the 13 metric ton boilers has ten burners that can use gas or oil. There is one supply fan for each boiler. There is one induced draft flue gas for three boilers that feed their combustion air into a common stack. Four of the boilers surveyed during the audit had the outlet damper for the supply air at the full open position.

The combustion analyzer was used on two of the boilers - boilers #4 and #5 - during a two day period. The results of these tests are summarized in *Table 1*.

Table 1. Combustion Analysis Results

Boiler	Fuel	Stack Temp (°C)	Oxygen (%)	Carbon Monoxide (ppm)	Excess Air (%)	Efficiency (%)
DAY1 #5	Gas	181	15.5	1751	252	66
DAY1 #4	Gas	230	8.7	>2500	75	57
DAY2 #4	Gas	320	7.7	2381	55	58

The first day of analysis for boilers #4 and #5 showed very low combustion efficiency. The excess air was high for both boilers. During the test the boiler operator was asked to reduce the combustion air entering the boiler. He proceeded to close the damper on the supply fan, but the more he closed the damper, the higher the excess air would go for both boilers. After assuring that the communication was clear on what we were asking, we sat down with the boiler operator to determine the cause of the opposite effect seen by closing the dampers. It was determined that the boiler "blast" doors were open during the test, and that the induced draft fan was causing the air flow to increase.

We asked the boiler operator to close the doors on all the boilers and on the second day we proceeded to measure the combustion efficiency of boiler #4. The excess air was reduced by 25%, but the efficiency increased by only 1% because the exhaust temperature was much higher on the second day. What also was noteworthy was that when the operator was asked to close the supply fan damper, the excess air did indeed drop to 35% excess air.

All the combustion tests taken indicate a very high level of carbon monoxide in the flue gases, which significantly decreased boiler efficiency. Most of the tests performed showed unacceptable high temperatures of flue gas exhausted to the atmosphere. After inquiring about the cause of this, we were told that the path of the air through the air preheaters on the boiler was probably blocked by debris that had fallen down on the dampers, thereby greatly reducing the heat recovery of exhausted combustion air and greatly reducing efficiency.

3.3 Turbine/Control Room Area

The turbines and control room are also very old. The Brown Boveri turbine was built in 1929. The turbine and control room are quite well maintained especially considering the age of the equipment. There are some problems with the delivery of oil to the Brown Boveri turbine. In general, though, the control of the electrical system is fairly well automated and not a significant problem area, other than the age of equipment.

3.4 Air Compressor Room

High pressure compressed air is used for testing of pressure vessels. There are four 300 kW air compressors located in the main compressor room that provide air at 7 atm. The fifteen year old reciprocating compressors are three stage and have intercoolers. The waste heat is not used for any purpose and is released to the atmosphere. All compressors have intake air ducts for outside air intake.

A power analyzer should be used to evaluate the average load profile of these compressors, to determine the appropriate controls to increase efficiency. It may also be justified to use separate compressors to supply the low pressure air required in the plant instead of using reducing valves. It may also be economically justifiable to reduce energy use by replacing some of the pneumatic equipment with electric motors. At best the compressor can provide

only 55% of the input energy, while electric motors can provide 90%. In addition, the use of the waste heat from intercoolers and aftercoolers may also be economically justified. Of course, a strict maintenance program to detect and repair air leaks is strongly recommended.

3.5 Forging/Heat Treatment Area

The hammer in the forging area is an example of equipment which could be converted from compressed air to an electric driven press, with considerable benefit to the factory.

There are five gas fired heat treatment furnaces located in the area and a total of ten for the plant. The one annealing furnace that was in operation during the audit was tested for combustion efficiency.

The furnace has four burners that use 25 m^3/hr of natural gas to heat treat 3000 kg of steel at 460 °C. The combustion analysis indicated the following:

- Oxygen: 11.4%
- Carbon Dioxide: 5.4%
- Stack Temperature: 310 °C
- Excess Air: 106%
- Efficiency: 68%

The high excess air was measured with the front door completely closed, not always possible for some of the furnaces. The control of excess air is through valves for each burner. Additional air is induced into the furnace through cracks. The operator of the furnace adjusts the air to the burners by observing the flame color.

Another major user of natural gas found in the welding areas is the preheat burner. The material for welding must be kept at a certain temperature to properly perform the necessary weld. As displayed in Photograph One (Appendix A), the preheat burner nozzle applies a flame to a rotating tank to maintain a consistent temperature. The preheat device uses a burner nozzle that does not provide the ability to regulate combustion air. The temperature of the material is also not accurately measured, which leads to over heating and waste of gas fuel.

3.6 Foundry Area

The foundry area has the highest electrical load of the entire plant. The three large furnaces consume about half the 5 to 6 MW required by the plant. During the audit, only one of the electric arc furnaces was in operation. The approximate size of this arc furnace, built in 1951, is 250 cubic feet with a capacity of one metric ton per hour. The hydraulic control for this arc furnace is very antiquated. The consumption of energy for the furnace varies from 920 to 1500 kWh/metric ton depending on the material heated. During the audit

the high temperature infrared thermometer was used. The arc temperature was measured at 1700 °C and the average outside wall temperature was 271 °C.

4.0 Summary of Results

The results of the auditing effort include both short and long-term recommendations for energy conservation measures. The short-term measures recommended lead to the recommendations for equipment purchases to be delivered in the second phase of the project.

4.1 General Results

The results of the audit emphasize the inefficiency of the old boilers and the electricity use of the electric furnaces. It was found that the combustion efficiency of the boilers could be significantly increased. One of the plant's largest energy problems at this point is the availability of natural gas. In the winter the gas pressure is too low to use and the plant is forced to use oil. The oil use creates residue that reduces the capacity and efficiency of the boiler.

Plant management is facing many short and long-term decisions that will directly affect their energy consumption. Much of the equipment needs to be replaced or overhauled in the near future. At present, they do not have the proper tools and instruments to obtain the information to make sound economic decisions regarding energy efficiency projects. The short-term recommendations for this plant are to provide these tools.

GRIRO personnel have the knowledge necessary and are in the best position to justify further short-term and long-term energy efficiency projects within the context of other production factors. In fact, they have asked the audit team to provide the costs of other useful equipment, that is not included in the final recommended list, for consideration by plant management.

4.2 Short-Term Recommendations

As mentioned above, the recommended short-term measures are generally related to providing the tools to justify further energy efficiency projects. However, many of the tools used will also be used immediately to greatly increase the efficiency of the plant. The following section describes the recommendations and provides the energy savings possible to justify the measure. The specifications for the recommended equipment are contained in Section 4.6.

1. Combustion Analysis

The use of a combustion analyzer is recommended to tune the boilers and allow them to run closer to the optimum excess air for the type of fuel used. While performing the combustion analysis during the audit, an efficiency problem caused by the open blast doors was identified. Once the blast doors were closed the excess air was reduced by 25%, and with proper air preheating the efficiency would have increased by 8%. In addition, we

recommend a hand-held combustion air analyzer that can be used easily to make frequent measurements to maintain proper fuel and air ratios during varying operating conditions for the boilers and the gas fired furnaces.

Using the results of the combustion analysis performed on the boilers, the average boiler combustion efficiency was 63%. It is estimated that with the equipment specified, this could reasonably be expected to increase to 75%. With this efficiency increase the annual savings would be:

Energy saved:	53,000 Gcal
Gas saved:	6 million m^3
Oil saved:	63 Metric tons
Total cost saved:	16.9 million lei ($482,000 at 35 lei/$)

The economic justification of the equipment recommended and payback is as follows:

Combustion analyzer:	$ 5,300
Hand-held analyzer:	$ 800
Total	$ 6,100

Based on the energy savings calculated for the increase in efficiency from using this equipment, the payback would be about one week.

2. Gas Flow Measurement

The gas flow meters that are at the facility are broken or not accurate. One reason the facility is in need of an accurate gas meter is that the supply of gas is not always monitored by the supply system correctly. To verify the amount charged to the company they need a meter accurate to within 1%. We are recommending two gas meters for .05 and .6 atm gas flow. These would also provide an example of the type of meter they may want on other gas fired equipment.

The total boiler efficiency cannot be determined if the fuel flow rates are not provided. The measurement of overall boiler efficiency can indicate problems and justify energy conservation measures. It can also increase the system efficiency by indicating the most efficient boiler to operate. From the combustion analysis, the variation in boiler combustion efficiency was 5% to 10%. It is therefore conservative to estimate a 2% increase in efficiency by operating the most efficient boilers. With a 2% increase in boiler efficiency the annual savings would be:

Energy saved:	8833 Gcal
Gas saved:	1 million m^3
Total cost saved:	2.8 million lei ($80,000 at 35 lei/$)

The economic justification of the equipment recommended and payback is as follows:

Two gas meters	$ 11,000

Based on the energy savings calculated for the increase in efficiency from using this equipment, the payback would be about two months.

3. Monitoring of Heating

The areas where accurate temperatures measurements could improve efficient use of fuel include the heat treatment furnaces, the preheating for welding, and the electric furnaces. When the material is heated to a higher temperature than necessary, or for a longer time, fuel is wasted. It is very difficult to estimate the energy savings due to reduced heating requirements because of the many variables and data required. The recommended instruments will allow this data to be gathered and be used to increase the efficient use of the heating equipment. The instruments recommended are high and low temperature infrared thermometers, and a digital thermometer. A conservative estimate of increased efficiency from the use of these instruments is .5% of the fuel and electricity required to heat the material. With this efficiency increase the annual savings would be:

Energy saved:	7,200 Gcal
Gas saved:	81,000 m^3
Electricity saved:	35,000 kWh
Total cost saved:	300,000 Lei ($8,600 at 35 Lei/$)

The economic justification of the equipment recommended and payback is as follows:

Infrared therm. (high):	$2,400
Infrared therm. (low):	$2,200
Digital thermometer:	$650
Total	$5,250

Based on the energy savings calculated for the increase in efficiency from using this equipment, the payback would be about eight months.

4. Fluid Flow Measurements

There is no accurate measurement of oil or water flow in the plant. With accurate measurement of oil flow to the boilers, the most efficient boilers can be selected to operate. It is estimated that by using the most efficient boilers the system efficiency can be raised by 2 to 5%. The recommendation is for one portable ultrasonic flow meter that can also be used to measure water flows for thermal energy balance calculations. With an increase in oil burning efficiency of 3%, the annual savings would be:

Energy saved:	745 Gcal
Oil saved:	81 metric tons
Total cost saved:	325,000 lei($9,300 at 35 lei/$)

The economic justification of the equipment recommended and payback is as follows:

Ultrasonic flow meter	$7,900

Based on the energy savings calculated for the increase in efficiency from using this equipment, the payback would be about ten months.

5. Electric Load Reduction

There is about 5 MW of connected electrical load within the plant. About half of this load is used by the electric furnaces in the foundry. The main air compressors have a total connected load of about 1.2 MW and most of the rest of the load is spread over electric motors for pumps and fans. The energy profiles of the air compressors are not presently known by the plant personnel because they do not have the instruments required to determine this profile. We recommend a power analyzer to determine the air compressor energy use to optimize the system.

Some of the system changes that can be justified with an energy profile of these compressors include using appropriate controls, using separate compressors to supply the low pressure air required in the plant instead of using reducing valves, replacing some of the pneumatic equipment with electric motors, using the waste heat from intercoolers and aftercoolers, and developing a maintenance program to detect and repair air leaks. The efficiency increase from just one of these measures would be significant. The power analyzer can also be used on centrifugal fans and pumps to justify variable speed drive systems.

Energy conservation measures identified with the power analyzer for the air compressor system will be at least an increase of 5%. The annual energy savings from a 5% increase in efficiency for the air compressor system would be:

Energy saved:	174 Gcal
Electric savings:	200,000 kWh
Total cost saved:	400,000 lei($1,400 at 35 lei/$)

The economic justification of the equipment recommended and payback is as follows:

Power analyzer	$5,700

Based on the energy savings calculated for the increase in efficiency from using this equipment, the payback would be about six months. For a five year payback on the whole cost of a project that saved 5% of the compressor energy, they could spend about $60,000.

4.3 Long-Term Recommendations

The main consideration for long term measures for the plant is the age of the equipment involved. The recommended long term energy efficiency measures in this report must be considered in conjunction with the plant's other long term objectives and economic prospects.

A. Repair or Replace Air Preheaters

There is a great loss of energy up the stack of the boilers because the preheaters for combustion air are not functioning properly. The efficiency of each boiler could be improved 5% to 10% by recovering the heat lost. The preheaters should be repaired to operate properly. Replacing the preheaters may not be economical given the age of the equipment.

B. Automatic Combustion Control

Once the preheaters are fixed, consideration should be given to automatic combustion control. The newer 50 metric tons/hr boiler should be given the first consideration. Automatic combustion control or oxygen trim systems can reduce the excess air to the minimum required and provide the highest efficiency at all load conditions. The older boilers had high levels of carbon monoxide in the flue gas, indicating a lack of good mixing with the air provided. The 50 metric ton/hr boiler should be checked for this condition before an oxygen trim system is recommended.

C. Upgrade Arc Furnace

A detailed energy analysis needs to be performed on the present arc furnace to determine the economic advantages in upgrading the existing furnace or replacing the furnace. Consideration should be given to possible increased insulation levels, better control, and firing enhancement measures, such as supplemental oxyfuel barriers.

D. Condensate Return

The annual costs of not providing condensate return should be addressed including increased energy costs, water treatment costs, and costs incurred by not treating the water above the capacity available. The cost of providing some condensate return may be low enough to meet payback criteria established by the plant.

E. Replace Preheat Burners

A considerable quantity of gas is used by the gas burners that preheat metal requiring welding. The present burner system is quite antiquated and should be replaced with burners that have more control over flame application and combustion air. In addition, an

automatic control may be considered to optimally provide the heat required to meet the specified temperature.

F. Optimize Air Compressor Operation

This was discussed in the justification of the power analyzer, which would be a necessary tool in analyzing the air compressor system. The measures involved in optimizing the air compressor system include: using finer controls; supplying the low pressure air required with separate compressors; replacing some of the pneumatic equipment with electric motors; using the waste heat; and developing a maintenance program to detect and repair air leaks.

4.4 Replication Potential

As was stated earlier, GRIRO is the only plant in Eastern Europe having authorization to use the ASME U and U2 stamps. The plant is unique in Romania in that aspect. However, there are many plants in Romania that have old boilers, large electric and gas furnaces, and high pressure compressed air systems. The basic needs and recommendations described for the GRIRO plant would easily apply to these other plants.

4.5 Pricing and Policy Issues

The pricing of the fuel both bought and sold by GRIRO is a very important factor in determining the justification of some energy efficiency measures. The price of oil, gas and electricity is set by the government. The selling price of the electricity and thermal energy generated is also set by the government. Until the prices established are favorable to produce and sell the energy, GRIRO will probably maintain only the level of production that is required to meet the thermal loads of the district heating system.

Although the plant is losing money by producing the required thermal energy, they have been provided oil by the government and have been allowed to remain operating while other industries were forced to shut down. The next year could provide many other changes to their economic setting as GRIRO becomes more of a private company.

Another factor in the costs associated with their business is the sole sourcing of some of their raw materials. A major advantage to GRIRO's economic situation is the large percent of export business, but because they have been a private company for only one month, they are finding it hard to establish a credit line abroad.

4.6 Energy Conservation Equipment for Immediate Installation

1. Combustion Analyzer

ENERAC 2000
RS-232 Port/Internal Modem
220 Volt/50 Hz
SO_2 Sensor
No_x Sensor
Estimated Cost $5,300

The combustion analysis indicated that the efficiency of the boilers could be significantly increased. Boiler efficiency can be increased up to 10 percent in the oil fired boilers by using a combustion analyzer to determine the actual excess air during operation.

2. Portable Combustion Analyzer ($800)

Oxygen Sensor
Carbon Monoxide Sensor
Maximum Temperature: 1000 °C
Estimated Cost $800

This will be used primarily to check boiler efficiency to provide information for manual adjustments to air/fuel ratio.

3. Two Gas Flow Meters

One Meter for Natural Gas at:
- .05 atm.
- 6000 m^3/hr max. flow

One Meter for Natural Gas at:
- .60 atm.
- 6000 m^3/hr max. flow

Better than 1% precision for both meters
Estimated Cost $11,000

These meters will be used to accurately measure gas flow into the central boiler system from two pressure sources.

4. High Temperature Infrared Thermometer

Digital Hand-held Temperature Sensor
Temperature Range: 600 to 3000 °C
Estimated Cost $2,400

This thermometer will be used to determine accurate temperatures of combustion chamber, heat treating oven and preheated metal for welding. An accurate reading of temperature allows better control and less over heating which wastes energy.

5. Low-Temperature Infrared Thermometer

Digital Hand-held Temperature Sensor
Temperature range: 0 to 1000 °C
Estimated Cost $2,200

The best instrument to quickly and accurately determine surface temperatures of pipes and other vessels is an infrared temperature sensing "gun". From the additional information on temperatures that this sensor will provide, it will be very easy for the plant personnel to make the calculations to determine the economic justification of adding insulation.

6. Hand-Held Digital Thermometer

Surface Probe
Immersion Probe
Gas Probe
Estimated Cost $620

The digital thermometer should provide capability for measuring surface and fluid temperatures to 1000 °C. This instrument will allow determination of existing sensor accuracy as well as temperature information for improved control and justification for process changes.

7. Portable Ultrasonic Flow Meters

For Oil or Water Flow Measurements
Should be simple to use and have memory and totalizing capabilities.
Estimated Cost $7,900

These meters will primarily be used to measure oil flow into the boilers to assist in analysis of boiler efficiency and conservation project specification. Photograph Two in Appendix A displays an ultrasonic flow meter measuring actual water flow.

8. Portable Power Analyzer

Max. Voltage: 600 volts
Max. Current: 1000 amps
Memory (one week, with 15 min. readings)
Measure: volts, amps, vars, power factor, power

Ability to download to PC/spreadsheet
Hard copy printout
Estimated Cost $5,200

This power analyzer will be used to measure loads on electric equipment to assist in technical and economic justification of conservation projects.

5.0 Plant Management and Organization

The new plant management structure is shown in *Figure 1* (page 8). The organization has been recently formed, but is not yet officially approved by the general director. It is patterned after the Japanese organizational structure upon the recommendations from a report on management and business improvement possibilities written by a Japanese agency. The organization proposed is a rigid structure with few matrix elements apparent, although the staff interactions seem to be such that the exchange of ideas does occur.

The energy engineer (not shown on chart) is in charge of reviewing and recommending energy related projects to the production director. The final decision on the project is made by the production director after other production factors are considered. Given that the energy engineer has the time and staff to investigate the many energy conservation opportunities and the proper priority is allocated to the recommended projects. the new structure is a good step toward optimizing energy efficiency.

6.0 Implementation Phase

The implementation phase of the audit involved a return trip to the facility from August 12 to August 16, 1991. During this phase the main objective was to facilitate the installation and use of the equipment purchased for the facility based on the previously discussed recommendations. The distribution of the equipment on the site was performed by the Romanian Ministry of Industry. A representative from the ministry was also involved in this phase. The key elements were:

1. Distribution of portable measuring instrumentation;

2. Training for plant staff;

3. Installation of fixed energy efficiency equipment;

4. Review of draft audit report with plant staff;

5. Monitoring of the equipment;

6. Discussion of past and future conservation activities; and

7. Development of a specific plan for equipment utilization;

A draft of the Audit Report containing sections 1.0 through 5.0 was provided to the Ministry and plant staff for their review prior to the site visit.

6.1 Summary

All of the portable equipment was received and distributed by the Ministry before the end of the implementation phase. Mr. Petrescu was the Ministry representative on site. The primary plant contacts were Dr. Dan Ionitza, Plant Energy Engineer, and Mr. Serban Stroe, Chief of Energy and Mechanics. Training on the equipment was completed for plant staff who would use the equipment. Demonstrations of the power analyzing equipment included "down loading" of the power data collected to the EPSON PC. Software on the computer was demonstrated, including techniques in developing audit reports and project justification. The ultrasonic flow meter and hand-held thermometer were demonstrated on a main water pipe for the plant. The hand-held combustion analyzers were calibrated, and training was completed during sample tests of the steam boilers.

Two permanent gas flow meters were scheduled to be installed at the facility, but had not arrived as of the site visit. The responsibility of ensuring proper installation and commissioning the gas flow meters is with the new private Romanian engineering company, INSTAPART. During one site visit INSTAPART participated in determining the most appropriate location for flow meters. The meters will be placed on the main gas lines. This

will require coordinating with the gas supply company and obtaining their permission to install the meters. Mr. Mihai Georgescu of INSTAPART was also trained on the proper use and application of the ultrasonic flow meter at this facility.

The draft Audit Report was reviewed with Mr. Ionitza, Mr. Stroe, and Mr. Eugen Atanasiu, Director of Sales. They felt in general that the report was useful and that it provided a service in summarizing their primary energy concerns. They had some corrections and new prices for the energy costs listed in Section 2.4, but did not find other inaccuracies in the report. The plant has taken a number of steps to improve energy efficiency that are similar to those recommended in the Audit Report.

The equipment implementation plan was developed by the staff, and outlines the method and frequency with which the equipment will be used by the plant to reduce energy use.

6.2 In-Country Review of Draft Audit-Report

Each section of the draft Report was reviewed with the plant staff. They found no discrepancies in what was stated in the Plant Description, although they did have some comments regarding recent changes. As the Director of Production Mr. Radu Balan has replaced Mr. Ivanescu.

The responsibility for energy efficiency projects was further defined. The energy department develops ideas for larger projects and submits them to the vice president of manufacturing. For smaller or relatively low-cost measures, the energy department has the authority to allocate funds toward these projects as appropriate. These projects will be prioritized by projected payback.

Comments on the calculations in the Energy Profile related to increases in fuel and electricity prices since the first site visit. The price of natural gas has increased by 5% to 2.94 lei/m^3. The price of electricity purchased by the plant has increased by 40% to 2.8 lei/kWh, but the selling price has increased by 43% and allows the plant to make some profit in the production of electricity that is sold back to the national system. (note: the calculations of cost savings in the report uses the old prices).

Thermal energy production has also become profitable. Thermal energy is now sold to the district heating system at 648 lei/Gcal, while the production costs have remained at about 500 lei/Gcal. However, steam is still sold to industrial users at 400 lei/Gcal, so the plant is still losing money on industrial steam. The overall positive money flow for thermal and electric production has encouraged plant management to pay closer attention to the types of system improvements that may help optimize their output and efficiency.

Plant management could find no inaccuracies with the plant energy profile figures or with the calculations of energy savings in Section 4.0. They agreed with the main energy efficient problems listed in Section 3.1 and did not have any additional items.

In general, the audit was described as very informative with the added benefit of providing an outside view for the vice president to consider. Management also felt the development of contacts with U.S. manufacturers will allow them to better obtain updated information.

6.3 Energy Efficiency Measures Adopted by the Facility

The plant has repaired three of their boilers' preheaters by replacing the piping in the preheater as suggested in the recommended measures in Section 4.3. They repaired the preheaters in June, two months after the initial audit site visit. Management said that the audit helped them to decide to repair the preheaters. They plan on changing the piping on the other three boilers this year.

Plant management does not plan to install automatic combustion on the older boilers and will use the ENERAC combustion analyzer instead. This is because the boilers are very old and may need to be replaced soon. They plan to perform a study on upgrading the arc furnace using the Dranetz power analyzer. They are planning on repairing the tank used in their condensate return system to maximize the condensate returned. They also feel a penalty should be charged to the industrial steam users for the lack of condensate return.

Plant management plans to replace the preheat burners used in the welding process. Information was obtained for them from the U.S. manufacturers of preheat torches. They will perform a study on the air compressor system using the Dranetz meter to assist in identifying measures to reduce energy consumption. They also plan to set up a preventive maintenance program that will detect air leaks and repair them.

6.4 Management Results

The proposed organizational structure is discussed in Section 5.0. Griro has now implemented the basic structure as shown in Figure 1, but there are some new names to sections and directors. The differences related to energy efficiency projects are that the Production Director is now called the Vice-President of Manufacturing, and that the Energy/Mechanics Section is now a part of the Maintenance and Repair Division. This hierarchy indicates that there is an additional layer between Vice-President/Director and the Energy Office that was not originally proposed.

The structure should allow communication between the energy office and the Vice-President of Manufacturing, who makes decisions on capital improvements in general. The separate energy office facilitates focusing on energy issues and justification of future projects. The privatization of the company was also discussed. A law was recently passed that will allocate 30% of companies such as Griro to their workers through the distribution of stock, expected to be completed by the end of the year. The remaining 70% will still be owned by the state at this time. This should provide an incentive for workers to increase energy efficiency.

6.5 Implementation Plan

The staff was asked at the beginning of the site visit to develop a utilization plan for the equipment purchased and delivered to the plant. During the visit utilization options were discussed for individual equipment. Following is the utilization plan developed by plant personnel:

1. Combustion Analyzer (ENERAC)

The combustion analyzer will be used in the thermo-power plant for the daily analysis of combustion gases. The results obtained will then be used to adjust the boiler for most efficient combustion. A more efficient application of this analyzer is the long-term and periodic monitoring of combustion. Through data collection and analysis, the problems and defects of each boiler will be studied. From the studies a list of annual repair projects will be developed.

The combustion analyzer is a key element in minimizing fuel consumption and reducing boiler repair costs by facilitating the preparation of a thermal balance sheet specifying the boiler's performance. It is their intention to prepare programs for periodic analysis under various operating conditions (seasonal, fuel type, thermal load, etc.) by accurately registering the efficiency results.

2. Portable Combustion Analyzer

This type of analyzer will be used as required especially in the forging area for the heat treatment and combustion gas analysis of the forging furnaces. Air-gas mixtures will be adjusted to obtain efficient combustion. The test will be performed during the heat process and the air-gas mixture immediately adjusted. This analyzer will be intensively used for each heat or treatment option. For more rapid tests this analyzer will be also used in the thermo-power plant for analyzing the boiler combustion. The results will be registered in separate documents in the fabrication technology division.

3. Gas Flow

The plant intends to use these meters to measure the total gas consumption for the two supply stations. By using this apparatus they will accurately know the gas consumption of the shop and the points where gas consumption could be reduced. The existing measuring units are worn out and are not reliable.

4. High-Temperature Infrared Thermometer

This thermometer will be used in the process of steel making in order to periodically determine the mixture temperature and accurately specify steel making time. The melting

is performed in induction or arc furnaces that consume about 1 MW each. They will also use the thermometer for determining the weld preheating temperature. It will be used daily.

5. Low-Temperature Infrared Thermometer

This thermometer will be used to develop a temperature chart of heated surfaces (furnaces, boilers, steam pipes, etc.) which will be used during future repair works, increasing refractory or insulation levels. This thermometer may also be used for determining the temperature of various subassemblies not having temperature sensors, under operating conditions (turbine bearings, etc.).

6. Hand-held Digital Thermometer

This type of thermometer will be very useful for determining the temperature of working surfaces, such as welding and bearing surfaces, and fluids. It is easy to use and will be used daily.

7. Portable Ultrasonic Flow Meter

This apparatus will be used for experimental determination of oil and water flows in the power plant. Presently, the oil flow is calculated empirically. This meter will partially compensate for the lack of oil flow meters. Plant staff intend to prepare a method for calculating consumptions under various loads and operating conditions to calculate the oil use more accurately. The main objective will be to optimize burner oil flows and boiler operation, and perform a boiler energy balance. See Appendix A, Photograph Two for an example of an ultrasonic flow meter in use.

8. Portable Power Analyzer (Dranetz)

This analyzer will be intensively used for performing measurements at the transformation posts as well as at the most important power consumption points. Some of these important consumption points include:

- Induction and arc furnaces (1 MW)
- Air compressors (300 kW)
- Large machine tools (200 kW)
- AC cranes (400 kW)
- Rolling machine press (250 kW).

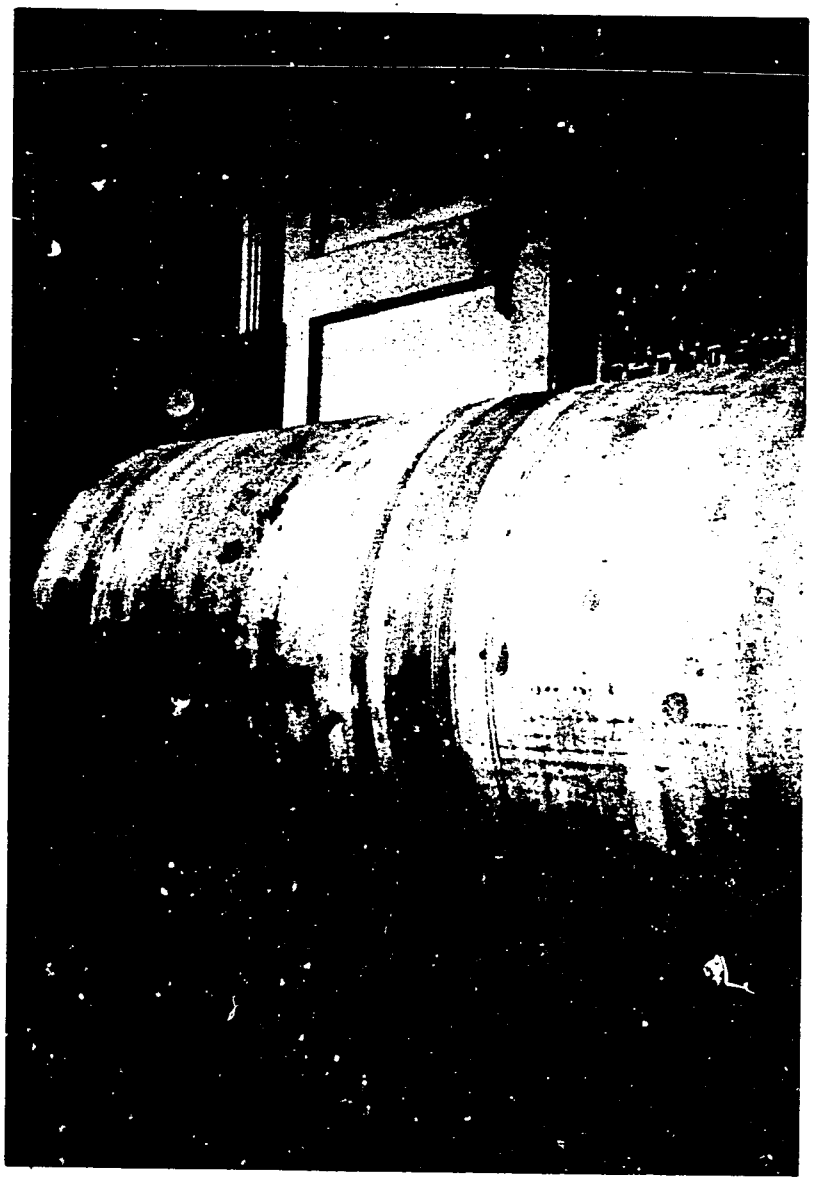
They will prepare overall energy balance sheets on each aggregate and calculate present efficiency levels. They will estimate the refurbishing costs with a view to reducing energy losses due to faulty electric supply of transformers as well as due to excessive consumption of capacitors. This apparatus will be constantly used. A computer has been supplied by the facility (IBM PC 286) for use with the Dranetz and for other energy analysis requirements.

6.6 Expected Energy Savings

For some equipment use an energy savings estimate was not possible due to the number of unknown variables. The plant did make some estimate of energy savings for much of the equipment, in particular applications. A fuel savings of 15% for the boilers is expected by the use of the ENERAC combustion analyzer, and a 10% increase in efficiency is estimated for combustion improvements on the heat treatment and forging furnaces.

It is estimated that a 7% increase in energy efficiency in steel making will result from the use of the high temperature infrared thermometer and a 3 to 4% increase in efficiency will result from the use of the low temperature infrared thermometers. The use of the power analyzer (Dranetz) is expected to justify changes that will increase electric efficiency throughout different areas of the plant by 15%. Wherever possible, the plant staff plans to collect data throughout the year to determine the actual effect of the equipment on energy efficiency.

APPENDIX A
Photographs



1. A worker uses an open gas flame to preheat the weld area.

2. Mr. Ionitza uses the ultrasonic flow meter to measure actual water flow.

APPENDIX B
List of Abbreviations

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
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
K	= Kalvin
kcal	= kilocalories = 1 thousand calories = 3.968 BTU
Kcs	= 29.77/$1 US
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
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
metric ton	= 1 thousand kilograms = 1.1023 U.S. tons
mg	= milligrams
min	= minute
MJ	= megajoules
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
PF	= power factor
ppm	= parts per million
psi	= pounds per square inch
psig	= pounds per square inch (gauge)
R	= thermal resistance
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
W	= watts
yr	= year