ENERGY EFFICIENCY AUDIT REPORT
WOLA DISTRICT HEATING PLANT

Elektrociepłownia Zeran (Wola)
Warsaw, Poland

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ACKNOWLEDGEMENTS

The IRG Industry Energy Audit Team for Poland wishes to express sincere thanks to the plant management and technical personnel for the valuable time and effort spent in preparing for the audit visit to the plant. The cooperation shown by the plant facilitated the communication and exchange of ideas and experiences in the area of energy management. IRG also would like to thank the U.S. Agency for International Development, European Development Resources, Office of Energy and Infrastructure for coordinating the entire project.

It is the hope of the Audit Team that the exchange established through this initiative be maintained in the future.
### ABBREVIATIONS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.I.D.</td>
<td>U.S. Agency for International Development</td>
</tr>
<tr>
<td>BTU</td>
<td>British thermal unit</td>
</tr>
<tr>
<td>GJ</td>
<td>glaga joule</td>
</tr>
<tr>
<td>IRG</td>
<td>International Resources Group, Ltd.</td>
</tr>
<tr>
<td>MPa</td>
<td>millipascal</td>
</tr>
<tr>
<td>MW</td>
<td>mega watt</td>
</tr>
<tr>
<td>m³</td>
<td>cubic meters</td>
</tr>
<tr>
<td>psi</td>
<td>parts per million</td>
</tr>
<tr>
<td>zł</td>
<td>zloty; unit of Polish currency</td>
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</table>
PREFACE

In the wake of the political and economic collapse of the Soviet Union, the nations of Central and Eastern Europe confront an energy situation for which there is no historical precedent. Overnight long-standing supply agreements for oil, natural gas and electricity supplies from the Soviet Union have been curtailed or discarded with attendant dramatic increases in the prices of these commodities. In addition, as the veil of secrecy has been lifted in these nations, the devastating legacy of years of neglect of coal and other fossil fuel pollution and an aging, largely unsafe, and unregulated nuclear power industry are vital issues that need to be addressed in light of the fundamental structural reform of these Central and Eastern European economies. Democracy for these countries means change amidst great political and economic uncertainty.

To support the transition from Soviet-based dependence to democracy, based on free market principles, the United States, in 1989, instituted a program to assist the countries of Central and Eastern Europe with humanitarian aid, technical assistance and direct economic aid. The U.S. focused initially on Poland and Hungary, where this transition was in its most advanced stages. Since that initial commitment to Poland and Hungary, the U.S. has expanded its focus to include Czechoslovakia, Bulgaria, Romania and Yugoslavia as technical assistance recipients in Eastern and Central Europe. In the future, large scale assistance is likely to be given to the Baltic States, Estonia, Latvia and Lithuania, as well as the republics of the former Soviet Union - and possibly Albania.

Grants and other assistance to Central and Eastern Europe already account for a U.S. commitment of $1.5 billion since 1989. In Fiscal Year 1991, alone, grant assistance to the region totaled about $450 million. Many of these special assistance grants were funded through the U.S. Agency for International Development, with implementation assistance by various U.S. agencies and private sector organizations.

One important initiative under the U.S. technical assistance program was the U.S. Agency for International Development Emergency Energy Program for Eastern and Central Europe, Component #1: Industrial Energy Efficiency Improvement. This program was designed to address regional energy sector problems on a short-term basis and to identify and implement energy efficiency initiatives. This effort combined in-plant, on-the-job training with identification and implementation of energy management practices and low-cost measures to be implemented during the period of the contract work. This report outlines the activities of the Industrial Energy Efficiency Improvement project in one plant in Poland.

The purpose of the Industrial Energy Efficiency work was to improve in the short-term the efficiency of energy use by industry. Specific objectives included:

1) fostering improved management of energy use in industrial plants by identifying and implementing immediately cost-effective "low cost/no cost" energy efficiency improvements;

2) transferring energy auditing and management techniques including financial and economic analysis techniques; and
providing equipment to implement low-cost options, to improve monitoring and energy management, and to identify additional energy efficiency opportunities.

To accomplish these objectives the following actions were undertaken:

1) Eight industrial facilities were selected as target plants for audits. The plants were selected on the basis of:
   - potential for significant energy savings;
   - the likelihood that the plants will continue operating in the new economic climate;
   - applicability of results to similar plants in Poland to which the energy conservation measures developed in this program could be applied.

2) Two Audit Teams went to Poland on two separate occasions, each Team visiting four or five plants to perform energy audits and conduct training.

3) The Teams identified, specified, and procured energy efficiency equipment to be used by the plants to implement short-term energy efficiency improvements.

4) Representatives of the Audit Teams returned to the plants in October 1991 to assist in implementation of the audit recommendations, and to monitor the energy improvements actually achieved.

5) The Teams presented a wrap-up workshop for plant managers and technical staff of the participant plants and other similar plants throughout the country. The seminar was held in Warsaw October 8-9, 1991.

The Cogeneration Audit Team audited five plants (Figure 1):

- Blachownia Steam Power Plant - Kędzierzyn-Koźle
- Łęg Thermal Electric Power Station - Kraków
- The Thermal Power Company, Plant No. 2 - Łódź
- Wola District Heating Plant - Warsaw
- Cogeneration Plant, Zakłady Azotowe - Włocławek

The Audit Team collected data at every plant on the costs of producing steam and electricity, primarily using plant records, audit measurements, and interviews with plant officials. In some cases, the Audit Team counselled the plants in the establishment of systems for cost accounting in the plant, particularly where it related to energy costs per unit of output. The Industrial Energy Efficiency activities had tremendous success and generated letters of support from several plant managers.
Figure 1  Location of plants audited by the IRG team
Program Rationale

While this program was clearly a logical starting point for improved energy use patterns, it is only a beginning. Although all activities under the Industrial Energy Efficiency project were conducted using a relatively small budget for equipment purchases, the energy savings results were significant. Thus, the program demonstrated the tremendous potential for energy savings through low cost and no cost mechanisms. Moreover, these programs represented important energy savings initiatives that were implemented on a timely basis, within a matter of months.

These initiatives should serve as a cornerstone for a new way of approaching energy savings in Poland. They represent the lowest cost and most readily implemented energy savings initiatives available. Furthermore, the energy savings techniques/measures identified and implemented in this Emergency Energy Program should be applicable to other similar facilities and process units throughout Poland. As a result, these low cost techniques for improving energy efficiency, and thereby improving economic efficiency in industrial facilities, should serve as a model for restructuring energy use in the Polish industrial sector.

The project also highlighted a number of issues that fundamentally affect the ability of industrial entities to solve energy problems. Basic issues such as industrial energy pricing, environmental regulation, legal reforms, corporate organization and management structure, personnel training, and the overall economic environment all affect the ability of industrial concerns to implement energy savings opportunities. Thus, the Industrial Energy Efficiency Improvement project attempted to address issues of micro-level plant organization and management, training, and economic evaluation at each of the plants. In addition, the IRG Team has outlined key macro-level issues which must be addressed by the Government of Poland before comprehensive energy efficiency initiatives are enacted. These issues are addressed in this report as well as in Industrial Profile Report and the Policy and Institutional Analysis Report for Poland, both prepared as part of the Industrial Energy Efficiency Improvement project.

Ultimately, the IRG Team is convinced that the overwhelming potential for energy and cost savings in the Polish industrial sector will provide sufficient incentive for plant managers and industrial executives to actively promote the need for reforms that encourage energy conservation and improved economic efficiency.
EXECUTIVE SUMMARY

As part of the U.S. Agency for International Development (A.I.D.)-funded Emergency Energy Program for Eastern and Central Europe, the International Resources Group (IRG) Cogeneration Audit Team visited Poland in April 1991 to conduct an energy efficiency audit of The Wola District Heating Plant in Warsaw, Poland. The overall purpose of the audit was to assist Wola in identifying low- or no-cost opportunities to save energy. In addition, the Audit Team trained key plant personnel in modern methods of energy management as practiced in the United States.

Wola was chosen for inclusion in the Industrial Energy Efficiency Improvement Project based on assessments by the project definition team, which included IRG Vice President Charles Ebinger and IRG Team Leader Gerald Decker. The Team evaluated the following issues to decide which plants should be included in the project:

- potential for energy savings, from low cost or no cost activities;
- overall economic status (i.e., would the plant survive removal of price subsidies and/or privatization?); and
- replicability of the project activities and experiences at similar plants throughout Poland.

Following the April 1991 visit, the IRG Team returned to the U.S. and arranged the procurement of equipment to be used by the Wola Plant to implement the low-cost/no-cost energy efficiency initiatives identified.

After the equipment was ordered, the Team returned to Poland in October 1991 to learn the progress the Wola plant had made in implementing the recommendations and to provide additional advice on equipment installation and key energy management issues.

1.1 Plant Background

Wola supplies part of the Warsaw District Heating System with thermal energy. Wola is an oil-fired plant built between 1974 and 1980, and produces only thermal energy, and having no turbines for generating electricity. All the heating and cogeneration plants in the Warsaw system are operated by the Thermal Power Company of Warsaw. From an administrative standpoint, Wola is an operating department of the Thermal Power Plant-Zeran, one of the most efficient cogeneration plants in Poland.

Originally, Wola was designed to use a gas turbine and meet peak demand. However, due to lack of natural gas supplies, the plans to use a gas turbine were abandoned. Similarly, due to excess demand in the system, Wola began operating throughout the heating season (roughly October 1 to May 1).

The plant’s fuel consumption in 1990 was 85,157 tons of fuel oil No. 3, with the average cost of this fuel oil 712,000 zloty (zl) or $75 per ton. The price for fuel oil peaked at 1,300,000 zl/ton during the Gulf War, and then dropped to 800,000 zl/ton ($84/ton). Fuel costs represented 65.33% of the plant's variable costs for producing thermal energy. During 1990, the average cost was 30,454 zl/giga joule (GJ) (about $3.20/GJ), and the average price received
for thermal energy was 40,333 zl/GJ (about $4.25/GJ). Wola produced 3,089,438 GJ of thermal energy in 1990.

Low-cost opportunities for energy conservation identified by the IRG Cogeneration Audit Team principally involved improvements in combustion efficiency, thermal energy use, steam recovery, and general plant housekeeping and maintenance. In addition, the Team recommended strategic, operational, and management changes to improve the plant's overall economic status.

Since the five plants visited by the Audit Team had many similarities, it was useful for the Audit Team to develop comparative information on the plants. Tables summarizing this comparative information are included in Appendix III; these outline boiler operating conditions, distribution of the costs of production, specific heat consumption to produce electricity and thermal energy, coal pricing, fuel oil pricing, and personnel/functional structures.

1.2 Results of the Emergency Energy Program

As part of the audit process, the Team recommended several items of equipment be purchased under the Emergency Energy Program. Items purchased included:

- Infrared Thermometer
- In-Situ Oxygen Analyzer
- Steam Traps

These recommendations are summarized below in Table 1; this table also summarizes estimated energy savings for each item, a key criterion used in recommending the purchase of specific equipment. Given the need for high impact energy savings results, all equipment purchased had payback periods of one year or less. In addition, special attention was given by the IRG Team to procuring equipment that would produce results in energy savings that could be replicated in plants throughout Poland. Thus, the Team focused on steam systems, combustion systems, and heat losses, areas in which most plants in Poland would be deficient.
Table 1. Equipment Procurement

<table>
<thead>
<tr>
<th>Equipment Item</th>
<th>Cost</th>
<th>Annual Savings</th>
<th>Type of Savings</th>
<th>Payback Period (years)</th>
<th>Fuel Oil (tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Infrared Thermometer</td>
<td>$427</td>
<td>$1,700</td>
<td>steam</td>
<td>0.24</td>
<td>27</td>
</tr>
<tr>
<td>In-situ O₂ Analyzer</td>
<td>$9,553</td>
<td>$38,700</td>
<td>combustion</td>
<td>0.25</td>
<td>613</td>
</tr>
<tr>
<td>Steam Traps</td>
<td>$2,619</td>
<td>$33,000</td>
<td>steam</td>
<td>0.08</td>
<td>523</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$12,599</td>
<td>$73,400</td>
<td></td>
<td></td>
<td>1163</td>
</tr>
</tbody>
</table>

Unlike many other technical assistance projects, the Industrial Energy Efficiency Improvement project was an action-oriented initiative, designed to demonstrate the potential for energy savings in Poland by actually implementing energy efficiency projects in selected facilities. This audit report is intended to provide the reader with a background against which to view the actions implemented under this project. This report outlines the observations, comments, and recommendations of the Audit Team, gathered during the initial plant audit in April 1991, and from subsequent discussions with plant managers.

To allow a more comprehensive evaluation of the results of this initiative, specific project results will be presented in the summary reports for the project. Therefore, this audit report focuses on the costs, benefits, and problems associated with each energy efficiency option. In addition, the report briefly outlines management, training, policy, and institutional factors that affect the ability of plants to achieve energy efficiency improvements.
2. PLANT PERSPECTIVE

2.1 General Background

The Warsaw District Heating System is supplied with thermal energy by three coal-fired cogeneration plants and two heating plants, of which Wola is one. Wola is an oil-fired plant which produces only thermal energy and has no turbines for generating electricity, and thus it serves as an operating department of the Thermal Power Plant-Zeran, one of the most efficient cogeneration plants in Poland.

Designed as a peak demand plant to be used only for periods of short-term excess energy demand, Wola has been used throughout the heating year (roughly October 1 to May 1) due to excess demand in the system. The other heating plant in the Warsaw district heating system is Kewerczyn, a coal-fired facility. Kawenczyn has a capacity of 740 thermal megawatts (MW), compared to 580 for Wola. In addition, a new cogeneration plant was being built at Proszków (11 kilometers from Warsaw). When the new plant is completed in two years, Wola may return to being a peak demand plant as initially planned. The new plant at Proszków will initially produce thermal energy; however, turbines will be added later for electricity production if sufficient financing is available.

Originally, Wola was designed to use a natural gas turbine. However, that plan was abandoned due to a shortage of natural gas at the time the plant was commissioned. Recently, the plan was reconsidered, and the costs of returning to the use of natural gas at the plant were being evaluated at the time of audit. A French company has made an offer to install a gas turbine to be driven by the exhaust gas from an external combuster.

In 1992, there was no excess thermal capacity in the Warsaw system. Similarly, in 1989, it was estimated that there was a 1,000 MW deficit in electricity production. However, increases in electricity prices since 1990 have significantly reduced electricity demand, so that in 1991 the electricity deficit was approximately 700 MW.

Heat losses in the Warsaw District Heating system have historically been very high. Insulation was generally poor in all the plants of the system, and individual private flats and commercial facilities served by the heating system had no end-use metering or control devices in place. Consequently, even with a desire to reduce energy use in the residential and commercial sectors, consumers were not able to conserve thermal energy use. Historically, heating costs for residences and commercial buildings were set by the size of residence or commercial space, and energy costs included in the rent. There was no incentive for the end users to conserve heat within the system. Moreover, since the District Heating System was allowed to pass costs on to its consumers, plants within the system had no incentive to conserve energy in production and distribution processes.

2.2 Plant Statistics

The Wola facility was built between 1974 and 1980 and has five hot water boilers of 116 thermal MW each, as well as five small steam boilers used to provide steam for heating buildings and tracing oil lines. The small steam boilers consumed about 3% of the total amount of fuel consumed by the facility.
The five hot water boilers were designed and built in the USSR. Four are identical, with 16 individually controlled burners each; the fifth is of a newer design with only three burners.

The plant's fuel consumption in 1990 was 85,157 tons of fuel oil No. 3 (corresponds to U.S. fuel oil No. 6) and the average cost of this fuel oil was 712,000 zlotys (zl) or $75/ton. The price for fuel oil peaked at 1,300,000 zl/ton during the Gulf War, then dropped to 800,000 zl/ton ($84/ton).

In 1991, Wola purchased fuel oil from the refinery at Plock, Poland, a relationship which predated the change of regimes in Poland in 1989. At the time of the October 1991 visit, the plant had begun negotiating with an American company (Astra) and a Dutch company to investigate future supply options.

The 1991 cost of producing thermal energy at Wola is shown below.

**Variable costs:**

<table>
<thead>
<tr>
<th>Item</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel</td>
<td>65.33%</td>
</tr>
<tr>
<td>Purchased electricity</td>
<td>5.66%</td>
</tr>
<tr>
<td><strong>Total variable cost</strong></td>
<td><strong>70.99% (59,462 zl/GJ)</strong></td>
</tr>
</tbody>
</table>

**Fixed costs:**

<table>
<thead>
<tr>
<th>Item</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Materials and supplies</td>
<td>0.66%</td>
</tr>
<tr>
<td>Wages (production only)</td>
<td>2.72%</td>
</tr>
<tr>
<td>Repairs</td>
<td>14.50%</td>
</tr>
<tr>
<td>Authorization</td>
<td>3.65%</td>
</tr>
<tr>
<td>Other production costs</td>
<td>2.48%</td>
</tr>
<tr>
<td>General costs</td>
<td>5.10%</td>
</tr>
<tr>
<td><strong>Total fixed cost</strong></td>
<td><strong>29.11% (37,035 zl/GJ)</strong></td>
</tr>
</tbody>
</table>

**Total cost** = 96,497 zl/GJ

Total production cost for thermal energy is equal to $5.50 per million BTUs, slightly higher than U.S. values for similar quantities of energy produced.

During 1990, the average cost for thermal energy was 30,454 zl/GJ (about $3.20/GJ), and the average price received for thermal energy was 40,333 zl/GJ (about $4.25/GJ). Since Wola produced 3,089,438 GJ of thermal energy in 1990, Wola earned a profit of about $3,250,000. The 1991 figures for production costs reflect increases in energy input, raw material, and labor prices, caused by movement toward free market pricing in the economy as a whole.

The plant employs 146 people, including 10 university-trained professionals. Wola keeps its entire work force employed on maintenance and repairs during the five months that the plant is not required for production of thermal energy.
Wola supplied thermal energy to the District Heating System on the following schedule in 1991:

<table>
<thead>
<tr>
<th>Month</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sept. 1</td>
<td>50% of capacity</td>
</tr>
<tr>
<td>Nov. 15</td>
<td>75% of capacity</td>
</tr>
<tr>
<td>Dec. 15</td>
<td>100% of capacity</td>
</tr>
<tr>
<td>Mar. 1</td>
<td>75% of capacity</td>
</tr>
<tr>
<td>April 1</td>
<td>50% of capacity</td>
</tr>
<tr>
<td>May 1 (approx.)</td>
<td>shut down until Sept. 1</td>
</tr>
</tbody>
</table>

During the audit, the IRG Team discovered that Wola was unable to recover any heat from flue gas emissions due to the low dew-point of these emissions. The Team also learned there was a fairly high concentration of SO₂ in the flue gas as a result of the sulfur content (2%) of the fuel oil used. Any condensation with a high level of SO₂ would be very corrosive, thus, cooling has been avoided. The Team discussed possible options to address this problem with plant management, one of which will be outlined in Section 5 of this report.

The flow rate of water through the District Heating System was about 2.5 m/sec. This resulted in a typical residence time for water in the system of about 2-2.5 hours. The furthest distance that Wola pumped heating water is six kilometers. In the summer, when the Wola facility is idle, the longest pumping distance in the Warsaw system is 23 km.

The Team learned that about 1.5% of the hot water delivered to the Heating System typically is lost, primarily due to leaks in the system. The District Heating System pays for this water, but passes the cost on to its customers. Thus, as discussed above, there was little incentive for the plant to improve its efficiency under such a system and cost/price structure.

2.3 Operating Status of the Wola Plant

Since Wola supplies thermal energy exclusively to the Warsaw District Heating System, the plant operates only about seven months of the year. For the other five months of the year, the facility remain idle, and the work-force conducts routine maintenance and modification functions. The Plant closes down for the summer in early May 1991, shortly after the first Audit Team visit. During this shutdown period, the management initiated a number of activities recommended in April. These activities include attention to the following areas:

1. **EXCESS AIR** - Some improvements were made in the inlet air flaps to give better control of the air flow into the combustion zone.

2. **AIR LEAKS AROUND THE PRE-HEATERS** - A large effort was made to correct potential air leaks around the air pre-heaters. Initial examination of the results suggested that this activity significantly reduced the potential sources of leakage.

During this period, the Wola Plant also increased its computer capability with two IBM PS-2 terminals added to its central computer; this computer has the capability to handle 15 terminals. The computer system now may be used for recording data only. However, in the
future, it is hoped that process control capability will be added, once the instruments and valves are adjusted to accommodate automatic control functions.

During the April visit, the Director of the Wola plant asked the IRG Cogeneration Audit Team for information on low nitrogen oxide (NOx) burners for oil and natural gas. Wola was found to be over the permissible level of NOx emissions, and needed to reduce the emissions to acceptable levels. The Director was interested in investigating the option of installing improved burners to address this issue.

The plant was also investigating means of reducing SO2 emissions at the time of the April audit. However, they had not identified any serious options for addressing this problem at the time of the initial audit. The Audit Team discussed options for addressing this problem with the plant management. The Director also asked the Audit Team for information and prices on devices to measure NOx and SO2.

2.4 Current Fuel and Energy Prices

In 1991, price subsidies for energy inputs were significantly reduced, causing most energy prices to rise to close to world prices. Fuel oil used in the Wola plant came from two main sources at two different prices; the plant paid 780,000 zl/ton for delivered fuel oil from Plock, and 900,000 zl/ton (delivered) from Gdansk. Earlier in 1991, the plant reported it paid 920,000 zl/ton (delivered) for Polish No. 3 fuel oil from Plock.

The price at which Wola purchased electricity from the Polish National Grid was increased from 350 to 440 zloty/kWh on September 30, 1991. This represented an increase of approximately $0.008, from the previous price of $0.032/kWh to about $0.040/kWh.

Although the Wola plant does not use coal, they monitor these prices, since the price affects Wola's ability to compete with coal-burning cogeneration plants that also provides thermal energy to the Warsaw District. Coal prices continued to increase throughout 1991 by about 5% per month. As a result, Wola became increasingly competitive with the coal-fired suppliers within the Warsaw District Heating System.

The price Wola received for delivered thermal energy in October 1991 was 56,000 zl/GJ for its supplies to the District Heating system, or $4.83/million BTU. In April 1991, however Wola reported the cost to produce thermal energy was about 40,000 zl/GJ. Thus, 1991 price allowed the plant to make enough profit to cover the portion of the year the plant remained idle.
2.5 Measurements

The Audit Team obtained operating data at Wola by:

a) Visiting control rooms and recording operating data displayed on the various instruments.

b) Using a portable Enervac gas analyzer to measure concentrations of oxygen (O₂), carbon dioxide (CO₂), sulfur dioxide (SO₂), and nitrogen oxide (NOₓ) in the flue gas.

c) Using an Omega Infrared Temperature Monitor to spot-check surface temperatures of insulated pipe, exposed surfaces, and operating equipment.

d) Interviewing plant personnel.

e) Observing plant operations.

The boiler measurements are included in Appendix III.

These measurements were used to calculate boiler excess air levels, estimated air leakage, heat losses via inadequate insulation, and operating levels as percent of capacity. This information, augmented by observations and interviews, was the basis for the recommendations made by the Audit Team.

Analysis of this information resulted in the following general conclusions:

1. Boilers were operating at excess air levels of at least 40%, depressing boiler efficiency by 2% to 3%.

2. There were significant air leaks in the combustion space, reducing boiler efficiency by several percent.

3. There were numerous instances of inadequate, damaged, or missing insulation throughout the plant.
3. ENERGY MANAGEMENT

3.1 Energy Management Program

The Wola Plant did not have a formal program to emphasize energy saving activities at the time of the April audit. However, the Manager of the Production Department, responsible for ad hoc energy management activities, had conducted some activities prior to the arrival of the Audit Team. Activities which occurred in 1991 included:

- Energy consumption measurements - energy consumption is measured periodically. The last comprehensive review conducted at Wola prior to the arrival of the Audit Team was in December 1990, done by the Institute for Heat Engineering (Łódź) under the supervision of Mr. Aleksander Krucki.

- Fuel oil and electricity consumption is monitored daily; energy consumption is then calculated and analyzed for each boiler.

- Thermal energy production is monitored daily.

- Data is correlated regularly to compare overall plant performance with goals.

3.2 Training and Energy Management Requirements

1. Economics and Project Evaluation

Personnel at Wola, as in most plants visited by the IRG Cogeneration Audit Team, had little understanding of techniques commonly used in the United States to evaluate the economic efficacy of energy investment projects. These methods include calculating:

- Return on investment;
- Net present values;
- Discounted cash flow; and
- Sensitivity.

Training key personnel to use these techniques will help the Wola District Heating Plant analyze investment alternatives and prioritize projects.

2. Long-Range Strategic Planning

In cooperation with other plants supplying the Warsaw District Heating System, Wola seemed to have given much attention to the development of a long-term strategic plan. The Audit Team recommended resources be devoted to additional formal training in strategic planning to improve upon corporate capabilities in this area. Development of a truly comprehensive long-term strategic plan will require:

- Forecasts of demand for electric and thermal energy;
- Analysis of corporate strengths and weaknesses;
- Analysis of competitive influences;
Definition of alternative possible long-range courses of action; and
The ability to evaluate alternatives.

If developed in cooperation with other plants in the Warsaw District, a comprehensive strategic plan could guide the investment of resources and help assure the most efficient (and profitable) supply of thermal energy to the District.
4. ENVIRONMENTAL CONSIDERATIONS

Given time constraints, the IRG Cogeneration Audit Team was not able to conduct a comprehensive survey of environmental aspects of plant operations. However, the Team did note some problems, and discussed them with plant management. This section briefly outlines the nature of these discussions.

Wola was found to have been pretreating its own boiler water, with satisfactory results. However, the plant was producing SO₂ emissions in excess of legislated environmental standards, which recently were revised to limit emissions to 0.20 mg/m³ down from 0.35 mg/m³. Prior to the limit reduction, Wola was in compliance.

To meet these new regulations, Wola predicted that the plant will have to purchase fuel oil with a sulfur content of 0.5%, a higher quality than has previously been used at the facility. Until the change in environmental standards, Wola had been using 2% fuel oil (2% sulfur content). Fuel oil of higher quality is available, but is significantly (up to 50% more) more expensive. The American company Astra offered to sell oil with 0.8% sulfur to Wola, and discussions regarding this possibility began in October 1991. A decision to purchase this from Astra would be reflected in higher production costs versus the cost to the company of non-compliance with the environmental legislation.

The Director of the Wola Plant was also concerned with nitrogen oxide (NOₓ) emissions at the plant, since these too exceed environmental regulatory standards, and the plant was beginning to investigate options for resolving this problem. As with the SO₂ emissions, implementation of a solution should follow a thorough assessment of the economic, as well as technical costs and benefits of each option.
5. ENERGY EFFICIENCY IMPROVEMENT OPTIONS

Opportunities for Energy conservation were identified by the IRG as a result of Team observations and audit measurements, plant inspections by other organizations (i.e. the Institute for Heat Engineering), and through discussions with plant technical personnel and managers. Listed below are options for improving energy efficiency use within the plant. Clearly, all these practices and projects will help conserve energy in the facility. However, given the reality of scarce resources for implementing these projects, the IRG Audit Team recommended some be given priority; this prioritization is included in Section 6.

This section is designed to present various options discussed during the course of the Industrial Energy Efficiency Improvement project. Thus, in this section, the IRG Team presents the merits and deficiencies of each proposal. Since the Team did not recommend that each proposal be implemented, this section includes caveats about projects the Team did not endorse. Ultimate decisions regarding implementation of alternative options will depend upon the criteria set by the plant management – including acceptable payback periods – and upon the overall corporate strategy.

5.1 Short-term Options

For the purposes of this report, "short-term" options refer to "no-cost" items which will not require hard currency, but may require small scale local currency investments, and "low-cost" options refer to those which may require limited amounts of hard currency. Each should be possible within the existing framework of plant expenditures (i.e., złoty purchases, small hard currency purchases, improved maintenance, and housekeeping) and all will have rapid payback periods.

1. Identify and Eliminate Excess Air in the Furnaces

The boilers at Wola were operating at very high excess air levels at the time of the April audit. Measured excess air levels in Boilers No. 2 and No. 4 were more than 50%; efficient operation is usually between 12-20%. Each 5% increase in excess air results in a 0.35% decrease in boiler efficiency. These levels were high as a result of air leaks in the combustion chamber. In addition, as in other plants in Poland, oxygen analyzers, where in place, were not reliable. Appendix IV details the costs and benefits associated with these high levels of excess air.

The Audit Team presented the possibility that continuous oxygen analyzers be purchased for use on the boilers. The analyzers, which could be installed when the air leaks in at least one boiler had been reduced to a reasonable level, will help regulate the flow of oxygen to the boilers, aiding combustion efficiency.

2. Repair and Maintain Insulation
Although the insulation in the plant appeared to be in generally good condition, there were a number of areas, particularly around the pipe joints, where the insulation had deteriorated and significant heat losses were occurring.

An exposed surface with a temperature of 180 °C resulted in losses of 800-1,000 BTU/hour per square foot of exposed surface, or about 4 Tons/year of steam per square foot. Effective insulation should reduce this loss by 80-90%.

One option for decreasing heat losses due to poor insulation would be to regularly check the state of insulation throughout the plant and make any necessary repairs. In addition, use of an Infrared Thermometer will assist staff in detecting sources of heat loss. Appendix IV also contains information on costs and benefits associated with this option.

3. Installation of Soot Blowers

At the time of audit, it was necessary to shut down each of the four older boilers approximately every 10 days to wash accumulated dirt and scale off the fire side of the tubes. This accumulation caused a reduction in heat transfer to the tubes, which in turn, increased exhaust gas temperature. If the tubes were clean, the exhaust gas would be about 140-150 °C. When dirt and scale build up on the tubes increase as operations continued, this temperature will rise towards 200 °C.

Calculations related to this problem (see Appendix V) showed an increase of 20 °C in flue gas temperature decreased boiler efficiency by 1.0 to 1.5%. Since a 0.7% decrease in efficiency results in additional fuel oil costs of 600 tons/year, an average reduction of 20 °C in flue gas temperature should save 1,000-1,400 tons/year. At the current price of 800,000 zł/ton for fuel oil, savings resulting from the resolution of this problem could be about 1,000,000,000 zł/year (about $100,000/year).

Installation of soot blowers was an option proposed for resolution of this problem. It is common practice, both in the U.S. and in Poland, to use "soot blowers," which use steam or air to blow accumulations off boiler tubes during operation, so that boiler efficiency is maintained without shutting the boilers down; none of these had previously been equipped with soot blowers.

At projected prices, savings from the installation of soot blowers could be $150,000. Additional savings will result from a reduction in costs incurred when boilers are shut down, cleaned, and then restarted. The Institute of Heat Engineering has designed soot blowers suitable for installation in the convection sections of the Wola boilers. Six blowers will be required for each boiler. The Institute for Heat Engineering estimated that it will cost 30,000,000 zł each to design and install suitable soot blowers for Wola.

It was not clear that Wola had sufficient steam generating capacity to supply many soot blowers. As such, this key issue should be explored before a final decision is made regarding implementation of this option. However, it would be prudent to conduct a trial of the soot blower option by installing a representative soot blower on a boiler at Wola. If the soot blowers were effective in maintaining boiler efficiency, the option should be re-evaluated, accounting for both technical and economic factors.
The cost for installing soot blowers for all boilers will be approximately 900,000,000 zł ($100,000) plus installation costs. The cost for equipping one boiler with the requisite number of blowers (6) will be 30,000,000 zł. The total cost for equipping all boilers will likely be between $200,000 - $250,000 including the necessary steam or air connections. Savings from this initiative were estimated to be between $100,000 - $150,000/year in fuel, including saving shut-down and start-up costs. The pay-back period was estimated to be about 12 months.

4. Install Dew Point Monitor

Wola has been unable to recover heat from flue gas emissions due to the low dew point. Moreover, the high concentration of sulfur dioxide (SO₂) in the flue gas suggests condensation from the flue gas would be very corrosive. Thus, recovery of this heat has not been a priority.

One option for addressing this problem would be the installation of a dew point monitor to analyze the requisite dew point for recovery of condensation. In this regard, Wola will be able to evaluate the costs and benefits of this option by reviewing Zaklady Azotowe Wloclawek's experiences with a similar problem. It is not clear however, that the installation of the monitor will be sufficient to address the problem related to the low dew point. In addition, it is also not clear that the sulfur dioxide problem will further complicate the implementation of this project. Thus, more thorough investigation of this option must precede any decision regarding this option. Further discussion of this option, conducted during the October 1991 return visit, is included in Appendix VIII.

5.2 Long-term/Capital Intensive Options

The plant also investigated means of reducing SO₂ emissions at the time of audit, but had not identified any serious options for addressing this problem. The Audit Team discussed options for addressing this problem with the plant management. Junkalor (an East German company) produces a device for measurement, but the quality and reliability of the instrument are reputed to be poor. Wola urgently requires a device to monitor SO₂ emissions on a continuous basis. The Audit Team will attempt to locate such information (on instruments to monitor NOₓ and SO₂), but is not optimistic that economic means are available. The best hope for controlling NOₓ emissions seems to be to obtain modern well-designed burners for the oil-burning boilers at Wola. The Institute for Heat Engineering (Łódź) has some background in burner design, but will need more information to come up with a burner design suitable for Wola.

1. Replacement of Existing Burners

Burners in place at the time of the audit were older burners incapable of addressing a number of issues, including the necessity of reducing SO₂ and NOₓ emissions. Moreover, the existing burners will not be compatible with an automatic control system now being considered for the plant. As such, options relating to the modification or replacement of these boilers have been proposed.

Each boiler was equipped with burners; these could be replaced with six steam or pressure atomizing burners. The Institute of Heat Engineering (Łódź) has designs for this type of burner. The modification will also require:
New fans and air supply system;
- Rebuilding of screens;
- New steam and oil supply system; and
- Installation of controls on air, oil, and steam flows to each burner.

The total cost will be approximately $150,000/boiler.

Assuming major air leaks into the boiler are also corrected, these new burners could be operated at excess air factors of 1.1 - 1.15, about 0.1 lower than the best that could be realized with present burners.

Savings would result from an improvement of at least 0.7% in boiler efficiency, plus reduced maintenance and down-time. At current rates (85,157 tons/year of fuel oil), about 600 tons/year of fuel oil would be saved. At the current price of $84/ton, total fuel savings is about $50,000 per year. At higher rates and projected prices, savings could reach $100,000/year. Maintenance and labor savings might double this to a maximum savings of $200,000/year.

Unlike the present burners, the new burners would also be suitable for use with an automatic control system and would reduce NOx and SO2 emissions. The maximum savings rate would yield a payback period of 3-4 years given the high level of investment required. As such, a decision regarding implementation of this option would need to reflect plans for the long-term future of the Wola plant, as defined through economic analysis of the plant's competitiveness.

2. Upgrade Instrumentation

If air leaks are brought under control and the burner systems are modernized, consideration should then be given to upgrading instrumentation throughout the plant so that the boilers can be operated continuously at the most efficient level. Upgrading would include:

- Installation of capacity and gas velocity measuring devices on all five boiler exhausts;
- Installation of SO2 and NOx measuring devices on all five stacks;
- Installation of CO, CO2, and relative humidity measuring devices on all boiler systems; and
- Installation of O2 measuring devices on all remaining boilers.

After the instrumentation is upgraded, a computer system for monitoring and controlling operations could be installed. The plant already investigated UNICON 700 control units, produced by a unit of Lear Siegler Corp, as a possible system. However, other options need to be investigated since the UNICON 700 does not appear to have the capacity needed for the Wola plant.
6. RECOMMENDATIONS AND CONCLUSIONS

6.1 Implementation Priorities

The IRG Cogeneration Audit Team recommended the items listed in Section 5.1 and summarized below be purchased for the Wola Plant under the Emergency Energy Program. These items included:

<table>
<thead>
<tr>
<th>Item</th>
<th>Estimated Purchase Cost</th>
<th>Estimated Benefit</th>
<th>Payback Period*</th>
</tr>
</thead>
<tbody>
<tr>
<td>One Continuous Oxygen Analyzer</td>
<td>$13,000</td>
<td>$33,600/yr.</td>
<td>5 months</td>
</tr>
<tr>
<td>Two Soot Blowers</td>
<td>6,000</td>
<td>Experimental</td>
<td>12 months</td>
</tr>
<tr>
<td>One IR Thermometer</td>
<td>895</td>
<td>$2,000/yr.</td>
<td>6 months</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>$19,895</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Note that pay-back period is calculated based on a rough estimate of the installed cost (including transportation, inspection, installation, etc.) of the equipment items.

Details about the items purchased for Wola are identified in Appendices IV and VI. The final estimates of costs and benefits of these purchases are also summarized in Table 1 presented earlier in this report.

The Audit Team believes the highest priority activity at the Wola plant should be to reduce air leaks into the combustion chambers of the boilers. Industrial boilers, by their nature, are not airtight; however, most well-run boilers have only a small proportion of air leaks into the combustion chamber. Wola appears to have 25-30% leakage.

During the idle period, it is recommended the plant attempt to identify and seal significant leaks. These maintenance activities alone could improve boiler efficiency by 2%, saving 1,700 tons/year of fuel oil, with a current value of about $140,000/year.

As an interim measure, Energopomiar, a Polish power engineering company, suggested stack dampers be partially closed to create back-pressure in the boiler. The objective is to increase the draft in the combustion chamber from -4 mm Hg to +1 mm Hg (or more). This should significantly reduce air leaks into the system.

The Audit Team believes no significant investment should be made in the Wola plant until leakage is controlled.

Moreover, the Audit Team recommends, in addition to the low cost items specified for purchase after the April audit (listed above), the following items be considered priorities for the Wola Plant:
1. **SOOT-BLOWERS** – In cooperation with The Institute for Heat Engineering, Wola should carefully evaluate the economics of installing soot-blowers in all furnaces. If the evaluation shows a payback period of less than 24 months, the plant should approach A.I.D. or The World Bank for assistance with the funding.

2. **IN SITU OXYGEN ANALYZERS** – The oxygen analyzers provided by A.I.D. in this project should be installed and monitored carefully. If they permit operation of the boilers at excess air levels that result in improvement of boiler efficiency by at least 0.7%, A.I.D. funds should be made available to support the installation of oxygen analyzers on all boilers.

3. **MODERN LOW NOₓ BURNERS** – In cooperation with The Institute for Heat Engineering, Wola should analyze the costs and benefits of installing new burners in at least the four oldest boilers. If the analysis appears to be quite favorable and has a payback period of less than three years, Wola should seek help to assemble an investment package to offer to potential investors. Because of the positive impact such a program would have on pollution reduction, World Bank funds may also be available.

4. **AUTOMATIC CONTROL SYSTEMS** – Wola should continue its program to install computer systems in the plant and in the administrative area. Because benefits are difficult to quantify, this effort will probably have to be financed internally.

5. **DISTRICT HEATING WATER PUMPS** – Conversion of large water pumps to permit control of the flow by varying the pump speed can save large amounts of energy. Calculations of the potential benefits for the Steam Power Plant Blachownia are included in Appendix VII. The Wola Plant should undertake an evaluation of this opportunity, as its water pumping system is much larger than Blachownia's.

### 6.2 Conclusions After Second Visit

Unlike other plants visited in Poland, Wola has only one customer, the Warsaw District Heating System, and that customer is relatively impervious to fluctuations in the economic climate. Thus, the current downturn in the economy has not seriously affected the plant to date. This may change when the heating season begins later in the Fall, but will certainly have less impact on Wola than other cogeneration plants, which depend on private industrial customers for at least part of their revenue.

Wola has been diligently following up on Audit Team recommendations while the plant was shut down over the summer. Results of those efforts will not be known until operations begin in the Fall of 1992.

Although the Wola Plant and equipment are fairly old, the facility is well-situated to remain profitable for the foreseeable future. The only customer is reasonably predictable, so Wola can schedule its operations to meet economic demands. Coal prices will continue to rise, while Wola's fuel will not, so Wola's competitive position with respect to the other suppliers to the Warsaw District Heating System should continue to improve.
The principal dark cloud on the horizon is pollution. Wola is using fuel oil containing about 2% sulphur, and has no means at present to control the emission of SO\textsubscript{2}. As Poland establishes regulatory limits and imposes penalties for violations, the Wola Plant will increasingly be in an unfavorable position. Lower sulphur fuel oil is available, but at a significant premium (50%) in price. The Audit Team doubts Wola can, or should, pay such a premium. The better course of action is to investigate means of scrubbing, or otherwise eliminating, SO\textsubscript{2} from the flue gas.

Modern burners designed to produce very little NO\textsubscript{x} during combustion would probably keep Wola within the regulatory limits on NO\textsubscript{x} emissions. The main obstacle is money, as it will cost about $150,000 per boiler to design, fabricate, and install new burners with the peripheral piping and controls necessary.

Overall, the Audit Team believes Wola is a sound place to invest in improved thermal energy production for the future. The potential profitability is such that investment packages should be able to be assembled that would attract the necessary funding.
APPENDIX I

AUDIT ACTIVITIES

April 1991

At each plant, the Audit Team followed approximately the following procedure:

Day 1
Presentation by Team of program objectives and goals to plant management and administrators.
- Detailed discussion of plant responses to questionnaire given them in February.
- Quick, "get acquainted" tour of facilities.

Day 2
More detailed tour and inspection of facilities.
- Extensive collection of operating data, both from plant instruments and from portable instruments carried by the Audit Team.

Day 3
Preparation of preliminary report of findings and recommendations.

Day 4
Presentation of seminar on "Energy Conservation" by Gerald Decker to 10 - 20 representatives of plant management and operating supervisory personnel.
- Presentation and discussion of preliminary report with plant management.
- Transfer to the next facility.
MEETING PARTICIPANTS
April, 1991

Wola District Heating Plant

Mr. Zbigniew Skórzewski
Mr. Jerzy Bogusz
Mr. Stanisław Jankowski
Mr. Aleksander Sopiński
Mr. Andrzej Szadkowski
Mr. Zbigniew Kędzierski
Mrs. Wanda Bardadyn
Mr. Wojciech Kułagowski

Director of Wola Plant
Manager of Production Department
Manager of Boilers Department
Manager of Electrical and Automatic Dept.
Manager of Repairs and Workshop Dept.
Manager of Repairs and Legalization Laboratory
Manager of Chemical Laboratory
Chief Engineer

International Resources Group, Ltd.

Mr. Gerald Decker
Dr. Richard Heiny
Mr. John Pangborn

Team Leader
Engineer
Engineer

Energopomiar

Mr. Zdzisław Gleras
Mr. Adam Zemła

The Institute of Heat Engineering (Lódź)

Mr. Aleksander Krucki
Dr. Andrzej Kapitaniak

Department Manager
# APPENDIX III

## AUDIT MEASUREMENTS AND COMPARATIVE STATISTICS

During the period April 20 - 23, 1991, the Cogeneration Audit Team took a number of control measurements at the Wola District Heating Plant. Water Boilers No. 2 and 4 were examined. Water boilers are often shut down due to higher temperature (about 8°C). These measurements were compared with the results of accurate tests carried out previously by Institute of Heat Engineering - Łódź, Poland.

### AUDIT MEASUREMENTS AND CALCULATIONS

<table>
<thead>
<tr>
<th></th>
<th>Boiler Number 2</th>
<th>Boiler Number 4</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Date of test</strong></td>
<td>22.04.91</td>
<td>22.04.91</td>
</tr>
<tr>
<td></td>
<td>05.12.88¹</td>
<td>3rd quarter of 1990²</td>
</tr>
<tr>
<td><strong>Feed Water:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>temperature °C</td>
<td>103</td>
<td>105</td>
</tr>
<tr>
<td>pressure MPa</td>
<td>1.75</td>
<td>1.81</td>
</tr>
<tr>
<td>volume t/h</td>
<td>2450</td>
<td>2250</td>
</tr>
<tr>
<td></td>
<td>2260</td>
<td>2340</td>
</tr>
<tr>
<td><strong>Exit Water:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>temperature °C</td>
<td>127</td>
<td>136</td>
</tr>
<tr>
<td>pressure MPa</td>
<td>1.35</td>
<td>1.36</td>
</tr>
<tr>
<td></td>
<td>1.25</td>
<td>1.36</td>
</tr>
<tr>
<td><strong>Production Rate</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MWₚ</td>
<td>68.2</td>
<td>80.9</td>
</tr>
<tr>
<td></td>
<td>100.9</td>
<td>96.8</td>
</tr>
<tr>
<td><strong>Capacity</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MWₚ</td>
<td>116</td>
<td>116</td>
</tr>
<tr>
<td></td>
<td>116</td>
<td>116</td>
</tr>
<tr>
<td><strong>Fuel Oil:</strong></td>
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<td></td>
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<tr>
<td>temperature °C</td>
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<td>124</td>
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<tr>
<td>pressure MPa</td>
<td>2.05</td>
<td>2.81</td>
</tr>
<tr>
<td></td>
<td>2.47</td>
<td>2.85</td>
</tr>
<tr>
<td><strong>Number of burners on line</strong></td>
<td>14³</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td><strong>Flue Gas:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>temperature °C</td>
<td>188</td>
<td>215</td>
</tr>
<tr>
<td>O₂ %</td>
<td>4.7</td>
<td>7.4</td>
</tr>
<tr>
<td></td>
<td>175/170</td>
<td>7.4</td>
</tr>
<tr>
<td></td>
<td>170</td>
<td>7.44</td>
</tr>
<tr>
<td>Excess air factor</td>
<td>1.29</td>
<td>1.54</td>
</tr>
<tr>
<td></td>
<td>1.51</td>
<td>1.52</td>
</tr>
<tr>
<td>Efficiency %</td>
<td>89.98</td>
<td>86.7</td>
</tr>
<tr>
<td></td>
<td>89.36</td>
<td>89.7</td>
</tr>
</tbody>
</table>

### COMPARATIVE STATISTICS


³ Each boiler burns about 11 tons of oil per hour at capacity.
### Table 1. Boiler Operating Conditions

<table>
<thead>
<tr>
<th></th>
<th>Blachownia (Kędzierzyn - Kozle)</th>
<th>Leg (KróKów)</th>
<th>Plant No. 2 (Łódź)</th>
<th>Wola (Warsaw)</th>
<th>Zaklady Azotowe (Wloclawek)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Boiler #8</td>
<td>Boiler #12</td>
<td>Boiler #1</td>
<td>Boiler #3</td>
<td>Boiler #5</td>
</tr>
<tr>
<td><strong>STEAM PRODUCTION:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity, T/hr.</td>
<td>120</td>
<td>215</td>
<td>360</td>
<td>430</td>
<td>120</td>
</tr>
<tr>
<td>Measured, T/hr.</td>
<td>98</td>
<td>158</td>
<td>365</td>
<td>355</td>
<td>100</td>
</tr>
<tr>
<td>Pressure, MPa</td>
<td>8.2</td>
<td>9.5</td>
<td>12.3</td>
<td>12.2</td>
<td>8.6</td>
</tr>
<tr>
<td>Temperature, °C</td>
<td>480/505</td>
<td>500/495</td>
<td>533/536</td>
<td>535</td>
<td>490</td>
</tr>
<tr>
<td><strong>STACK TEMPERATURE:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Before heater, °C</td>
<td>540°C</td>
<td>370/390</td>
<td>315°C</td>
<td>230°C</td>
<td>188</td>
</tr>
<tr>
<td>After heater, °C</td>
<td>195/185</td>
<td>138/140</td>
<td>135</td>
<td>160/150</td>
<td>207/211</td>
</tr>
<tr>
<td><strong>FLUE GAS ANALYSIS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(before air heater)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>O₂ (a)</td>
<td>5.2%</td>
<td>3.9%</td>
<td>6.3/4.9</td>
<td>5.5%</td>
<td>5.3%</td>
</tr>
<tr>
<td>CO₂ (b)</td>
<td>12.7%</td>
<td>12.5%</td>
<td>12.5/14.5</td>
<td>15.7%</td>
<td>-</td>
</tr>
<tr>
<td>SO₂</td>
<td>10 ppm</td>
<td>77 ppm</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>NO₂</td>
<td>110 ppm</td>
<td>92 ppm</td>
<td>215 ppm</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>EXCESS AIR LEVEL</td>
<td>51%</td>
<td>23%</td>
<td>37%</td>
<td>35%</td>
<td>34%</td>
</tr>
</tbody>
</table>

---

4  Wola capacity is stated in Thermal Megawatts (MW_t).

5  In many boilers there were separate measurements for the left- and right-hand sides of the stacks. In those cases, the two sides are reported as left/right.
<table>
<thead>
<tr>
<th></th>
<th>Blechownia (Kędzierzyn-Koźle)</th>
<th>Łęg (Kraków)</th>
<th>Plant No. 2 (Łódź)</th>
<th>Wośa (Warsaw)</th>
<th>Zakłady Azotowe (Włościelewsk)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel</td>
<td>48.3%</td>
<td>50.9%</td>
<td>49.2%</td>
<td>49.2%</td>
<td>35%</td>
</tr>
<tr>
<td>Electricity</td>
<td>-</td>
<td>7.8%</td>
<td>49.2%</td>
<td>49.2%</td>
<td>35%</td>
</tr>
<tr>
<td>Supplies</td>
<td>0.9%</td>
<td>0.8%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wages</td>
<td>3.5%</td>
<td>2.9%</td>
<td>5%</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>Overhauls</td>
<td>29.8%</td>
<td>23.5%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depreciation</td>
<td>5.2%</td>
<td>3.5%</td>
<td>5%</td>
<td>5%</td>
<td></td>
</tr>
<tr>
<td>Environmental</td>
<td>8.6%</td>
<td>7.9%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overhead</td>
<td>3.6%</td>
<td>2.7%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100.0%</td>
<td>100.0%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Cost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>zl/KWH</td>
<td>230</td>
<td>87</td>
<td>246</td>
<td></td>
<td>351 (purch from grid)</td>
</tr>
<tr>
<td>zl/GJ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>30454</td>
</tr>
<tr>
<td>Sales Price</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>zl/KWH</td>
<td>178.5</td>
<td>99</td>
<td>152</td>
<td></td>
<td></td>
</tr>
<tr>
<td>zl/GJ</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Table 3. Specific Heat Consumption\(^6\) to Produce Electricity and Thermal Energy

<table>
<thead>
<tr>
<th></th>
<th>Blachownia</th>
<th>Łódź</th>
<th>Plant No. 2</th>
<th>Wola(^7)</th>
<th>Zakłady Azotowe</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unit Energy/KWH</strong></td>
<td>12,516 kJ/KWH</td>
<td>9,602 kJ/KWH</td>
<td>4,810 kJ/KWH (^6)</td>
<td>12,210 kJ/KWH</td>
<td></td>
</tr>
<tr>
<td><strong>Unit Energy/KWH</strong></td>
<td>(11,865 BTU/KWH)</td>
<td>(9,103 BTU/KWH)</td>
<td>(4,560 BTU/KWH)</td>
<td>(11,547 BTU/KWH)</td>
<td></td>
</tr>
<tr>
<td><strong>Efficiency</strong></td>
<td>28.8%</td>
<td>37.5%</td>
<td>74.8%</td>
<td>29.5%</td>
<td></td>
</tr>
<tr>
<td><strong>Unit Energy/GJ</strong></td>
<td>1,229 MJ/GJ</td>
<td>1,169 MJ/GJ</td>
<td>1,150 MJ/GJ</td>
<td>1,197 MJ/GJ</td>
<td></td>
</tr>
</tbody>
</table>

\(^6\) Data were calculated from average results for 1990.

\(^7\) Wola produces no electricity.

\(^6\) This data for Łódź may be incomplete.

\(^9\) 1990 data were not available.
### Table 4. Coal Pricing

<table>
<thead>
<tr>
<th>Blachownia (Kędzierzyn-Kozle)</th>
<th>Łag (Kraków)</th>
<th>Plant No. 2 (Łódź)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1990 Price (Average)</strong></td>
<td>73,993 zl/Ton</td>
<td>91,958 zl/T.</td>
</tr>
<tr>
<td>Consumption</td>
<td>771,124 tons</td>
<td>1,156,941 tons</td>
</tr>
<tr>
<td>Source</td>
<td>6 collieries</td>
<td>3 mines</td>
</tr>
<tr>
<td>Heating Value</td>
<td>16,000 - 18,000 kJ/kg, (6880 - 7740 BTU/lb.),</td>
<td>(17,000-22,000 kJ/kg range, 13,590 kJ/kg average, 8760 BTU/lb.)</td>
</tr>
<tr>
<td>Sulfur Content</td>
<td>0.8%</td>
<td>0.7-0.8%</td>
</tr>
<tr>
<td>Ash Content</td>
<td>27.9% (average), (10-32% range)</td>
<td>18%</td>
</tr>
<tr>
<td><strong>1991 Prices</strong></td>
<td>200,000 zl/T</td>
<td>139,000 zl/T (Jan.), 160,000 zl/T (Apr.), +33,000 zl/T delivery cost</td>
</tr>
<tr>
<td>Comments on Purchasing</td>
<td>Prices are increasing about 5% per month. Supply options are limited.</td>
<td>Monthly price increases. Price depends on H.V., % Ash, % S</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Theoretically, can buy wherever they want. Really, limited choice.</td>
</tr>
</tbody>
</table>

**NOTE:** These prices were obtained in April, 1991. At that time the conversion rate was about 9,500 zl/$1.00 U.S. By October, 1991, the conversion rate had risen to about 11,100 zl/$1.00 U.S.
Table 5. Fuel Oil Pricing

<table>
<thead>
<tr>
<th></th>
<th>Blachownia (Kędzierzyn - Koźle)</th>
<th>Łódź (Kraków)</th>
<th>Plant No. 2 (Łódź)</th>
<th>Wola (Warsaw)</th>
<th>Zakłady Azotowe (Wóclawek)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990 Price (Average)</td>
<td>824,215 zl/T</td>
<td>795,115 zl/T</td>
<td>-</td>
<td>720,349 zl/T</td>
<td>800,000 zl/T</td>
</tr>
<tr>
<td>Source</td>
<td></td>
<td></td>
<td></td>
<td>Plock</td>
<td>Plock, Gdansk</td>
</tr>
<tr>
<td>Heating Value</td>
<td></td>
<td>40,328 kj/kg</td>
<td>40,160 kj/T.</td>
<td>40,700 kj/kg</td>
<td>40,700 kj/kg</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(17,350 BTU/lb.)</td>
<td>(17,270 BTU/lb.)</td>
<td>(17,500 BTU/lb.)</td>
<td>(17,500 BTU/lb.)</td>
</tr>
<tr>
<td>Sulfur Content</td>
<td></td>
<td>2%</td>
<td></td>
<td>2%</td>
<td></td>
</tr>
<tr>
<td>Pricing history:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sept. 1990</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oct. 1990</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pricing forecast:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Feb. 1991</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>April 1991</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Projected</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Possible Future</td>
<td>Coal is the primary fuel; fuel</td>
<td>Coal is the primary fuel; fuel</td>
<td>Coal is the primary fuel; fuel</td>
<td>Negotiating with:</td>
<td>Amsterdam proposed $60- sources</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Netherlands Co.</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Polish Co.</td>
<td></td>
</tr>
</tbody>
</table>

NOTE: Conversion rate - $1.00 = 9,500 zlotys (April, 1991).
Table 6. Personnel/Functional Structure
(Number of persons employed in each function)

<table>
<thead>
<tr>
<th></th>
<th>Biachownia (Kędzierzyn - Kozle)</th>
<th>Łeg (Kraków)</th>
<th>Plant No. 2 (Łódź)</th>
<th>Woia (Warsaw)</th>
<th>Zaklody Azotowe (Wioławk)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>S</td>
<td>U</td>
<td>Total</td>
<td>S</td>
</tr>
<tr>
<td>Prod'n Op'ns</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Turbine</td>
<td>200</td>
<td>23</td>
<td>7</td>
<td>435</td>
<td>66</td>
</tr>
<tr>
<td>• Boilers</td>
<td></td>
<td></td>
<td></td>
<td>140</td>
<td>9</td>
</tr>
<tr>
<td>• Coal Hdg.</td>
<td></td>
<td></td>
<td></td>
<td>63</td>
<td>12</td>
</tr>
<tr>
<td>• Water Trt.</td>
<td></td>
<td></td>
<td></td>
<td>42</td>
<td>8</td>
</tr>
<tr>
<td>Elect. Maint.</td>
<td>97</td>
<td>16</td>
<td>6</td>
<td>146</td>
<td>16</td>
</tr>
<tr>
<td>• Elect. Prot.</td>
<td></td>
<td></td>
<td></td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Mech. Maint.</td>
<td>153</td>
<td>23</td>
<td>8</td>
<td>520</td>
<td>109</td>
</tr>
<tr>
<td>Contr. &amp; Env.</td>
<td>6</td>
<td>-</td>
<td>3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td>15</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Purch., Etc.</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Institute</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Management</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>15</td>
<td>3</td>
</tr>
<tr>
<td>Unaccounted</td>
<td>88</td>
<td></td>
<td></td>
<td>197</td>
<td></td>
</tr>
<tr>
<td>Totals</td>
<td>620</td>
<td>65</td>
<td>30</td>
<td>1,355</td>
<td>213</td>
</tr>
<tr>
<td>MW Capacity</td>
<td>1220 Th MW (est'd)</td>
<td></td>
<td></td>
<td>2000 Th MW</td>
<td></td>
</tr>
<tr>
<td>Pers./MW</td>
<td>0.57</td>
<td></td>
<td></td>
<td>0.68</td>
<td></td>
</tr>
</tbody>
</table>

S = Supervisory personnel
U = University-trained professionals
APPENDIX IV

JUSTIFICATION FOR PURCHASE OF EQUIPMENT

CONTINUOUS OXYGEN (O₂) ANALYZERS FOR STACK GAS

Install reliable continuous O₂ analyzers on boiler stacks so that operating conditions can be adjusted to keep excess air supplied to the boilers at optimum levels. Presently, the Wola plant is operating at excess air levels of 50% or more, when the optimum level is about 15%. With reliable O₂ analyzers the excess air level can be reduced by at least 10%, resulting in about 0.7% improvement in efficiency of boiler operation. At the plants we visited in Poland, typical fuel consumption per boiler was:

- Coal-fired boilers: 15 tons/hour
- Oil-fired boilers: 7 tons/hour

Current (April, 1991) prices for fuel were:

- Coal: 200,000 zł/ton ($21/ton)
- Fuel oil: 800,000 zł/ton ($84/ton)

When these prices are adjusted for quality and heating value, they are within 10% of current U.S. prices.

A 10% reduction in excess air level will result in the following savings for a typical boiler operating 6,000 hours per year:

- Coal-fired boilers:
  - 630 tons/yr. coal saved = $13,000/yr.

- Oil-fired boilers:
  - 300 tons/yr. oil saved = $25,000/yr.

These are believed to be minimum savings; most plants should realize 1.5 to 2.0 times these savings.

Reliable O₂ analyzers including remote reading instruments are available from several U.S. suppliers at prices of around $6,000, excluding probes or terminals, depending upon the exact model purchased. Shipping and installation for a model such as the Johnson-Yokogawa, would bring the total cost to approximately $27,000 (six probes, 2 for each boiler). The payback periods would be approximately 10 months.

In addition to the direct economic benefit, there will be a significant environmental benefit, because emissions of NOₓ and SO₂ will be reduced. Typical Polish coal contained 0.8% sulfur and fuel oil contained 2% sulfur. The savings described above would reduce SO₂ emissions by:

- 10 tons/year for coal-fired boilers, or
12 tons/year for oil-fired boilers.
The reduction in NO$_2$ emissions would be similar.

PRELIMINARY QUOTES (not firm or final) for O$_2$ analyzers meeting the attached specifications:

<table>
<thead>
<tr>
<th>Supplier</th>
<th>Price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Johnson-Yokogawa</td>
<td>$4,437.00*</td>
</tr>
<tr>
<td>Bailey Controls</td>
<td>3,129.00</td>
</tr>
<tr>
<td>Ametek, Thermox Div.</td>
<td>3,570.00 or 5,700.00</td>
</tr>
<tr>
<td>Land Combustion</td>
<td>5,092.00</td>
</tr>
</tbody>
</table>

The Audit Team recommends that ONE continuous Oxygen Analyzer be purchased for installation in Boiler No. 2 at the Wola plant.

Because of the flexibility of their instruments and the apparent extent of their European service network, the Audit Team recommends that Johnson-Yokogawa should be the preferred supplier. However, in the judgment of the Audit Team all the listed suppliers manufacture O$_2$ analyzers suitable for the intended use in Poland.

* The price given for the Johnson-Yokogawa oxygen analyzer is the basic price for the model recommended. Additional probes and terminals will increase the price.
INFRARED THERMOMETERS

In the Wola plant there were a few instances of inadequate, damaged, or missing insulation. At the energy costs experienced under the Communists, it may not have been regarded as worthwhile to make sure that all hot surfaces were insulated and that the insulation was maintained well. At world prices for energy, however, good insulation definitely pays. For example, 200 meters of poorly insulated 10 cm. diameter steam line can lose heat equivalent to about 340 Tons/yr. of steam. This is an economic loss of about $1,700/year. The cost of insulating the steam line properly is certainly less than $2,000, so the minimum return on investment is 85%.

The easiest way to detect heat losses is by using an IR (infrared) thermometer to measure the surface temperatures. When "hot spots" are observed, a maintenance crew can be assigned to check them and to repair or replace the insulation if appropriate.

Hand-held battery-operated IR thermometers are available from Omega Engineering, Inc. (Stamford, Connecticut) for $895 each. Two were used by the Audit Teams in Poland, and were left -- one with Energopomiar, and one with The Polish Foundation for Energy Efficiency.

The Audit Team recommends that one IR thermometer should be purchased for detection of "hot spots" where significant heat losses may be occurring.

RECOMMENDED VENDOR:

Omega Engineering, Inc.
One Omega Drive
Box 4047
Stamford, CT 06907-4047

MODEL: No. 0571C Infrared Thermometer-C display

PRICE: $895.00 each

International Resources Group, Ltd.
May 1992
APPENDIX V

PARTICIPANTS IN THE DISCUSSIONS
October, 1991

The discussions took place in the main conference room at the Wola Plant headquarters. The Team made one trip into the plant to examine possible locations for the oxygen analyzers when they arrived for installation. The participants included:

WOLA PLANT REPRESENTATIVES:

Mr. Zbigniew Skórzewski  Director of the Wola Plant
Mr. Jerzy Bogusz  Manager of the Production Department
Mr. Stanislaw Jankowski  Manager of the Boilers Department
Mr. Aleksander Sopinski  Manager of the Electrical and Automatics Department
Mr. Andrzej Szadkowski  Manager of Repairs and Workshop Department
Ms. Wanda Bardadyn  Manager of the Chemical Laboratory
Mr. Zbigniew Kędzierski  Translator (at the time of the original visit, Mr. Kędzierski was Manager of the Repairs and Legalization Laboratory for the Wola Plant; he has since accepted a position with the Polish National Grid and returned to the Wola Plant to assist with the discussions).

Mr. Sławomir Arciszewski

IRG AUDIT TEAM:

Dr. Richard L. Heiny  IRG, Ltd. Audit Team Leader
Mr. Zdzislaw Gieras  Head of the Boiler Guarantee and Operation Testing Department, Energopomiar
Mr. Adam Zemła  Kierownik Działu Turbinowego, Energopomiar
Mr. Aleksander Krucki  Senior Engineer, Institute for Heat Engineering (Lodz)
Dr. Andrzej Kapitaniak  Department Manager, Institute for Heat Engineering (Lodz)
APPENDIX VI

ITEMS OF EQUIPMENT PURCHASED FOR THE WOLA PLANT

Item 1: Two Johnson-Yokogawa in situ oxygen analyzers with one probe, one probe protector, and one converter each.

Item 2: Ten Armstrong Model 1811 stainless steel inverted bucket type steam traps with 3/4-inch pipe connections and 1/4-inch orifices.

Item 3: Five Armstrong Model 1812 stainless steel inverted bucket type steam traps with 1-inch pipe connections and 1/4-inch orifices.

Item 4: One model IR-550 portable infra-red temperature measuring instrument from Davis Instruments Company.

The Audit Team was unable to locate a portable analyzer for CO₂, CO, SO₂, and NOₓ which the manufacturer would recommend for regular use in a production facility. All such analyzers seemed to be designed for intermittent laboratory or experimental use.
APPENDIX VII

AN ESTIMATE OF THE COSTS AND BENEFITS OF MODIFYING LARGE PUMPS

The estimates in this Appendix are based on information provided by the Steam Power Plant Blachownia in Kędzierzyn, Poland. The information is included only for comparison purposes. Any estimates for the Wola Plant should be based on Wola Plant data.

The Audit Team recommends modifying the water pumps so that water flow to the heating system at Blachownia can be controlled by controlling the pump speed. At present, the three large pumps operate at constant speed, and water flow is controlled by throttling the outlet flow from the pumps. This system wastes pumping energy. Blachownia has estimated that changing the variable speed control will save about 6.5 million KWH/year.

- At current Blachownia costs to produce electricity (230 zł/KWH) the savings would be about $157,000/year.
- At a more realistic cost of $0.06/KWH, the savings would be about $390,000.

The plant has estimated the conversion cost as follows:

- Modify three pumps and impellers:
  - 250 million zł each = 750 million zł

- Rewire four motors (including one spare):
  - 300 million zł each = 1,200 million zł

- Total cost = 1,950 million zł ($200,000).

At current costs, the payback period would be 15 months. At projected costs, the payback period is 6 months.

The Audit Team recommends that this project be supported.
APPENDIX VIII

DISCUSSIONS OF THE SOOT BLOWERS

Representatives from Wola and The Institute for Heat Engineering have given this issue a lot of attention since the original visit. The conclusions are:

- It will probably require three or four soot-blowers, rather than two, to get an adequate trial of effectiveness.
- The soot-blowers will be somewhat more expensive than originally anticipated. Instead of costing about $3,000 each, they may cost as much as $7,000 each.
- It may be more expeditious and less expensive to purchase commercial soot-blowers from a manufacturer in the U.S. than to have them designed and fabricated by the Institute for Heat Engineering.
- It is estimated that the soot-blowers will require 3 tons/minute of steam to operate satisfactorily. The steam conditions should be: 10.5 atm. pressure 190° - 200° C. temperature (The 10.5 atm. pressure is necessary to give the blowers the range to reach all the tubes).
- Wola has five small steam boilers that normally provide steam for tracing oil lines, etc. These boilers have ample capacity to operate the soot-blowers.
- The soot-blowers should be installed in Boiler No. 3.
- For regular operation (not for trial), there should probably be four, and possible eight, soot-blowers per boiler.
- The installation cost would be relatively small – perhaps $2,000 per boiler.
- Wola Plant personnel can handle all aspects of installation and operation of the soot-blowers.

One point which was not agreed upon was whether the soot-blowers should be designed as "singles" or as "doubles". A "single" is designed to extend all the way across the boiler compartment from one side; "doubles" are designed to extend half-way across, so there must be two shorter soot-blowers at each location. Operation of the "singles" might be simpler, but the "doubles" may be more effective.

The Audit Team stated that the current AID budget probably would not have sufficient funds to implement the soot-blower program at the currently estimated cost. Also, it was suggested that the economic viability of soot-blowers should be re-examined in light of the new higher estimate of costs. It was originally estimated that six soot-blowers costing $3,000 each would service one boiler, and would improve boiler efficiency by 1.0-1.5%. This would result in a pay-back period of about eight months. However, if eight soot-blowers were needed for
each boiler, and each soot-blower costs $7,000, the pay-back period is much longer, and there may be more productive opportunities to use the available funds.

The Wola Plant indicated that, if the U.S. AID budget could support $20,000 of the expense, the Plant could probably fund the rest of the cost.

The Audit Team requested that The Institute for Heat Engineering (Mr. Krucki and Dr. Kapitaniak) supply them with specifications and drawings (if possible) of the soot-blowers that would be needed. When this descriptive material is received, the Audit Team will try to get some quotes from potential suppliers in the United States.