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ENERGY EFFICIENCY AUDIT REPORT THE THERMAL POWER COMPANY, PLANT NO. 2

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LIST OF ACRONYMS/ABBREVIATIONS

A.I.D.	U.S. Agency for International Development
BTU	British thermal unit
°C	degrees Celsius
GJ	giga-joules
Hz	hertz
IRG	International Resources Group, Ltd.
MPa	millipascale
MWh	megawatt hours
ppm	parts per million
Va	var
zł	złotys; Polish unit of currency

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The IRG Industry 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. 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 Industry Audit Team that the exchange established through this initiative be maintained and expanded in the future.

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 uncertainly.

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

3) 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-Kozle
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.

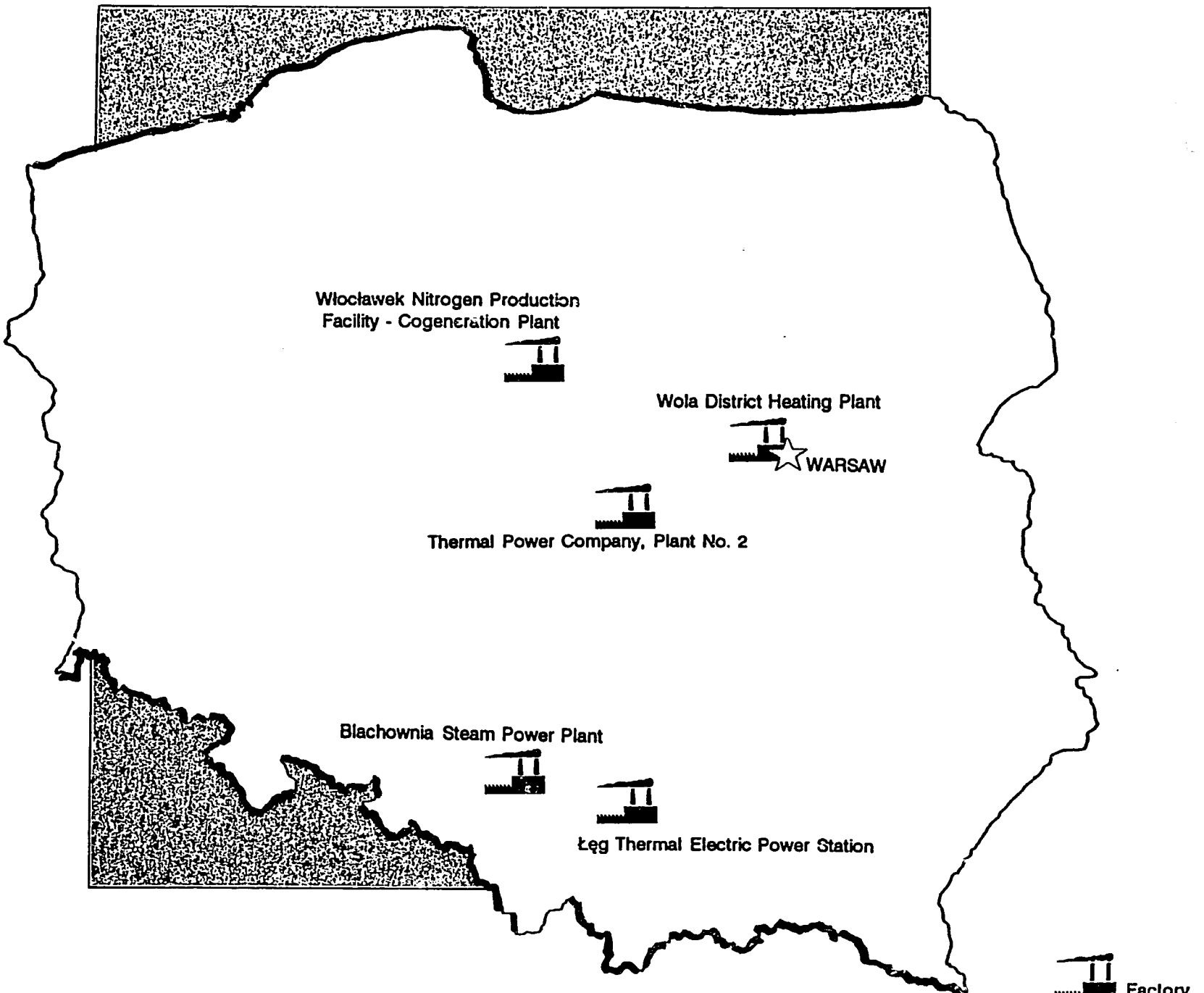

Figure 1 Location of plants audited by the IRG team

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.

1. 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 Thermal Power Company, Power Plant Number 2 in Łódź, Poland. The objective of the audit was to assist plant personnel in identifying low-cost/no-cost opportunities for improving energy efficiency. In addition, the Audit Team trained key plant personnel in modern methods of energy management as practiced in the US.

Łódź was included in the Industrial Energy Efficiency Improvement project based on assessments made by the project definitional team, which included IRG Vice President Charles Ebinger and IRG Team Leader Gerald Decker. The Team evaluated the following issues to decide which plants to include 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 visit, the IRG Cogeneration Audit Team returned to the U.S. and arranged the procurement of equipment to be used by Łódź 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 what progress Łódź had made in implementing recommendations as well as the following issues: 1) Equipment purchased through A.I.D. for use by Plant No. 2; 2) Plans for the Energy Management Workshop to be held in Warsaw on October 8-9; 3) Plant experiences with SO_3 injection technology; and 4) Other Plant No. 2 energy efficiency requirements. Details learned during these discussions are included in the main text of this report.

The Team's objectives were to identify opportunities energy conservation for both the short- and long-term; estimate the quantities of energy that could be saved at the plant; estimate the costs of energy lost; conduct a seminar on energy conservation for plant staff; and to train seminar participants in the use of the energy measurement instruments the Team brought from the United States. In addition, the Team conveyed basic information about the operation of industrial facilities in a market economy, including economic techniques for evaluating investments, incentive programs for implementing management directives, and basic market assessment (both supply and demand) strategies.

To accomplish these objectives, the IRG Cogeneration Audit Team collected data at each plant visited to make informed decisions regarding opportunities for improving energy efficiency. Data were accumulated from several sources, including plant instrumentation, field measurements (using a portable ENERAC 2000 stack gas analyzer purchased for the project),

plant records, independent reports, and interviews of plant operating personnel. Information about measurements taken during the audit and general plant statistics are included **Appendix II.**

1.1 Plant Background

The Thermal Power Company at Łódź sells thermal energy and electricity to the Polish national grid, and supplies thermal energy to the local district heating system. However, the Thermal Power Company, unlike most other facilities in Poland, owns and operates both the power production facilities and the district heating system. The facility operates four thermal power plants.

Overall, the Łódź District Heating System has 600 km of hot water piping and 50 km of steam piping. The Company supplies thermal energy to 75% of the population of Łódź (population = 820,000) and 90% of the local industry. To meet local demand, the company consumes 2.5 million tons of coal per year. In 1990, Plant No. 2, consumed 592,680 tons of coal and 990 tons of Fuel Oil Number 3.

Total energy generated by the plant in 1990 was 4,357,000 giga-joules (GJ) of steam to local industrial users, 4,008,000 GJ of hot water for the District Heating System, and 361,526 megawatt hours (MWh) of electricity to the Polish grid. Approximately another 430,000 GJ of electricity and thermal energy were used within the plant.

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

Since the five plants visited by the IRG Cogeneration Audit Team had many similarities, it was useful for the Audit Team to develop comparative information on the plants; tables summarizing this information are included in **Appendix III.** These tables include boiler operating conditions, distribution of production costs, 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 pieces 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 energy savings results 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 are deficient.

Table 1. Equipment Procured under the A.I.D.-funded Emergency Energy Program

Equipment Item	Cost	Annual Savings	Type of Savings	Payback Period (years)	Coal (tons)
Infrared Thermometer	$427	$1,700	steam	.24	83
In-situ O_2 Analyzer	$9,553	$38,700	combustion	.25	600
Steam Traps	$2,619	$34,000	steam	.08	528
TOTAL	$12,599	$74,400			1211

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 report is intended to provide the reader with a background against which to view the actions implemented under this project. This report also outlines the observations, comments, and recommendations of the Audit Team, gathered during the initial plant in April 1991, and from subsequent discussions with plant managers.

To allow a more comprehensive evaluation of the results, specific project results will be presented in the summary reports for the project. Therefore, the Energy Efficiency 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 and Comments

The Thermal Power Company at Łódź was similar to the other five plants visited by the IRG Cogeneration Audit Team in that the primary product at each facility was thermal energy. The plant also produced and sold electricity to the Polish national grid and supplied thermal energy to the local district heating system. However, in Łódź, unlike in most other cities in Poland, one organization owned and operated both the power production facilities and the district heating system.

The technical skill and qualifications of the plant managers and the supervisory staff at the Łódź facility were quite good, although few people had any background in the economic evaluation of projects. Plant No. 2 employs a total of 690 people, including 50 supervisors and 16 university-trained technical professionals.

In this regard, the plant is considered to be over-staffed, employing several times as many operating personnel as in a comparable U.S. plant.

Łódź had virtually no automatic control systems; data were displayed in the control rooms, but adjustments in flow rates, temperatures, and pressures were made manually. Management indicated a plan currently exists to replace these facilities with modern technology. However, until capital is available for this major project, management intends to make every effort to lower costs and improve efficiency.

Plant Number 2 was constructed during the period 1958 - 1968 and includes nine coal-fired boilers, with 1,200 tons/hour of steam generating capacity. The plant also has seven turbines/generator sets with 180 MW total capacity and two oil-fired hot water boilers used only to meet peak demand.

In 1990, Plant No. 2 consumed 592,680 tons of coal and 990 tons of Fuel Oil Number 3. Since that time, coal prices have increased an average of 5% each month. In April 1991, coal prices averaged 230,000 zł/ton ($24/ton), and Fuel Oil Number 3 prices averaged 800,000 zł/ton ($84/ton). Since the completion of the audits, the exchange rate has moved from 9,554 zł= US$1 to 11,100 zł= US$1.

The total energy generated by the plant in 1990 was:

■ Steam to local industrial users	4,357,000 GJ (45.0%)
■ Hot water to District Heating System	4,008,000 GJ (41.5%)
■ Electricity to the Polish grid	361,526 MWh (13.5%) (1,301,000 GJ)
■ Electricity & thermal energy used within the plant	430,000 GJ
Total production	10,096,000 GJ

The total production figure represents about 58% of boiler capacity and approximately 29% of turbine/generator capacity.

2.2 Plant Statistics

The Thermal Power Company at Łódź operates four plant facilities which produce thermal and electrical energy. These plants include Plant No. 1 -- 40 years old and providing only thermal energy; Plant No. 2 -- 30 years old, providing both thermal and electrical energy; Plant No. 3 -- 20 years old, providing thermal and electrical energy; and Plant No. 4 -- a 10 year-old plant, providing both thermal and electrical energy. The IRG Cogeneration Audit Team concentrated its efforts on Plant Number 2.

The Łódź District Heating System, of which the Thermal Power Company is a part, has a total of 600 km of hot water piping, and 50 km of steam piping. The Company supplies thermal energy to 75% of the population of Łódź (population = 820,000) and 90% of the local industry. To meet local demand, the company employs 3,500 people and consumes about 2.5 million tons of coal each year.

Each plant within Łódź has its own manager and supervisory staff. The company provides many support functions to all the plants. General support activities provided include purchasing, accounting, engineering, and other administrative functions. Major maintenance and overhaul projects at the plant are conducted by outside contractors, with smaller jobs and emergencies being handled by plant maintenance personnel.

In 1990, The Thermal Power Company made a profit of $19 million, primarily from the sale of thermal energy. Conversely, electricity sales were highly unprofitable as a result of national price controls. The price of electricity has been set unilaterally by the Polish government at a low level in an attempt to control inflation. Consequently, the Thermal Power Company expected to lose at least $15 million on electricity sales in 1991.

In 1991, Plant No. 2 paid penalties of about $6 million/year for emissions over the legislated limit for airborne emissions. Plant management staff were concerned that local or national authorities may in the future order the plant to reduce operations or shut down to reduce pollution in Łódź. Consequently, the plant has investigated options for reducing airborne emissions.

2.3 Operating Status

This section provides a brief characterization of the operating status of Plant Number 2 during the period of the Industrial Energy Efficiency Improvement project. The Team made recommendations and provided equipment specifications that reflected expectations of future energy prices, key supply and demand factors, and availability of necessary improvement capital. These recommendations also considered salient features of the plant's operating situation; these are outlined below.

At the time of the initial visit, turbines 1, 3, and 5 and boiler number 1 were all down for routine maintenance; boilers 8 and 9 had been shut down previously for operating problems. The plant was only producing 631 tons/hour of steam (52.5% of capacity), and the auxiliary oil-fired boilers were not operating.

The plant was using about 40% of its fly ash to make bricks and the remainder for road construction. With the possibility that in the future there may be no need for fly ash in road-building, the plant began investigating other potential markets for this product.

The IRG Cogeneration Audit Team observed that only about 63% of the steam condensate was reused, and none of the process steam sent to local industry was returned as condensate. These losses amounted to 400 tons/hour and caused Plant No. 2 to have an abnormally high demand for make-up boiler water. Potential recovery of lost condensate was an appropriate future area for technical assistance.

Team members also observed that boilers No. 1, 2, and 3 were worn out, being more than 30 years old each and constructed using antiquated designs.

About three weeks prior to the Audit Team's initial visit, an oil line on Turbine/Generator Set No. 5 broke and caught on fire. Although there was no significant damage to the turbine, since it had been partially dismantled and was undergoing repairs, there appeared to be some damage to the turbine environment and minor smoke damage.

2.4 Measurements

The Audit Team obtained operating data at Plant No. 2 (Łódź) by:

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

b) Using a portable Enerac 2000 gas analyzer to detect concentrations of oxygen (O_2), carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrogen oxide (NO_x) 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.

Measurements taken from the turbine/generator sets are included in **Appendix III**; boiler measurements are also presented in this appendix.

These measurements were used to calculate boiler excess air levels, turbine/generator efficiencies, estimated air leaks, heat losses due to inadequate insulation, and operating levels

as percent of capacity. This calculated information, augmented by observations and interviews, was the basis for the recommendations of the Audit Team.

Results indicated:

1. Boilers were operating at excess air levels of 20% to 40%, which was depressing boiler efficiency by 0.7% to 2%.

2. Turbine/generator sets were operating at 72% to 76% internal thermal efficiency, a fairly good level.

3. There was significant leakage (maybe as much as 9% by volume) of air into the preheaters, seriously reducing heat recovery.

4. There were numerous instances of inadequate, damaged, or missing insulation throughout the plant.

3. ENERGY MANAGEMENT

3.1 Energy Management Program

The Thermal Power Company has a strong energy management program designed to encourage employees to save energy. This program receives a high level of support from the plant management, and includes a number of energy saving incentives. These initiatives are:

- A portion of annual profits are set aside to provide incentive bonuses to employees;
- Bonuses are awarded for cost-saving suggestions put into practice;
- Energy-saving suggestions receive a 50% higher bonus; and
- Employees can earn up to 20% of their annual wages in bonuses.

In addition to specific incentives, management requires all employees attend seminars and training sessions on cost- and energy-saving issues. Moreover, every five years, each employee connected with operations must pass an examination which includes questions on energy-saving.

3.2 Strategic Planning

Łódź has made several key steps related to long-term strategic planning. These steps include:

1. **Completion of detailed projections for energy demand through 2020 for the individual districts in Łódź.** The overall forecast was:

1990	-	2580 MW
1995	-	2828 MW
2000	-	3078 MW
2010	-	3546 MW
2020	-	4003 MW

These projections correspond to growth rates of:

1990-2000	-	1.8% per year
2000-2020	-	1.3% per year

Although the forecasted growth rates may be low, the plant had sufficient capacity (which currently is underutilized) to provide for demand growth of up to 3% within the next 10 years.

2. **Development of a plan to install major links between individual plants so that the most efficient facilities can be used to meet demand.** The proposed links are:

   - Connect the steam lines between Plant No. 2 and Plant No. 4.
   - Tie this connection into the existing steam line linking Plants No. 1 and 3. (The estimated cost of these two steps is $6-7 million)
   - Connect the Plant No. 3 and Plant No. 4 water systems. (Estimated cost is $6-7 million)

   Savings from these initiatives was estimated at $5 million per year, at 1991 costs. The World Bank tentatively agreed to finance these projects.

3. **Exploration of alternatives for meeting SO_2 and NO_x regulations in place by 1998.**

4. **Investigation of programs to encourage thermal energy conservation throughout the system.** By some estimates, at least 25% of the thermal energy is wasted.

The IRG Cogeneration Audit Team strongly supported these strategic planning activities and suggested Łódź become involved in developing a comprehensive, long-range strategic plan. In addition, it was recommended the Thermal Power Company employ a qualified outside (Polish or U.S.) expert to conduct an economic analysis of the entire system be to define and compare alternative strategies for meeting the electric and thermal energy demands in the future. Possible alternatives to consider include:

- Modernization of Plant No. 2 as now planned;
- Elimination of Boilers #1, #2, and #3, and modernize the rest of Plant No. 2.;
- Closing of Plant No. 1 and conversion of Plant No. 2 to thermal energy only; and/or
- Closing of Plant No. 2 (an extreme case, probably useful only to establish a base economic case).

This study should be conducted before major financial commitments are made; the study could be completed for $60,000 - $100,000, since much of the data already have been compiled by the Thermal Power Company and the IRG Team.

3.3 Training and Energy Management Requirements

1. Economics and Project Evaluation

Personnel at Plant No. 2, as in most plants visited by the Audit Team, had little understanding of techniques commonly used in the U.S. to evaluate 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 Thermal Power Company analyze investment alternatives and prioritize project options.

2. Long-Range Strategic Planning

The Thermal Power Company had already given much attention to developing a long-range strategic plan. The Audit Team recommended resources be devoted to additional formal training in strategic planning to improve upon The Thermal Power Company's ability to develop such plans. Development of a truly comprehensive long-range strategic plan will require:

- Forecast of demand for electric and thermal energy;
- Analysis of corporate strengths and weaknesses;
- Analysis of competitive influences;
- Definition of potential alternative long-term courses of action; and
- Development of the ability to evaluate alternatives based on established criteria.

Since the Thermal Power Company operated both the energy producing facilities and the district heating system in Łódź, it has a unique opportunity to benefit from that managers that are trained in strategic planning concepts.

3.4 USAID Sponsored Energy Management Workshop

While visiting the Łódź in October, the IRG Team described the Workshop to be conducted in Warsaw on October 8 & 9, and invited the management of Plant No. 2 to attend and make a presentation regarding its experiences with SO_3 injection for the benefit of other attendees.

The Workshop was sponsored by the U.S. Agency for International Development and conducted by the IRG Team, with support from the Polish Ministry of Industry (Mr. Roman Łuczkiewicz) and the World Bank (Mr. Ian Hume). The Director of the Łódź Plant attended, along with two members of his staff. Łódź representatives made a presentation at the workshop on Plant No. 2's experience with SO_3 injection.

4. ENVIRONMENTAL CONSIDERATIONS

The IRG Team noted that Plant No. 2 exceeded existing regulatory limits for particulate emissions by a significant amount, since its electrostatic precipitators were very old, and since the ash content of the coal used in the plant was much higher than the plant was designed to handle. Replacement or reconstruction of the precipitators will be very expensive (estimated at $23 million for all nine boilers). Consequently, the plant began a search for more affordable solutions.

Injection of low concentrations of SO_3 or SO_3 and NH_3 was an option considered by plant management since it had been shown to have positive effects on precipitator performance. This technology is used widely in the U.S. and Western Europe, and there was a commercial installation of this type in Poland. The Łódź facility provided details about its experiences with SO_3 injection to the IRG Team. Details of this experience are included in **Appendix VII**.

5. ENERGY EFFICIENCY IMPROVEMENT OPTIONS

Energy conservation opportunities were identified by the IRG Team 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. 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. These include option proposed by the IRG Team, officials at the plant, and in some cases, options proposed by outside organizations. In this section, the IRG Team intends to present the merits and deficiencies of each proposal. Since the Team did not recommend that all proposals be implemented, this section includes caveats about the projects the Team did not endorse. The 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, while "low-cost" items may need limited amounts of hard currency. Each is possible within the existing framework of plant expenditures (ie. zloty purchases, small hard currency purchases, improved maintenance, and housekeeping) and will have rapid payback periods.

1. Identify and Eliminate Excess Air in the Furnaces

The boilers in Plant No. 2 were operating at excess air levels in the range of 26-42%. Efficient operation usually was between 12-20% (each 5% increase in excess air resulted in about a 0.35% decrease in boiler efficiency). These levels were high due to the unreliability of the oxygen analyzers in place at the plant prior to the audit. To compensate, the plant was operating on the "safe" side of optimum excess air levels. **Appendix IV** details the costs and benefits associated with high levels of excess air.

The Audit Team recommended one continuous oxygen analyzer be purchased and installed on Boiler No. 4 or Boiler No. 7, since these boilers were operating at the least efficient levels.

2. Purchase and Install Steam Traps

Plant No. 2 experienced difficulties with leaks and steam trap failure on higher pressure steam lines prior to the visit of the Audit Team. Traps in place at the time were made in Poland,

since no higher quality steam traps were available in Eastern Europe when the initial purchase was made.

The Audit Team recommended 15 stainless-steel, inverted bucket steam traps be purchased and installed on appropriate lines at Plant No. 2. The performance of these traps should be monitored; if the improvement is as expected, The Thermal Power Company should begin replacing all faulty or unreliable steam traps. **Appendix IV** includes details on trap sizes, costs, and estimated payback periods.

3. Repair and Maintain Insulation

Although the insulation in the plant was in generally good condition, there were a number of instances of:

- Places, particularly pipe joints, where the insulation had deteriorated; and
- Uninsulated pipe in the region of reducing stations.

In one case, the surface temperature of exposed pipe and fittings was measured at 18°C. Poorly insulated surfaces result in losses of about 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 amount this by 80-90%.

The Audit Team recommended that the plant regularly check the state of insulation and conduct appropriate repairs; they also suggested that one Infrared Thermometer be purchased to use in detecting sources of heat loss.

4. Eliminate Air Leaks around the Air Pre-Heaters

Experiences in other plants of similar age and condition in Poland suggested there would be significant air leaks in Plant No. 2. Such leaks into the system around the air pre-heaters reduce boiler efficiency. As such, the plant should check for this during scheduled overhauls of the boiler systems and make any necessary repairs.

5.2 Long-Term/Capital Intensive Options

1. Extend continuous oxygen analyzers to Boilers 4-9

Boilers are operated in two blocks: 4, 5, 6 and 7, 8, 9. Thus, the continuous oxygen analyzers should be installed so each block has its own control room. These items would cost about $6,000 - $10,000 per boiler. Johnson-Yokogawa Corp. manufactures a multi-probe oxygen analyzer which can monitor up to eight probes from one panel-mounted instrument.

A reduction of 10% in the excess oxygen level will improve boiler efficiency by 0.7%. In 1990, each block consumed about 200,000 tons of coal. As such, a 0.7% improvement in efficiency will save approximately $33,600/year. One of these instruments with six probes (two

for each boiler) will cost roughly $14,400; shipment and installation will bring the total cost to $27,000, with a payback period of 10 months.

The Audit Team recommended the oxygen analyzer purchased in Phase I be moved to Boiler No. 3, with multi-probe analyzers to be installed on Boilers 4, 5, & 6 and Boilers 7, 8, & 9.

2. Rebuild Electrostatic Precipitators on All Boilers

Plant No. 2 was concerned about the amount of ash particulates discharged from the plant. The present electrostatic precipitators were only about 85% efficient, and the plant was discharging seven times the permitted quantity of ash into the air. The plant management had developed a proposal to replace or rebuild the electrostatic precipitators on all nine boilers at a total cost of about $23 million.

As an interim measure, Plant No. 2 explored the possibility of investing in the injection of SO_3 into the flue gas to improve precipitator efficiency. This measure had the potential to improve the efficiency to about 93%. The cost was estimated at $700,000 per boiler.

The SO_3 injection technology will not reduce plant emissions to the level mandated by law, but will cut them in half, contributing directly to plant cost savings by reducing the amount of environmental penalties levied on the plant.

At the time of the Audit Team's October visit, Plant No. 2 was running a trial with a borrowed SO_3 injection unit. After a one week trial on Boiler No. 8, the precipitator efficiency was about 95%. This compared to 80 - 85% efficiency without the SO_3 injection.

The Audit Team recommended:

- Plans be made to phase Boilers 1, 2, & 3 out of operation. The boilers are very old, and the plant personnel describe them as "worn out." In any case, the capacity of these boilers was rarely needed at 1991 demand levels.

- A recognized expert on SO_3 injection technology be called in to advise Plant No. 2 on the most appropriate SO_3 or SO_3/NH_3 system to use at the plant, and to help develop reliable estimates of the costs and benefits. The cost of such services is likely to be about $20,000.

- No further action be taken on rebuilding or replacing the present precipitators until a thorough economic and strategic analysis defines the long-term future of the plant.

3. Install automatic controls on Boilers 4-6 and 7-9

A rough estimate indicated the cost of installing automatic controls on boilers 4-6 and 7-9 would be $150,000 for each block. At the time of the Team's return visit, all adjustments to operating conditions were still made manually. However, essentially all data needed for

installation of automatic control was available in the control room, with the exception of the requisite additional instruments and electronics.

The benefits of automatic controls for the plant would include improved boiler efficiency, fewer interruptions of operations due to faster response conditions, and reduced need for labor. Thus, a 0.5% improvement in efficiency could yield savings of $24,000/year for each block at current operating rates and coal prices. At projected prices and capacity operation, the savings will be $75,000 - $100,000/year per block. The payback period was calculated to be six years, under 1991 conditions. The Audit Team noted the improvement in efficiency resulting from installation of automatic controls would be likely greater than 0.5%, including the pay-back period.

4. Modify the water pumps

The Audit Team recommended modifying the water pumps, which are responsible for pumping hot water to the district heating system, so water flow can be controlled by varying pump speed rather than by throttling water flow at the pump outlet.

Plant No. 2 pumps 6,300 tons/hour of water (28,000 gal./min.) to the District Heating System.

The plant had not obtained data on the cost of conversion or of potential benefits at the time of the audit. However, the Team observed that since Łódź No. 2 supplied more thermal energy than the Blachownia facility to its heating system, savings should be at least as great. The costs would be higher in proportion, but the payback periods should be similar:

15 months at current electricity value

6 months at projected electricity value

The Audit Team recommended that this project be implemented if projected costs and benefits are confirmed. An analysis of the Blachownia situation is outlined in **Appendix V.**

5.3 Additional Energy Efficiency Improvement Options Identified During the Second Visit

Between the first and second visits of the IRG Team, plant personnel listed other needs in the plant that would enable them to make significant energy efficiency improvements. Due to time constraints, Team members were unable to examine each of these in detail; thus, these ideas are outlined below.

Each option involved the purchase of some equipment. Evaluations of the payback periods for the items, especially the capital intensive items, such as the SO_3 injection system, must be evaluated in light of economic criteria (including non-subsidized pricing frameworks), environmental criteria (especially impending emissions regulatory legislation) and plant cash flows.

In addition, other capital intensive options outlined above should be reevaluated in light of possible equipment purchases. For example, replacement or reconstruction of some of the electrostatic precipitators may be postponed if a decision is made to purchase the SO_3 injection system.

1. **Boiler House**

- Installation of Pentol SO_3 injection system on at least two boilers. (Estimated cost for two units is $1,000,000.)
- Governor valves for the boiler feed water system. Parameters: 16 MPa at 200 °C. 0-180 tons/hour flow rate. Ten units are needed.
- Flue gas analyzers for all nine boilers.
- Automatic control systems for water pumps (1,200 KW each) in District Heating System lines for Boilers No. 10 and 11 to eliminate throttling losses.

2. **Machine Room**

- Automatic control system for pumps serving the District Heating System. It was suggested that a control system using power thyristers and fluid couplings should be installed. Maximum pump flow is 1,200 tons/hour.
- Monitoring system for diagnostic purposes for both the boiler feed water pumps and the District Heating System hot water pumps.
- A portable device for measuring air leakage in the steam turbine vacuum system. (Devices based on ultrasound may be available, but are likely to be expensive.)
- A device for water level control in the deaerator water tank.
- Information about parts inventory management, as it is practiced in the U.S.

3. **Relay Laboratory**

- Laboratory frequency generator with an operating range of 20-60 Hz. power output -- above 20 Va; voltage output -- 100-220 volts. The purpose is for frequency relay calibrations.
- Portable universal meter: current range -- 10 amps; voltage range -- 600 - 1000 volts. Four units are needed.
- A current transformer to be used in adjusting the works of electromagnetic relays.

4. **Electrical Department**

- A thermo-vision set.

5. **Automatics Department**

- Portable flue gas analyzer.
- A computerized system for gathering and reporting plant operating data.

6. **Mechanical Department**

- Equipment for arc-welding, argon shielded.
- Equipment for forced ventilation removal of welding gases.

As with all other investment and improvement options, the Team did not make specific recommendations unless they could be supported through appropriate data analysis and economic evaluation. Consequently, the Audit Team recommended that the plant conduct comprehensive analyses of all improvement options that were serious possibilities for implementation. In the training seminars during the audit, and at the final workshop in Warsaw, the Team outlined techniques for evaluating investments, using consistent, economically based criteria for decision making and strategic planning.

6. RECOMMENDATIONS AND CONCLUSIONS

The Audit Team recommended that preparation of a comprehensive long-range strategic/economic plan be a pre-condition for continued A.I.D. or World Bank support for all major investments. Most enterprises in Poland appear to lack the resources and/or experience to develop their own long-range plans, and might require training and technical guidance to formulate a useful strategic plan. However, without such planning and analysis, many investment projects will have little chance of long-term success.

6.1 Implementation Priorities

The Audit Team recommended the items listed in **Section 5.1** and summarized below be purchased for Plant No. 2 under the Emergency Energy Program. These include:

	Estimated Purchase Cost	Estimated Benefit	Payback Period*
One Continuous Oxygen Analyzer	$14,000	$33,600/yr.	5 months
Ten Steam Traps	1,300	$12,000/yr.	3 months
Five Steam Traps	1,590	$12,000/yr.	3 months
One IR Thermometer	895	$ 2,000/yr.	6 months
TOTALS	$17,785		

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

Details items purchased for Łódź Plant No. 2 are identified in **Appendices IV and VI.** Final estimates of costs and benefits of these purchases are described the Executive Summary.

The Team also recommended when considering larger-scale investment in Plant No. 2, the following projects should be given high priority:

- Purchase and installation of oxygen analyzers on Boilers 4-9.
- Purchase and installation of SO_3 injection systems on Boilers 4-9.
- Modification of the hot water pumps to the District Heating System so that the flow rate can be controlled by varying pump speed rather than by throttling the water flow.

Furthermore, key plant personnel should be given intensive training in economic evaluation, strategic planning and prioritization of projects.

6.2 Conclusions After Second Visit

The Łódź Plant No. 2 was a well-managed facility that was trying in every way to upgrade equipment and performance. Moreover, because the four energy plants and the district heating system were owned and operated by the same entity -- The Thermal Power Company -- the Łódź system was in an excellent position to use facilities optimally and to get the most out of investments in energy-saving projects.

The Thermal Power Company (Łódź) represented one of the greatest opportunities for investment in Poland. In addition, given the high quality of management and professional personnel, The Thermal Power Company will benefit greatly from training programs in economic evaluation and other modern management techniques.

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.

APPENDIX II
MEETING PARTICIPANTS
April 1991

Thermal Power Company

Mr. Zdzisław Szyda	Director of Plant No. 3 and Director of the Thermal Power Company
Mr. Jan Olszácki	Chief Technical Specialist
Mr. Włodzimierz Kędziora	Chief of Technology for the Thermal Power Company

International Resources Group, Ltd.

Mr. Gerald Decker	Team Leader
Dr. Richard Heiny	Engineer
Mr. John Pangborn	Engineer

Energopomiar

Mr. Adam Zemla
Mr. Zdzislaw Gieras

Polish Foundation for Energy Efficiency

Dr. Slawomir Pasierb

Polytechnic Institute, Gliwice

Dr. Jan Nadziakiewicz

APPENDIX III
AUDIT MEASUREMENTS AND COMPARATIVE STATISTICS

During the period April 16 - 19, 1991, the Cogeneration Audit Team took a number of control measurements at the District Heating Plant No. 2. Turbines No. 2, 4, 6 and 7 and Boilers No. 2, 3, 4, 5, 6 and 7 were examined. Turbines No. 1, 3, 5, and Boiler No. 1 were down for scheduled maintenance. Boilers No. 8 and 9 were shut down for operating reasons.

The first turbines in this plant were built in 1958. The most recently constructed turbine was No. 7, built ten years later in 1968.

AUDIT MEASUREMENTS

A. BOILERS

Boiler Number		2	3	4	5	6	7
Feed water:							
pressure	MPa	12.5	12.7	12.5	13.2	12.6	12.5
temperature	°C	148	192	215	210	210	190
Steam:							
output	t/h	104	100	102	110	95	120
pressure	MPa	9.3	9.6	9.0	8.5	8.6	9.6
after boiler temp.	°C	507	490	500	500	500	502
Flue gas temperature after air heater	°C	248/234	207/211	195/192	180/182	170/170	150/160
O_2 before air heater	%	5.3/3.8	5.3/-	8.5/6.0	7.5/6.1	-/6.7	-/-
Temperature of incoming combustion air	°C	285	295	273	258	265/270	262/256

B. TURBINES

Turbine Number		2	4	6	7
Inlet Steam:					
flow	t/h	140	160	300	105
pressure	MPa	9.1	8.9	8.8	9.0
temperature	°C	480	490	500	500
Extraction Steam:					
flow	t/h	120	-	-	-
pressure	MPa	0.83	0.02	-	-
temperature	°C	278	-	-	-
Power output	MW	14.0	23.8	21.0	16.5
Cooling Water:					
inlet temperature	°C	16.5	-	-	-
outlet temperature	°C	18.5	-	-	-
Outlet pressure	kPa	-	-44.7	0.82	-0.23
temperature	°C	47	86	-	110

C. BOILER EFFICIENCY CALCULATION *

Value	Unit	Boiler Number								
		1	2	3	4	5	6	7	8	9
Design boiler output	t/h	120	120	120	140	140	140	140	140	140
Boiler efficiency	%	89.70	90.84	88.79	87.88	89.37	89.79	88.72	87.45	89.81
Tolerance of boiler efficiency calculations	%	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Boiler output	MW_{th}	87.6	88.8	86.7	97.7	99.4	99.8	98.7	97.2	99.9
Heat delivered to boiler	MW_{th}		97.7				111.2			
Coal consumption	t/h		17.84				20.3			
Losses:										
flue gas	%	8.22	7.60	8.75	8.98	8.42	7.21	9.07	9.96	7.74
combustibles in flue gas	%	0.008	0.007	0.009	0.009	0.009	0.008	0.009	0.011	0.009
combustibles in slag	%	0.872	0.299	0.689	0.208	0.208	0.400	0.333	0.245	0.400
heat content of slag	%	0.057	0.051	0.055	0.050	0.050	0.052	0.051	0.051	0.052
combustibles in ash	%	3.372	0.448	0.941	2.139	2.139	1.22	1.000	1.563	1.269
heat content of ash	%	0.119	0.104	0.109	0.110	0.110	0.098	0.099	0.126	0.100
surroundings	%		0.650				0.620			

* calculations are based on data from Operation Control Department of the plant within the period: January - March 1991

COMPARATIVE STATISTICS

Table 1. Boiler Operating Conditions

	Blachownia (Kędzierzyn - Kozle)		Łęg (Kraków)		Plant No. 2 (Łódź)		Wola[1] (Warsaw)		Zakłady Azotowe (Włocławek)	
	Boiler #8	Boiler #12	Boiler #1	Boiler #3	Boiler #3	Boiler #5	Boiler #2	Boiler #4	Boiler#2	Boiler#3
STEAM PRODUCTION:										
Capacity, T/hr.	120	215	380	430	120	140	116 MW_{th}	116 MW_{th}	260	230
Measured, T/hr.	98	158	365	355	100	110	2,450 (68.2 MW_{th})	2,250 (80.9 MW_{th})	110	180
Pressure, MPa	8.2	9.5	12.3	12.2	9.6	8.5	1.75	1.81	9.3	9.2
Temperature, °C[2]	480/505	500/495	533/536	535	490	500	103	105	505	510
STACK TEMPERATURE:										
Before heater, °C			540 °C	370/390	310 °C	290 °C			268 °C	327 °C
After heater, °C	195/185	138/140	135	160/150	207/211	180/182	188	215	123	148
FLUE GAS ANALYSIS (before air heater)										
O_2 [2]	5.2%	3.9%	6.3/4.9	5.5%	5.3%	7.5/6.1	4.7%	7.4%	5.5%	4.8%
CO_2 [2]	12.7%	12.5%	12.5/14.5	15.7%	-	-			12.5%	12.9%
SO_2	10 ppm	77 ppm	-						753 ppm	207 mgm
NO_x	110 ppm	92 ppm	215 ppm						233 ppm	485 mgm
EXCESS AIR LEVEL	31%	23%	37%	35%	34%	48%	29%	54%	35%	29%

(1) Wola capacity is stated in Thermal Megawatts (MW_{th}).

(2) 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 2. Distribution of Costs of Production
(E.E. = Electrical Energy; E.C. = Thermal Energy)

	Blachownia (Kędzierzyn - Kozle)		Łęg (Kraków)		Plant No. 2 (Łódź)		Wola (Warsaw)		Zakłady Azotowe (Włocławek)	
	E.E.	E.C.	E.E.	E.C.	E.E.	E.C.	E.E.	E.C.	E.E.	E.C.
Fuel	48.3%	50.9%	49.2%	49.2%	35%	35%			60% (?)	54.7%
Electricity	-	7.8%							-	17.7%
Supplies	0.9%	0.8%								
Wages	3.5%	2.9%			5%	5%			1.6%	1.5%
Overhauls	29.8%	23.5%								
Depreciation	5.2%	3.5%							4.9%	10.4%
Environmental	8.6%	7.9%								
Overhead	3.6%	2.7%							0.7%	0.5%
Total	100.0%	100.0%								
Total Cost zł/kWh zł/GJ	230		87		246		351 (purchased from grid) 21563		400 (est) 250 (purchased from grid)	
Sales Price zł/kWh	178.5		99		152					
zł/GJ								40,333		

Table 3. Specific Heat Consumption[1] to Produce Electricity and Thermal Energy

	Blachownia (Kędzierzyn - Kozle)	Łęg (Kraków)	Plant No. 2 (Łódź)	Wola[2] (Warsaw)	Zakłady Azotowe (Włocławek)
Unit Energy/kWh	12,516 kj/kWh	9,602 kj/kWh	4,810 kj/kWh[4]		12,210 kj/kWh
Unit Energy/kWh	11,865 BTU/kWh	9,103 BTU/kWh	4,560 BTU/kWh		11,547 BTU/kWh
Efficiency	28.8%	37.5%	74.8%		29.5%
Unit Energy/GJ	[3]	1,229 MJ/GJ	1,169 MJ/GJ	1,150 MJ/GJ	1,197 MJ/GJ

NOTES:

[1] Data were calculated from average results for 1990.

[2] Wola produces no electricity.

[3] 1990 data were not available

[4] This data for Łódź may be incomplete.

Table 4. Coal Pricing

	Blachownia (Kędzierzyn - Kozle)	Łęg (Kraków)	Plant No. 2 (Łódź)
1990 Price (Average)	73,993 zł/Ton	91,958 zł/T.	
Consumption	771,124 tons	1,156,941 tons	592,680 tons.
Source		6 collieries	3 mines
Heating Value	16,000 - 18,000 kj/kg. (6880 - 7740 BTU/lb.	(17,000-22,000 kj/kg range 19,590 kj/kg average 8760 BTU/lb.)	20-21,000 kj/kg (8,600-9,030 BTU/lb.)
Sulfur Content	0.8%	0.7-0.8%	<1.0%
Ash Content		27.9% (average) (10-32% range)	18%
1991 Prices	200,000 zł/T	139,000 zł/T (Jan.) 160,000 zł/T (Apr.) +35,000 zł/T delivery cost	230,000 zł/T (Feb.) (delivered)
Comments on Purchasing	Prices are increasing about 5% per month. Supply options are limited.	Monthly price increases. Price depends on H.V., % Ash, % S Theoretically, can buy wherever they want. Really, limited choice.	Coal price is increasing about 5%/month

NOTE: These prices were obtained in April 1991. At that time the conversion rate was about 9,500 zł/$1.00 U.S. By October 1991, the conversion rate had gone to about 11,100 zł/$1.00 U.S.

Table 5. Fuel Oil Pricing

	Blachownia (Kędzierzyn - Kozle)	Łęg (Kraków)	Plant No. 2 (Łódź)	Wola (Warsaw)	Zakłady Azotowe (Włocławek)
1990 Price (Average)	824,215 zł/T	795,115 zł/T	-	720,349 zł/T (delivered)	800,000 zł/T.
1990 Consumption	4,755 T.	4,825 T.	990 T.	85,157 T.	149,240 T.
Source				Plock	Plock, Gdansk
Heating Value	-	40,328 kj/kg (17,350 BTU/lb.)	40,160 kj/T. (17,270 BTU/lb.)	40,700 kj/kg (17,500 BTU/lb.)	40,700 kj/kg (17,500 BTU/lb.)
Sulfur Content				2%	2%
Pricing history: Sept. 1990 Oct. 1990				400,000 zł/T 1,100,000 zł/T	
Pricing forecast: Feb. 1991 April 1991 Projected			1,380,000 zł/T 800,000 zł/T	1,300,000 zł/T 800,000 zł/T (+ 120,000 zł/T frt.) 700,000 zł/T	1,300,000 zł/T 600,000 zł/T
Possible Future sources	Coal is the primary fuel; fuel oil use is small and not critical	Coal is the primary fuel; fuel oil use is small and not critical	Coal is the primary fuel; fuel oil use is small and not critical	Negotiating with: Astra (U.S.) Netherlands Co. Brokers in Poland $70/T fob port in Poland	Amsterdam proposed $60-70/T.

NOTE: Conversion rate - $1.00 = 9,500 zlotys (April, 1991)

Table 6. Personnel/Functional Structure
(Number of persons employed in each function)

	Blachownia (Kędzierzyn - Kozle)			Łęg (Kraków)			Plant No. 2 (Łódź)			Wola (Warsaw)			Zakłady Azotowe (Włocławek)		
	Total	S	U	Total	S	U	Total	S	U	Total	S	U	Total	S	U
Prod'n Op'ns	200	23	7	435	66	27				63		1	81	8	0
• Turbine							80	9	3						
• Boilers							140	9	4						
• Coal Hdlg.							63	12	2						
• Water Trt.							42	8	1						
Elect. Maint.	97	16	6	146	16	12	82	8	4	26		1	66	7	2
• Elect. Prot.							11	2	1						
Mech. Maint.	153	23	8	520	109	42				15		2	62	7	1
Contr. & Env.	6	-	3				22	2	1	12		1	67	8	1
Transport	15	1													
Purch., Etc.	3		3							14		1			
Institute	5														
Management	3	3	3	15	3	3				6	6	4			
Unaccounted	88			197			250			4			10		
Totals	620	65	30	1,355	213	100	690	50	16	150	?	10	286	30	4
MW Capacity	1220 Th MW (est'd)			2000 Th MW			1050 Th MW (est'd)			580 Th MW			655 Th MW (est'd)		
Pers./MW	0.57			0.68			0.66			0.26			0.44		

S = Supervisory personnel
U = University-trained professionals

APPENDIX IV

JUSTIFICATION FOR PURCHASE OF EQUIPMENT

CONTINUOUS OXYGEN (O_2) ANALYZERS FOR STACK GAS

Install reliable continuous O_2 analyzers on boiler stacks so that operating conditions can be adjusted to keep excess air supplied to the boilers at optimum levels. Presently, the boilers in Plant No. 2 operate at excess air levels of 26-42%, when the optimum level is about 15%. With reliable O_2 analyzers the excess air level can be reduced by at least 10%, resulting in at least 0.7% improvement in efficiency of boiler operation. At the plants included in the Emergency Energy Program 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 fual 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; Plant No. 2 should realize 1.5 to 2.0 times these savings.

Reliable O_2 analyzers <u>including remote reading instruments</u> are available from several U.S. suppliers at prices of around $6,000 excluding probes or terminals, depending on the model purchased. Shipping and installation for a model such as the Johnson-Yokogawa model would bring the total cost up to approximately $27,000 (six probes, 2 for each boiler). The payback period would be approximately 10 months.

In addition to the direct economic benefit, there will be a significant environmental benefit from the installation of this equipment, since emissions of NO_x and SO_2 will be reduced.

Typical Polish coal contains 0.8% sulfur and fuel oil contained 2% sulfur. The savings described above will reduce SO_2 emissions by:

10 tons/year for coal-fired boilers, or
12 tons/year for oil-fired boilers.

The reduction in NO_x emissions would be similar.

Preliminary quotes (not firm or final) for O_2 analyzers are:

Johnson-Yokogawa	$4,437.00*	
Bailey Controls	3,129.00	
Ametek, Thermox Div.	3,570.00	or
	5,700.00	
Land Combustion	5,092.00	

The Audit Team recommended that one continuous Oxygen Analyzer be purchased for installation in Boiler No. 4 or Boiler No. 7 at Plant No. 2.

Because of the flexibility of their instruments and the apparent extent of their European service network, the Audit Team recommended 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 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 to the level of $14,400 for six probes; two terminals.

STEAM TRAPS

Present steam traps (manufactured in Poland or East Germany) allow significant leakage of steam and condensate and are a maintenance problem. Recommended steam traps are produced by the Armstrong Machine Works in Three Rivers, Michigan.

The Dow Chemical Company is a large user of steam traps; after extensive investigation and years of experience, the Dow experts strongly recommended that only Armstrong inverted bucket traps be considered. The Audit Team supported this recommendation.

In addition to being a manufacturer of high quality steam traps in the U.S., Armstrong has a strong presence in Europe. It has a manufacturing facility in Liege, Belgium, and Sales/Service offices in many cities including Warsaw.

Steam losses through defective steam traps vary depending on steam pressure, trap size, and trap condition. Maximum losses are in the range of:

Small traps: 20 lbs./hr. at 30 psig; 70 lb./hr. at 150 psig

Medium traps: 120 lbs./hr. at 30 psig; 450 lb./hr. at 150 psig

Large traps: 1000 lbs./hr. at 30 psig; 3,700 lb./hr. at 150 psig

Armstrong suggested that an "average" maximum loss is about 200,000 lb./month, and that an "average" installed cost of a steam trap is about $300. Using a typical steam value in the U.S. of $5.00 per 1,000 pounds, each $300 investment in steam traps will yield the following benefits:

100% failure	-	$12,000/year
50% failure	-	$ 6,000/year
10% failure	-	$ 1,200/year (three-month payback)

VENDOR: Steam Specialty Products
Armstrong Machine Works, Inc
816 Maple Street
Three Rivers, Michigan 49093

REPRESENTATIVE IN POLAND:

Slovenijales Ljubljana
Przedstawiecstwo w Polsce
Ul. Swietokrzyska m. 37
Pl. 00-116 Warszawa
Poland

Telephone: 48-22-20 56 05

Armstrong manufactures Cast Steel Traps, Stainless Steel Traps, and Cast Iron Traps. Because of the combination of reasonable price and durability, the Audit Team recommended that stainless steel traps should be purchased for use in Plant No. 2.

The recommended traps to be purchased are:

- Ten (10) medium-sized traps:

  Armstrong Stainless Steel Trap Mcdel No. 1811
  Pipe connection = 3/4"
  Orifice diameter = 1/4"

- Five (5) larger traps:

  Armstrong Stainless Steel Trap Model No. 1812
  Pipe connection = 1"
  Orifice diameter = 1/4"

Armstrong has the following list prices for these traps:

Model 1811	=	$130
Model 1812	=	$318

The Armstrong representative indicated that discounts may be available for the quantities indicated.

INFRARED THERMOMETERS

During the initial visit to Plant No. 2, the Audit Team observed a number of instances of inadequate, damaged, or missing insulation. At the energy costs experienced under the former regime, 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 recommended that one IR thermometer be purchased for use by Plant No. 2.

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

APPENDIX V

MODIFY HEATING WATER PUMPS SO PUMPING SPEED CAN BE VARIED

The heating water pumping situation at Plant No. 2 was very similar to that at Blachownia. Since the Audit Team had no figures on the costs and benefits for Plant No. 2, it assumed that the economics would be very similar to Blachownia. The following is a quote from the audit report for Blachownia:

> "Modify water pumps so that water flow to the heating system can be controlled by controlling 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 wastes pumping energy. The plant has estimated that changing to variable speed control will save about 6.5 million kWh/year.
>
> "At current Blachownia costs to produce electricity (230 zlotys/kWh) the savings will be about $157,000/year.
>
> "At a more, realistic cost of $0.06/kWh, the savings will be about $390,000.
>
> The plant has estimated the conversion cost as follows:
>
> - to modify three pumps and impellers:
>
> 250 million zł each= 750 million zł
>
> - to rewire four motors (including one spare):
>
> 300 million zł each= 1,200 million zł
>
> Total cost = 1,950 million zł
> or about = $200,000

The IRG Team estimated that at current costs, the project will have a payback period of 15 months. At projected higher costs, the payback period could be as low as six months.

The Audit Team recommended that this project be supported.

APPENDIX VI
EQUIPMENT PURCHASED FOR PLANT NO. 2

Following the visit in April, the Audit Team arranged for the purchase of the following items for Plant No. 2:

1. Two Johnson-Yokogawa in situ Oxygen Analyzers with one probe each.
2. Ten Armstrong inverted bucket type stainless steel steam traps, Model 1811 with 3/4-inch pipe connections and 1/4-inch orifice.
3. Five Armstrong inverted bucket type stainless steel steam traps, Model 1812 with 1-inch pipe connections and 1/4-inch orifice.
4. One infra-red thermometer, Model IR-550 from Davis Instrument Co.

In October 1991 it was agreed that the Oxygen Analyzers would be installed on Boilers No. 4 & 7. The plant engineers selected sites for installation of the steam traps; they installed the traps in locations where reasonable estimates of reduction in steam losses could be made. These particular traps are limited to maximum pressures of about 450 psi (about 3 MPa), and the plant representatives stated they had numerous suitable sites.

The IR thermometer will be used immediately to detect imperfections in insulation and other sources of heat loss.

APPENDIX VII
PLANT NO. 2 (ŁÓDŹ) EXPERIENCES WITH SO_3 TECHNOLOGY

Plant No. 2 leased a packaged SO_3 injection unit for a trial period of one month. The unit was produced by Pentol (a Dutch firm) under license from Valco, the U.S. originator of the technology. In this unit, SO_2 gas was passed over a V_2O_5 catalyst where it was oxidized to SO_3 and then injected into the stack gas prior to the electrostatic precipitators. Pentol operated the unit on site for the test. Pentol was very pleased with the test conditions and results; they gave Plant No. 2 two weeks additional trial at no charge.

The electrostatic precipitators at Łódź No. 2 operate at efficiencies in the range of 80-85%, far below accepted good practice of >98%. The Thermal Power Company is presently paying substantial penalties -- up to $3 million per year -- because of their failure to operate within the regulatory limits for particulate emissions.

The SO_3 injection system was tested on Boiler No. 8:

Manufacturer	Rafako (Polish)
Age	26 years
Capacity	140 T/hr. of steam at 10.7 MPa
Coal consumption	14-16 T/hr.
Coal quality	18,000-19,000 kj/kg
	22-25% ash

Several levels of SO_3 concentration were tested at different boiler loadings. Only one injection point was used because the flue gas channel was very short. Pentol recommended that there should be at least one second residence time between the injection point and the entrance to the precipitators.

Three independent observers monitored the trials and measured the results:

Łódź city environmental authorities
The Heating Institute (Łódź)
The Thermal Power Company

The system operated very reliably; the key results were:

Precipitator Efficiency

	Before	After	Change
Left side	82%	96.8%	+ 14.8%
Right side	77%	93.2%	+ 16.2%
Average	79.5%	95.0%	+ 15.5%

During the trials, the particulate emission rate was 140 kg/hr., compared to the regulatory limit of 124 kg/hr. (Plant personnel believe that the regulatory limit will be met if they burned coal with 12-18% ash, for which the boiler was designed).

Assuming a linear relationship between efficiency and particulate emissions, the use of SO_3 resulted in reduction of emissions by about 420 kg/hr. -- a very impressive result! In Poland, the penalty for excessive emissions is a charge per kilogram; 1800 zł/kg is a typical charge. For a boiler that operates 6,000 hrs./yr. the savings will be:

420 kg x 6,000 hr. x 1,800 zł = 4.5 billion zł
or about $400,000/yr. per boiler.

The estimated installed cost of an SO_3 injection system is $700,000, with an operating cost of about $100,000/yr. This gives a pay-back period of about 28 months.

The Pentol charge for providing and operating the trial unit was 90,000 DM (about $56,000) for one month.

Plant No. 2 intends to purchase and install two commercial injection units as soon as it can arrange the financing. It has negotiated a payment schedule with Pentol:

30% at signing
30% upon delivery of equipment
20% when operation begins
20% after two years of operation

The price of one unit, including spare parts, manuals, and training, is about $600,000.

The Audit Team suggested that this is an excellent project economically (because of the potential for savings on penalties) and socially (because of the reduction in atmospheric pollution). Strictly speaking, the project is not an energy efficiency project, but it has the effect of reducing energy costs and frees up resources to work on other aspects of power plant operation.

APPENDIX VIII
MEETING PARTICIPANTS
OCTOBER 4, 1991

Mr. Zdzisław Szyda	General Director of Plant No. 3
Mr. Jan Olszacki	Chief Engineer for Plant No. 2
Mr. Zdzisław Sobczak	Deputy Director of Plant No. 2
Mr. Meier	Plant No. 2
Dr. Richard Heiny	Team Leader, IRG Audit Team
Mr. Zdzisław Gieras	Energopomiar
Mr. Adam Zemła	Energopomiar
Dr. Jan Nadziakiewicz	Technical Institute (Gliwice)
Mr. Aleksander Krucki	Institute for Heat Engineering (Łódź)

APPENDIX IX
PRE-AUDIT QUESTIONNAIRE

During the Reconnaissance Mission in February, questionnaires were given to managers at each plant. The purpose of these questionnaires was to provide the IRG Audit Team with as much basic and descriptive information as possible about the plant, prior to the April audit. The Audit Team used the responses to the questionnaires to get a good preliminary description of the plant's facilities, organization, and operation prior to the audit. The Team was thus able to make the most of its one week audit of the plant.

The following pages include:

A. The questionnaire, prepared by IRG.

B. The Łódź Plant No. 2 responses, prepared by Mr. C. Gurbiel, Head of the Energetics Department