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ENERGY EFFICIENCY AUDIT REPORT
STEAM POWER PLANT BLACHOWNIA

Poludniowy Okreg Energetyczny
Electrownia "Blachownia"
Kedzierzyn-Kozle, Poland

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ABBREVIATIONS

A.I.D.	U.S. Agency for International Development
Btu	British thermal unit
GJ	giga joules
IRG	International Resources Group, Ltd.
kg	kilogram
kWh	kilowatt hour
MPa	millipascale
mWh	megawatt hours
ppm	parts per million
psi	pounds per square inch
zl	zloty, Polish currency unit

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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.

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.

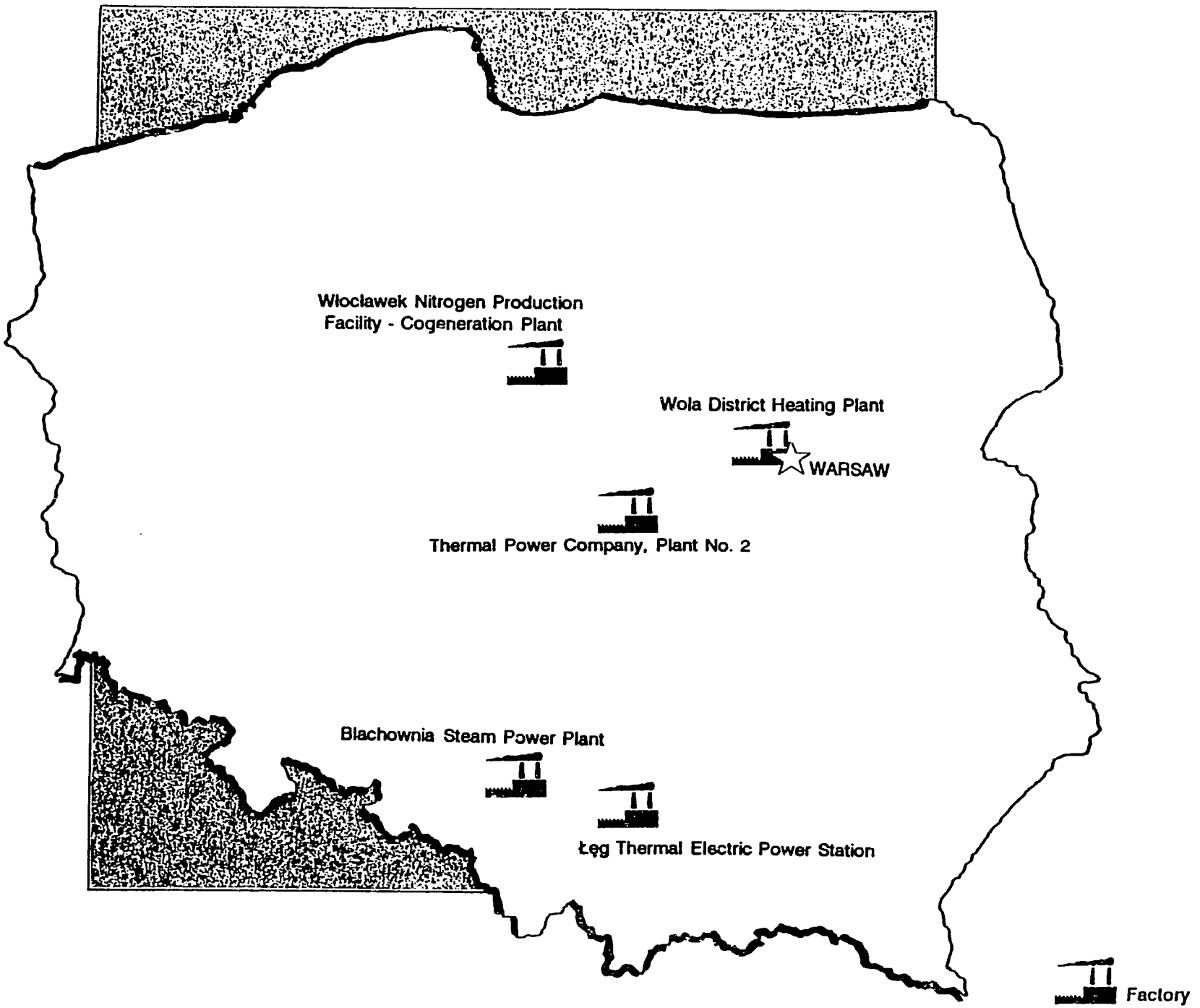
4) Representatives of the Audit Teams returned to the plants in October 1991 to assist in implementation of the audit recommendations, and to monitor the energy improvements actually achieved.

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 Industry Audit Team audited four plants (**Figure 1**):

Huta Ostrowiec, Steel Plant - Ostrowiec-Swietokrzyska
Zaklady Azotowe Wloclawek, Nitrogen Plant - Wloclawek
Zaklady Azotowe Kedzierzyn - Kedzierzyn-Kozle
Cement Plant Wierzbica - Wierzbica

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.


Włocławek Nitrogen Production
Facility - Cogeneration Plant
Wola District Heating Plant
WARSAW
Thermal Power Company, Plant No. 2
Blachownia Steam Power Plant
Łęg Thermal Electric Power Station
Factory

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 Steam Power Plant Blachownia in Kędzierzyn-Koźle, Poland. The objective of the audit was to assist plant personnel in identifying low- and no-cost opportunities to improve energy efficiency. In addition, the Audit Team trained key plant personnel in modern methods of energy management as practiced in the US.

The Blachownia plant was chosen for the Industrial Energy Efficiency Project based on assessments 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 1991 visit, the IRG Cogeneration Audit Team returned to the U.S. and arranged for procurement of equipment to be used by Blachownia 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 Blachownia had made in implementing the recommendations. Discussions during the second visit to the plant focused on some of the no-cost recommendations made by the Team, as well as:

- Equipment purchased for Blachownia;
- Plans for the Energy Management Workshop to be held in Warsaw on October 8-9, 1991;
- Use of SO_3 injection to reduce particulate emissions into the atmosphere;
- Current status of coal prices; and
- Blachownia's operating status.

During this visit, the Team identified opportunities for energy conservation for both the short- and long-term; developed estimates of the quantities of energy to be saved; estimated the costs of energy lost; conducted a seminar on energy conservation for plant staff; and trained seminar participants to use energy measurement instruments 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 (for both supply and demand) strategies.

To accomplish these objectives, the 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 regarding measurements taken during the audit and general plant statistics are included in **Appendix II**.

1.1 Plant Background

The Blachownia Steam Power Plant produces thermal energy and electricity for sale to the Polish national grid and supplies thermal energy and process steam to a nearby chemical plant. The oldest plant at the facility was built between 1955 and 1958, and has eight boilers and four turbine/generator sets. Energy costs for coal and electricity comprise more than 50% of total production costs for both electrical and thermal energy production. Total energy generated by the plant in 1990 was 821,685 megawatt hours (MWh) of electricity or approximately 42% of turbine capacity, and 3,139,086 giga-joules (GJ) of thermal energy, 31% of boiler capacity, including steam for the turbines.

Low-cost opportunities for energy conservation identified by the Audit Team principally involved improvements in combustion efficiency, thermal energy use, steam recovery, 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 IRG Cogeneration 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 II**; these tables outline boiler operating conditions, distribution of 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 pieces of equipment be purchased under the Emergency Energy Program. Items purchased included:

- Infrared Thermometer
- In-Situ Oxygen Analyzer
- Condenser Tube Cleaner
- Steam Traps

These recommendations are summarized below in **Table 1**; this table also summarizes estimated energy savings for each item, a key criteria 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 result 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 Procured under the 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	$8,435	$38,000	combustion	.22	630
Condenser Tube Cleaner	$11,941	$84,000	steam	.14	10,850
Steam Traps	$2,619	$33,000	steam	.08	528
TOTAL	$23,422	$156,700			12091

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. This report also 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 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 Blachownia Steam Power Plant was similar to the other plants visited by the Cogeneration Audit Team in that the major product of the plant is thermal energy. The plant also produces electricity for sale to the Polish national grid and supplies thermal energy and process steam to a nearby chemical plant.

The technical capability of plant managers and supervisors was quite good, with a relatively high number of university-trained personnel employed at the plant. However, very few individuals had any background in economic project evaluation. This lack of experience with market economics made longer-range strategic planning at this plant problematic.

The plant had essentially no automatic control systems. As such, data were displayed in the control rooms, but adjustments in flow rates, temperatures, and pressures were made manually. Control rooms were clean and well-designed, but the actual instruments were not up-to-date. Also, there appeared to be no recording instruments in the plant, making it impossible to evaluate historical data.

At the time of the audit, Blachownia furnished no thermal energy to the Kędzierzyn City District Heating System. The large chemical plant (Zakłady Azotowe Kędzierzyn) on the opposite side of Kędzierzyn provided thermal energy to the system, and comprised one-half of the city's needs; the balance was furnished by several small local hot water boilers. Management of the Steam Power Plant Blachownia had tentative plans to supply heat to the city, but these plans were on hold -- due to lack of capital -- as of October 1991. Under this plan, Blachownia and Kedzierzyn would supply all the city's needs, and the small boilers would cease operations.

2.2 Plant Statistics

Plant Number I at Blachownia was built between 1955 and 1958, and has eight boilers and four turbine/generator sets. The boilers have a steam cpacity of 960 tons/hour, and the turbine/generator sets have a maximum capacity of 220 megawatts (MW).

Plant Number III at the Blachownia facility was constructed in 1967, and has two boilers and two turbine/generator sets. These boilers have a capacity of 430 tons/hour of steam, and the turbine/generator sets have a maximum capacity of 61 MW.

All boilers at Blachownia are coal-fired; thus, in 1990, the plant consumed 771,124 tons of coal. According to plant data, the cost factors for the production of electrical and thermal energy for fuel (coal) were 48.3% for electricity production and 50.9% for thermal energy production. For electrical energy, the cost factor for the production of thermal energy was 7.8%. Other cost factors are shown below:

	Electrical	Thermal
Wages	3.6%	2.9%
Maintenance	29.8%	23.5%
Environmental costs	8.6%	7.9%
Materials & supplies	0.9%	0.8%
Depreciation	5.2%	3.5%
Misc. overhead	3.6%	2.7%

Total energy generated by the plant in 1990 was 821,685 MWh, which is about 42% of turbine capacity, and 3,139,086 GJ of thermal energy, or about 31% of boiler capacity, including steam for the turbines.

Approximately 620 people are employed at this facility, including about 65 supervisory personnel and 30 university-trained technical professionals.

2.3 Current Operating Status

At the time of audit, the technical state of the boilers made it possible for the plant to maintain design output, but not design steam pressures. Boiler efficiency was of less than optimal quality, primarily due to combustion conditions, air leak around the pre-heaters, poor quality fuel, and unreliable controls.

The turbines in Plant III were operating satisfactorily at the time of the audit. The turbines in Plant I (Nos. 1-4), however, had been operating since the early 1950s, and output was limited to about 90% of design capacity.

There were few opportunities to improve energy efficiency in the turbine area of the plant since the turbine section ran well despite the fact that it was a relatively old installation. Turbine efficiencies were measured and found to be:

Turboset #2	-	72.8%
Turboset #4	-	76.0%
Turboset #8	-	71.0%

On the basis of the data collected during the audit (see **Appendix II**) and on measurements taken previously by Energopomiar (a power engineering company) it appeared the water flow of the condenser was too low. For example, Units #2 and #4 were operating at 7,100 and 6,000 cubic meters/hour, respectively, instead of the optimum rate of 9,500 cubic meters/hour. This situation caused significant vacuum loss in the condenser, resulting in losses of power and/or fuel.

Loss of vacuum caused excess coal consumption of 11,000 tons/year. At projected future coal prices of $26/ton, savings were estimated at $286,000/year from improvements in this area.

Feed water to the boilers was of high quality. Inspection of some turbine blades revealed little erosion or deposits, indicating the plant had maintained this level of quality for a long time.

Due to the recession, Blachownia was operating below normal rates at the time the IRG Cogeneration Audit Team visited the plant. The only customer for Blachownia's steam product was the nearby chemical plant, and that plant was taking steam at about one-third its historic rate. The chemical plant supplied by Blachownia produced ethylene, polyethylene, ethylbenzene, and coal tar chemicals (carbochemicals).

2.4 Current Status of Coal Prices

In 1990, Blachownia used 771,124 tons of coal at an average price of approximately 74,000 zł/ton. By April, 1991, the average coal price in Poland had risen to 200,000 zł/ton (about $21/ton at April exchange rates), and was forecasted to continue rising to the world price of $26/ton. Recession in the Polish economy caused national coal production to drop from 180 million tons/year (historic output level) to 140 million tons/year in 1991.

The Director of Blachownia highlighted the fact that coal prices were increasing at about 5% per month. In the new "free" market, Blachownia theoretically could purchase its coal from alternative suppliers and negotiate to get favorable prices. In reality, however, the plant was limited to traditional suppliers, since they had no experience in or resources to investigate alternative supply options and logistical arrangements. A comparison of Blachownia's coal pricing situation with two other power plants in Poland is outlined in **Appendix II**.

2.5 Measurements

The Audit Team obtained operating data at Blachownia by:

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

b) Using a portable Enerac gas analyzer to measure 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 on the turbine/generator sets and boilers are also included in **Appendix II**. These measurements were used to calculate excess air levels in the boilers, turbine/generator efficiency, estimated air leakage, heat losses due to 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.

Results included the following general observations:

1. Boilers were operating at excess air levels of 20% to 40%, 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 significant air leaks (maybe as high as 9% by volume) into the preheaters, 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

At the time of audit, Blachownia had no special training or incentive programs emphasizing energy savings. However, each plant operator had to pass an examination every five years to remain qualified, and this examination had a component devoted to energy saving concepts. Ultimately, however, energy conservation had not received much attention in the plant, at either a theoretical or a practical level, prior to the initiation of the Industrial Energy Efficiency project.

3.2 Training and Energy Management Requirements

1. Economics and Project Evaluation

Personnel at Blachownia, as in most plants visited by the Audit Team, appeared to have little understanding of techniques commonly used in the U.S. to evaluate projects. These methods include calculation of:

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

Training of key personnel to use these techniques will help Blachownia analyze alternatives and prioritize investment projects.

2. Long-Range Strategic Planning

Blachownia had no long-range strategy to guide managers in allocating resources and programming activities. A comprehensive strategic plan should be developed based on economic evaluation of investment options. Development of such a plan will require:

- Forecast of demand for electric and thermal energy;
- Analysis of corporate strengths and weaknesses;
- Analysis of competitive influences;
- Definition of possible alternative long-range courses of action; and
- The ability to evaluate alternatives and to select the most appropriate alternatives under the circumstances.

Blachownia would benefit substantially if key managers were trained in elements of strategic planning.

3. Housekeeping/Quality of Operation

The Team's extensive experience with American industry has demonstrated that the quality of "housekeeping" in a production operation is an exact reflection of the overall quality

of the industrial operation. Managers of the most efficient and successful operations invariably insist on the highest standards of performance in every area. This demand for consistent excellence is communicated to the work force and results in neat and clean facilities as a by-product of efficient operations.

Housekeeping at Blachownia was among the worst the Audit Team observed, yet the managers and administrators of this facility were obviously competent and capable. The Audit Team concluded that there was a fundamental need for more direct communication between management and the work-force to guide the operating personnel toward quality and excellence in all activities. No matter how competent and hard-working management is, the plant will only operate as well as its operating personnel.

The Audit Team recommended Blachownia institute a mandatory training program, supported by incentives and penalties, to establish high standards of performance among the entire work-force.

4. Energy-Saving Programs

An extension of the training program should focus on energy saving opportunities, and include recognition of a variety of energy saving activities and provide monetary awards to employees who make significant individual contributions to energy conservation in the plant.

The program should also include:

- Establishment of energy goals per unit of production, such as:
  - Pounds of coal per 1,000 pounds of steam produced;
  - Energy consumption per kilowatt hour (kWh);
  - Energy consumption per GJ;
- Energy goals per shift and per department.

Shifts and departments should be recognized (possibly with a company-sponsored dinner) when they achieve an important goal.

3.3 USAID Sponsored Energy Management Workshop

An Energy Management Workshop was conducted in Warsaw on October 8 and 9, 1991. It was sponsored by the U.S. Agency for International Development with strong support from the Polish Ministry of Industry (Mr. Roman Łuczkiewicz) and the World Bank (Mr. Ian Hume). The management of Blachownia sent representatives to participate. Although the Director and the Chief Power Engineer, who were extremely supportive of the project, were unable to attend, two other representatives presented the results of the project.

4. ENVIRONMENTAL CONSIDERATIONS

During the audit, the IRG Cogeneration Audit Team noted that Blachownia had a fairly serious problem with particulate emissions. As of April 1992, there was no official regulatory limit for such emissions in Kędzierzyn, postponing the necessity of addressing this issue. However, Blachownia managers expect environmental legislation will establish such a limit in the near future, and anticipate that this limit will be 90 kg/hour per boiler. In contrast, the plant was emitting more than 200 kg/hour per boiler of particulates at the time of the audit.

In the Kędzierzyn-Kózle region, environmental legislation sets penalties for particulate emissions at the following levels:

- 180 zł/kg for "normal" emissions -- rates that are below the regulatory limit.
- 1,800 zł/kg for "excessive" emissions -- rates that exceed the regulatory limit.

If the eight older Blachownia boilers each emit 200 kg/hour of particulates for 6,000 hours per year, then the annual penalty for Blachownia would be 9.5 billion zlotys/year ($860,000/yr).

Electrostatic precipitators on the eight older boilers at Blachownia were very old, and were performing at an estimated efficiency of 85% (98+% is generally regarded as good performance for electrostatic precipitators). The Director estimated Blachownia could meet the regulatory limit if efficiency were to improve to 95%. Two newer, larger boilers were operating within the projected regulatory limits.

The Audit Team reviewed with the Blachownia management the experience of the Łódź plant. with its trial of SO_3 injection. The successes of the Lodz experience suggested a similar solution might be replicated at Blachownia. A summary of the Łódź experience is included in **Appendix II**.

As shown above, the loss attributable to environmental penalties would amount to more than $100,000 per boiler per year. The savings potential was approximately equal to the annual operating cost of an SO_3 injection system, as estimated by the personnel at Łódź Plant. SO_3 injection did not, therefore, appear to be an economically viable solution for Blachownia's particulate emissions problem under current environmental legislation.

However, for each 20 kg/hour a boiler exceeds 200 kg/hour emissions, the equivalent of an additional $20,000 penalty (approximately) is placed on each boiler per year. Thus, if the emissions from the plant exceeded 200 kg/hour per boiler, or if the environmental standards become more rigid, the investment in SO_3 injection systems may be more economically feasible. Because the Blachownia plant used smaller boilers, the investment for the injection system could be less than the $600,000 per unit estimated for Łódź Plant No. 2. More precise information on actual emissions rates and investment costs was needed before the benefits of SO_3 injection could be calculated accurately.

5. ENERGY EFFICIENCY IMPROVEMENT OPTIONS

Opportunities for energy conservation were identified by the IRG Team as a result of Team observations and audit measurements, plant inspections by other organizations (ie. 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 Cogeneration Audit Team recommended some be given priority; this prioritization is included in **Section 6**.

This section presents various options discussed during the course of the Industrial Energy Efficiency Improvement project. These include options proposed by the IRG Team, officials at the plant, and in some cases, options proposed by outside organizatons, and highlights the merits and deficiencies of each proposal. Since the Team did not recommend 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, while low-cost items require limited amounts of hard currency. Each is possible within the existing framework of plant expenditures (i.e., 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

It appeared Blachownia boilers were operating at excess air levels as high as 40%; efficient operation is usually in the range of 12-20%. Each 5% increase in excess air results in 0.35% decrease in boiler efficiency. It was recommended special attention be given to improving the operation of Plant III (Boilers No. 11 and 12), since due to its age and poor condition, Plant I (Boilers No. 1-8) may not be operating after 1996.

Excess air levels were high as a result of the unreliability of the present oxygen analyzers. To compensate, the plant was operating on the "safe" side of optimum excess air level. See **Appendix III** for details of costs and benefits.

The Audit Team recommended one continuous oxygen analyzer be purchased and installed on Boiler No. 11 at Blachownia.

2. Cleaning of Condenser Tubes

Due to the poor quality of water available to Blachownia, the plant was experiencing severe fouling of tube surfaces in the steam condensers. The Team recommended condenser tubes be cleaned as a priority area for action.

The Audit Team recommended one Conco Systems tube cleaner be purchased for use at Blachownia.

3. Purchase and Install New Steam Traps

The Blachownia facility experienced considerable difficulty with leakage and failure of steam traps in use on higher pressure steam lines. Traps previously used in the plant were made in Poland; plant management indicated no higher quality steam traps had been available in Eastern Europe.

The Audit Team recommended the purchase and installation of 15 stainless steel inverted bucket steam traps on appropriate steam lines at Blachownia. The performance of these traps will be monitored; if the improvement is as expected, Blachownia should begin replacing all faulty or unreliable steam traps.

4. Repair and Maintain Insulation

Although plant insulation appeared to be generally in good condition, there were a number of instances of:

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

In one case, the surface temperature of exposed pipe and fittings was measured at 180 °C. This resulted 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. Proper insulation should reduce this by 80-90%.

The Audit Team suggested the plant regularly check the state of insulation and improve some each month. Moreover, the Team recommended that one Infrared Thermometer be purchased for use in detecting sources of heat loss. See **Appendix III** for information on costs and benefits.

5. Eliminate Air Leaks around the Air Pre-Heaters

Air leaks in the system around the air pre-heaters were reducing boiler efficiency. Flue gas analyses indicated these leaks amounted to 9% by volume of flue gas for Boiler #8. Similar leaks were most likely occurring around all air pre-heaters. The plant should make modifications to reduce leakage during overhauls of the boiler systems.

5.2 Long-term/Capital Intensive Options

In general, there was little standardized long-term strategic planning to guide the plant management in justifying and prioritizing major investments. However, the following are long-term plans that plant management had examined. Audit team evaluations of these options are also included, along with descriptions of each proposed project.

1. Modify water pumps

The Audit Team recommended modifying pumps so water flow to the heating system could 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 system wastes pumping energy. Plant management estimates that changing to variable speed control will save 6.5 million kWh/year.

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

The plant 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

The total cost would be approximately 1,950 million zł ($200,000). At current costs, the payback period is 15 months; at projected costs, however, the payback period would be reduced to 6 months.

The Audit Team recommended this project be supported.

2. Replace the eight older boilers and four older turbines

The Audit Team recommended replacing the eight older boilers and four older turbines with:

- Three fluid-bed pulverized coal boilers; and
- Two condensate-type extraction turbines.

The fluid-bed combustion technology greatly reduces sulfur dioxide (SO_2) pollution. This type of turbine operates at considerably higher efficiencies than the present 35 year-old turbines.

The capacity of the new equipment will be:

Thermal steam	94 MW
Thermal water	99 MW
Electricity	64 MW
TOTAL	257 MW

The new equipment will replace about 620 thermal MW of capacity. (At present demand levels, the reduction in capacity of 363 MW is not needed).

A rough estimate of the total cost is $100 million. According to plant management, the project is in the design phase. Tentative orders for new boilers have been placed with a Polish manufacturer licensed by EVT (Germany); tentative orders for the turbines have been placed with a Polish manufacturer under license from Asea Brown Boveri (Switzerland).

Plant management indicated the planned replacement is justified by both economics and reduction in pollution. However, no economic data were presented. Fluid-bed combustors will have SO_2 emissions of 5 tons/year; emissions of SO_2 from the present eight boilers be replaced are approximately 5,000 tons/year.

The Audit Team recommended a detailed study of the economic and environmental benefits be completed before additional support is given to this project.

3. Conduct Strategic Analysis of Blachownia

The Audit Team recommended a broad strategic analysis of Blachownia's future be undertaken before long-term investment commitments are made. Points that should be considered include:

- Plant age - almost every instrument and piece of equipment must be replaced if the plant is to be economically viable over the long-term in a competitive environment.

- Blachownia presently supplies steam to a small near-by chemical plant, but none to the city District Heating system. Given that demand is less than 50% of Blachownia's present capacity, the analysis must consider whether the future operation of Blachownia is economically justified.

- The large chemical plant on the other side of Kedzierzyn-Kozle has its own power generating plant and supplies thermal energy to the local District Heating System. The analysis should evaluate whether both the chemical facility and Blachownia are required to meet local energy needs.

6. RECOMMENDATIONS AND CONCLUSIONS

The Audit Team recommended preparation of a comprehensive long-range strategic/economic plan be a pre-condition for continued A.I.D. or World Bank support of all major investments. It may be productive for A.I.D. or the World Bank to support development of long-range strategies for most enterprises in Poland for which investments are being considered. Most enterprises appear to lack the resources and/or the experience to be able to develop their own long-range plans.

6.1 Implementation Priorities

It is recommended the items listed in **Section 5.1** of this report be purchased for Blachownia under the Emergency Energy Program:

	Estimated Purchase Cost	Estimated Benefit	Payback Period*
One Continuous Oxygen Analyzer	$10,000	$13,000/yr.	9 months
One Condenser Tube Cleaner	8,000	$47,000/yr.	2 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	$21,785		

* 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 regarding items purchased for Blachownia are identified in **Appendix V**; final estimates of costs and benefits of these purchases are summarized in the Executive Summary.

The Audit Team recommended all items be purchased and put into use as quickly as possible. In addition, the Team recommended an extensive analysis of the options for Blachownia be conducted as quickly as possible. No additional significant investments should be made in the facility until such a study has been completed, and a long-term strategy has been developed. An outline of the study is included in **Appendix VII**.

Meanwhile, certain low- and no-cost energy-saving measures and actions should be undertaken. These include the recommendations listed in **Section 5.1** above:

- Identify and Eliminate Excess Air in the Furnaces
- Clean Condenser Tubes

- Install New Steam Traps
- Repair and Maintain Insulation
- Eliminate Air Leakage around the Air Pre-Heaters.

The Audit Team has no doubt that Blachownia will aggressively pursue these and other options.

The longer-term and/or more expensive options to save energy and costs should be postponed until a satisfactory long-term strategy is agreed upon. Some options are outlined under **Section 5.2**:

- Modify Water Pumps
- Replace the Eight Older Boilers and Four Older Turbines

Finally, key personnel at Blachownia should be exposed to intensive training programs in economics, project evaluation, and strategic planning as outlined in **Appendix VII**.

6.2 Conclusions After Second Visit

Blachownia management focused on following up on the recommendations made by the IRG Cogeneration Audit Team in April. Progress was limited, since the recession in the Polish economy severely restricted plant-operating rates. However, with the installation of the equipment purchased under the Industrial Energy Efficiency project, rapid progress toward a more energy efficient plant is expected.

Based on economic estimates made using available data, SO_3 injection is unlikely to be an economically viable way to resolve Blachownia's particulate emissions problem in the near term. Other solutions must therefore be investigated and evaluated using economic criteria.

The Conco Condenser Tube Cleaner System will be very useful to Blachownia, and will provide significant savings in the future.

Blachownia must also find other sources of revenue to survive in a competitive environment. If additional sources of revenue cannot be found, serious consideration should be given to phasing out significant portions of Blachownia's capacity. It could possibly survive as a smaller enterprise, operating only the two newer and larger boilers and phasing out the eight older boilers. The most likely and obvious source of new revenue at this time is to provide thermal energy to the Kędzierzyn City District Heating System.

APPENDIX I

AUDIT ACTIVITIES
April 1991

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.
- Brief "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 supervision.

- Presentation and discussion of preliminary report with plant management.
- Transfer to the next facility.

APPENDIX II

AUDIT MEASUREMENTS AND COMPARATIVE STATISTICS

AUDIT MEASUREMENTS

BLACHOWNIA I

			Turboset Number	
Position	Value		2	4
1	Power output	MW	37.5	42.0
2	Steam consumed	t/h	170	183
3	Inlet pressure	MPa	7.8	8.1
4	Temperature	°C	485	500
5	Steam to condenser	°C	49	44
6	Condensate after condenser	°C	46	42
7	Cooling water inlet	°C	24	22
8	Cooling water outlet	°C	33.5/35.0	33.5/37.0
9	Temperature difference: (8) - (7)	°C	10.2	13.2
10	Temperature difference: (5) - (8)	°C	14.8	8.8
11	Internal thermal efficiency:	°C	12.8	16.8

BLACHOWNIA III

Position	Value		Turboset Number 8
1	Power output	MW	12
2	Steam consumed	t/h	145
3	Inlet pressure	MPa	7.6
4	Inlet temperature	°C	490
5	Outlet-back pressure	MPa	0.64
6	Outlet-temperature	°C	238
7	Internal thermal efficiency	%	74.0

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

	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 (purch 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. Alternate 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 III

JUSTIFICATION FOR PURCHASE OF EQUIPMENT

CONTINUOUS OXYGEN (O_2) ANALYZERS FOR STACK GAS

The team recommended installation of 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, all plants are operating at excess air levels of 28 - 40%, 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 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 O_2 analyzers <u>including remote reading instruments</u> are available from several U.S. suppliers at prices of $6,000 or less per boiler stack, depending upon the exact model purchased. Shipping and installation will bring the total coast up to a maximum of $10,000 per boiler stack. At $10,000 per stack, the payback periods are:

Coal-fired boilers	-	9 months
Oil-fired boilers	-	5 months

In addition to the direct economic benefit, there will be a significant environmental benefit, because 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 will be similar.

PRELIMINARY QUOTES

The preliminary quotes for O_2 analyzers meeting the attached specifications were:

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 Johnson-Yokogawa continuous Oxygen Analyzer be purchased for installation in Boiler No. 11 at Blachownia.

Because of the flexibility of their instruments and the apparent extent of their European service network, the Audit Team recommended that Johnson-Yokogawa be the preferred supplier. However, in the judgment of the Audit Team all the listed suppliers which manufacture O_2 analyzers are suitable for intended use in Poland.

* The price for the Johnson-Yokogawa oxygen analyzer is the price for the basic model. Additional probes and terminals will add to the price. The installed continuous oxygen analyzer, thus, might cost as much as $18,000 - $24,000, but could service up to four boilers.

CONDENSER TUBE CLEANERS:

Fouling of condenser tubes results in a number of undesirable impacts on turbine/generator operation:

- Heat transfer rates in the condenser are reduced, resulting in reduced capacity of the condenser.
- Either the pounds of steam condensed is reduced, or the back-pressure at which the steam is condensed is increased.

Fouling of condensers by cooling water is common; the extent of fouling is dependent upon impurities or organisms which may be in the cooling water that is circulated through the condensers. Because of the very large volumes of water required in power plant condensers, it is generally not practical to pre-treat the water to remove all the potential causes of fouling.

Because of severe pollution in most of the rivers in Poland, the potential for fouling of condenser tubes appears to be considerably higher than in the U.S.

In a paper presented at the American Power Conference, it was stated:

"For a 200 megawatt unit a net reduction of turbine back pressure of only 1/10 inch of mercury saves the utility up to $100,000 annually."

(1/10 inch of mercury is 0.049 lb./sq. in. At the pressure in the condenser at Blachownia, a decrease of 0.1 inch of mercury in back pressure will result in an increase in the specific volume of steam passing out of the turbine of about 2%. This will cause the turbine to produce about 2% less energy at the same steam flow rate. At the back pressure in the Blachownia turbines, less than a 1 °C increase in condensate temperature will be required to cause 0.1 inch of mercury increase in back pressure. Very mild fouling will result in at least a 1 °C rise in condensing temperature).

Blachownia has a design capacity to produce 281 MW of electricity. In 1990, Blachownia actually produced 821,685 MWH of electricity, equivalent to an average operating rate of 95 MW. Assuming that the savings quoted above are approximately the savings that will be realized in Poland--that is $100,000 savings per 200 MW--then the approximate savings that will be realized by using tube cleaners at Blachownia are:

At capacity:	$140,000/year
At 1990 rates:	$47,000/year

Conco Systems, Inc. (Verona, PA) has estimated that a suitable condenser tube cleaning system for Blachownia will cost about $8,000. At 1990 rates, this is approximately a 2-month payback.

The Audit Team recommended that one condenser cleaning system be purchased for Blachownia.

Recommended vendor:

Conco Systems, Inc.
135 Sylvan Street
Verona, PA 15147

Representative in Poland:

Jerzy Krysicki
Conco-East
Ul. Pizciolinni 6/m 27
02-769 Warszawa, Poland

The Blachownia plant researched potential suppliers of condenser tube cleaners and concluded that Conco was the most suitable for their use.

SPECIFICATIONS:

Condenser tube size:	21 mm ID
Condenser material:	MA 73 Aluminum brass

Total package to include:

Pump
Pressure nozzle
100 feet (30 meters) inlet hose
100 feet (30 meters) high pressure discharge hose
200 Conco cleaner units

STEAM TRAPS

Present steam traps (manufactured in Poland) 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 very large user of steam traps; after extensive investigation and years of experience, the Dow experts strongly recommended 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 psi; 70 lb./hr. at 150 psi

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

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

Armstrong suggested that an "average" maximum loss will be about 200,000 lb./month, and that an "average" installed cost of a steam trap is about $400. Using a typical steam value in the U.S. of $5.00 per 1,000 pounds, each $400 investment in steam traps should yield the following benefits:

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

The Audit Team recommended that fifteen (15) stainless steel traps be purchased for installation at Blachownia.

The recommended traps are:

- Ten (10) medium-sized traps:

  Armstrong Stainless Steel Trap Model 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 some discounts may be available for the quantities indicated.

INFRARED THERMOMETERS

In Blachownia, there were quite a few instances of inadequate, damaged, or missing insulation. At the subsidized energy costs in existence under the former regime, it may not have been worthwhile to make sure that all hot surfaces were insulated and that the insulation was well maintained. At world prices for energy, however, good insulation definitely is worth the investment. 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 "hot spots" where significant heat losses may be occurring

RECOMMENDED VENDOR:

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

MODEL: No. 0571C Infrared Thermometer-C display

PRICE: $895.00 each

APPENDIX IV

PARTICIPANTS IN THE DISCUSSIONS
October, 1991

The discussions were held in the office of Mr. Wiacek, the Director of the plant. Participants were:

Mr. Zdzisław Wiącek	Director of Steam Power Plant Blachownia
Mr. Zygmunt Chyłek	Chief Engineer for Steam Power Plant Blachownia
Dr. Richard Heiny	IRG Cogeneration Audit Team Leader
Mr. Zdzisław Gieras	Energopomiar
Mr. Adam Zemła	Energopomiar
Dr. Jan Nadziakiewicz	Polytechnic Institute (Gliwice)

APPENDIX V

ITEMS OF EQUIPMENT FOR BLACHOWNIA

Following the April 1991 visit, the following equipment was purchased for shipment to Blachownia:

Item 1: One Johnson-Yokogawa in situ-type Zirconia Oxygen Analyzer with one probe, one probe protector, and one converter. (As a result of changes in needs by some of the other plants examined during the team's return visit, this was later changed to: One Johnson-Yokogawa in situ-type Zirconia Oxygen Analyzer with four probes, four probe protectors, one averaging converter, and one recorder).

Item 2: One Conco Condenser Tube Cleaning System.

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

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

Item 5: One Dickson Model IR-550 Infrared Temperature Measuring Instrument.

The Chief Power Engineer described the results of the previous cleaning which was done by a contractor who used a Conco Condenser Tube Cleaning System that was essentially a duplicate of the system Blachownia had just received. Key points were:

- The cleaning required about 1,000 individual cleaners.
- Two condensers with a total of 7,500 tubes were cleaned.
- The total cost was about 25 - 28,000 zlotys (about $2,500, or the cost of about 120 tons of coal).
- The condensers must be cleaned about twice a year in order to maintain heat transfer efficiency.
- The benefit in improved condenser capacity was estimated to be equivalent to 2,500 tons per year of coal, for a net savings of 2,260 tons per year of coal or about $37,000 per year. This is equivalent to a four-month payback.

The Blachownia representatives asked a number of questions regarding the pressure capability of the Armstrong steam traps. The Armstrong literature states that the Model 1811 traps can be used on Steam lines with pressures up to about 450 psi (about 3 MPa) and the Model 1812 traps are good up to somewhat higher pressures. Blachownia will install some of the steam traps immediately in suitable locations and monitor their performance.

APPENDIX VI

DESCRIPTION OF SO_3 INJECTION TRIALS TO DETERMINE THE EFFICIENCY OF SO_3 AS A MEANS OF REDUCING PARTICULATE EMISSIONS

prepared by

THE THERMAL POWER COMPANY (Łódź)

The Trials were performed on Boiler No. 8 in Plant No. 2 during the month of April, 1991. A full report was presented at the Energy Management Workshop in Warsaw on October 9, 1991 by

Mr. Zdzisław Sobczak
Z-ca Dyrektora d/s Elektrocieplowni nr 2
Zespół Elektrocieplowni w Łódź

Plant No. 2 (Łódź) Experience with SO_3 Injection Technology

Plant No. 2 is significantly exceeding the regulatory limits for particulate emissions because its electrostatic precipitators are very old, and because the ash content of the coal is much higher than the plant is designed to handle. Replacement or rebuilding of the precipitators is very expensive (estimated at $23 million for all nine boilers), so the plant is searching for more economic solutions. Injection of low concentrations of SO_3 or SO_3 and NH_3 has been shown to have a very positive effect on precipitator performance. The technology is beginning to be used fairly extensively in the U.S. and Western Europe, and there is one commercial installation in Poland.

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 its 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	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 believed that the regulatory limit would 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 operated 6,000 hrs./yr. the savings is:

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 they can arrange the financing. They have 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 believes 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 VII

AN OUTLINE OF A STUDY TO DEFINE THE LONG-TERM STRATEGIC OPTIONS FOR STEAM POWER PLANT BLACHOWNIA

The U.S. AID Cogeneration Audit Team believes that, with some knowledgeable assistance, the management of Steam Power Plant Blachownia is capable of carrying out the studies necessary to define and analyze the long-term options that are open to the plant. The following comments are intended to offer some guidance as to approach, and are not intended to be definitive or limiting. The Blachownia management knows far more about the details of the plant capabilities and needs than the Audit Team, and can certainly develop its own approach. The Audit Team recommended that Blachownia follow a more-or-less classical approach to strategic planning;

A. Define a corporate mission;

B. Make a detailed inventory of corporate strengths and weaknesses;

C. Develop a list of alternative courses of action which are realistically open to the plant;

D. Analyze these courses of action in the light of the resources that are likely to be available and select a few (no more than two or three) for more detailed analysis; and

E. Carry on a detailed analysis of those few alternatives, and select the one that is the best match with the corporate mission and resources.

In the following sections, the Audit Team outlines suggestions about how Blachownia might approach this strategic analysis.

A. Define a Corporate Mission

Definition of a corporative mission can only be done effectively by the upper-level management of the company, with input from all key managers. The statement of mission should explicitly define what the enterprise expects to do in the way of providing products and services to its customers.

The Audit Team suggests that a committee should be appointed, including at least one or two of the highest ranking managers in the plant. This committee should be assigned the responsibility for considering long-term options for the mission of the Steam Power Plant Blachownia, and for presenting its recommendations to senior management. The committee will need to consider what options are realistically open, and relate those options in a general way to Blachownia's capabilities. The statement of mission should be short and definitive, without a lot of descriptive or limiting phrases.

For example, a mission statement might be:

"By 1995, Steam Power Plant Blachownia will supply 50% of the thermal energy requirements of the city of Kedzierzyn. In addition, it will supply steam and thermal energy to private enterprises to the maximum extent possible. Electricity will be supplied to the Polish National Grid only when it is incrementally profitable for Blachownia."

This is not intended to be a recommended mission statement, but is only an example of what a mission statement should be.

As Blachownia proceeds through the rest of the study, it may be necessary to return to and revise the mission statement because resource limitations may be identified; or market analyses may indicate that the markets initially chosen are not appropriate.

B. Detailed Inventory of Corporate Strengths and Weaknesses

The Audit Team did believe it was not qualified to comment seriously on these factors. Examples cited below indicate the types of things that might be considered:

Possible Strengths:

1. Quality of the work force
2. Management capability
3. Geographical location with respect to potential customers
4. Positive relationship with the city of Kedzierzyn
5. Experience in producing electricity and thermal energy
6. Favorable position with respect to long-term fuel supply
7. Unique technology or technical capabilities (and any other strengths which can be defined).

Possible Weaknesses:

1. Age of most of the equipment
2. Lack of connection to the city district heating system
3. Few potential customers within reasonable distance
4. Lack of capital resources
5. Too many people on the payroll

6. Too much capacity for immediate needs

(and any other weaknesses which may be pertinent to the long-range future of the plant).

It is essential that the strengths and weaknesses be analyzed with extreme objectivity. No "wishful thinking" should be allowed to intrude, and thus cause Blachownia to adopt plans for which it does not truly have the resources. Once again, senior management must be intimately involved.

C. ALTERNATIVE COURSES OF ACTION

Senior management, assisted by appropriate staff, should define as many alternative courses of action as possible that are consistent with the mission statement and in general with the strengths and weaknesses of the enterprise. No potential course of action should be eliminated because it is "frivolous" or "ridiculous"; all should be listed without critical evaluation at this time. By listing every conceivable possibility uncritically, it is often possible to come up with a course of action that has many advantages, but has never before been considered.

As many courses of action are defined, some may be suggested which are not completely consistent with the mission statement. These should not be discarded arbitrarily, but should be kept in mind as the study proceeds. There may be a later need to modify the mission statement, and these courses of action may become acceptable.

Basically, the key to a successful study is the willingness to consider actions or possibilities very broadly. Any restrictions are likely to result in the exclusion of some very desirable possibilities.

D. ANALYSIS OF THE COURSES OF ACTION

This is the point in the study where reality must take full control. Each course of action must be analyzed in terms of the strengths and weaknesses of the enterprise. All courses of action which require significant strengths that the enterprise does not, or is not likely, to possess, must be discarded. Minor weaknesses can be overcome, but experience has demonstrated that major weaknesses generally cannot be corrected on any realistic time scale. No course of action which requires the correction of a major weakness should be considered. Every organization has significant strengths, and courses of action should be chosen which will permit the organization to exploit these strengths.

As the courses of action are analyzed and the undesirable ones are discarded, some potentially desirable courses may remain which are not completely consistent with the mission statement. At this point, it is worthwhile to go back and review the mission statement. Can it be modified without dramatically changing the focus of the enterprise? Are the potential benefits worth it? If the answers are "YES", then the mission statement should be modified in order to keep these courses of action in the study.

Eventually, no more than two or three courses of action should be selected for further detailed analysis.

E. FINAL ANALYSIS

Once the two or three potentially desirable courses of action have been selected, they should be subjected to very serious in-depth analysis. This must include:

- Detailed economic analysis;
- Detailed analysis of the potential markets;
- Analysis of financial requirements and the ability of the enterprise to meet them;
- Preparation of ten year business/financial plans for each course;
- Analysis of competitive situation;
- Projections of costs and prices; and
- Discussions with key potential customers to determine whether expectations of their needs are realistic.

At this point it is often a good idea to recruit some outside experts to assist in the final selection. Despite the best of intentions, it is almost never possible for resident management to remain completely objective about the strengths and weaknesses of its organizations -- every manager believes that his people can do things that others cannot. An outside observer can help to identify the possible flaws in proposed courses of action.

The final selection of a strategic course of action, however, is the sole responsibility of the senior management of the enterprise. (Owners, of course, must be involved). This selection cannot be delegated to others because it is, for the foreseeable future, the most important decision which must be made in the interest of the enterprise.

APPENDIX VIII

PRE-AUDIT QUESTIONNAIRE

During the Reconnaissance Mission in February, questionnaires were given to each plant. The purpose was to get as much basic and descriptive information as possible prior to the Audit. The Audit Team used the responses to the questionnaires to get a good preliminary description of the plant facilities, organization, and operation prior to the audit.

The following pages include:

A. The questionnaire, prepared by IRG.

B. The Blachownia Plant responses to the questionnaire.