ENERGY EFFICIENCY AUDIT REPORT
IZIDA CERAMIC PLANT
Elin Pelin, Bulgaria

PREPARED BY:

INTERNATIONAL RESOURCES GROUP, LTD.
Washington, DC

and

ECOTECHPRODUCT, LTD.
Sofia, Bulgaria

U.S. EMERGENCY ENERGY PROGRAM FOR EASTERN & CENTRAL EUROPE
U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
BUREAU FOR EUROPE
WASHINGTON, DC 20523

May 1992
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OFFICE OF DEVELOPMENT RESOURCES
ENERGY & INFRASTRUCTURE DIVISION
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<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>A.I.D.</td>
<td>U.S. Agency for International Development</td>
</tr>
<tr>
<td>atm</td>
<td>atmospheres</td>
</tr>
<tr>
<td>GCal</td>
<td>giga calorie</td>
</tr>
<tr>
<td>GJ</td>
<td>giga joula</td>
</tr>
<tr>
<td>IRG</td>
<td>International Resources Group, Ltd.</td>
</tr>
<tr>
<td>kWh</td>
<td>kilowatt hours</td>
</tr>
<tr>
<td>lv</td>
<td>levas; Bulgarian unit of currency - At the time of the audit, 15lv = US$1.</td>
</tr>
<tr>
<td>m³</td>
<td>cubic meters</td>
</tr>
<tr>
<td>nm³</td>
<td>normal cubic meters</td>
</tr>
<tr>
<td>MM</td>
<td>Million</td>
</tr>
<tr>
<td>PPM</td>
<td>parts per million</td>
</tr>
</tbody>
</table>
ACKNOWLEDGMENTS

The Energy Conservation Audit Team of the International Resources Group, Ltd. (IRG) wishes to acknowledge assistance provided by the Ministry of Industry, the Committee on Energy, and its Inspectorate for Energy Utilization in arranging visits to participating facilities. IRG also would like to thank the U.S. Agency for International Development, European Development Resources Section, Office of Energy and Infrastructure for coordinating the entire project.

Work under the A.I.D.-funded Emergency Energy Program at the Izida Ceramic Plant, Sofia, was conducted through a cooperative effort by the factory management and staff; the Government of Bulgaria - a private sector energy conservation consulting firm; and IRG.

It is IRG's hope that the exchange established through this initiative is 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 uncertainty.

For Bulgaria, the general atmosphere of crisis in the regional energy sector is compounded by the fact that all of its natural gas and coke and most of its petroleum is imported. Moreover starting in April 1991, the electric power supply imported from the Soviet Union, which previously accounted for a significant amount of Bulgaria’s electricity supply, was cut off. Furthermore, domestic electricity production from nuclear power, previously a major source of energy, has been decreasing since the autumn of 1991, as the Kozloduy nuclear power station was taken off-line due to safety concerns. Given these concerns, energy efficiency must play a vital role in transformation of the energy and industrial sectors in Bulgaria.

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 Bulgaria.
Energy Efficiency Audit Report - Izida Ceramic Plant

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 Bulgaria to which the energy conservation measures developed in this program could be applied.

2) Two Audit Teams went to Bulgaria on two separate occasions, each Team visiting four 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 January 1992 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 Sofia January 27-29, 1992.

The Bulgaria Light and Heavy Industry Audit Teams each audited four plants:

**Light Industry**
- Serdika Dairy Processing Plant - Sofia
- Pharmacia Pharmaceutical Company - Stanke Dimitrov
- Parvi Mai Cotton Textile Processing Plant - Varna
- Dobritch Poultry Processing Plant - Tolbuhin
Figure 1. Location of eight industrial plants audited by the IRG team.
Energy Efficiency Audit Report - Izida Ceramic Plant

Heavy Industry
Izida Ceramic Facility - Elin Pelin
Kremikovtzi Steel Plant - Sofia
Chimco Ammonia and Urea Facility - Vratza
Sodi Soda Ash Plant - Devnia

The Audit Teams collected data at every plant on the energy costs per unit of production, primarily using plant records, audit measurements, and interviews with plant officials. In some cases, the Audit Teams counselled the plants on 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.

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 Bulgaria. 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 Bulgaria. 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 Bulgarian 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 Bulgaria 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 Bulgaria, 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 Bulgarian industrial sector will provide sufficient incentive for plant managers and industrial executives to actively participate in reforms that encourage energy conservation and improved economic efficiency.
1. EXECUTIVE SUMMARY

This report briefly discusses the preliminary energy-efficiency evaluation and improvement audit conducted at the Izida Ceramic Plant in April 1991. The Izida facility is located in Elin Pelin, a suburb of Sofia. This facility is really two discrete plant units, with one plant devoted to the production of porcelain houseware products and the other to tile products. There are 680 employees at the plant, and the facility appears to be profitable (based on accounting records). The porcelain plant is older and utilizes a significant amount of manual labor, while the tile plant is two years old and mostly automated.

The plant uses purchased electricity, gas, and oil; the major energy constraint is electricity, which is often cut between during peak hours. The plant electricity quota for 1991 was reduced to 75% of that allowed for 1990. The only energy consumption data available at the time of the audit was that of 1990; in that year, the plant consumed 9 million m$^3$ of natural gas and 20 million kWh of electricity, with natural gas costing approximately 112.6 lv/1000 m$^3$ and electricity costing 0.055 lv/kWh. In 1991, these prices had risen considerably, to 767.16 lv/m$^3$ and 0.271 lv/kWh.

Overall, the plant appeared to be in good condition. Plant management staff have already taken steps toward implementing significant energy improvements, although no formal energy committee exists. Among plant managers, there was an awareness of key energy management issues, and comments and suggestions of the energy conservation Audit Team were well received.

The Team toured and inspected the plant, conducted audit tests, implemented a training program, recommended changes to improve energy efficiency, and specified instrumentation to save energy and improve the long-term economic viability of the plant.

Team members have identified some low-cost items and practices (requiring Bulgarian investment), a number of high-payout energy savings investments, and other longer term studies and capital-intensive investments. Future energy-conservation practices and programs, monitoring future energy usage, and the transfer of technology to other similar facilities were discussed. The total low-cost energy savings potential is estimated at 5,900,000 lv/year.

During the audit, the Team discussed techniques, such as suggestion boxes, energy savings competitions, reward schemes, establishment of a long-term conservation committee, and other programs, to encourage improved energy awareness.

The transfer of information under this program to other plants will be accomplished through technology seminars and meetings between specialists; technical reports and similar information will be distributed by the Inspectorate on Energy Utilization.

Since major energy inputs at the plant are natural gas and electricity, air and water pollution problems are limited.
Results of the Emergency Energy Program, Industrial Energy Efficiency Component

As a contribution to the improvement of energy efficiency in this plant, some new equipment and instruments were purchased by International Resources Group through the U.S. Agency for International Development, under the Emergency Energy Program. Items included:

- Emissions Gas Analyzer
- Air Flow Meter
- Pressure Reducing Station
- Natural Gas Flow Indicator
- Centrifuge
- Steam Traps
- Portable Temperature Indicator
- Portable Thermocouple Checker

Additional capital-intensive investments were outlined for the long term; all recommendations are summarized in Table 1.
### Table 1: Summary of Opportunities for Energy Savings, Izida Ceramic Plant

<table>
<thead>
<tr>
<th>I. Electricity Savings Measures Evaluated</th>
<th>Investment (000s lv)</th>
<th>Energy Savings KWh/yr (000)</th>
<th>Value of Energy Savings (000s lv)</th>
<th>Payback Period (years)</th>
<th>Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Porcelain Plant-Closing Furnace &amp; Drier Doors</td>
<td>-*</td>
<td>44</td>
<td>13</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>Improve Lighting, Clean Windows</td>
<td>-*</td>
<td>10</td>
<td>3</td>
<td>0.1</td>
<td>yes</td>
</tr>
<tr>
<td>Match Transformers &amp; Motors to Load</td>
<td>-*</td>
<td>160</td>
<td>48</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>Optimize Compressed Air &amp; Power Usage</td>
<td>-*</td>
<td>13</td>
<td>4.5</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>Total Electricity</td>
<td>-</td>
<td>227</td>
<td>68.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>II. Thermal Energy Savings Measures Evaluated</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Study and Optimize Boiler Combustion</td>
<td>-*</td>
<td>150</td>
<td>15</td>
<td>-</td>
<td>yes</td>
</tr>
<tr>
<td>Cooler for Wagons</td>
<td>10</td>
<td>200</td>
<td>20</td>
<td>0.5</td>
<td>yes</td>
</tr>
<tr>
<td>Recover Heat From Steam: Condensate of Porcelain Driers</td>
<td>30</td>
<td>1,641</td>
<td>60</td>
<td>0.5</td>
<td>yes</td>
</tr>
<tr>
<td>Improve Gas Usage Porcelain Glazing Furnace cycle</td>
<td>120</td>
<td>192</td>
<td>18</td>
<td>6.7</td>
<td>no</td>
</tr>
<tr>
<td>Improve Temperature Measurement</td>
<td>15</td>
<td>400</td>
<td>36</td>
<td>0.4</td>
<td>yes</td>
</tr>
<tr>
<td>Calibration of Temperature Devices</td>
<td>15</td>
<td>400</td>
<td>36</td>
<td>0.4</td>
<td>yes</td>
</tr>
<tr>
<td>Improve Furnace Combustion Efficiency</td>
<td>45</td>
<td>16,666</td>
<td>1,500</td>
<td>0.1</td>
<td>yes</td>
</tr>
<tr>
<td>Improve Tier Feed Prep.</td>
<td>45</td>
<td>2,489</td>
<td>91</td>
<td>0.5</td>
<td>yes</td>
</tr>
<tr>
<td>Total Thermal Energy Conservation Measures</td>
<td>280</td>
<td>22,138</td>
<td>1,776</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total Potential Electric and Thermal Savings = 1,844,500 leva per year

NOTE - Where necessary for currency conversions, an exchange rate of 15 leva to $1 has been used in this report, since it was the exchange rate in effect at the time the audit work was conducted. In January 1992, the exchange rate value was closer to 25 leva per $1.

* These are "no cost" options as defined in the "Energy Efficiency Improvement Options". They involve low-level leva expenditures that can be made within current plant budget by changing operational procedures.

International Resources Group, Ltd.
May 1992
2. PLANT BACKGROUND

The Izida Ceramic Plant is situated about 30 km from Sofia; the facility consists of two main plants, one which produces porcelain and the other which produces floor tiles. Annual plant production averages approximately 3,200,000 pieces of porcelain (1,000 tons) and 800,000 m² of floor tiles. The plant uses purchased electricity, gas, and oil. The major energy constraint is electricity, which is often cut during peak hours. The plant electricity quota for 1991 was reduced to 75% of that allowed for 1990.

There are 680 employees at the plant, and the facility appears to be profitable (based on accounting records). While the porcelain plant is older and utilizes a significant amount of manual labor, the tile plant is only two years old and mostly automated. It was constructed almost exclusively using Italian equipment and processes.

Preparation of the raw material mass at the facility occurs as follows:

- From storage, raw materials with a water content of 37% go to the atomizing dryer; there, the material is dried until it reaches a moisture content of 4%. This moisture content is extremely important for producing quality floor tiles.

- The drying process is achieved by burning large amounts of natural gas (350 nm³/hour) in an atomizing dryer.

- Next, tiles are formed by presses; there are three presses in the plant, at 75 KWh each.

- Tiles are then dryers in rolling dried which have a natural gas consumption of 60 m³/hour.

- When the tiles are glazed, they are automatically transferred to the furnaces on small rail cars. Furnaces use natural gas at the rate of 250 m³/hour and are automatically controlled.

- Packing, storage, and shipment are accomplished through a combination of manual and mechanical means.

2.1 Porcelain Production

There are ten drums for grinding the crude material, each electrically driven by 18.5 KWh motors. After grinding is completed, excess water is removed by filter press and extruded. Upon removal of excess water, the raw material goes to the product fabrication line for molding into various pieces. Wet molded pieces are then dried in one or more of the 11 driers. These driers operate on steam and heat-circulated air to a temperature of 40 - 60 °C. Burning for the process takes place in the biscuit furnace, which uses electricity to heat the material to 1,000 °C. Glazing includes manually dipping individual pieces into a glazing mixture before proceeding to the electrical glazing furnace, where the material is heated to 1,300 °C in the presence of a reducing atmosphere furnished by introducing natural gas (incomplete combustion) on 34 burners (Figures 2 and 3).
FIGURE 2. DIAGRAM OF IZIDA'S PORCELAIN GLAZING FURNACE OPERATIONS

FIGURE 3. DIAGRAM OF IZIDA'S GLAZING-TILE ROLLING FURNACE OPERATIONS
The reduction of the iron in the clay produces white instead of yellow finished product.

Hand decoration of the glazed material takes place in a separate room. This area has forced ventilation and recently changed from benzene to methylene chloride as the solvent.

Tables 2 and 3 present energy consumption and price information.

**Table 2. Price of Energy Sources**

<table>
<thead>
<tr>
<th></th>
<th>1990</th>
<th>1991</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Natural gas</td>
<td>112.6 lv/1000nm³</td>
<td>767.2 lv/1000nm³</td>
</tr>
<tr>
<td>2. Electric power</td>
<td>0.055 lv/1 KWh</td>
<td>0.271 lv/1 KWh</td>
</tr>
<tr>
<td>3. Water</td>
<td>0.516 lv/1 m³</td>
<td>0.936 lv/1 m³</td>
</tr>
</tbody>
</table>

**Table 3. Energy Consumption**

<table>
<thead>
<tr>
<th></th>
<th>1990</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Natural gas</td>
<td>9 MM nm³</td>
</tr>
<tr>
<td>2. Electric power</td>
<td>20 MM KWh</td>
</tr>
<tr>
<td>3. Water</td>
<td>350,000 m³</td>
</tr>
</tbody>
</table>

Until 1986, primary energy inputs for the plant were electricity and oil residue. After the reconstruction of the plant (floor tiles and steam station), natural gas was substituted as the primary liquid fuel. Use of natural gas proved to be an economic option for the plant, and has obvious positive environmental benefits as well.
2.2 Boiler Operations

Throughout the facility, there are three installed steam boilers, each having a capacity of 4 tons per hour (9.6 GJ/hour) of steam. The boilers operate at pressures of 4.5 to 5.0 atm, utilizing natural gas and mazut (fuel oil). No data regarding consumption of gas/kg steam was available.

Steam is used in the dryers and for building heating, so demand for steam varies from summer to winter and with humidity levels. Although the boilers have the capability to use mazut as a fuel source, natural gas has been used exclusively since 1986. Team members observed there was no preheating on either fuel.

Boilers were manufactured in the Georgi Kirkov Works in Sofia (Model KM-4) and have a steam pressure of 2 bar for heating and 5 bar for processing, with temperatures of 147 °C. The boiler feed water is condensate and make-up. Make-up water is treated by sodium-cationic principle.

Part of the steam (4 atm. of pressure) is used to dry porcelain products. The rest, which is reduced to pressures of 2 atm, is used for heating and hot-water supply for a working room. The three boilers work a total 11,000 hours/year on the average.

Results from the flue gas analysis for the boilers are included in Appendix V.

2.3 Lighting

Energy costs for lighting represent approximately 15% of total energy expenses. Thus, savings from lighting could have a significant impact on the overall plant energy bill.

Team members observed lighting quality and intensity throughout the plant, although no detailed audit measurements were taken. However, cursory examinations revealed that many bulbs and fixtures were dirty, significantly reducing light intensity per unit of electricity consumed. Many windows were also dirty, preventing natural light from entering working areas and increasing the amount of electric lighting required.

The Audit Team recommended the plant clean up light fixtures, reflectors, and windows to improve the lighting of electric lights and to allow natural light to enter. Team members also recommended the plant replace old incandescent lamps with sodium vapor lamps if this investment was found to be financially attractive.

2.4 Heating

At the time of the April 1991 audit, approximately one-third of all building heating was achieved through use of returned condensate, clearly demonstrating plant staff understanding of the value of returned condensate. Total energy consumption, from all sources, used for heating was about 73,406 GJ/year in April. The Energy Conservation Audit Team recommended additional steps be taken to utilize return condensate.
2.5 Electric Power Load

During the April 1991 audit, the IRG Energy Conservation Audit Team examined the power utilization for electrical equipment throughout the Izida complex. Measurements of the specific power load were taken for equipment contributing heavily to electricity demand at the facility.

Overall, electric motors in this plant were quite old, diminishing overall plant efficiency. The rolling mill required extra power for starting, so motors are oversized for normal operation. Without major design changes and equipment replacements, the possibilities for electrical savings using current equipment appear limited.
3. ENERGY MANAGEMENT

3.1 Energy Management Structure

The energy department at the plant is responsible for energy management. Currently, reports are given to corporate managers and division chiefs by the Energy and Industrial Departments, with the Chief of Power Engineering (an electrical engineer) responsible for energy management issues.

A program is already in place to encourage reasonable energy consumption. Gas consumption is metered and reported for tile production and at the main gas pipeline; an additional gas meter will be installed for the porcelain production facilities. Every month, meters at the electrical substation are checked for accuracy. Future monitoring of energy is expected to reflect expenditure information. Close attention will be given to control of the variables affecting the return on investment.

3.2 Energy Management Seminar

Recognizing the importance of energy management in determining the overall efficiency of industrial energy use, team members presented a seminar in April 1991 which addressed a number of energy management issues. Recommendations presented in the seminar were designed to provide an overall framework for improved energy management and training related to energy efficiency. The outline of the seminar is included in Appendix III.

Issues crucial to any discussion of energy management include:

- **Economic Principles** - it is important in any energy management regime to view energy costs as production input costs. In addition, concepts related to the benefits and costs of energy efficiency investments and return on investment must be analyzed.

- **Energy Management Programs** - specific programs which could help foster an energy ethic within a plant should be encouraged. These programs could include incentive/disincentive, "turn out the lights" campaigns, etc. A comprehensive energy management program also should incorporate an effective mechanism for energy cost accounting. Such a mechanism might require the purchase of and training in the use of computer accounting software.

- **Energy Monitoring** - successful improvement in energy utilization in an industrial facility is contingent upon continued monitoring of energy use. Increased energy prices in Bulgaria have forced new emphasis on this issue. As such, energy efficiency training must encompass economic justifications for the selection of instruments to monitor energy use.

- **Energy Surveys** - energy surveys and audits similar to the one conducted under the Emergency Energy Program should be part of an overall energy management
framework. In particular, energy surveys should attempt to regularly evaluate such important areas as:

- steam leaks
- condensate leaks
- insulation opportunities (water, steam, refrigeration)
- electrical opportunities
- lighting
- water leaks
- air leaks

Issues addressed at the April seminar were discussed in greater detail at the January 1992 Energy Management Workshop in Sofia, during which a representative of the Izida plant made a presentation.

3.3 Training Requirements

As outlined in the energy management seminar, training in energy awareness, economics, and energy cost accounting are crucial elements to improving plant energy efficiency. At almost every level, improved training in economics, data collection, and low-cost energy management techniques would yield significant energy savings.

It is important that divisions within the company responsible for overseeing energy utilization and energy efficiency activities receive training in key areas including:

- energy cost accounting - this type of training would be particularly useful if it involved learning practical skills related to the use of energy cost accounting software packages. Even if it is possible to purchase and utilize more sophisticated computer accounting programs, personnel can learn the basic tools used to maintain solid cost accounting standards within the plant.

- energy efficiency investment planning - again, training in investment planning would be extremely useful if it included familiarization with tools used in some energy investment planning programs such, as the "Envest" program.

Consequently, the present plant training program of 10 - 15 days/year should emphasize the development of an energy ethic in all plant personnel, touching on these topics. Although many personnel were already familiar with some of the material covered in the seminars, it is useful to re-emphasize technical issues enhancing energy efficiency in a comprehensive manner. Moreover, special attention should be given to training energy managers and others working in the Energy Department.
4. ENVIRONMENTAL CONSIDERATIONS

The major source of environmental pollution at Izida is the emission of 30,000 nm³ per hour of air containing tile dust from the presses. The dust first goes through a wet cyclone for partial removal of solids, and effluent air is discharged. Izida management is aware of the emissions situation and has taken measurements to ensure the dust content of the emissions conforms with current environmental regulations. However, in the current climate of environmental activism in Bulgaria, future emissions standards may be more rigorous, mandating that Izida investigate options to reduce its dust content.

Water containing solids goes from the cyclone to a settler for solids concentration. Approximately 12.9 tons/month of sludge from the entire plant is land filled. The total water from all settlers is 32,000 m³/month and is sent to an industrial waste disposal facility elsewhere.

Management staff also indicated that no other environmental control or monitoring equipment for air treatment were needed to comply with Bulgarian environmental standards. There are other water-solid separators elsewhere in the plant, but the IRG Energy Conservation Audit Team did not receive any data about these during the audit.
5. ENERGY EFFICIENCY IMPROVEMENT OPTIONS

Listed below are options for improving energy efficiency within the plant. Clearly, all these practices and projects will help conserve energy. However, given the reality of scarce resources for implementing these projects, the IRG Energy Conservation Audit Team recommended some be given priority; this prioritization is included in Section 6. This section outlines the wide variety of options available for energy efficiency improvement. Ultimate decisions regarding implementation of alternative options will depend upon criteria set by plant management -- including acceptable payback periods, and upon the overall corporate strategy.

5.1 "No-Cost" Options

"No-cost" items mentioned in this report will be initiated at the plant’s expense, in cases where expenditures are involved. Although few of these recommendations are literal "no-cost" propositions, it should be possible to implement them within the existing framework of plant expenditures (i.e. leva purchases, improved maintenance, and housekeeping).

1. **Keep the furnace and drier doors closed in the porcelain plant.** Savings should be 44,000 Kwh/year or 13,000Lv/year.

2. **Repair lights, keep light covers and windows cleaned.** Savings should be 10,000 KWh/year or 3,000 Lv/year.

3. **Change transformers and motors.** Wherever possible use spares to match running loads. Savings from this project should be 160,000 KWh/year or 48,000 Lv/year.

4. **Keep doors and windows closed for entry plant.** Savings should equal 980 Gcal/year or 98,000 Lv/annually.

5. **Study and optimize boiler combustion.** This should result in Savings of 150 Gcal/year or 15,000 Lv/year.

6. **Optimize amount of compressed air and power used.** Savings of 13,000 KWh/year or 4,500 Lv/year should be gained.

5.2 Low-Cost Options

Local investment and installation labor for low-cost initiatives will be provided by the Ceramics Plant. Hard currency for some low-cost items will be available under the A.I.D.-funded Emergency Energy Program.

1. **Install a cooler to cool wagons from the glazing furnace, using air, and recover this heat by using it in the driers.** A blower, cooling shed, and related duct work would have a realized cost of about 10,000 lv, with savings of 20,000 lv/year.
2. **Recover heat from steam condensate of porcelain driers.** Recover steam by extracting heat from it through the addition of a subcooling coil to driers. There are 11 driers, with four to be converted first. The condensate, after subcooling, will be returned to the boilers. Savings of 60,000 l/year and 0.37 tons/hour of steam are expected from the investment of 30,000 l.

3. **Install flow meters and pressure reducing station.** The glazing furnace (porcelain line) uses 34 gas burners to provide a reducing atmosphere to reduce black ferric oxide to white ferrous oxide, thus eliminating discoloration and product rejection. Flow meters for the inlet natural gas and air are required to control gas usage and operations, and a defective second stage pressure controller must be replaced. Investment is estimated at $8,000, and savings will be at least 18,000 l/year or 24,000 m³/year of gas.

4. **Purchase/install temperature measurement equipment.** There are many points where skin and internal temperatures must be measured to control heat efficiency and product quality. Savings for equipment to accomplish this are estimated at a minimum of 48,000 nm³/year of natural gas or 36,000 l/year. Total investment will be approximately about $1,000.

5. **Purchase/install a portable millivoltmeter.** This instrument would be used to check all thermocouples in the plant and ensure the corresponding temperature is in the range of 0 - 1600 °C and between 0 to 61 millivolts. The cost will be about $1000, saving an estimated 36,000 l/year.

6. **Purchase/install flue gas analyzers for all fired furnaces.** For all fired furnaces and boilers, a flue gas analyzer is required to maintain combustion efficiency. Investment is projected at $3,000, and savings are estimated at 1.5 million l/year or 2 million nm³ gas per year.

7. **Purchase/install a continuous moisture analyzer, continuous slurry analyzer, or centrifuge.** Water content of the dry-tile feed material varies in the dryer, creating quality control problems and heat-loss. A continuous moisture analyzer, or if too expensive, water analyzer and a continuous analyzer for the feed solid would help. Investment is estimated at $3,000 with savings estimated as much as 120,000 nm³/year of gas or 91,000 l/year.

8. **Install a boiler natural gas supply flowmeter.** This instrument is useful for heat balance purposes. The required investment would be about $3,000, with a possible savings of 91,000 l/year. This flowmeter would measure 1,500 nm³/hour at 6 atm. pressure, with a pipe size of 108 mm in diameter.

9. **Install a gas supply flowmeter.** Installing a flowmeter for the entire tile shop is necessary for usage control check. The pipe size is 108 mm in diameter, with flow rate at 6 atm.
5.3 Capital Intensive Options

To evaluate these options, an exchange rate of 15 lv = US$1 is used. Prices used for utilities in this report are based on April 1991 price quotes provided by the plant.

1. Tile hot air drier studies were recommended to automatically relate the natural gas usage and water content of the product. The studies would also examine the entire feed prep system, and would cost about 70,000 lv; the investment figure includes a seven day study. Savings are expected to be a minimum of 140,000 m³/year of natural gas or 106,400 lv.

2. Replace electric furnaces with gas furnaces. The following project is intended to save electricity, whose supply has been cut by 25% and may be cut further, and to enhance plant viability through production increases. About 50% of the production is exported and is a source of hard currency. The investment required is estimated at about US$ 4 million. Plant management would like to replace two electrically heated furnaces in the porcelain production with two gas fired furnaces of 45 m³ and 50 m³ volume.

Another electrical furnace could be replaced with a gas furnace. The inside dimensions of the furnace are 40 m long X 1.2 m wide and 0.3 m high. These furnaces were made by "Cast," of Faenza, Italy. A conveyer line to and from the furnaces for the wagons would be included with the gas furnace. This would eliminate 8.0 million KWh/year of critically short electric power (2.24 million lv/year), replace this with 4 million nm³/year of gas or 3.04 million lv/year, and double production capacity of the porcelain line.
6. RECOMMENDATIONS AND CONCLUSIONS

The following recommendations and conclusions represent those areas which the Energy Conservation Audit Team believes should be priorities for the Izida Plant.

6.1 Improved Energy Management Practices

Priority areas for corporate energy management at Izida should be the extension of training initiatives designed to improve energy efficiency awareness, data collection techniques, energy cost accounting, and energy investment planning capabilities. In addition, the activities of the energy committee should be expanded, and incentives given to encourage energy savings by all plant personnel.

In conjunction with improved training, management should establish energy program criteria, including minimum acceptable investment payback criteria and incentive/disincentive schemes for encouraging energy savings. In addition, management should attempt to conduct a comprehensive evaluation of all investment options, both low cost and capital intensive to determine 1) the cost of the required investment and 2) the payback on the investment (in terms of energy saved, losses avoided or production increases), to prioritize investment opportunities.

6.2 Improved Operating Practices and Operational Changes

The following recommendations reflect changes in operating practices, housekeeping, and maintenance which can yield significant energy savings with minimal investment cost. These recommendations include focusing attention on housekeeping, motors, condensate and steam systems, instrumentation, load management, boilers, furnaces, and dryers.

1. **Housekeeping**
   Keep the furnace and drier doors closed in the porcelain plant. Repair lights, keep light covers and windows cleaned. Keep doors and windows closed.

2. **Motors**
   Change transformers and motors. Wherever possible, use spares to match running loads.

3. **Condensate**
   Recover heat from steam condensate of porcelain driers. Recover steam by extracting heat from it by adding a subcooling coil to driers. There are 11 driers and probably four will be converted at first. The condensate after subcooling will be returned to the boilers.

4. **Load/Flow Management**
   Optimize amount of compressed air and power used.

5. **Instruments**
   Install flow meters and pressure reducing station. Flow meters for the inlet natural gas and air are required to control gas usage and operations. Purchase/install temperature measurement equipment. There are many...
points where skin and internal temperatures must be measured to control heat efficiency and product quality. Install a portable millivoltmeter to check all the thermocouples in the plant. Install flue gas analyzers for all fired furnaces to maintain combustion efficiency. Install a continuous moisture analyzer, a continuous slurry analyzer or centrifuge. Install a boiler natural gas supply flowmeter for heat balance. Install a gas supply flowmeter.

6. **Boilers**
   Study and optimize boiler combustion. Measure flue gas content to ensure optimal air levels.

7. **Furnaces**
   Install a cooler to cool wagons from glazing furnace using air and recover this heat by using it in the driers. A blower, cooling shed, duct work would be required.

8. **Dryers**
   Investigate the benefits and costs of tile hot air driers to automatically relate the natural gas usage and water content of the product. The study should examine the entire feed prep system.

6.3 **Recommended Capital Investments**

**Equipment Purchased under the Emergency Energy Program**

1. **Emissions Gas Analyzer**
   This instrument will be used to determine the volume of carbon monoxide, carbon dioxide, oxygen, sulfur dioxide and nitrogen oxide in flue gases, to improve combustion efficiency. This item costs $5,916 and will result in more than $85,000 in energy savings.

2. **Centrifuge**
   The centrifuge will be used to determine the weight and percentage of water in a fine powder (kaolin) used in ceramic production. The cost of this item was $582, and it will result in approximately $1,777 in energy savings.

3. **Nat'l gas flow indicator**
   This equipment will measure total gas supply to the glazing furnace to provide a reducing atmosphere. The cost of this item was $2,403 and the energy savings will be valued at nearly $6,000.

4. **Air flow meter**
   The air flow meter for the glazing furnace will enable the plant to monitor normal air flows to the furnace to ensure optimal glazing efficiency. The cost of this item was $5343, and it will yield up to $70,000 in energy savings.
5. **Steam traps**

The steam traps will help in the recovery of condensate and to maintain thermal efficiency. These are located in different parts of the tile shop for space heating and will save condensate. The cost was $5,592, and they will help to save over $6,600 in energy costs.

6. **Port. Temp Indicator**

There are many points in the plant where skin and internal temperatures must be measured to control heat efficiency and product quality. This instrument will allow the plant to make those measurements. The cost of this item was $1,942, and it will yield energy savings of over $4,000.

7. **Port. therm. checker**

This portable thermocouple checker is a device for relating millivolts for checked thermocouple to temperature. This instrument would be used to check all the thermocouples in the plant and to provide the corresponding temperature needed in the range of 0 - 1600 °C and 0 to 61 millivolts. The cost was $461, and the resulting savings will be approximately $2,400.

8. **2nd stage pressure reducing station**

This pressure reducing station for natural gas feed to the glazing furnace will help improve the efficiency of the gas burners. The cost of this item was $512, and the resulting savings will be nearly $10,000.

Details on the specifications and justifications for this equipment are included in Appendix II.

**Other Recommended Capital Projects**

Since the Agency for International Development is not in a position to finance all of the opportunities available for energy efficiency improvements, the IRG Energy Conservation Audit Team recommends a number of other investment projects for the plant to implement on its own. These recommendations include:

1. **Flue Gas Analyzers**

Since combustion efficiency in the boilers is a priority for management, and since this investment has significant energy savings potential, the plant should consider the installation of some continuous, in-situ oxygen/flue gas analyzers.

2. **Continuous Moisture/Continuous Slurry Analyzers**

The plant may wish to consider the purchase of these items if the centrifuge is not sufficient to improve both energy efficiency and product quality.
3. **Steam Traps/Insulation**

As part of an effort to return condensate, the plant may wish to consider the purchase of steam traps and condensate line insulation to improve the efficiency of condensate return.
APPENDIX I

PARTICIPANTS IN THE MEETING AT IZIDA CERAMIC PLANT

April 1991

<table>
<thead>
<tr>
<th>Name</th>
<th>Attendees Position</th>
<th>Speak or Understand English</th>
<th>* Have You Made E.C.S.</th>
</tr>
</thead>
<tbody>
<tr>
<td>J. Nikolova</td>
<td>Mechanical Engineer</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>C. Gergov</td>
<td>Chief of the Ship &quot;Frita&quot;</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>S. Vladimirov</td>
<td>Dept. for Control and Automation</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>G. Krastev</td>
<td>Mechanic</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>P. Deskov</td>
<td>Adjuster</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>C. Vutex</td>
<td>Process Engineer</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>P. Grigorov</td>
<td>Workshop</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>N. Koleva</td>
<td>Manager of Porcelain dept.</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>V. Ketskarov</td>
<td>Deputy Director</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>S. Angelov</td>
<td>Specialist in Furnaces and Driers</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>C. Cholev</td>
<td>Deputy Director</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>S. Mitcheva</td>
<td>Power Engineer</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>I. Svilenev</td>
<td>Specialist in Furnaces</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>S. Savov</td>
<td>Mechanic</td>
<td>no</td>
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<tr>
<td>M. Dimitrov</td>
<td>Specialist in Floor Tile Shop</td>
<td>no</td>
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</tr>
<tr>
<td>G. Slavtchev</td>
<td>Main Process Engineer</td>
<td>no</td>
<td></td>
</tr>
<tr>
<td>R. Spasov</td>
<td>Specialist in Control and Automation</td>
<td>no</td>
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</tbody>
</table>

* Energy Cost Studies
APPENDIX II
EQUIPMENT SPECIFICATIONS AND JUSTIFICATIONS FOR THE PURCHASE OF EQUIPMENT
IZIDA COMPANY, ELIN PELIN

The recommended equipment is listed in order of priority. All equipment supplied must be in metric units, 220 volts/50 Hertz, with a two year supply of consumable and critical parts (spares). In addition, two operating and maintenance manuals and the appropriate batteries or charger must also be provided. Complete units with all parts for operation are to be supplied for use in Bulgaria.

1. **Portable flue gas and emission analyzer.** To determine volume % (dry) CO (to 10% minimum), CO₂, O₂, combustible hydrocarbons, SO₂ and NOₓ (the latter if no additional or significant increase in cost). Also soot determination should be included. Print out of results desirable, temperature indicator to 1,300 degrees C and a draft gauge to ± 100 mm water desired. If moisture can be determined, this would be desirable, but not necessary. Cost about $3,000.

2. **Centrifuge.** To determine weight % of water in a fine powder such as kaolin. The normal water contains 4.7 weight %, and an accuracy to ± 0.1 weight % water is desired. To be located in a dusty factory atmosphere. Cost about $600.

3. **Natural gas flow indicator.** To measure total gas supply to glazing furnace to provide a reducing atmosphere. Accuracy minimum 95% highly reproducible. Vertical pipe, 70 mm I.D. and 76 mm O.D. (steel), total straight length about 3 meters. Normal flow is 60 nm³ at a pressure of 6 bar, ambient temperature. Pressure drop not to exceed 0.2 bar. Flow range 20 - 100 nm³/hour. Instrument to be completely self-contained, as only electricity is available.

4. **Air flow meter for glazing furnace.** Normal flow range 170 - 770 nm³/hour. Ambient temperature inlet pressure 10 mm of water, allowable pressure drop = 2 mm of water (vendor to specify if this is suitable). Flow to be in a rectangular duct 200 mm high, 170 mm wide. Straight horizontal length to be specified by vendor. Accuracy 95 % minimum, in order location. Only electricity is available.

5. **A number of steam traps** are required for recovery of condensate and to maintain thermal efficiency. These are located in different parts of the tile shop for space heating and will save condensate. Investment costs $1,000 and a savings of 10,000 l/v, equivalent to 100 Gcal/year. Four traps will have inlet pipe size = 57 mm O.D. and six traps will have inlet pipe size 35 mm O.D. Bucket traps with air vents desired, inlet pressure range 0.5 -1 atm. normal. Provide dirt trap and inlet blow down screen filter. Screen copper or S.S., bodies of carbon steel or equivalent. Trap capacity of condensate to be normally 0.4 tons per hour.
6. **Portable temperature indicator for skin and internal temperature.** 0 - 1,600 °C 98% accuracy more than may be used if necessary.

7. **Portable thermocouple checker** and device for relating millivolts for checked thermocouple to temperature, °C at least types thermocouples used 0 - 6 MV range. Thermocouples include iron - constant in or nickel - nickel chrome, PIRd - PI.

8. **Second stage pressure reducing station** for natural gas feed to glazing furnace. To reduce a flow normally of 30 to 100 nm³/hour at ambient temperature from 1.8 bar to 120 mm of water. Steel inlet pipe size is 50 mm I.D., 57 mm O.D. Stable, adjustable downstream press control desired. Exit pipe is 70 mm I.D., 76 mm O.D. Flow range 30 - 200 nm³/hour.
APPENDIX III

TRAINING SEMINAR

PRESENTED BY
U.S. ENERGY AUDIT TEAM

I. Introduction

1.1 Economics - Workers

1.1.1 Why Do These Things
1.1.2 Profitability Cost/Unit of Production

1.1.2.1 Raw Materials
1.1.2.2 Utilities - Steam, Power, Water Sewer, etc.
1.1.2.3 Maintenance
1.1.2.4 Labor
1.1.2.5 Packaging, Shipping
1.1.2.6 Overhead, Mgmt., Taxes, Depreciation
1.1.2.7 Profit

1.1.3 Buying Power
1.1.4 Borrowing Power

2.0 Topics for Discussion
2.1 Boilers
2.2 Steam, Distribution & Condensate Recovery
2.3 Heating and Ventilation
2.4 Lighting
2.5 Water, Hot and Cold
2.6 Refrigeration
2.7 Air Compressors
2.8 Pumps
2.9 Process
3.0 Transportation
3.1 Implementation

2.1 Boilers

2.1.1 Excess Air
2.1.2 Stack Gas Analysis, Draft Gauge
2.1.3 Stack Temp - Prevent Condensation and Corrosion
2.1.2 Preheat Air and Water

International Resources Group, Ltd. May 1992
2.1.2.1 Air Preheat Increases efficiency 2% with every 100°F, 300°F or more gives 5-10% increases

2.1.3 Steam, Fuel and Stack Temp, Press and Flow Measurement
2.1.4 High Efficiency Motors and Fans
2.1.5 Fans Have Capacity Control
2.1.6 Insulation
2.1.7 Cogeneration

2.2 Steam Distribution, Condensate Recovery

2.2.1 Keep Lines Shot as Possible and Sized Properly, Low Press. Drop.
2.2.2 Recover as much Condensate as Economically Beneficial
2.2.3 Keep Insulation Repaired and Proper Thickness
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2.2.5 Match Distribution System and Users as Closely as Feasible Use Desuperheaters Where Hot Steam not required
2.2.6 Leaks

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2.3.2 Central Units
2.3.3 Secondary Entrances, Double Windows
2.3.4 Efficient Units
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2.4 Lighting

2.4.1 Reflectors
2.4.2 Flood Lights
2.4.3 Halide or Sodium
2.4.4 Conservation - State of Mind

2.5 Water, Hot and Cold

2.4.1 Insulation
2.4.2 Exchange
2.4.3 Recirculate and Heat or Cool
2.4.4 Wash Down, Unnecessary Usage, Leaks

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2.6.1 Match Demand with Supply Temperature Wise Avoid Large Change in Temperature

2.6.1.1 Economizers, Pump Liquid
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2.6.3 Avoid High Discharge Pressures
   2.6.3.1 Vent Non-Condensible
   2.6.3.2 Use Right Condenser Coolant
2.6.4 Avoid High ∆P's and Drops Across Valves
2.6.5 Avoid High Press. Drop in Low Press. Lines
2.6.6 Use Low Stage Diffuser Vanes
2.6.7 Insulation
2.6.8 High Efficiency Motors
2.6.9 Adequate Liquid in Evaporator
2.6.10 Right Refrigerant

2.7 Air Compressors
   2.7.1 High Efficiency Motors and Compressor
   2.7.2 Capacity Control
   2.7.3 Don’t Compress Higher Than Necessary
   2.7.4 Stop All Leaks, Large and Small
   2.7.5 Avoid Unnecessary Usage, Air Hoses
   2.7.6 Don’t Use Inst. Air For Tools
   2.7.7 On P.D. Compressors Keep Valves in Good Shape

2.8 Pumps
   2.8.1 Hi Efficiency Motors and Pumps
   2.8.2 Match Pump Performance With Needs; Don’t Oversize on Volume or Pressure
   2.8.3 Stop Shaft Seal Leaks
   2.8.4 Right Motor Size and Voltage

2.9 Process
   2.9.1 Eliminate Large ∆T's and ∆P's
   2.9.2 Save Heat, Cross-Exchange or Steam Generation
   2.9.3 Eliminate Bottlenecks and Increase Production
   2.9.4 Eliminate Waste by Improving Process or Make Use of Waste
   2.9.5 Install Analyzers and Controllers to Give Smoother and Closer Control
   2.9.6 Cut Down on Waste, Improve Environment
      2.9.6.1 Raw Materials - Quality and Price
      2.9.6.2 Recycle Off-Spec Material
      2.9.6.3 Improve Quality to Eliminate Problems with Users
      2.9.6.4 Change Containers to Reusable
      2.9.6.5 Improve Mixing in Reactions that Require
      2.9.6.6 Improve Catalyst
2.9.6.7 Improve Distillation Column by Enlarging Part, Adding Trays, Changing Feed Point, Altering Operating Pressure, Preheat Feed, Increase Line Sizes, Improve Control by Automation

2.9.6.8 Condense Vents

2.9.6.9 Eliminate Leaks

2.9.7 Insulation

3.1 Implementation

3.1.1 Measurement

3.1.1.1 Steam, Elec., Util.

3.1.2 Analysis of Streams

3.1.2.1 Stack Gas, Other Pertinent Losses

3.1.3 Work on Big User, Losers

3.1.4 Develop Energy Ethic (Everything Costs Money)

3.1.4.1 Energy Committee

3.1.4.2 Contests - Recognition - Rewards
VARIATIONS IN BOILER EFFICIENCY LOSSES WITH CHANGES IN FITTING RATES

2.5% constant excess $O_2$

Excess $O_2$ vs load (2.5% at full, 10% at 20% load)
I. INTRODUCTION

Why is energy conservation important? The simplest answer is that it makes a firm more profitable. By practicing good energy management techniques through a well structured and organized company plan, management and employees become more aware of how energy is being used, of the actual costs of energy, and of the methods and equipment that can be used to control and reduce energy waste.

Energy management is a disciplined activity, organized for the more efficient use of energy without reducing production levels or lowering product quality, safety, or environmental standards. The underlying principle is cost effectiveness. Energy management therefore requires both technical and financial evaluations. A systematic and structured approach to energy management is required to identify and to realize full potential savings.

It is apparent that many companies and plants have not identified even simple energy conservation measures with short payback periods, and many who have identified such opportunities fail to implement them. Many studies show that the main barriers to action on energy conservation are:

* lack of knowledge of what is technically possible
* inappropriate financial analysis methods
* management attitudes towards energy efficiency

The greatest successes generally occur at companies where management visibly supports an integrated energy management program.

At the plant level, benefits include:

* lower production costs and higher profits
* better competitive position
improved ability to withstand future energy cost increases
improvements in productivity in general
environmental benefits

The potential benefits of solid energy management are entirely dependent on the nature of the plant concerned. However, savings for a plant which is starting an energy management program are often 20 to 30 percent of present energy consumption, and even more in many cases. For most firms, energy conservation makes very good business sense.

II. THE ENERGY MANAGEMENT APPROACH

2.1 Where To Start

How does a company begin to address the problem of controlling energy consumption and costs? The answer will depend to a great extent on the company concerned -- its current organization and management philosophy. Two points are particularly important.

* top management must be fully committed to controlling energy costs
* the appropriate organization must be set up to implement, and be accountable for, the energy management program

2.2 Top Management Commitment

The decision of company management to control energy costs is a vital first step. This must be clearly stated and understood by all within the company. An important part of top management commitment is to set up the responsible organization for implementing the energy management program. This is commonly at two levels, the Energy Manager and the Energy Committee.

2.3 The Plant Energy Committee

Because energy concerns different departments within a firm, an effective energy management program will involve many people. In some companies, a committee is formed to include representatives of important departments. While unnecessary bureaucracy must be avoided, there are advantages to having an active Energy Committee at the plant:

* it can encourage communications and the sharing of ideas
* it can serve to obtain agreements on energy saving projects which affect more than one department
* it can provide a stronger voice to top management than a single manager normally could

Membership will depend on existing management structures at the type and quantity of energy used. When should the Committee meet? Normally a monthly meeting is usual, so that monthly production and energy consumptions may be reviewed, including a comparison of actual performance against previously set targets. Other items for the agenda should be a review of the status of energy conservation investments, in progress or planned.
2.4 The Energy Manager

Forming an Energy Committee is not enough: someone is needed to implement the policies and directives of the Committee, and to provide the data needed by the Committee to make decisions. Appointing an Energy Manager is therefore an essential step in implementing an energy management program in most companies. The role will vary from company to company but he will normally be concerned with the following tasks:

- collecting and analyzing energy related data regularly
- monitoring energy purchases
- identifying energy saving opportunities
- developing projects to save energy, including the necessary technical and economic evaluations
- implementing energy saving projects
- maintaining employee communications and public relations

In some companies, particularly the smaller ones, the Energy Manager may report directly to the General Manager or Plant Manager and may be part-time. Larger companies may appoint a full-time Energy Manager and give him one or more technical assistants, thus forming an "energy conservation group". Wherever possible, the Energy Manager or Group should be independent of the main operating departments: reporting to the highest level, such as the Plant Manager, can often give the needed independence and authority.

The skills and experience of the Energy Manager need careful consideration. Technical competence is usually regarded as the primary qualification, although this may not be as important as often thought. In smaller companies, good technical skills may be helpful because the Energy Manager will probably carry out much of the work himself. In a larger company, where technical skills are more readily available, the Energy Manager may well be someone with experience in accounting or general management.

The particular skills that are important for an Energy Manager include administration and communication. Most Energy Managers need to spend much of their time convincing their colleagues and top management to take a specific line of action. Some typical qualifications are:

- familiarity with the plant, processes and quality needs
- ability to collect and analyze data
- knowledge of energy-consuming equipment and factors affecting its efficiency
- engineering skills to size and select equipment, supervise installation and ensure correct maintenance
- ability to communicate and interact well with both plant management and with line operators and maintenance workers
- good judgement to know when to call upon outside help such as consultants or equipment vendors
- proper perspective of the role played by energy in the company, in relation to other elements such as raw materials, capital and labor
- ability to use initiative, a "self starter"
Above all, the Energy Manager needs an open mind to view problems from different perspectives and the skill to convince others that savings are both possible and worthwhile if the right measures are taken.

III. MEASURING ENERGY AND ITS COSTS

3.1 Introduction

Energy management is concerned with the efficient transfer of the energy in fuels and electricity into useful work or heat. It is essential to be able to measure energy inputs and outputs, using various types of meters and instruments, either fixed in the plant or, in some cases, portable. It also requires knowledge of fuel, steam and electricity characteristics to enable comparisons to be made on a common basis.

3.2 The Heating Values of Fuels

An important characteristic of an energy source is the energy contained per unit of mass or volume (the heating value, heat of combustion or calorific value). There are two values associated with fossil fuels, a higher (or gross) heating value and a lower (or net) heating value. The higher heating value includes the latent heat of water vapor formed during combustion as it condenses back to the liquid state. The heating value generally determined in the laboratory is the higher value. The difference between the higher and lower heating values for a fuel is a function of the hydrogen content of the fuel, as this determines the amount of water formed. Some typical ratios of lower to higher heating values are:

<table>
<thead>
<tr>
<th>Fuel</th>
<th>Ratio LHV/HHV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Natural gas</td>
<td>0.90</td>
</tr>
<tr>
<td>Fuel oil</td>
<td>0.94</td>
</tr>
<tr>
<td>Coal</td>
<td>0.98</td>
</tr>
<tr>
<td>Electricity</td>
<td>1.00</td>
</tr>
</tbody>
</table>

In carrying out energy related calculations, it generally makes little difference which heating value is used. The essential principle is to be consistent and use the same basis for all fuels. The convention used should always be clearly stated.

3.3 Unit Energy Costs

An important step to controlling energy costs in a plant is to determine the unit costs of the different energy forms. For example, the cost may be constant, irrespective of the level of consumption (e.g., 150 USD per ton of a specified fuel oil). Some fuels and electricity may have a tariff which varies in accordance with the quantity consumed in a set period of time (e.g., 4.5 US cents per kWh of electricity up to 100 kWh per month, 2.5 cents per kWh thereafter). There may also be other complication factors, such as a "demand charge" for electricity or gas, which is a cost element set by the highest actual level of demand in the period (e.g., 25 USD per kW maximum demand) or even by the maximum contract or maximum allowable connected load.

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Some forms of energy are also subject to a surcharge for peak period. Electricity consumption may be subject to a "power factor penalty" through which the plant is penalized if it consumes too much reactive power.

For practical reasons, it may often be more meaningful for energy savings calculations for the Energy Manager to compute the marginal cost of energy, that is, the cost incurred for consuming one more unit of the particular form of energy (or conversely, the amount saved by consuming one unit less of the particular energy form). A cost-conscious manager will know the unit cost of his energy consumptions and will think in terms of cost savings when he observes operations that are perhaps not optimum or when he suggests priority for a particular maintenance job.

3.4 The Cost of Steam

This is a special case of the unit costs mentioned above. The plant Energy Manager should calculate the cost of steam and advise plant managers. The basic calculation requires the cost of boiler fuel, fuel heating value, water costs, condensate recovery temperature and rate, boiler efficiency and the steam characteristics: these are sufficient for estimating a "marginal" steam cost, one that ignores the labor cost for boiler and steam system operation, maintenance costs and the cost of capital investment. For most practical purposes, the marginal cost is sufficient for making decisions on energy saving actions or investments, as these are usually based on differences between costs and savings for various options, and the "excluded" costs are typically the same for all options.

A plant Energy Manager can develop his own graph to show his own plant situation most accurately. A graph provides a simple way of evaluating the relative merits of different fuels, the benefits of improvements in boiler efficiency, or the savings possible from reducing steam use.

3.5 Energy Accounting

Accounting for energy, in its simplest terms, means keeping accounts of energy consumption and energy purchases for the plant. At a more detailed level, it may mean assigning energy costs to different departments. The term "monitoring" is used for maintaining a careful check of energy consumption and, usually, to analyzing energy use.

IV. DATA ANALYSIS

4.1 Graphing the Data

Data should be presented graphically as a better appreciation of variations is almost always obtained from a visual presentation. For example, charts of energy consumption and production against time are drawn at many plants and are usually more enlightening than columns of numbers. However, these graphs tell us little about the relationship between energy and production and therefore are not useful for energy management. Unfortunately, many plants fail to go beyond the drawing of the basic graphs, whereas further simple analysis is needed to give us a great deal more useful information quite quickly.
4.2 Energy-Production Relationships

For a typical plant, a plot of "energy used per month" against "monthly production" can reveal a great deal about energy efficiency. Separate graphs should be drawn from fuel and electricity use. For most plants, the energy-production graph will be a straight line. There are two components of the energy consumption:

* energy directly related to production (mP)
* energy not directly related to production (e)

The energy used by the plants is the sum of the two components, represented by the basic equation for a straight line:

\[ E = mP + e \]

where \( E \) is the monthly energy consumption, \( P \) is the corresponding monthly production, \( m \) represents the slope of the line and \( e \) is the y-axis intercept (daily or weekly data can be used also). Physically, "e" refers to non-production related energy, that is, energy losses or energy used for general plant services:

* lighting, office equipment, ventilation fans
* space conditioning (heating or cooling)
* unnecessary idling of production equipment
* energy in the steam lost in leaks
* radiation and convection heat losses from boilers
* heat losses from steam distribution piping

A graph of \( E \) against \( P \) will quickly show the Energy Manager the proportion of energy consumption which corresponds to non-productive energy (services and losses). If this is high, the Energy Manager can look for ways of cutting down "e", for example:

* replace old lighting units by high efficiency lighting
* eliminate leaks from the compressed air system
* ensure equipment is switched off when not in use
* improve the insulation of the steam distribution system

To cut down on the use of "productive" energy, he might:

* reduce process temperatures to the minimum permissible
* optimize combustion efficiency of boilers and furnaces
* install a heat recovery system

Through such measures, the Energy Manager will seek to reduce the slope of the E-P line as well as reduce "e".

Scattering of points in the E-P graph is a general indication of the level of energy management in the plant. Widely scattered points usually mean that energy use is not properly controlled and operating practices in general are poorly defined and inadequately monitored by supervisors and managers.
4.3 Specific Energy Consumption

Many plants calculate Specific Energy Consumption (SEC) regularly. SEC is the energy used per unit of output, $E$ divided by $P$. For a typical plant, where the $E$-$P$ relationship is a straight line, we have:

$$SEC = \frac{E}{P} = m + \frac{e}{P}$$

A graph of SEC against $P$ will therefore be a curve, not a straight line. Figure 4.3 shows a typical SEC-$P$ graph: points lying below the curve represent improved efficiency in energy use relative to the "average performance" represented by the curve itself. Figure 4.3 also shows two points, A and B. The Specific Energy Consumption is certainly lower at B and many engineers think therefore that the point with the highest energy efficiency is B. Indeed, if the energy, production and SEC data are merely shown as a table of numbers (as too many plants do) it is quite easy to draw this erroneous conclusion. When the points are shown on a graph, it becomes clear that B is a point at which energy efficiency is relatively low while A represents a time of good operation at high energy efficiency, albeit at a low production level.

Specific Energy Consumption figures therefore have little meaning unless they are associated with a production rate. Following SEC alone is not the answer to good energy management in any plant where the production rate varies more than a few percent from day to day or month to month.

4.4 The CUSUM Technique

A simple quantitative procedure allows the Energy Manager to evaluate plant performance month by month and to estimate savings made through implementing energy conservation measures (or conversely, the losses occurring due to deficiencies in performance). The method is known as the CUSUM technique, as it relies on calculating "the Cumulative Sum of Differences". The method is applied in the following way:

1. Plot the E-$P$ graph for a period in which operations were generally similar and during which no major energy conservation measures were introduced.

2. Find the best fit straight line for the data points.

3. From each time period, compute the estimated energy use from the straight line equation.

4. Calculate the differences between calculated energy use and actual energy consumption for corresponding periods.

5. Compute the cumulative sum of these differences.

If the differences between actual and calculated energy consumption are random, some positive and some negative, then the cumulative sum of these differences should fluctuate around zero. If there are any significant changes in energy efficiency after the "base period" for...
which the straight line was derived, the differences will accumulate (either positive or negative)
and a graph of CUSUM against time will show this clearly.

The Energy Manager can thus determine quantitatively the impact of a change in energy
efficiency by examining the CUSUM graph. The procedure may be illustrated by a simple
example:

Energy consumption and production data were collected for a plant over a period of 18
months. During month 9, a heat recovery system was installed. Using the plant monthly data,
estimate the savings made with the heat recovery system. The plant data are:

<table>
<thead>
<tr>
<th>E monthly energy use</th>
<th>P monthly production</th>
</tr>
</thead>
<tbody>
<tr>
<td>toe/month</td>
<td>tons/month</td>
</tr>
<tr>
<td>1</td>
<td>340</td>
</tr>
<tr>
<td>2</td>
<td>340</td>
</tr>
<tr>
<td>3</td>
<td>380</td>
</tr>
<tr>
<td>4</td>
<td>380</td>
</tr>
<tr>
<td>5</td>
<td>300</td>
</tr>
<tr>
<td>6</td>
<td>400</td>
</tr>
<tr>
<td>7</td>
<td>280</td>
</tr>
<tr>
<td>8</td>
<td>424</td>
</tr>
<tr>
<td>9</td>
<td>420</td>
</tr>
<tr>
<td>10</td>
<td>400</td>
</tr>
<tr>
<td>11</td>
<td>360</td>
</tr>
<tr>
<td>12</td>
<td>320</td>
</tr>
<tr>
<td>13</td>
<td>340</td>
</tr>
<tr>
<td>14</td>
<td>372</td>
</tr>
<tr>
<td>15</td>
<td>380</td>
</tr>
<tr>
<td>16</td>
<td>280</td>
</tr>
<tr>
<td>17</td>
<td>280</td>
</tr>
<tr>
<td>18</td>
<td>380</td>
</tr>
</tbody>
</table>

* Step 1 -- plot the E-P graph for the first 9 months
* Step 2 -- draw the best fit straight line
* Step 3 -- derive the equation of the line

The steps are completed in Figure 4.4 and the equation is:

\[ E = 0.4 \, P + 180 \]

* Step 4 -- calculate the expected energy consumption based on the equation
* Step 5 -- calculate the differences between calculated and actual energy use
* Step 6 -- compute the cumulative sum of differences
These steps are done in the table below:

<table>
<thead>
<tr>
<th>Step</th>
<th>E act</th>
<th>P</th>
<th>E calc</th>
<th>Fact-Ecalc</th>
<th>CUSUM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>340</td>
<td>380</td>
<td>332</td>
<td>+8</td>
<td>+8</td>
</tr>
<tr>
<td>2</td>
<td>340</td>
<td>440</td>
<td>356</td>
<td>-16</td>
<td>-8</td>
</tr>
<tr>
<td>3</td>
<td>380</td>
<td>460</td>
<td>364</td>
<td>+16</td>
<td>+8</td>
</tr>
<tr>
<td>4</td>
<td>380</td>
<td>520</td>
<td>388</td>
<td>-8</td>
<td>0</td>
</tr>
<tr>
<td>5</td>
<td>300</td>
<td>320</td>
<td>308</td>
<td>-8</td>
<td>-8</td>
</tr>
<tr>
<td>6</td>
<td>400</td>
<td>520</td>
<td>388</td>
<td>+2</td>
<td>-6</td>
</tr>
<tr>
<td>7</td>
<td>280</td>
<td>240</td>
<td>276</td>
<td>+4</td>
<td>-2</td>
</tr>
<tr>
<td>8</td>
<td>424</td>
<td>620</td>
<td>428</td>
<td>-4</td>
<td>-6</td>
</tr>
<tr>
<td>9</td>
<td>420</td>
<td>600</td>
<td>420</td>
<td>0</td>
<td>-6</td>
</tr>
<tr>
<td>10</td>
<td>400</td>
<td>560</td>
<td>404</td>
<td>-4</td>
<td>-10</td>
</tr>
<tr>
<td>11</td>
<td>360</td>
<td>440</td>
<td>356</td>
<td>+4</td>
<td>-6</td>
</tr>
<tr>
<td>12</td>
<td>320</td>
<td>360</td>
<td>324</td>
<td>-4</td>
<td>-10</td>
</tr>
<tr>
<td>13</td>
<td>340</td>
<td>420</td>
<td>348</td>
<td>-8</td>
<td>-18</td>
</tr>
<tr>
<td>14</td>
<td>372</td>
<td>480</td>
<td>372</td>
<td>0</td>
<td>-18</td>
</tr>
<tr>
<td>15</td>
<td>380</td>
<td>540</td>
<td>396</td>
<td>-16</td>
<td>-34</td>
</tr>
<tr>
<td>16</td>
<td>280</td>
<td>280</td>
<td>292</td>
<td>-12</td>
<td>-46</td>
</tr>
<tr>
<td>17</td>
<td>280</td>
<td>280</td>
<td>294</td>
<td>-4</td>
<td>-50</td>
</tr>
<tr>
<td>18</td>
<td>380</td>
<td>500</td>
<td>380</td>
<td>0</td>
<td>-50</td>
</tr>
</tbody>
</table>

* Step 7 -- plot the CUSUM graph -- see Figure 4.5

* Step 8 -- estimate the savings accumulated from use of the heat recovery system

From Figure 4.5, we see that the CUSUM graph fluctuates around the zero line for several months and then drops sharply after month 11. This suggests that the heat recovery system took almost two months to commission and reach proper operating conditions, after which steady savings have been achieved. Based on the graph, savings of 44 toe have been accumulated in the last 7 months. This represents savings of almost 2 percent:

\[
\frac{44 \times 100}{(2352 \text{ toe})} = 1.9 \%
\]

The CUSUM technique is a simple but remarkably powerful statistical method which highlights small differences in energy efficiency performances. Regular use of the procedure allows the Energy Manager to follow his plant performance and to spot any trends at an early date.

4.5 Performance Evaluation

Evaluation of plant performance is best done by regularly comparing the actual energy consumption with the expected consumption. Differences between actual energy use and standards based on past performance will reveal either improvements or a deterioration in
performance. The regular data indicate if and where failures have occurred and trigger the
necessary remedial action: the data also provide quantified evidence of exactly how successful
any energy conservation measures have been.

It is important that performance evaluations be carried out promptly at the end of each
month. A review of plant performance is a useful task for the plant Energy Committee. If the
analysis is left for too long, it becomes much more difficult to account for any discrepancies that
are observed, and of course it is always desirable that corrective measures be taken as soon
as possible.

4.6 Monitoring and Targeting

"M & T" is a management approach that enables firms to manage energy as a
controllable resource in the same way as they manage other resources such as raw materials
and manpower. M and T helps companies eliminate waste and also provides the incentive for
further improvement by giving concrete evidence of successful energy conservation activities,
from which the economic benefits of energy management become evident.

Central to the success of M and T is the establishment of "energy accountable centers"
for which targets can be set. A center might consist of an individual machine, a process
department or even the entire site. Recording and reporting procedures for the centers should
be set up. Each center should correspond to a nominated individual responsible for operational
achievements in that area. Tying resource consumption to those responsible for operational
achievement is a key factor in the M and T system since it focusses attention on those with
authority to effect improvements in performance. It is also essential that those held accountable
for energy performance should be able to assess that performance and have the pertinent
information on which to base judgements, decisions and actions to bring about improvements.

Targets may be set using a detailed engineering analysis of operations, or can be
developed using historical data such as that described earlier. Graphs of E-P and SEC-P will
reveal the occasions when energy efficiency are particularly high, and thus it would be
reasonable to use the best historical performance (or something close to that) as a challenging
but attainable target.
APPENDIX V

AUDIT MEASUREMENTS

1. GLAZING FURNACE FLUE GAS ANALYSIS

Sample of glazing furnace exit gas to atmosphere:

Time: 10:45  
Date: 04-16-91  
Fuel gas - not relevant  
Combustion efficiency - not relevant

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient temperature</td>
<td>24 °C</td>
</tr>
<tr>
<td>Stack temperature</td>
<td>107 °C</td>
</tr>
<tr>
<td>( O_2 )</td>
<td>19.3%</td>
</tr>
<tr>
<td>CO</td>
<td>20 ppm</td>
</tr>
<tr>
<td>( CO_2 )</td>
<td>0.9%</td>
</tr>
<tr>
<td>Combustible gases</td>
<td>0.0%</td>
</tr>
<tr>
<td>Stack draft</td>
<td>0.2 inches of water</td>
</tr>
<tr>
<td>( NO_x )</td>
<td>0.0</td>
</tr>
<tr>
<td>( SO_2 )</td>
<td>0.0</td>
</tr>
</tbody>
</table>

Temperature readings were made throughout the plant; as presented above, a lot of energy is available.

1 - 297 °C  
2 - 127 °C  
3 - 180 °C  
4 - 295 °C - temperature of outer pieces of porcelain after standing a while.

2. Tile furnace sample #1

Time: 10:15  
Date: 04-16-91  
Fuel - natural gas: 8 000 Kcal/m³  
Combustion efficiency 75.7%

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient temperature</td>
<td>20 °C</td>
</tr>
<tr>
<td>Stack temperature</td>
<td>236 °C</td>
</tr>
<tr>
<td>( O_2 )</td>
<td>10.3%</td>
</tr>
<tr>
<td>CO</td>
<td>88 ppm</td>
</tr>
<tr>
<td>( CO_2 )</td>
<td>6.0%</td>
</tr>
<tr>
<td>Combustible gases</td>
<td>0.0%</td>
</tr>
<tr>
<td>Stack draft</td>
<td>not measured</td>
</tr>
<tr>
<td>Excess air</td>
<td>87%</td>
</tr>
<tr>
<td>( NO_x )</td>
<td>54.0 ppm</td>
</tr>
<tr>
<td>( SO_2 )</td>
<td>10.0 ppm</td>
</tr>
</tbody>
</table>
2. **TILE FURNACE FLUE GAS ANALYSIS**

Tile furnace sample # 2 - Purge air

Time: 10: 28  
Date: 04-16-91  
Fuel - natural gas: 8 000 Kcal/nm³  
Combustion efficiency not relevant

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient temperature</td>
<td>23 °C</td>
</tr>
<tr>
<td>Stack temperature</td>
<td>198 °C</td>
</tr>
<tr>
<td>$O_2$</td>
<td>21%</td>
</tr>
<tr>
<td>CO</td>
<td>0</td>
</tr>
<tr>
<td>CO$_2$</td>
<td>0</td>
</tr>
<tr>
<td>Combustible gases</td>
<td>0</td>
</tr>
<tr>
<td>Stack draft</td>
<td>0</td>
</tr>
<tr>
<td>Excess air</td>
<td>0</td>
</tr>
<tr>
<td>NO$_x$</td>
<td>0</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>0</td>
</tr>
</tbody>
</table>

Flow to atmosphere is about 260 m$^3$/min, which offers a possibility of cross-exchange for building heating.

3. **BOILER FLUE GAS ANALYSIS**

One sample on flue gas was run during the audit. Only one boiler was operating at sample time.

Time: 09: 50  
Date: 04-16-91  
Fuel - natural gas: 8 000 Kcal/nm³  
Combustion efficiency 76.0%

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ambient temperature</td>
<td>19 °C</td>
</tr>
<tr>
<td>Stack temperature</td>
<td>240 °C</td>
</tr>
<tr>
<td>$O_2$</td>
<td>9.8%</td>
</tr>
<tr>
<td>CO</td>
<td>0</td>
</tr>
<tr>
<td>CO$_2$</td>
<td>6.3%</td>
</tr>
<tr>
<td>Combustible gases</td>
<td>0.0</td>
</tr>
<tr>
<td>Stack draft</td>
<td>not measured</td>
</tr>
<tr>
<td>Excess air</td>
<td>78 %</td>
</tr>
<tr>
<td>NO$_x$</td>
<td>42.0 ppm</td>
</tr>
<tr>
<td>SO$_2$</td>
<td>0</td>
</tr>
</tbody>
</table>

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