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ENERGY EFFICIENCY AUDIT REPORT "SODI", SODA ASH PLANT

Devnia, Bulgaria

PREPARED BY:

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Washington, DC

and

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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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LIST OF ACRONYMS/ABBREVIATIONS

A.I.D.	U.S. Agency for international Development
atm	atmospheres
GCal	gigacalories
IRG	International Resources Group, Ltd.
KWh	kilowatt hours
lv	levas
m^3	cubic meters
MM	million
t	ton

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 "Sodi" Soda Ash Plant, Devnia, was conducted through a cooperative effort by the factory management and staff; Committee on Energy; Ecotechproduct -- 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 uncertainly.

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.

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 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 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 **(Figure 1)**:

<u>Light Industry</u>
Serdika Dairy Processing Plant - Sofia
Pharmacia Pharmaceutical Company - Stanke Dimitrov
Parvi Mai Cotton Textile Processing Plant - Varna
Dobritch Poultry Processing Plant - Tolbuhin

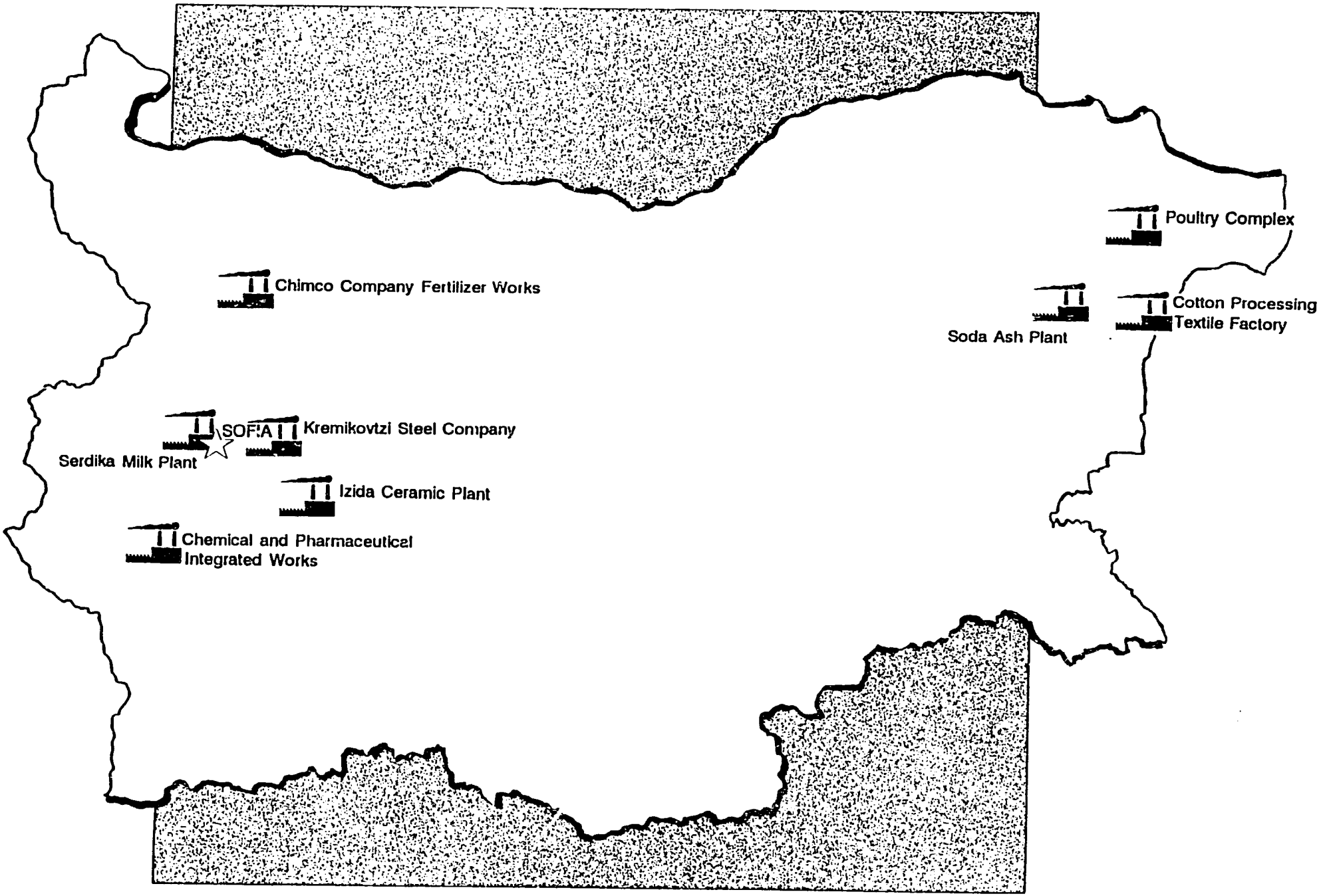


Figure 1. Location of eight industrial plants audited by the IRG team.

Factory

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 costs of producing steam and electricity, primarily using plant records, audit measurements, and interviews with plant officials. In some cases, the Audit Teams 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.

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 promote reforms that encourage energy conservation and improved economic efficiency.

1. EXECUTIVE SUMMARY

This report briefly discusses the preliminary evaluation and improvement campaign conducted at the "Sodi" Soda Ash Plant from April 25 through May 1, 1991. This campaign was compeleted by a Energy Conservation Audit Team led by two IRG representatives, Theodore Baba and Mel Heidner, and was accompanied by members of the Committee for Energy and staff of Ecotechproduct a private sector energy services company. The IRG Team met with key members of the plant staff to discuss Salient energy efficiency issues (see **Appendix I** for complete list of participants). Outlined below is a review of salient features of the plant, focusing on energy utilization. The exchange rate used in this report is 15 levas = U.S. $1.

The Soda Ash Plant is located at Devnia, on the Black Sea, about 300 miles from Russia. It was previously part of the "Polychim" complex, which also consists of a PVC Plant and Synthetic Fertilizer Plant, and is the only soda ash plant in Bulgaria. The plant contains three main production lines, the last of which was commissioned about 1977. About 80% of its product is exported and earns hard currency. Annual production from the plant is about 1,200,000 tons per year, mostly in light density products.

A rough estimate suggests that 60% of total production costs at the plant are due to energy expenses. Annual energy consumption at the plant in 1990 was 2,217,289 Gigacolories (GCal) and 137,577,466 kilowatt hours (KWh). Energy sources include coke, wood, purchased electric current, and steam. Power and steam of 31 atmospheres (atm.) are purchased from an on-site power house, and raw water from a local source.

As of May 1990, the plant was allowed to purchase equipment with up to 50% of the hard currency earned by product export. As a result, plant staff are actively undertaking a modernization program. In fact, the plant helped to co-finance two items of equipment purchased as a part of the A.I.D.-sponsored Emergency Energy Program.

"Sodi" has active programs in energy training, maintenance, efficiency, and conservation. These programs are unusual in that staff at top management levels participate, and penalties can be levied against personnel or department responsible for wasteful energy practices.

Liquid pollution is a problem recognized by the plant, although they have not yet determined how to deal with this issue. There is a substantial amount of material (calcium slurry of hydroxide, calcium chloride, and brine) sent to a large sludge pond. Liquid overflow goes to a canal and then to the Black Sea. The canal is periodically dredged and sludge is removed for land fill.

An engineering evaluation of the electrical controller of the brine system pump was conducted, and a preliminary design scheme for disposing of a polluting nitric oxide -nitrogen dioxide stream from the Synthetic Fertilizer Plant was discussed.

1.1 Results of the Emergency Energy Program, Industrial Energy Efficiency

New equipment and instruments were purchased under the Emergency Energy Program. These items include:

- Level-Indicating Modulating Controller
- Variable Frequency Device

A summary table of opportunities for energy savings based on low- and no-cost considerations is summarized in **Table 1**.

Table 1. Summary of Opprotunities for Energy Savings - "Sodi" Soda Ash Plant

1. No Cost/Low Cost Measures Evaluated	Investment Cost (lv)	Energy Savings KWh/year or GCal/year	Value of Energy Saved (lv/year)	Payback Period (years)	Recom's
1. Wash Tubular Coolers	-	-	-	-	NEI
2. Maintain Carbonization Column Temp.	0*	-	200,000	-	yes
3. Regular Cleaning of Calcination Heater	0*	675 GCal	136,000	-	yes
4. Maintain Gas Temperature	345,000	1800 GCal	363,000	.95	yes
5. Variable Speed Control for Brine Feed	675,000	50,000 KWh	299,650	1.3**	yes
6. Purchase Two Flue Gas Analyzers	150,000	-	-	-	yes
2. Capital Intensive Measures Evaluated					
1. Desuperheat Steam	2,010,000	-	800,000	2.5	NEI
2. Automate Process Line Control System - Absorption & Distillation Plant	2,000,000	-	500,000	4	NEI
3. Automated Product Storage	47,550,000	-	-	-	NEI
4. Install Small Soda Ash Furnace	137,500,000	-	68,000,000	2	NEI
5. Install Thermal Compressor	36,250,000	-	15,000,000	2.4	NEI
6. Replace bicarbonate filters	33,000,000	-	1,000,000	33	no
Grand Total	259,170,000	-	86,298,650		

NEI - Not enough information available about key investment parameters, including management payback requirements, etc. at the time of audit to recommend implementation of the project. The Team does not suggest that these investments are not sound, but stresses a more comprehensive analysis of the return on these investments must be conducted before investment funds are allocated.

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

* These are "no-cost" investments as defined in Section 5 of the report.

** This investment was recommended for 2 reasons. The first was that the price of electricity was expected to increase significantly, greatly lowering the payback period. In addition, "Sodi" offered to help finance the investment at a level such that the financial payback for AID was less than 2 years.

2. PLANT BACKGROUND

The "Sodi" Soda Ash Plant was previously part of the "Polychim" complex, which also consists of a PVC Plant and Synthetic Fertilizer Plant. This plant is the only soda ash production facility in Bulgaria, and is consequently a large complex. The plant had 2,343 employees at the time of the audit, and had been operated continuously, 24 hours a day, 365 days per year.

Using the "Solvay" process, annual plant production capacity is 930,000 tons of light soda ash and 130,000 tons dense soda ash. On average, about 80% of this product is exported and earns hard currency. All raw materials used in the production process are obtained locally. At the plant, brine is received as a concentrated solution via pipe line, as is some CO_2. Ammonia is brought from the adjacent Fertilizer Plant, limestone arrives by buckets from a local quarry, and coke comes from local and foreign sources. Power and steam (31 atm.) are purchased from an on-site power house and raw water from a local source. Shipping is done by boat and rail.

The plant consists of three main production lines, the last of which was commissioned in 1977. As of May 1990, the plant was allowed to purchase equipment with up to 50% of the hard currency earned by product exports. As a result, plant staff are actively engaged in a facility modernization program. Moreover, the plant has relatively strong program in energy training, maintenance, efficiency, and conservation. These programs enables plant managers to offer incentives and levy penalties to encourage efficient energy utilization.

Liquid pollution is a problem recognized by the plant, although they have not yet determined how to deal with this issue. There is a substantial amount of material (calcium slurry of hydroxide, calcium chloride, brine) sent to a large sludge pond. The liquid overflow goes to a canal, and then to the Black Sea. The canal is periodically dredged, and the sludge removed for land fill.

An engineering evaluation of the brine electrical controller of the system pump was conducted by the Audit Team, and a preliminary design scheme for disposing of a polluting nitric oxide -nitrogen dioxide stream from the Synthetic Fertilizer Plant was discussed.

Tables 2 through 6 outline key raw material, production, and energy consumption figures for the plant.

Table 2. Raw Material Consumption at the "Sodi" Soda Ash Plant.

Materials	Consumption/ per year	Origin	Transfer Method	1990 Price lv/t (m^3)
Limestone	1,293,600 t	Quarry	Cable line	8.65 lv/y
Crude brine	5,752,800 m^3	Solution	Pipe line	8.9 lv/m^3
Amnonia water	39,900 t	Fertilize plant	Pipe line and lorry	960 lv/t
Coke	112,420 t	Coke plants	Rail, ship	2.720 lv/t
Ammonia bisulfite	7,600 t	Chemical works	tanker	1,600 lv/t

Table 3. Raw Material Prices (as of 1991).

Material	Price 1991
Limestone	8.65 lv/t
Crude brine	9.12 lv/m^3
Ammonia water	365 lv/t
Coke	2,200 lv/t
Ammonia bisulfite	1,300 lv/t

The plant also uses recycled materials as raw materials, including 1,000 m^3 of ammonia as ammonia brine. Similarly, the plant utilizes previously used waste products, including 250 tons of slime from brine purification.

Plant energy sources include coke, wood, purchased electric current, and steam. The steam comes in turn, from the power house.

Table 4. Energy Consumption for 1990 (in GCal)

Process line	Unit	Quantity
Lime	GCal	10,978
Soda ash light	GCal	2,11,562
Brine purification and chemical water treatment	GCal	2,219
Dense soda	GCal	59,212
Sanitation	GCal	18,350
External consumers	GCal	10.968
Total	GCal	2,217,289

Table 5. Electricity Consumption for 1990 (in KWh)

Process unit	No. of KWh
Lime	11,747,100
Soda	68,836,990
Brine purification and chemical water treatment	4,924,740
Water, steam, gas and brine supply unit	35,391,860
Limestone Quarry	7,050,874
Others	1,067,700
Lighting	4,458,202
Losses	4,100,000
Total	137,577,466

At the time of the audit, approximately 60% of the cost of the final product was made up of energy input expenses.

Table 6. Major Consumers of Energy Per Unit of Output

Type of Energy	Unit	Quantity	Current Price 1991
1. Electricity	KWh	133 KWh/t	273 lv/1000 KWh
2. Heat	GCal	2.35 GCal/t	202 lv/GCal
3. Coke	ton	0.1064 t/t	2,200 lv/t

NOTE: Measurement and testing results from the April energy audit are included in **Appendix V.**

Energy Usage for 1990

An energy balance that includes all energy usage is prepared monthly at the plant, comparing usage with standards. In addition, all changes and expansions are noted. Electrical energy statements are prepared quarterly and submitted to the State Inspectorate for Energy Utilization, as is an annual report.

There is a nationwide energy savings contest held by the Inspectorate with monetary awards to the best performers when money is available. The Soda Ash Plant has received this award in the past. A sophisticated program of electrical measurement and data collection has been designed, which consists of supervising 160 points of usage, with every shift having information from these 160 points. After the annual report, monetary awards will be made to the best performers. This design was done in Bulgaria at a cost of 500,000 levas cheaper than an

estimate offered by an outside firm. This system is expected to be in service by the end of 1991. A similar system for all energy usage is envisioned.

3. ENERGY MANAGEMENT

3.1 Energy Management Structure

Energy usage at the plant is controlled by engineers in the sub-stations, where usage data is recorded every hour. Every ten days an electrical balance report is issued, and at the end of the month a total balance is prepared. All usage must be in conformity with the loadings submitted by the energy authorities at the beginning of the year. Variables such as KWh/per ton of soda ash are monitored, with the daily, peak, and nighttime rates given for electricity. This rate of power consumption is regulated by authorities for the whole plant and must be divided into usage for the different units, including complete handling of all aspects of soda ash production.

A standard unit of usage for each production area is set, and measurements taken to assure compliance. At the end of the month, usage is reviewed at a meeting of the Energy Utilization Committee, compared to standards, and reviewed with the plant management; if significant deviations are noted, responsible parties are requested to explain these. At these meetings, proposals for improvement, change, or modification are discussed and submitted to the technical department for appraisal and recommendations. Another committee, which includes the plant manager, inspects the plant twice a month for obvious energy losses. The plant management cooperates fully with the program, and fines are levied for wasteful energy practices.

3.2 Energy Management Seminar

Recognizing the importance of energy management in determining the overall efficiency of industrial energy use, the Energy Conservation Audit Team presented a seminar at the "Sodi" plant which addressed a number of energy management issues. Recommendations presented in the seminar were designed by team members 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. For example, such a mechanism might require the purchase 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; and

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 dealt with in more detail at the January 1992 Energy Management Workshop in Sofia, at which a representative of "Sodi" made a presentation. An excerpt of the presentation on energy management practices made by Mr. Barry Tunnah at this seminar is included as **Appendix IV**.

3.3 Training Requirements

Personnel training at the plant is under the direction of Mrs. Gradeva. The main influx of personnel is from the two major vocational schools in the area. The Soda Ash Plant also sponsors a school in Devnia to train people in various basic scientific and mechanical areas; this training can last up to three years. The operating plant is used as a laboratory for on-the-job training in conjunction with the school. An employee that does not attend the company school, but is hired based on other training, completes a one-month training course and apprenticeship. During this time, employee knowledge is assessed through observation and interview. Based on results of this assessment, an individual is assigned one of three levels of pay. Individuals are not limited to one area of expertise, and can qualify for several post-graduate training courses in each area of specialization.

Normally, one fourth of the staff attends a training program annually. Refresher courses for major managers are also available, as well as language courses for those who desire them. Twice a year, management receives reports on training of the staff. The training program appears to have had great success in the past.

As outlined in the energy management seminar, training in energy awareness, economics, and energy cost accounting are crucial elements in assuring plant 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:

energy cost accounting - this type of training would be particularly useful if it involved learning practical skills related to the use of software packages in energy cost accounting. Even if it is not possible to purchase and use more sophisticated computer accounting programs, plant personnel can learn the basic tools used to maintain solid cost-accounting standards within the plant.

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

The seminar also highlighted other issues to be included in future plant training programs. The Energy Conservation Audit Team recommended that emphasis be given to developing an energy ethic in all plant personnel by touching on topics covered in the seminar given at the plant. Awareness of the importance of energy conservation, combined with the appropriate technical knowledge, will help promote an energy ethic within the plant and subsequently enhance energy savings.

4. ENVIRONMENTAL CONSIDERATIONS

Large volumes of liquid wastes containing suspended and dissolved solids are produced in the Ammonia-Soda Plant. The largest volume of waste is produced in the distiller operation, where for every ton of product soda ash, nearly 10 m^3 of liquid waste is produced, containing about one ton of $CaCl_2$ one half ton of NaCl, and other insoluble impurities. Traditionally this liquid waste, after settling of suspended solids in large basins occurs, has been discharged into local waterways.

An area of 1,500,000 m^2 is being used as the settlement basin. This pond is about seven kilometers from the soda ash facility and transfers to it are made by two pumps of 2,000 m^3/hour total output. There are five lines available for this transfer, and two are used at a time; extra lines are necessary due to corrosion on the pipe lines. Material is introduced into one side of the basin and allowed to flow to the opposite side with solids settling in the movement. It has a clear liquid overflow with a pH level of 9-10. The solid material that has settled has a dark grayish color which is due to material discharged from the Power Plant. The overflow is about 1.5 m^3/second with additional allowance for rain. As solids rise, this overflow is added to, about 1 m of liquid on top of the solids at the overflow area. There are a few stand pipes erected inside the basin to check the depth, which increases as the solid depth increases. This facility began as a natural basin, but during the past 17 years walls have been built with clay and limestone around two sides. The basin continued to be used until 2005, under current plans.

Geological and hydrological studies have been done at the site, and will be use to locate monitoring wells.

5. ENERGY EFFICIENCY IMPROVEMENT OPTIONS

Listed below are options for improving energy efficiency use within the plant. Clearly, all these practices and projects will help conserve energy in the facility. However, given the reality of scarce resources for implementing these projects, the IRG Audit Team made specific recommendations that some of these options be given priority. This prioritization is included in the Recommendations and Conclusions section. Nevertheless, this section outlines the wide variety of options that are available for energy efficiency improvement. The ultimate decision regarding implementation of alternative options will depend upon criteria set by the plant management, including acceptable payback periods, and upon the overall corporate strategy.

Investment requirements, energy savings, and the value of energy savings were prepared by plant staff, with investments expressed in US dollars.

5.1 No Cost Options

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

1. **Introduce a strict schedule for washing the tubular coolers.** Tublar coolers should be washed with water and CO_2, including soda furnace gas coolers, carbonization and absorption columns, distillation column gas coolers, and trickle coolers for ammoniated brine.

2. **Maintain an average temperature of the carbonization column.** Temperatures should be maintained between 56 °C and 59 °C; outside this range, the conversion of brine and formation of sodium bicarbonate decreases. This "no cost" initiative has an estimated input savings potential of 1 % of brine, valued at 200,000 lv/year.

3. **Initiate regular washing of the steam calcination heater tubes at three month intervals.** This project has an estimated energy savings potential of 675 Gcal/year, with attendant cost savings of 136,000 lv/year.

5.2 Low Cost Options

The second category of options are considered "low cost" items, which involve higher expenditures, including some hard currency costs. Team members recommended that some of these items be procured with the assistance of the USAID Emergency Energy Program. Itms in this category will have a rapid payback period. Equipment specifications for items to be purchased under the USAID project are given in **Appendix II.**

1. **Maintain gas temperature after the distillation column condenser below 69°C to conserve energy.** The estimated cost for this project is $23,000 for all 11 control valves; estimated energy savings are 1,800 GCal/year. Cost savings would be approximately 363,000 lv/year, with a payback period of just under one year.

2. **Provide variable speed control for one of the three brine-reservoir feed pumps.** A level indicating modulating controller and variable frequency could control the brine reservoir feed such that power will be saved by pumping no more brine than is required by the process; a controller for one of three pumps is required. Pump Speed will be controlled a 160 KW synchronous motor through variation of the electrical frequency (Hertz). Total estimated cost of this project is 675,000 lv, with estimated energy savings of 650,000 KWh/year, and energy cost savings of 299,650 lv/year at July 1991 electricity prices. In addition, the Soda Ash Plant agreed to co-finance this project with A.I.D., reducing their payback period for the investment to 1.3 years. With energy price increases, the payback period is expected to decrease.

3. **Purchase two portable analyzers.** These analyzers to be paid for by the plant would provide more accurate measurement of flue gases, and would cost approximately 150,000 lv.

5.3 Capital Intensive Options

This category includes items the Soda Ash Plant should consider to maintain the long-term viability of the plant. These recommendations are not restricted to energy conservation issues; costs and savings for these investments have been estimated by the plant.

1. **Desuperheat the steam** at 35 atm. and 450 °C to the tubular calciner heaters, utilizing condensate at 120 °C and 1.5 atm. of pressure. Seven lines of desuperheaters are to be equipped, primarily with existing equipment. Further, seven condensate injection valves should e added , with an inlet pressure of approximately 40 atm., and a discharge pressure of 34 atm. at 120° C; the flow rate of condensate is approximately 4.2 metric tons/h. The valve would be actuated by a temperature controller providing between 0.2 to 1 atm. air pressure. Valves should to be the throttling type -- hard or stellate faced -- and must be capable of withstanding 65 atm. inlet pressure. This flow rate will produce about 32 tons/hour of steam at 34 atm. and 270 °C in a line 50 mm in diameter. The estimated cost of this initiative would be 2,010,000 lv, with estimated cost savings of 800,000 lv/year and a payback period of 2.5 years.

2. **Automate control system for the first process line in the Absorption and Distillation Plant.** This project has an estimated cost of 2 million lv, and would save an estimated 500,000 lv/y, with a payback period of 4 years. The Soda Ash Plant would make this investment as 2 MM lv, and the construction would take two years.

3. **Automated product storage.** This project would maintain plant efficiency and operation when a soda ash furnace has to be repaired. Construction time would be three years, with an estimated cost of $1.37 million and 27 million lv.

4. **Install an additional smaller soda-ash furnace to increase production capacity.** The estimated cost of this project is $137.5 million lv, and would take four years to construct. Estimated product savings would be 44,000 tons/year, estimated cost savings would be 68 million and would include a lv, payback time of approximately 2 years.

5. **Install a thermal compressor for heat recovery from waste distillation fluid (for recovery of steam and reuse).** With a construction time of one year, estimated capacity would include 27 tons/h of steam suction minus 1,800 mm water, a discharge of 1.5 atm., and 3,000 KW. Estimated cost would be 36.25 million lv., with savings of 15 million lv/year, at a payback period of 2.4 years.

6. **Replace existing bicarbonate filters.** Initially, replace two filters with those made by "Klokner Humboldt Deutz" or equivalent. These will provide lower water content of the filter cake about 12.5 -13.5 weight % water, and have a capacity of 600 tons/day. The estimated cost is approximately 33 million lv, with estimated savings of 1,000,000 lv/year, and a payback period of 33 years.

6. RECOMMENDATIONS AND CONCLUSIONS

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

6.1 Improved Energy Management Practices

The first priority area for corporate management at Sodi should be the expansion of existing training initiatives to improve energy efficiency awareness, data collection techniques, energy cost accounting, and investment planning capabilities.

In conjunction with improved training, management should establish energy management criteria, including minimum acceptable investment-payback criteria and incentive/disincentive schemes to encourage energy savings. In addition, management should attempt to conduct a comprehensive evaluation of all investment options, both low cost and capital intensive to determine:

- cost of the required investment; and
- payback on the investment (in terms of energy saved, losses avoided or production increased) to prioritize investment opportunities.

6.2 Improved Operating Practices and Operational Changes

The following recommendations reflect changes in operating practices, housekeeping, and maintenance, and can yield significant energy savings with minimal investment cost. These recommendations include focusing attention on equipment maintenance, controls, and instrumentation.

1.	**Equipment Maintenance**	Maintain an average temperature of the carbonization column. Temperature should be kept between 56 °C and 59 °C; outside this range, the conversion of brine and formation of sodium bicarbonate decreases. Also, initiate regular cleaning of the steam calcination heater tubes at three month intervals, and maintain gas temperature after the distillation column condenser below 69 °C to conserve energy.
2.	**Controls**	Purchase and install variable speed controls for one of the three brine-reservoir feed pumps.
3.	**Instrumentation**	Purchase and install two portable analyzers.

6.3 Recommended Capital Investments

Equipment to be Purchased Under the Emergency Energy Program

1. Level Indicating Modulating controller
2. Variable Frequency Device

Details on the specifications and justifications for these items are included in **Appendix II.**

Other Recommended Capital Projects

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

1. **Flue Gas Analyzers** — These low cost items would help the plant monitor oxygen, carbon monoxide, carbon dioxide, sulfur dioxide, and nitrogen oxide contents of flue gases to improve combustion efficiency.

2. **Feasibility Studies** — Sodi should initiate a comprehensive investment evaluation program to assess and prioritize the major capital investments listed above.

APPENDIX I.

MEETING PARTICIPANTS
APRIL 1991
"SODI" SODA ASH PLANT

Name	Position
I. Bochukov	General Director
K. Penev	Deputy General Director/Chief of Research & Development
A. Apostolov	Chief Power Engineer
A. Ts. Penkov	Chief of Control and Automation Dept.
I. Ilev	Chief of Department
K. Yordanov	General Director - retired
K. Bankov	Chief of Department - retired
N. Nikolova	Inspector of Environment Protection
P. Grandeva	Director - Staff Training Department
N. Mateev	Chief of RECI-Varna
G. Stefanov	Deputy of Chief RECI - Varna

All participants in the meeting at the Sodi plant had participated in energy cost studies, however, with the exception of the IRG Audit Team members and subcontractors, none of the participants spoke English.

RECI - Regional Energy Conservation Inspectorate

APPENDIX II.

EQUIPMENT SPECIFICATIONS AND JUSTIFICATIONS FOR PURCHASE OF EQUIPMENT

"SODI" SODA ASH PLANT, DEVNIA

These equipment specifications and recommendations are for low cost items to be bought with US currency under the Emergency Energy Program. 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 appropriate batteries and/or chargers must also be provided. Complete units with all parts for operation are to be supplied for use in Bulgaria. Any parts that would be provided by other vendors, should be specified. All warranties and terms and required sketches for interpretation of proposal are to be provided with proposal.

It is recommended that two complementary items be procured for the Polychim Soda Ash Plant.

Estimated cost	$45,000
Estimated energy savings	650,000 KWh/y
Estimated cost savings	299,650 lv

1. **A level indicator/modulating controller in saturated brine.** Service at ambient temperature, to indicate and maintain the level of brine in a tank constant to within +/- 10 cm. by transmitting an electric signal to an indicating level controller, located in a control room. This starts and controls the output to the tank of brine from a pump, by a variable frequency regulator. Since the solution is saturated, a small decrease in temperature can result in solids depositing on any sensing element or lining espoused to the brine, which is also corrosive to carbon steel, etc. The vendor should take this into account in his proposal for a suitably designed sealed, no recessed D.P. cells, sonic devices, etc. will be considered. Air at 0.2 - 1 atm. (dry) is available, as also electricity 220 Volts, 50 Hertz. The tank is epoxy lined carbon steel, 3 meter diameter, flat top and bottom. Height (total) 3.0 meters. The brine level is to be maintained at 2.0 meters above the bottom. A 159 mm I.D. nozzle is available near the tank bottom and a large nozzle at the top. A full range indicator is desired with 99 % accuracy, particularly at the normal liquid level. The specific gravity of the brine normally is 1.21. Parts in contact or exposed to brine, shall be 316 S.S. or better. The transmitter is to have 24 Volts D.C. and have an output of 4-20 Milliamperes. Electrical code is I.E.C.67. Sonic devices and controllers (only as an example) include "Ninosonic DU 40", by "Endress and Hauser", and controller 6 DR 1012-INJ43 by "Siemens". Vendor shall specify whether its equipment has been used in such a service. Metric units only.

2. **Variable Frequency Device** to control the speed of a brine pump driven by a 160 KW synchronous motor. Normal speed is 3 000 R.P.M. Power is 380-415 Volts, 50 Hertz. The input signal shall be from the above (item 1) level controller at 4-20 Milliampere. Controller type 7,920 manufactured by "Lenze" or equivalent is suitable, range 1-100 Hz, optimum - 50Hz. Indoor location, provide dust protection. Submit information (proposal) to plant on both items (1, 2) before ordering "Lenze" representative in U.S. is at 311 Rte, 46 West, Fairfield, N.J.

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

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 Hi 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 Short 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
2.2.4 Check Steam Traps for Proper Sizing and Operation
2.2.5 Match Distribution System and Users as Closely as Feasible Use Desuperheaters Where Hot Steam not required
2.2.6 Leaks

2.3 Heating and Ventilation

2.3.1 Thermostats
2.3.2 Central Units
2.3.3 Secondary Entrances, Double Windows
2.3.4 Efficient Units
2.3.5 Hot Condensate Usage
2.3.6 Insulation
2.3.7 Idling Engineers

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

2.6 Refrigeration

2.6.1 Match Demand with Supply Temperature Wise Avoid Large ΔT's

2.6.1.1 Economizers, Pump Liquid

2.6.2 Multi Stage Centrifugal, Utilize Intermediate Stages
2.6.3 Avoid Hi Discharge Pressures

2.6.3.1 Vent Non-Condensibles
2.6.3.2 Use Right Condenser Coolant

2.6.4 Avoid Hi ΔP's and Drops Across Valves
2.6.5 Avoid Hi Press. Drop in Low Press. Lines
2.6.6 Use Low Stage Diffuser Vanes
2.6.7 Insulation
2.6.8 Hi Efficiency Motors
2.6.9 Adequate Liquid in Evaporator
2.6.10 Right Refrigerant

2.7 Air Compressors

2.7.1 Hi 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 ΔT's and ΔP'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

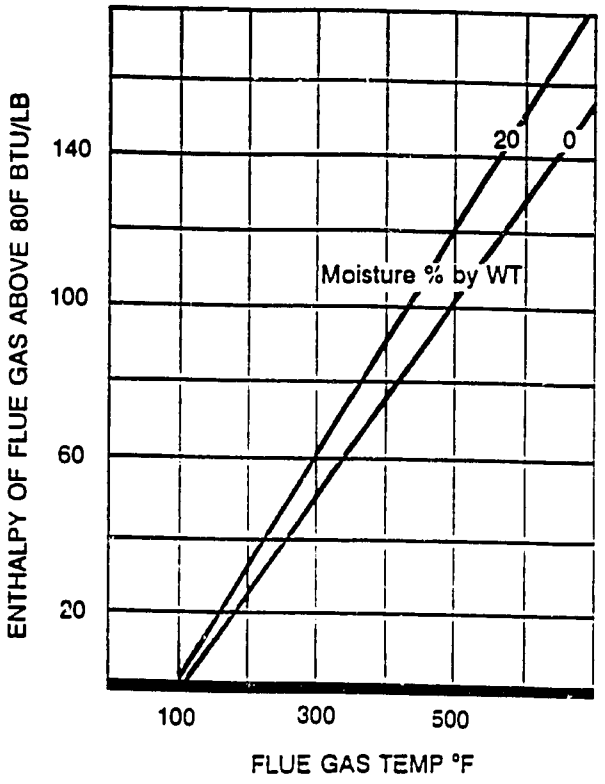
3.1.1.1 Steam, Elec., Util.

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 Cornmittee
3.1.4.2 Contests - Recognition - Rewards


ENTHALPY OF FLUE GAS ABOVE 80F BTU/LB
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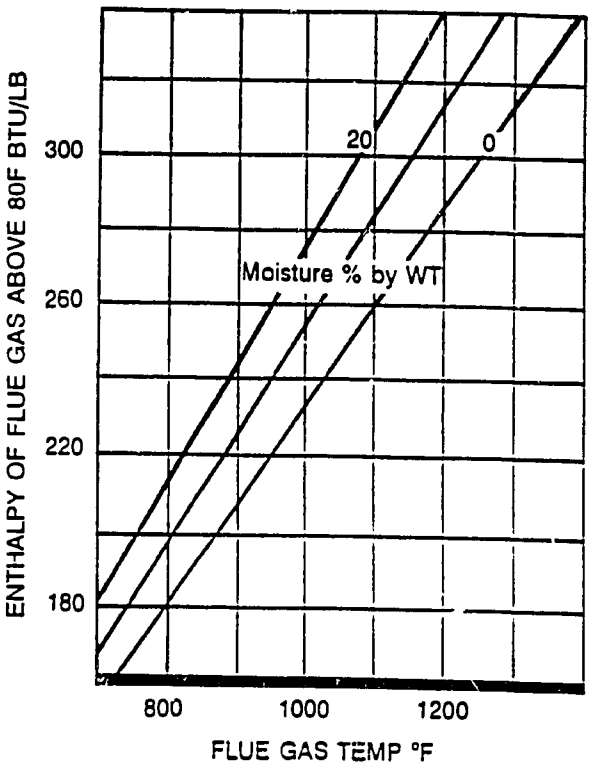
100
60
20
20
0
Moisture % by WT
100
300
500
FLUE GAS TEMP °F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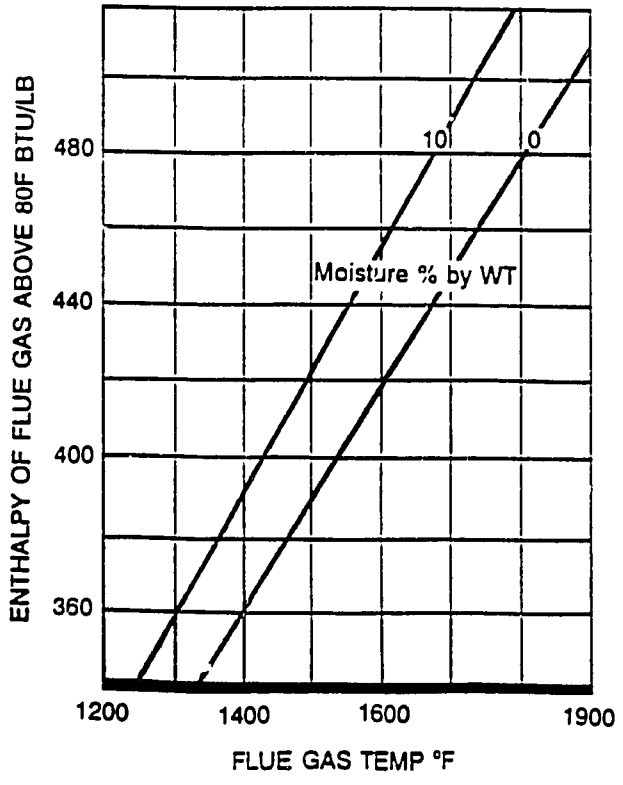
220
180
20
0
Moisture % by WT
800
1000
1200
FLUE GAS TEMP °F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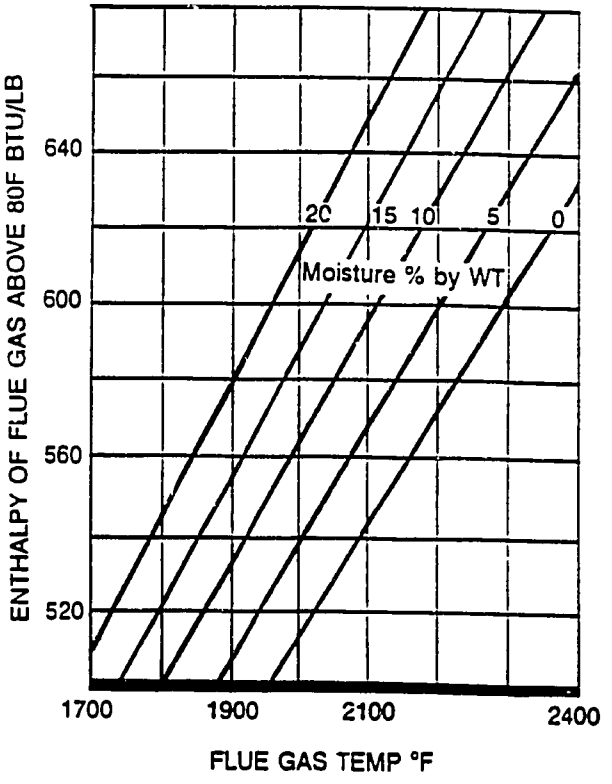
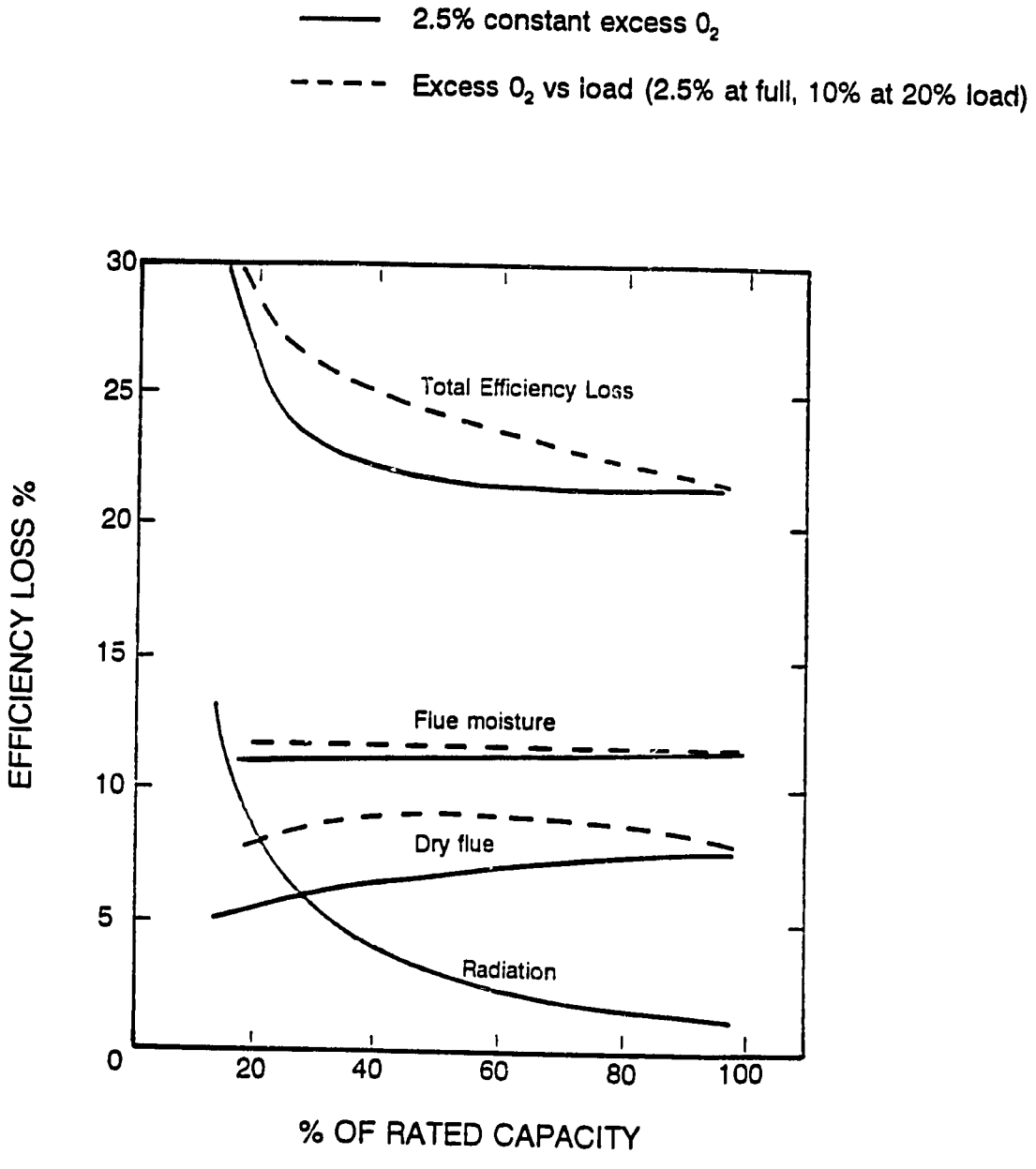
440
400
360
10
0
Moisture % by WT
1200
1400
1600
1900
FLUE GAS TEMP °F


ENTHALPY OF FLUE GAS ABOVE 80F BTU/LB
640
600
560
520
20
15
10
5
0
Moisture % by WT
1700
1900
2100
2400
FLUE GAS TEMP °F

VARIATIONS IN BOILER EFFICIENCY LOSSES WITH CHANGES IN FITTING RATES



APPENDIX IV

"ENERGY MANAGEMENT PRACTICES"

EXCERPT OF A PRESENTATION

BY MR. BARRY TUNNAH

AT THE

ENERGY MANAGEMENT WORKSHOP

SOFIA, BULGARIA

JANUARY 1992

ENERGY MANAGEMENT PRACTICES: A BRIEF REVIEW

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:

	Ratio LHV/HHV
Natural gas	0.90
Fuel oil	0.94
Coal	0.98
Electricity	1.00

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. 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 2these 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 convention 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 ton 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:

	E monthly energy use toe/month	P monthly production tons/month
1	340	380
2	340	440
3	380	460
4	380	520
5	300	320
6	400	520
7	280	240
8	424	620
9	420	600
10	400	560
11	360	440
12	320	360
13	340	420
14	372	480
15	380	540
16	280	280
17	280	260
18	380	500

* 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:

	E act	P	E calc	Eact-Ecalc	CUSUM
1	340	380	332	+8	+8
2	340	440	356	-16	-8
3	380	460	364	+16	+8
4	380	520	388	-8	0
5	300	320	308	-8	-8
6	400	520	388	+2	-6
7	280	240	276	+4	-2
8	424	620	428	-4	-6
9	420	600	420	0	-6

10	400	560	404	-4	-10
11	360	440	356	+4	-6
12	320	360	324	-4	-10
13	340	420	348	-8	-18
14	372	480	372	0	-18
15	380	540	396	-16	-34
16	280	280	292	-12	-46
17	280	260	284	-4	-50
18	380	500	380	0	-50

* 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:

$$\frac{44 \times 100}{\text{energy use in months 12-18 (2352 toe)}} = 1.9\ \%$$

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

FOR CALCINER	AMBIENT AIR
CO_2 - 53 %	NH_3 - 0.6 %
CO - 3 %	CO_2 - 2 %
H_2S - 1.5 %	CO - 1 %
O_2 - 8 %	H_2S - 1 %
NH3 - 3 %	NOx - ppm - 1 %
INERT REMAINDER	SO_2 - 2 %
	DUST - 10 mg/liter
	O_2 - in air
	N_2 - in air