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ENERGY EFFICIENCY AUDIT REPORT
KREMIKOVTZI STEEL COMPANY
COLD ROLLING MILL

Sofia, 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

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LIST OF ACRONYMS/ABBREVIATIONS

A.I.D.	U.S. Agency for International Development
atm	atmospheres
°C	degrees Celsius
GCal	giga-calories
IRG	International Resources Group, Ltd.
kWh	kilowatt hours
lv	levas; Bulgarian unit of currency-at the time of audit, 15 lv = U.S. $1
m^3	cubic meters
nm^3	normal cubic meters
PPM	parts per million
PVC	poly vinyl chloride
tn	tonne

ACKNOWLEDGMENTS

The Energy Conservation Audit Team of the International Resources Group, Ltd. (IRG) wishes to acknowledge assistance provided by the Bulgaria 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 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:

<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

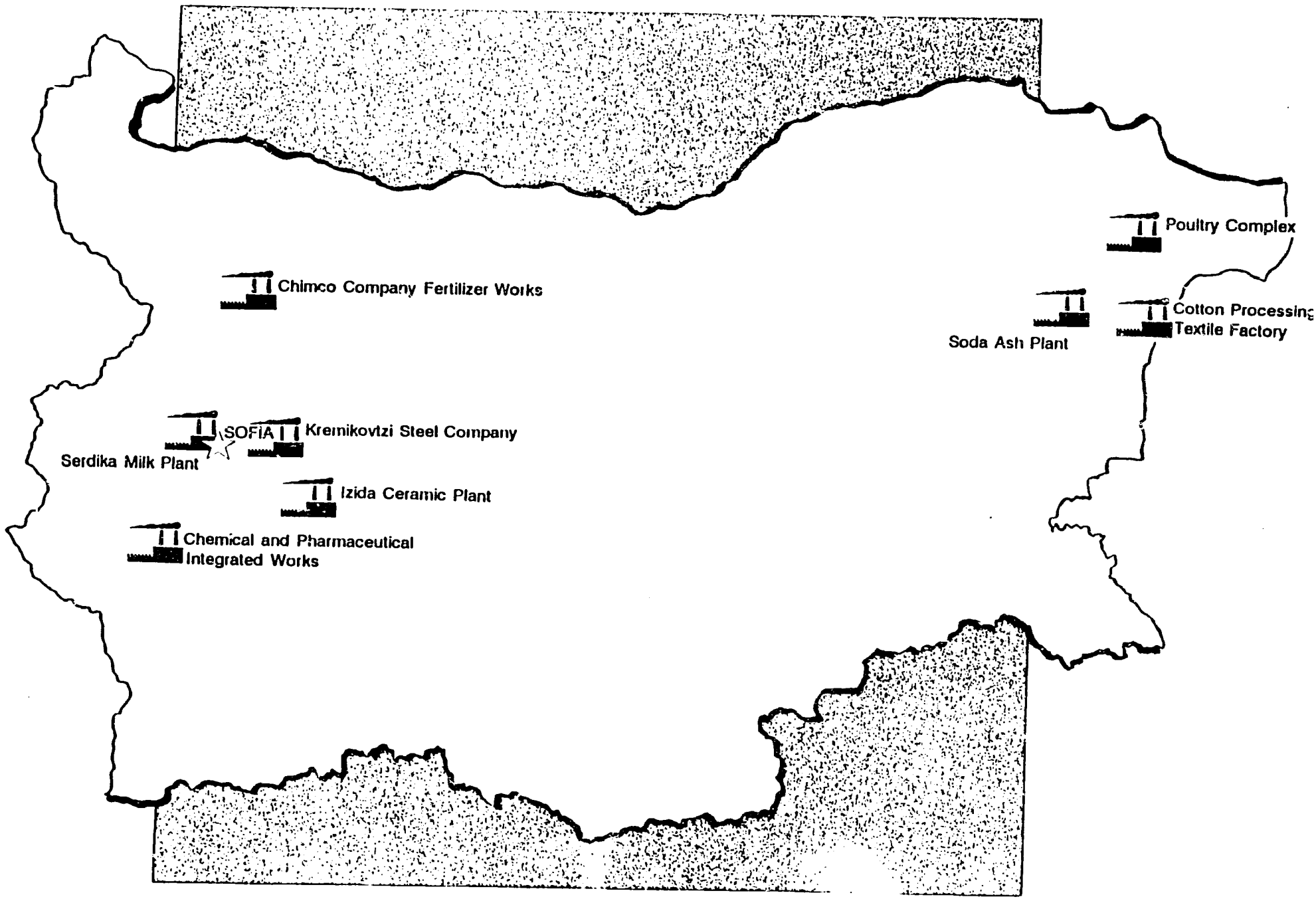


Figure 1. Location of eight industrial plants audited by tl G team.

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 the need for reforms that encourage energy conservation and improved economic efficiency.

1. EXECUTIVE SUMMARY

The IRG Energy Conservation Audit Team visited the Kremikovtzi Steel Company in April 1991 to implement the energy audit phase of the industrial energy conservation program conducted under the A.I.D. Emergency Energy Program.

Team objectives during the audit were to identify short- and long-term energy conservation opportunities, develop estimates of the quantities of energy that could be saved, estimate costs of energy lost, conduct a seminar on energy conservation for plant staff, and to train seminar participants in the use of the energy measurement instruments brought from the United States.

Team members concentrated efficiency efforts on Kremikovtzi's cold rolling facility, since there was not sufficient time to audit the entire company. The Team chose to focus on the cold rolling mill because opportunities for energy savings there seemed to be extensive.

The principal facilities at the Cold Rolling Complex are a steel strip rolling, cutting, and trimming line, a zinc plating (galvanizing) line, two acid pickling lines for the rolled steel plate, a tinning line, two continuous annealing furnaces, a large facility consisting of 47 Bell Furnace-type batch annealing furnaces, and a polyvinyl chloride (PVC) coating line.

At the Cold Rolling Complex, the primary fuels used are coke oven and blast furnace gas, which are produced within the complex itself. Management staff of the Cold Rolling Complex expressed an interest in the possible future use of natural gas. Currently, Kremikovtzi uses 171 million kilowatt hours (kWh) of electricity, 46 million m^3 of coke oven gas, and 57 million m^3 of blast furnace gas annually. Electric energy prices for the plant range from the peak rate of 560 lv/thousand kWh to 120 lv/thousand kWh.

Low-cost opportunities for energy conservation were identified by the Energy Conservation Audit Team and principally involved improvements in the use of thermal energy, of which annealing furnaces are thee principal users. Each furnace discharges high-temperature combustion gases into the atmosphere without energy recovery. Opportunities for saving thermal energy included improving combustion efficiency by reducing excess air supplied to the burners, adding piping insulation, using local heating units for work stations rather than heating the entire building in the winter, replacing broken building glass panes to reduce heat losses, and reducing losses from steam compressed air and hot water through improved maintenance and housekeeping.

Specific recommendations for energy savings included:

- instituting a policy of loading production facilities during off-peak periods;
- closing the metallurgical facilities which were idle under a program of reduced production;
- loading the large synchronous motors, operating as much as possible for partial compensation of the low power factor, and adding capacitor banks for further power factor compensation;

- optimizing the power supply circuit of the rolling mill and de-energizing as many as possible of the under-loaded transformers; and

- reducing the electrical power for illumination by splitting the lighting circuits, installing high pressure sodium vapor lighting, and cleaning all glass panes to reduce the electric power required for artificial lighting.

Results of the Emergency Energy Program, Industrial Energy Efficiency

New equipment and instruments were purchased by IRG under the A.I.D.-funded Emergency Energy Program. Items purchased included:

- Emissions Gas Analyzes
- Mass Flowmeter
- Portable Gas Velocity Measuring Device
- Steam Leak Detector/Industrial Stethoscope

Additional capital-intensive recommendations were made for implementation outside the scope of this project, and are summarized in **Table 1**.

Table 1. Summary of opportunities for energy savings, Kremikovtzi Steel Company

I. "No Cost" Energy Savings Measures Evaluated	Investment Required (000 lv)	Energy Savings KWh/yr (000) or GCal/yr	Value of Energy Savings (000 lv)	Payback Period (years)	Recom's
1. Energy Management Program/Personnel	0*	-	-	-	yes
2. Load Management	0*	9,500	27,000	-	yes
3. De-Energize Idle Facilities	0*	2,000	560	-	yes
4. Maximize Loading of Synchronous Motors (Power Factor Improvement and Reduced Penalty)	0*	-	500	-	yes
5. Optimize Power Supply Circuit	0*	500	200	-	NEI
6. Lighting Improvements	425	2,200	920	.5	yes
7. Adjust operation of thermal units	-	412 GCal	-	-	NEI
8. Increase degree of fuel gas heat utilization	0*	-	1,200	-	yes
9. Insulate plant pipe lines	0*	-	500	-	yes
10. Use spot heating units	0*	-	700	-	yes
11. Repair Steam Leaks at Packing Glands, Joints Faculty Steam Traps, Etc.	0*	-	10	-	NEI
12. Use hot cooling air from continuous annealing furnaces as combustion air	-	-	-	-	NEI

II. "Low Cost" and Capital Intensive Energy Savings ⟵ Measures Evaluated	Investment Required (000 lv)	Energy Savings KWh/yr (000)	Value of Energy Savings (000 lv)	Payback Period (years)	Recom's
1. Improve Combustion Efficiency in boilers/furnaces. Purchase flue gas analyzer	90	2.4 g + 2,700 KW	690	.1	yes
2. Install a Combustion Meter	-	-	-	-	NEI
3. Install a Flow Meter	90	-	90	1	yes
4. Install a Portable Gas Velocity Meter	45	-	-	-	yes
5. Install a Steam Leak Detector	7.5	-	-	-	yes
6. Install a Relative Humidity Gauge & Draft Gauge	-	-	-	-	NEI
7. Investigate Bell Furnace Projects	3000	15,500 GCal	1,500	2	NEI
8. Recover heat in continuous annealing furnace flue gases	1050	-	690	1.5	NEI
9. Connect flue gas ducts in continuous annealing furnace in a series	-	-	-	-	NEI
10. Install a system for automatic evaluation, monitoring, control of enurgy	150,000	-	-	-	NEI
Total	154,707.5	-	34,560		

NEI - Not enough information available about key investment parameters, including management payback requirements, etc. at the time of the 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 investment must be conducted before investment funds are allocated.

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

* These are "no cost" investments as defined in the "Energy Efficiency Improvement Options" section.

2. PLANT BACKGROUND

This section will provide an overview of the cold rolling facility at the Kremikovtzi Steel Company in Sofia. Relevant statistical data production and energy usage by the facility in 1990 are presented below.

The Cold Rolling Complex is composed of three primary plants, which include steel strip rolling, cutting and trimming line; a zinc plating (galvanizing) line; two acid pickling lines for the rolled steel plate; a tinning line; two continuous annealing furnaces; a large facility consisting of 47 Bell Furnace-type batch annealing furnaces; and a polyvinyl chloride (PVC) coating line.

Major fuels used at the complex are coke oven and blast furnace gas, all produced within the facility itself. The facility uses 171 million kWh of electricity, 46 million cubic meters (m^3) of coke oven gas, and 57 million m^3 of blast furnace gas annually. Electric energy prices for the plant range from the peak rate of 560 lv per thousand kWh to 120 lv per thousand kilowatt hours (kWh).

In Plant Number 1, the steel roll is continuously cleansed by a chemical treatment (pickled) in two lines, one employing sulfuric and the other hydrochloric acid. Plant Number 2 consists of a cold strip mill designed to continuously temper steel strip (0.4 -2.5 mm thick x 600 -1550 mm width). In addition, there are a number of batch annealing furnaces (Bell-type) that burn coke oven and blast furnace gas and heat the steel plate, shrouded in a steel casing containing a protective inert atmosphere of gas, to a temperature of 650 - 710° C. The heating and cooling cycle is periodic and variable; hot gases are exhausted to the atmosphere and represent a significant waste of energy.

Plant Number 3 within the Cold Rolling Complex contains a continuous cold strip mill, with a rolling plate 0.18 - 0.6 mm thick x 500 - 1050 mm wide. This rolling plate goes through a continuous annealing line, where the strip is heated to 600 - 650° C in a nitrogen-hydrogen atmosphere and then cooled in intervals to 65° C. Purified coke oven-gas burners supplement the radiant heat input. From there, annealed rolls of metal undergo further rolling for tempering in a skin pass mill before passing through a heating line of 450° C, and on through a continuous electrolytic tinning line (American design).

This Plant also includes a continuous hot-dip, zinc-plating line. The plate passes through two furnaces, including a preliminary furnace that heats coils of metal in a protective atmosphere to 450 -650° C using coke oven gas heat. Zinc is applied at about 450° C (in a protective gas atmosphere); the metal is then annealed in another furnace at 450 - 460° C, using coke oven gas as fuel.

At the time of the audit, plant staff had already taken steps to conserve energy, including shutdown of the metallurgical facilities, which under the conditions of the reduced production program were idle. This initiative resulted in an energy savings of 560,000 lv. Similarly, plant management increased the degree of fuel-gas heat utilization through the heat-recovery boiler K20, installed in the Continuous Hot-Dip Galvanizing Line. Savings resulting from this action were more than 1.2 million lv.

2.1 1990 Production

The 1990 production figures are presented in **Table 2.** Plant management was concerned about the production for 1991 given existing shortages of ore and pig iron, as well as the shortage of all types of energy.

Table 2. Production statistics

Type	Quantity (tons per year)
Sheet in Coils, Hot Rolled	776.000
Cut Cold Rolled Sheet	179.987
Cold Rolled Coils	38.517
Cold Rolled Sheets	38.365
Galvanized Sheet	60.103
Galvanized Coils	14.964
Profiled Galvanized Sheet	16.037
Galvanized Sheet with PVC	7.314
Galvanized Coils with PVC	16.797
Corrugated Galvanized Sheet with PVC	4.731
Tin Plate	49.695
Black Plate	9.374

Table 3 contains information about the demand for utility services, including electricity and water.

Table 3. Utilities annual consumption

	Usage	Cost (lv)	Comments
Electricity	171.0 mmKWh	170-560 *	
Natural Gas	-	-	
Coke Oven Gas**	46 mm nm^3	20.93	**Purified**
Blast Furnace Gas***	57 mm nm^3	4.93	
Drinking Water	775,000 m^3	437.16	
Fresh Water	2,921,000 m^3	35.0	
Steam	76,500 KCal	14.50	110/70 °C
Compressed Air	164,300 GCal	27.0	10 atm. 180 °C
Nitrogen	43 mm nm^3	14.0	0.45 MPa
Hydrogen	28 mm nm^3	850.0	
Oxygen	500,000 nm^3	1311.97	
Recycled Water	750,000 nm^3	375.0	
	48,689,000 m^3	35.0	

* Peak rate - 560 lv/th. KWh
Day-time rate - 280 lv/th. KWh
Night-time rate - 120 lv/th. KWh

** 4,000 Kcal/nm^3
*** 1,000 Kcal/nm^3

Prices shown in **Table 3** are from February 1991, while the new prices detailed in **Table 4** are from April 1991 and are given for reference. In addition, the electric power rate structure in Bulgaria did not include a demand charge at the time of the April audit, but a demand charge was likely to be added in the future.

In 1990, energy costs represented 40% or more of total production costs at the facility. Energy price increases, with all other things being equal, would increase the production costs per ton of product accordingly.

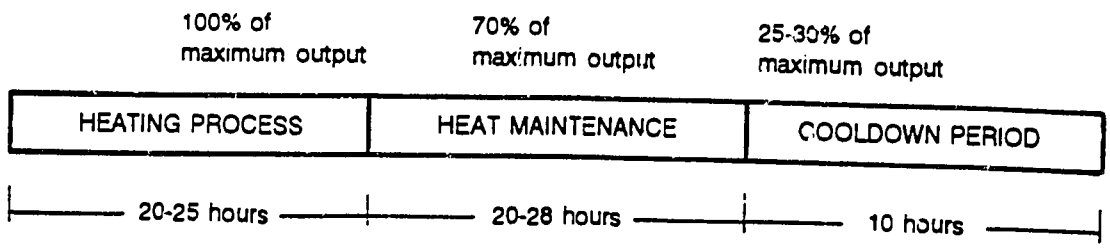
Table 4. Cost of energy resources (April 8, 1991)

No.	Resources	Unit	Avg. Consumer Price
1.	Electricity	lv/1000 kWh	314
2.	Natural gas	lv/1000 nm^3	765
3.	Coke oven gas	lv/1000 nm^3	423
4.	Coke oven gas, well-cleaned	lv/1000 nm^3	
5.	Blast furnace gas	lv/1000 nm^3	47
6.	Oxygen	lv/1000 nm^3	501
7.	Nitrogen	lv/1000 nm^3	301
8.	Hydrogen	lv/1000 nm^3	4273.58
9.	Steam -31 atm.	lv/Gcal	141
10.	Steam -10 atm.	lv/Gcal	98
11.	Steam for heating	lv/Gcal	200
12.	Hot water	lv/Gcal	96
13.	Drinking water	lv/1000 nm^3	1535
14.	Fresh water	lv/1000 nm^3	242
15.	Circulating water	lv/1000 nm^3	242
16.	Chemically treated water	lv/tn	5
17.	Fuel Oil	lv/tn	1542
18.	Compressed air	lv/1000 m^3	42
19.	Hot air	lv/1000 m^3	26

2.2 Bell Annealing Furnaces

The Bell Furnaces were designed to provide light annealing of steel strips (0.5-2 mm thick, and between 700-1300 mm wide) in a protective atmosphere (4% H_2, 96% N_2). There are 120 stands and 47 heating bells present in each furnace, and each is charged with 3-4 coils of rolling small strip. This coil stock is covered by a muffle, and cold purging is conducted on it for two hours. Following this, annealing begins. The material is heated to 690-710° C, then cooled to 125-140° C.

FIGURE 2. AMBIENT HEATING CYCLE



The heating cycle is shown in **Figure 2** above. For the first 20-25 hours, heating is at maximum output; once the appropriate temperature is reached, heat is controlled automatically at about 70% of the maximum level. During the cooling period, 25-30% of maximum heat is employed for as long as 10 hours, before all heat is removed and the material is allowed to fully cool. The mixture of coke oven and blast furnace gas burns in the space between the heating bell and the muffle at a combustion temperature of 950° C. The outlet temperature of the exhaust gas is 650-700° C. Consumption rate of the fuel gas mixture (coke + blast furnace gas) is 700 nm^3/hour. Each heating bell provides 2500-2600 nm^3/hour in exhaust gases. All heating data was furnished by the plant and was not verified for this audit.

The stand capacity was .8 tons/hour, with a calorific value of the typical mixture of 1,600 Kcal/nm^3. The standard gas pressure was 2,000 mm H_2O, and the number of burners/furnace was 16. Burner heat power was designed to be 13,000,00 Kcal/hour, and the design capacity gas consumption was 815 nm^3/hour. The average water consumption for a stands (protective gas cooling) was 5 m^3/hour, while the average protective gas consumption for a stand was 24 nm^3/hour. Finally, the protective gas pressure under the muffle was 70 mm H_2O.

Measurements taken during the April audit are included in **Appendix I**; the audit indicated that the largest deviation from normal operating parameters was found in the excess oxygen in the flue gas. Further analysis was needed to determine the optimum efficiency point for the existing burners, and whether replacement by more efficient burners would be justified. A 2.5% excess in oxygen can cause a 20% decrease in furnace efficiency, but maximum control could be realized with an in-situ analyzer. Even use of a portable oxygen analyzer, however, would yield a clear improvement.

Another source of potential energy savings was the utilization of energy in the flue gas stream that leaves the furnace. At the time of audit, gases were cooled by dilution with air vented through a stack to the atmosphere. It should be possible to recover much of this heat, but would involve a complete renovation requiring large capital expenditures.

Some thought might be given by the plant management to placing these units in a series, where hot gases from the first furnace would be directed to others. Additional makeup

gas might be needed to accomplish this task, but it would involve less than new fuel alone. Attention should also be given to increasing the surface area of the muffles to give maximum heat transfer through the shell. Finned heat exchanger tubes could be employed to increase the surface area.

2.3 Continuous Annealing and Process Line 8

The purpose of the continuous annealing process is the light annealing of low-carbon, cold roller strips (those between 0.16 - 0.5 mm thick, and 500-1050 mm wide) in a protective atmosphere (6% H_2, 94% N_2). The protective gas expenditure for this process was 800 nm^3/hour.

There are three sections to the continuous annealing and process line including the entry section (for cleaning), working section (for annealing), and the exit section (for cooling). Strip heating is performed by 84 radiant tubes with basic auxiliary burners in each one; the Energy Conservation Audit Team analyzed two of these burners. Results of the audit measurements, shown in **Appendix I**, highlight the fact that these burners were not performing at maximum efficiency (note the O_2 concentration). One burner had too much oxygen, the other not enough. The burner with low oxygen was producing carbon, noted upon the removal of the analyzer probe by discoloration of the filter on the sample line, and over-ranging of the analyzer's carbon monoxide detector. Further indication of inefficient burner operation was the number of blow-back reports observed.

The Average productive time for the burners is 6,337 hours/year. Further study of this unit would be recommended, since time did not allow the Team an opportunity to investigate further.

An analysis of the stack gas for the Bell Furnaces also was performed. While there are six vents to the atmosphere, Team members selected one at random for testing. Throughout the observations, numerous contaminants were found in the atmosphere around these furnaces.

FIGURE 3. BELL ANNEALING FURNACE

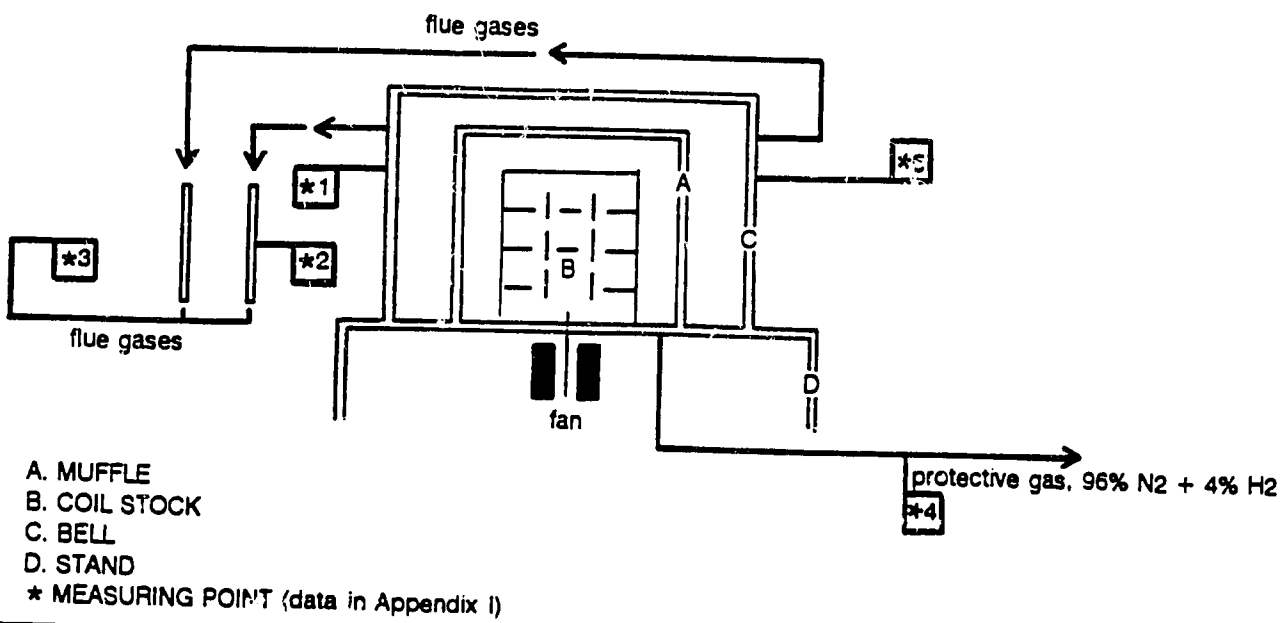
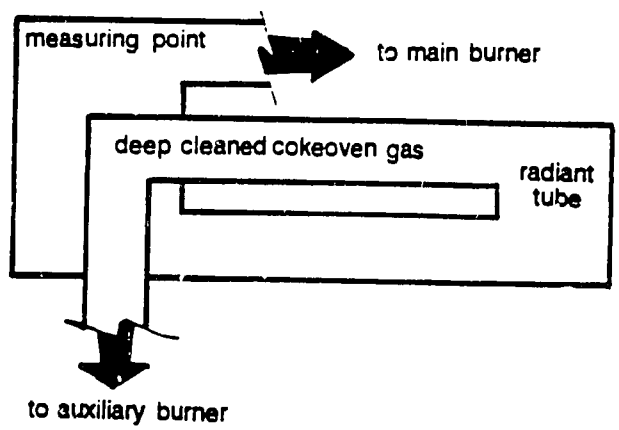


FIGURE 4. CONTINUOUS ANNEALING AND PROCESS LINE



3. ENERGY MANAGEMENT

3.1 Energy Management Structure

Managers at Kremikovtzi generally recognize the economic importance of deregulated energy prices on production costs and company competitiveness. However, attention to small, low-cost initiatives to save energy was not a priority at the plant, and there was no formal energy management structure at the plant prior to the April visit. All decisions regarding initiatives in energy efficiency were generally made at the corporate level, with little involvement from division supervisors or technicians. However, since the audit, plant management has made a concerted effort to extend training and incentive programs to include a wider cross section of plant personnel, so small maintenance and housekeeping opportunities to save energy will not be ignored in the future.

3.2 Energy Management Seminar

Recognizing the importance of energy management in determining the overall efficiency of industrial energy use, the IRG Energy Conservation Audit Team presented a seminar at the Kremikovtzi plant 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 IV.**

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, etc.;

- 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 - 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 during the January 1992 Energy Management Workshop in Sofia, at which a representative of the Kremikovtzi plant made a presentation. In addition, an excerpt of a presentation on "Energy Management Practices" given by Mr. Barry Tunnah of IRG at that workshop is presented in **Appendix VI.**

3.3 Training Requirements

As outlined in the energy management seminar, training in energy awareness, economics, and energy cost accounting are crucial elements in 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 particularly important that divisions responsible for overseeing energy utilization and energy efficiency activities, receive training in such key areas as:

- energy cost accounting - this type of training would be particularly useful if it involved practical skills training related to use of energy cost accounting software packages. Even if it is not possible to purchase and utilize 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, training in investment planning would be extremely useful if it included familiarization with the tools used in some energy investment planning programs such as the "Envest" program.

Included in future training programs should be an emphasis on developing an energy ethic in all plant personnel by touching on topics presented in the seminar. Although many were already familiar with some of the material covered in the seminar, it is fundamental to re-emphasize technical issues which enhance energy efficiency in a comprehensive manner. Awareness of the importance of energy conservation, combined with the appropriate technical knowledge, will promote an energy ethic within the plant and subsequently foster energy savings.

4. ENERGY EFFICIENCY IMPROVEMENT OPTIONS

Energy conservation opportunities were identified as either a result of test work, plant inspections, or through personnel awareness. At Kremikovtzi, there was a severe lack of instrumentation available, and hence no training program had been set up prior to the April audit that would have made operators aware of the importance of energy efficiency.

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 Energy Conservation Audit Team recommended some be given priority; this prioritization is included in **Section 5**. This section outlines the wide variety of options available for energy efficiency improvement. Ultimate decisions regarding implementation of alternative options will depend upon the criteria set by the plant management -- including acceptable payback periods -- and upon the overall corporate strategy.

4.1 No-Cost Options

For the purposes of this report, "no-cost" options refer to items which will not require hard currency, but may require small-scale local currency investments. These initiatives should be possible within the existing framework of plant expenditures (ie. leva purchases, improved maintenance, and housekeeping).

1. **Establish a high-level energy manager position in the Cold Rolling Complex headquarters office.** This position should be at the same level as Vice Manager of Production and should be provided with a small staff to complete daily monitoring and investigative activities.

   The proposed energy management office should establish energy conservation target goals; these targets would be developed in a cooperative study with the production department. To develop appropriate energy- conservation targets, methods of energy conservation would have to be listed, and then described according to technical approach, with the technical description sufficiently detailed to permit a reliable estimate of the quantities of energy that might be saved relative to the investment required, as well as the operation and maintenance costs of the measure. Energy targets, when achieved, would then become the operating norms required by management. A system of rewards and penalties should be established for workers and all levels of management.

2. **Load production management.** Load production facilities during the time when daily and nightly electric power is being consumed. Annual savings from this initiative would be approximately 9.5 million KWh, translating into more than 2.7 million lv per year.

3. **Close metallurgical facilities which are currently idle.** Annual savings would total approximately 560,000 lv.

4. **Maximize synchronous unit loads for partial compensation of the low power factor.** This initiative would require use of static compensators (capacitor banks), and would save of 500,000 lv/year in reduced penalties.

5. **Optimize the power supply circuit of the rolling mill.** Shut down low-load transformers. This project would result in savings of electric power of 500,000 kWh/year, valued at 200,000 lv.

6. **Split illumination sections.** Use of sodium lights will reduce the electric power required for illumination; this and other projects will combine to yield an annual saving of 920,000 lv. Total investment would be approximately 425,000 lv, with a payback of .5 years.

7. **Adjust operation of the thermal units.** Thermal efficiency could be improved by optimizing fuel combustion. It is estimated that if 20% of the fuel were saved (a target number), this would save 47 Gcal/hour, yielding an annual savings value of 5,567,000 lv. These savings would include 19.6 million nm^3 coke oven and blast furnace gas.

8. **Increase degree of fuel gas-heat utilization.** Use the heat ("heat-racovert") - recovery boiler K20, installed in the Continuous Hot-Dip Galvanizing Line, to accomplish this initiative. Estimated annual savings are 1.2 million lv.

9. **Insulate pipe lines of the plant.** Estimated annual savings of this initiative are 500,000 lv.

10. **Use spot heating units to improve labor conditions.** Regular insulation and sealing work can be done in the production premises and buildings, and will yield annual savings of approximately 700,000 lv.

11. **Repair leakages by patching shut-off valves, compensators, links and steam and hot water ducts.** This project is expected to yield annual savings of 10,000 lv.

12. **Use hot cooling air from the continuous annealing furnaces as combustion air.** No cost or benefit estimates for this project were available.

4.2 Low-Cost Options

This category includes near-term projects that, despite the relatively low expenditure levels will probably require some imports using hard currency. Equipment listed or referred to below is specified in **Appendix III**. Some items will be financed by the U.S. Agency for International Development.

1. **Improve combustion efficiency using flue gas analyzer to reduce excess air.** The flue gas analyzer could be used for all furnaces and boilers and would be portable. The top priority in this respect are the Bell Furnaces with a cost of 90,000 lv and a near term estimated savings of 690,000 lv (2.36 Gcal/hour + 2.7 MW); payback is estimated at .13 years.

2. **Install combustion meter to provide calorific data or equivalent for coke oven and blast furnace gas.** No data was available to estimate cost or savings for this project.

3. **Install flow meter to measure the total flow of mixed coke oven and blast furnace gas.** Estimated cost of this project is $6,000, with annual savings of 6,000 lv, and a payback period of one year.

4. **Install portable gas velocity meter to measure various gases, including air and flue gas.** Estimated cost of this initiative is $3,000; estimates of the annual energy savings were not available. Nonetheless, even without concrete data to estimate energy savings, this investment is anticipated to have a payback period of less than one year.

5. **Install steam leak detector for small leaks.** The cost of this item will be less than $500 and the estimated savings, although not quantified, suggest that this item would have a payback period of less than one year.

6. **Install relative humidity gauge and draft gauge.** No cost or savings estimates were available for this project.

4.3 Capital-Intensive Options

The following capital-intensive options to improve energy efficiency were discussed with plant management, and initial comments made concerning each. However, since requisite data, including plant payback period requirements, were not available for all options and feasibility studies had not been conducted, the IRG Energy Conservation Audit Team was not able to recommend specific options. Team members recommended a comprehensive evaluation be made of the technical and economic aspects of these investments prior to the commitment of any investment funds.

1. **Bell Furnace Thermal Efficiency.**

   Bell Furnaces are used for annealing rolls of sheet steel (strip), and operate in a "batch" or non-continuous mode, in which rolls of strip are stacked on a base and then covered with a vertical cylindrical mantle. Air in the volume inside the mantle is replaced with nitrogen and hydrogen (about four percent) mixture, and a blower circulates the nitrogen over the rolls of strip during the annealing cycle. Heat for annealing is provided by burners fuelled with a mixture of blast furnace gas and coke oven gas in the bell furnace. Combustion takes place in the annular volume inside the bell furnace and outside the mantle.

   During the process, hot combustion gases at temperatures up to 800° C are exhausted from the bell furnaces to a duct under the floor which carries the hot gases to chimneys for dispersion into the atmosphere. A compressed air-driven educator located at the hot gas outlet on the bell furnace provides the driving force for moving the gases from the furnace to the exhaust duct. Exhaust gas

force for moving the gases from the furnace to the exhaust duct. Exhaust gas temperatures from the furnaces are reduced at the educator outlet to about 300 °C due to the tempering effect of the air used to drive the eductor.

Investigative Topics Relating to Bell Furnace Improvement:

- **Heat recovery from flue gases.** Leave bell furnaces to produce steam, preheat air for combustion, or for other purposes. Since energy input prices are expected to rise in the future, cost savings from this type of investigation would be even greater. The cost of these investigations would be $200,000, and energy savings would be 15,000 - 16,000 Gcal/year, or 1.5 million lv annually. This project would have a payback period of 2 years.

- **Connect the combustion gas systems of the bell annealing furnaces.** Connect these systems in a series so that hot gases from one can be used to preheat one or more additional bell furnaces. The pressure drop and effect on the time cycle would also have to be examined. No cost or savings estimates for this project were available.

- **Increase the rate of heat transfer between the outer combustion zone and inner nitrogen blanketed volume of the mantle.** This should reduce the time required for preheating, and increase the ratio of heat beneficially used to heat lost in the exhaust gases and heat losses by radiation and convection from the outer surface of the bell furnace. This could be accomplished through:

  - Installing extended heat transfer surface (adding fins) on the mantle; and/or

  - Increasing the heat transfer film coefficient on one or both sides of the mantle by increasing the gas velocity at the surface.

  For the upper combustion gas side (outer side) of the mantle, use of vanes to provide swirl flow could be considered. For the inner (nitrogen) side of the mantle, redirecting the flow pattern from the nitrogen blower to provide more gas velocity at the inner surface of the mantle could also be considered and evaluated. Possibly increasing the volumetric capacity of the nitrogen blower, and thus the velocity of the circulating nitrogen gas could also be considered.

  No cost estimates for these initiatives are available.

2. Continuous Annealing Furnaces Efficiency

- **Recover heat in the flue gases of the continuous annealing furnaces.** This would require specification and purchase of heat recovery equipment. The cost of this investment would be $70,000, resulting in an

energy savings of 2.3 Gcal and 690,000 lv/year, with a payback period of 1.5 years.

- **Connect the flue gas ducts of the continuous annealing furnaces in a series.** Connect the ducts so hot flue gases from the first furnace can be used in other furnaces. The pressure drop and effect on the cycle and other process factors would have to be evaluated. No cost estimates or estimates of benefits were available.

3. **Install system for automatic evaluation, monitoring, control, and distribution of all types of energy in the entire complex.** This recommendation extends beyond the three cold rolling plants, but is included here because the project is already underway; the first phase has been implemented, and the second phase is being conducted now. Results of an attempted optimization of an energy subset using processes within the same complex may not be consistent with overall optimization.

   The staff of the Power Complex have prepared a list and specifications for more than 500 items related to this system. They estimate the cost of the entire system to be $10 million. Landis and Gyr, a Swiss firm, is a vendor of such a system. Honeywell, an American vendor, also has an electric control system of the type needed.

5. RECOMMENDATIONS AND CONCLUSIONS

The following recommendations and conclusions represent those areas which the IRG Energy Conservation Audit Team believes should be priorities for the Kremikovtzi Steel Company.

5.1 Improved Energy Management Practices

Priority areas for corporate energy management at Kremikovtzi should be the improvement of training initiatives designed to improve energy efficiency awareness, data collection techniques, energy cost accounting, and energy investment planning capabilities, and the establishment of a comprehensive energy management program, including an energy management committee and the hiring of an energy manager.

In conjunction with improved training, management should establish energy management criteria, including minimum acceptable investment payback criteria and incentive/disincentive schemes for encouraging energy savings. In addition, the 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.

5.2 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 energy management, condensate and steam systems, lighting, instrumentation and dryers, as well as in the operation of the boilers.

1.	**Energy Management**	Establish a high-level energy manager position in the Cold Rolling Complex headquarters office. The energy management office should establish energy conservation target goals. Investigate potential energy-savings projects for technical and economic costs and benefits, including the potential for heat recovery from flue gases, connecting the combustion gas systems of the bell annealing furnaces, increasing the rate of heat transfer between the outer combustion zone, and the inner nitrogen blanketed volume of the mantle.
2.	**Electric Power**	Establish a load management program for electricity. Close metallurgical facilities which under conditions of the reduced production program are currently idle. Maximize synchronous unit loads for partial compensation of the low power factor.

Optimize the power supply circuit of the rolling mill. Split illumination sections and use sodium lights to reduce electric power required for illumination.

3. **Thermal Power** — Adjust operation of the thermal units. Thermal efficiency could be improved through fuel combustion optimization. Increase the degree of fuel gas heat utilization and insulate pipelines throughout the plant. Use spot heating units. Repair leaks by patching shut-off valves, compensators, and steam and hot water ducts. Use hot cooling air from the continuous annealing furnaces as combustion air.

4. **Combustion** — Improve combustion efficiency using a portable flue-gas analyzer to reduce excess air in furnaces and boilers. Install a combustion meter to provide calorific data or its equivalent for coke oven and blast furnace gas.

4. **Instruments** — Install a flow meter to measure the total flow of mixed coke oven and blast furnace gas. Install a portable gas velocity meter for measuring various gases including air and flue gas. Install a steam leak detector for small leaks. Install a relative humidity gauge and a draft gauge.

5.3 Recommended Capital Investments

Equipment Purchased Under the Emergency Energy Program

1. **Flue 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. The cost of this item was $5,916, and the expected annual savings are $46,000.

2. **Mass Flowmeter** — This instrument will be used for monitoring the volumetric flow rate of a mixture of coke oven gas and blast furnace gas. The cost of this item was $5,981, and the expected annual savings will be approximately $6,000.

3. **Portable Gas Velocity Measuring Device** — This portable instrument will be used to measure velocities of combustion (flue) gases and air at temperatures of up to 1100° C, and at atmospheric pressure in ducts up to one meter in diameter. This item costs approximately $2,800.

4. **Industrial Stethoscope** — The industrial stethoscope will be used as a steam leak detector to check for leakages in steam traps. The cost of this item was $451, and the resulting energy savings are valued at least $4,000 per year.

Other Recommended Capital Projects

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

1. **Insulation** — As part of an effort to improve overall thermal energy efficiency, the plant may wish to consider the purchase of insulation to improve the efficiency of steam and condensate systems.

2. **Relative humidity gauge and a draft gauge.**

APPENDIX I
AUDIT MEASUREMENTS

The team of Goranov (Ecotechproduct), Heidner (IRG), Ivanov (Committee on Energy) and Naidenov (Kremikovtzi steel works) gathered the following information during the April audit.

1. BELL ANNEALING FURNACE MEASUREMENTS

Gas	Coke gas compos.	Blast-furnace gas
Carbon monoxide (CO)	5 - 7%	28 - 31%
Carbon dioxide (CO_2)	1.5 - 2.5%	8 - 10%
Nitrogen (N_2)	3 - 5%	56 - 59%
Methane (CH_4)	23 - 28%	0.2 - 0.5%
Hydrogen (H_2)	54 - 59%	1.2 - 2.0%
Oxygen (O_2)	0.03 - 0.08%	0.1 - 0.2%
Hydrocarbons	2 - 3%	
Calorific value	4000 Kcal/nm^3	1000 Kcal/nm^3
Density	0.444 kg/nm^3	1.306 kg/nm^3

2. CONTINUOUS ANNEALING AND PROCESS LINE MEASUREMENTS

	Burner 1	Burner 2
Ambient Temperature, °C	23	23
Stack Temperature, °C	518	561
Oxygen, %	11.0	1.1
Carbon Monoxide, PPM	0.0	Over
Combustible Gases, %	0.0	-
Oxides of Nitrogen, PPM	152	21
Sulphur Dioxide, PPM	0.0	518
Carbon Monoxide Alarm, PPM	50	50

3. AUXILIARY BURNER ANALYSIS

The fuel is deep-cleaned coke gas with calorific value of	4000 Kcal/nm^3
Gas medium temperature	800-850 °C
Strip temperature	600-650 °C
Working temperature	75 °C
Cooling chamber temperature	from 730 °C to 430 °C
Next strips are fast cooled	from 430 °C to 65 °C

in a fast cooling chamber. There are blocks where protective gas circulation is used to cool the strip.

The heating in the delay chamber is performed by electric resistors.

4. ADDITIONAL TECHNICAL DATA

Max. coke gas consumption	1850 mm^3/h
Coke gas pressure	1500 mm H_2O
Furnace heat power	725000 Kcal/h
Combustion products volume	12000 nm^3/h
Combustion products temperature	500-520 °C
Energy consumption	
Electric power	1398 KW
Steam	1.221 Gcal/h
Water	283 m^3/h
Compressed air	302 nm^3/h

Bell Annealing Furnace: I.D.=3 210 mm, H=6 375 mm

Items	Furnace 1				Furnace 8				Flue
	a.m.	s.	p.m.	s.	a.m.	s.	p.m.	s.	p.m.
	P1	P2	P1	P2	P1	P2	P1	P2	P3
Ambient Temperature, °C	21	22	29	30	23	23	30	29	29
Stack Temperature,°C	602	265	678	340	560	259	566	283	96
Oxygen, %	9.9	14.4	9.8	14.4	11.	14.6	8.9	14.0	19.1
Carbon Monoxide, PPM	17	0.0	48*	5*	2	27	0*	0*	48*
Combustible Gases, %	0.0	0.00	0.00	0.14	61	0.00	0.00	0.00	0.00
Oxides of Nitrogen, PPM	5	18	29	20	0.1	13	25	10	5
Sulphur Dioxide, PPM	29	0	43	0	1	9	41	0	0
Carbon Monoxide Alarm	24	50	150	150	26	50	150	150	150
	50				38				
					50				

NOTES: a.m. s. - a.m. measurements
p.m. s. - p.m. measurements
* - the data for carbon monoxide are not precise

Measuring Point No. 4: Protective Gas A.M. Samples

Ambient Temperature	°C 24
Stack Temperature	°C 295
Oxygen, %	0.0
Carbon Monoxide, PPM	Over
Combustible Gases, %	Over
Oxides of Nitrogen, PPM	21
Sulphur Dioxide, PPM	204
Carbon Monoxide Alarm, PPM	50

Measuring Point No. 5

A.M. Sample	< 150 °F
P.M. Sample	~ 200 °F

APPENDIX II
MEETING PARTICIPANTS

Some of the Bulgarians present at the April 1991 meetings and plant tours are listed below. It should be noted that the IRG Energy Conservation Audit Team met the foremen of some of the individual operation groups, and these individuals are not listed. Also, note that some of the individuals are connected with the entire complex (as opposed to the Cold Rolling Mill alone).

PARTICIPANTS IN THE MEETING AT KREMIKOVTZI

Name	Position	Plant
Peter Taskov	Chief Director (Engineer) Manager R&D Co.	Entire complex
Veselin Tomov	Metallurgic Energetics	
Dr. Evelina Katsarova	Deputy Manager and Asst. to V. Tomov	
Y. Yolov	Deputy Director Rolling mill #2	Entire complex
S. Kavdanski	Director Rolling mill #2	
A. Dermendjiev	Deputy General Director Rolling mills	
K. Krastev	Deputy Director Technology	Entire complex
I. Alexandrov	Senior Power Engineer Rolling mills	

In addition, International Resources Group was represented by Mr. Theodora Baba and Mr. Mel Heidner. Ecotechproduct representatives Peter Damianov, Plamen Goranov and Stefan Hristov were also present. The Committee on Energy's State Energy Inspectorate was represented by Todor Ivanov and Panaiot Hristov.

APPENDIX III

EQUIPMENT SPECIFICATIONS AND JUSTIFICATIONS FOR PURCHASE OF EQUIPMENT

KREMIKOVTZI IRON AND STEEL WORKS, SOFIA

1. **Portable Flue Gas Analyzer** -- to be used to analyze various gas streams including flue gases at temperatures up to 1,100° C. The gas is to be analyzed for volume percent (dry basis) of CO_2, CO, O_2 and SO_2. NO_x analysis capability should be included if there is no significant increase in the price or complexity of the instrument. The instrument must be capable of handling and analyzing at least 0.1% CO by volume. The instrument should indicate temperature and be capable of serving as a draft gauge, measuring at least 100 mm water differential at nominal atmospheric pressure. The instrument should have the capability of providing a printout of all measurements as volume percent on a dry basis and be capable of operating with rechargeable batteries. Readout and printout should be in degrees centigrade, with gas composition presented either as volume percent and draft in millimeters or centimeters of water. The instrument or its rechargeable battery shall operate from 240 volt, 50 hertz electric power.

2. **Mass Flowmeter or equivalent** -- to be used for monitoring volumetric flow rate of a mixture of coke oven gas and blast furnace gas. Gas conditions are 20° C and 800 mm of water gauge. Flow rates to be measured vary from 0 to 20,000 nm^3 per hour. Ratios of blast furnace gas and coke gas in the mixture may vary, but a nominal composition of the mixture would be one volume of coke oven gas to 2.5 parts of blast furnace gas. Traces of condensate (water) may be present. The meter must be weatherproof as it will be located outdoors, and have an inside pipe diameter of 1000 mm. Only 240 volt, 50 hertz alternating current is available; any electrical requirements for powering this instrument should be specified by the vendor. A rugged, low maintenance device is desired with an accuracy of 97 to 98 %. Reproduceability of gas volumes measured is most important.

   The instrument must be capable of transmitting its signal for a distance of up to 300 meters, and a basic readout recording device should be provided. Readout must be in metric units. Spare parts and supplies sufficient for operation of the instrument for two years should be supplied with the equipment. Two sets of complete installation and operating instructions are to be supplied with the instrument, and instructions should specify the upstream and downstream straight pipe lengths required for acceptable accuracy. The vendor should provide data on maximum pressure drop added to the piping system by installation of the instrument. If other equipment such as temperature indicators or pressure gauges are required for installation, these must be specified and supplied by the vendor.

3. **Portable Gas Velocity Measuring Device** -- to be used to measure velocities of combustion (flue) gases and air at temperatures of up to 1100 C., at atmospheric pressure in ducts up to one meter in diameter. The instrument should be rugged and simple, suitable for reliable service in a cold rolling steel mill environment. The instrument should be provided with spare parts and supplies necessary for a minimum

of two years of reliable operation. The instrument should provide readout in metric units. It should be supplied with and operated from either rechargeable batteries and 240 volt, 50 hertz electric power. It should be supplied with two complete sets of operating instructions.

4. **Steam Leak Detector, Trap Checker or Equivalent** -- Maximum capacity 2 kg per hour.

APPENDIX IV

TRAINING SEMINAR PRESENTED BY U.S. TEAM

KREMIKOVTZI STEEL COMPANY, COLD ROLLING MILL

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 Boiler
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

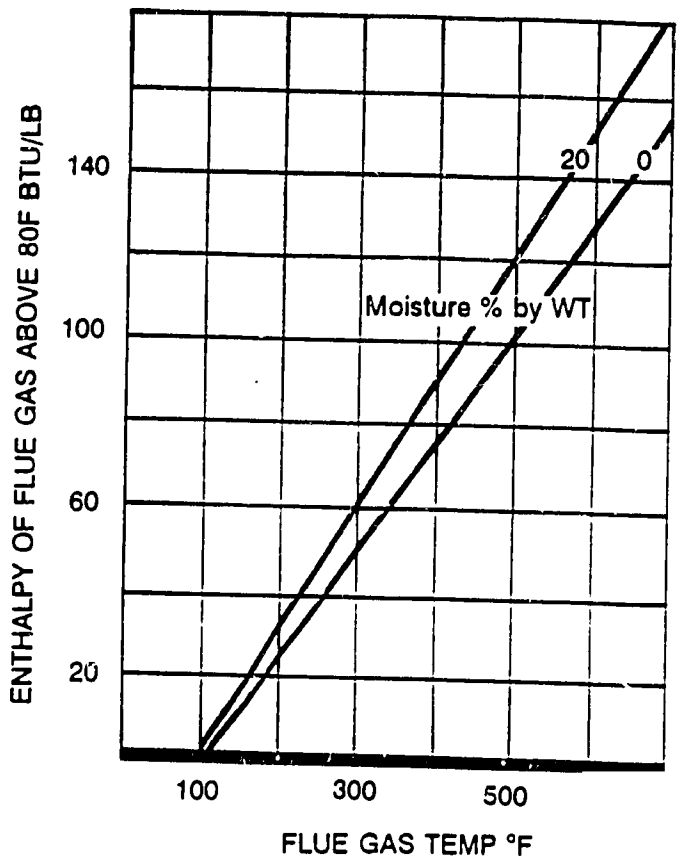
3.1.2.1 Stack Gas, Other Pertinent Losses

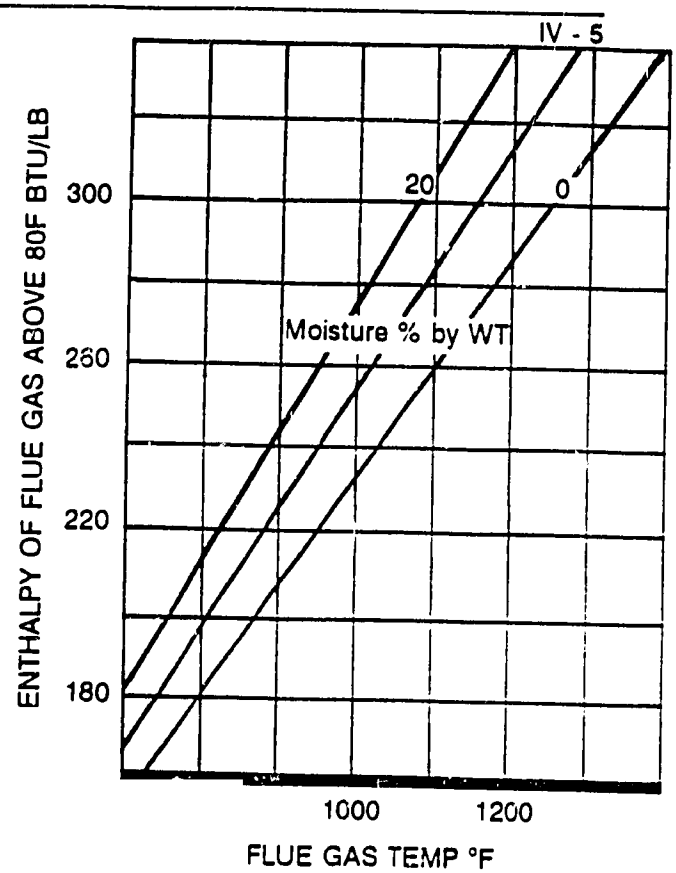
3.1.3 Work on Big User, Losers

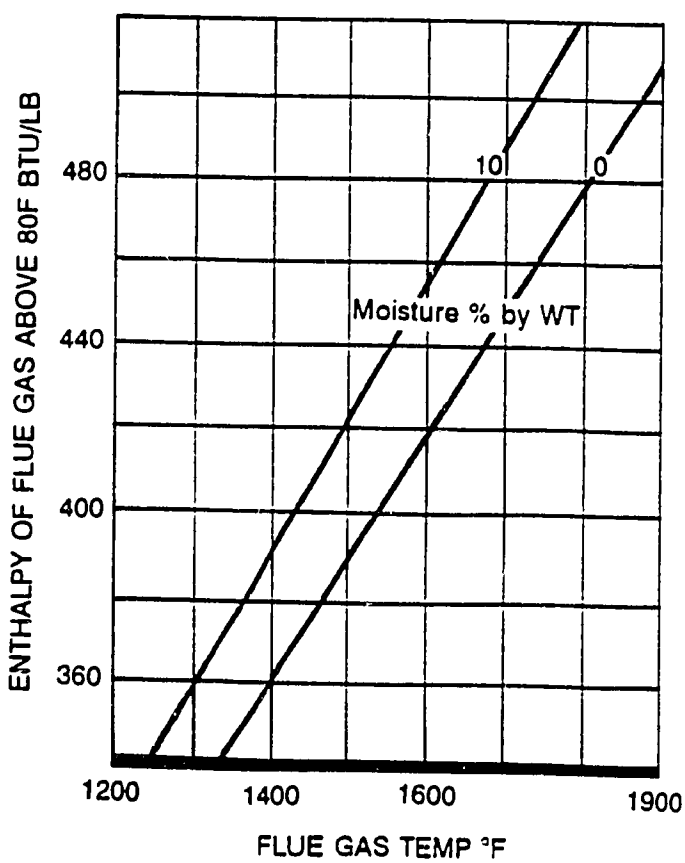
3.1.4 Develop Energy Ethic (Everything Costs Money)

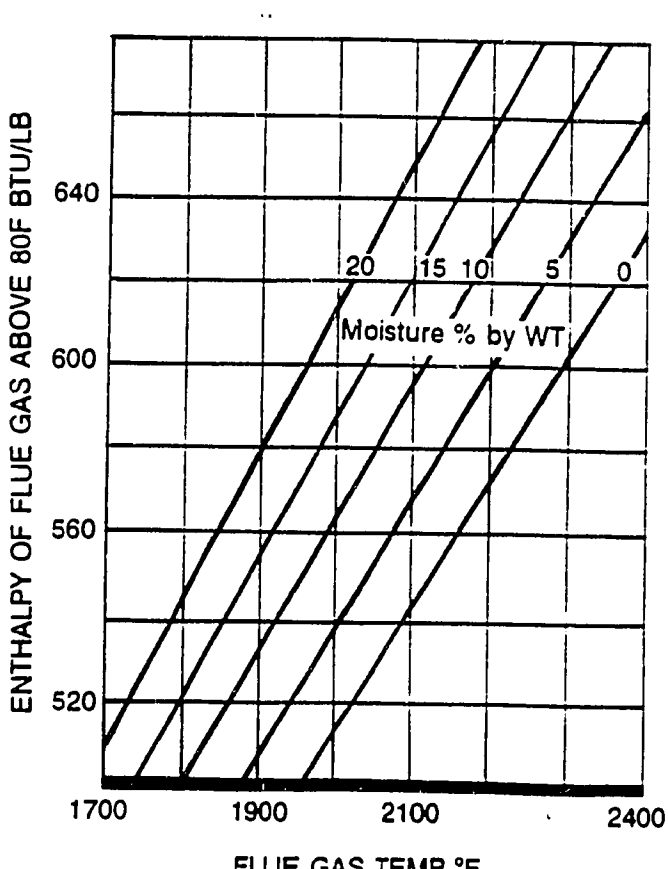
3.1.4.1 Energy Committee

3.1.4.2 Contests - Recognition - Rewards


ENTHALPY OF FLUE GAS ABOVE 80F BTU/LB
140
100
60
20
20
0
Moisture % by WT
100
300
500
FLUE GAS TEMP °F


IV - 5
ENTHALPY OF FLUE GAS ABOVE 80F BTU/LB
300
260
220
180
20
0
Moisture % by WT
1000
1200
FLUE GAS TEMP °F


ENTHALPY OF FLUE GAS ABOVE 80F BTU/LB
480
440
400
360
10
0
Moisture % by WT
1200
1400
1600
1900
FLUE GAS TEMP °F

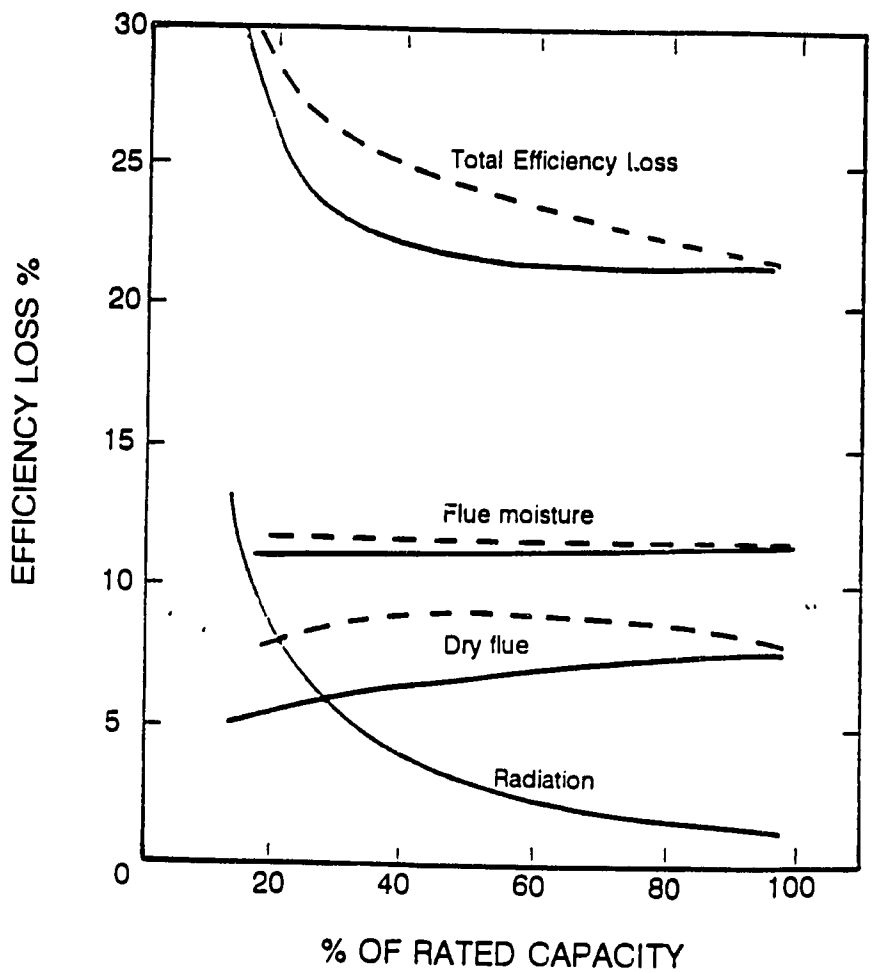

ENTHALPY OF FLUE GAS ABOVE 80F BTU/LB
640
600
560
520
20
15
10
5
0
Moisture % by WT
1700
1900
2100
2400
FLUE GAS TEMP °F

31

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)



APPENDIX V

SUPPLEMENTAL INFORMATION

KREMIKOVTZI STEEL WORKS - SOFIA

Note: This information is collected and analyzed by ECOTECHPRODUCT, Sofia

UNIT 1

Continuous Pickling Line No. 1
Purpose: to clean strip surfaces from oxides by means of H_2SO_4.

Energy consumption:

electric power	- 420 kW
steam	- 2.7 Gcal/hour
water	- 210 m^3/hour
compressed air	- 540 nm^3/hour

UNIT 2

Continuous Pickling Line No. 2
Purpose; to clean strip surfaces from oxides by means of HCl.

Energy consumption:

electric power	- 510 kW
steam	- 6.0 Gcal/hour
water	- 82.5 m^3/hour
compressed air	- 135 nm^3/hour

UNIT 3

Cold Strip Mill No. 1 (67")
Purpose: for cold rolling of strips with thickness of 0.4 -2.5 mm and width of 6.0 - 155 mm.
Electric power of 50 MW is established.
Energy consumption:

electric power	- 6,771 kW
steam	- 1,344 Gcal/hour
coolant	- 2630 mm^3/hour; ∂t = 10 - 20°C
compressed air (4 - 5 kg/cm^2	- 135 nm^3/hour

The steam is used to heat the oils and lubricants. The rolls are cooled by oil-in-water type coolant.
Productivity: 64 - 94 t of metal per hour
Operating time - 4,483 hours per year.

UNIT 4

Bell Annealing furnaces

Purpose: light annealing of steel strips (thickness 0.5 - 2 mm, width 700 - 1300 mm) in protective atmosphere (4% H_2, 96% N_2).

Th[illegible] are 120 stands and 47 heating bells. Each stand is charged with 3 - 4 coils of r[illegible]ng strip. The coil stock is covered by a muffle, protective gas is fed and a cold b[illegible]ing through is made for two hours. Next the annealing cycle begins (the material is [illegible]ated up to 690 - 710°C for a certain space of time and then is cooled down to 125 - 14[illegible]°C). The cycle is automatically controlled. The mixture of coke gas and blast-furnace gas burns out in the room formed by the heating bell and the muffle. The combustion temperature is 950°C. The outlet temperature of the exhaust gas is 650 - 700°C. The consumption rate of the gas mixture (coke gas and blast-furnace gas) is 700 nm^3/hour. Each heating bell gives 2500 - 2600 nm^3/hour exhaust gases.

Some additional technical data:

Stand capacity	- 0.8 t/hour
Calorific power of the mixture of coke gas and blast-furnace gas	- 1,600 kcal/nm^3
Gas pressure	- 2,000 mm H_2O
Number of burners	- 16
Burner heat power	- 81,500 kcal/hour
Heat power	- 1,300,000 kcal/hour
Maximum gas consumption	- 815 nm^3/hour
Average water consumption for a stand (protective gas cooling)	- 5 m^3/hour
Average protective gas consumption for a stand	- 24 nm^3/hour
Protective gas pressure under the muffle	- 70 mm H_2O

Gas	Coke gas composition	Blast-furnace gas composition
Carbon oxide (CO)	5 - 7%	28 - 31%
Carbon dioxide (CO_2)	1.5 - 2.5 %	8 - 10%
Nitrogen (N_2)	3 - 5%	56 - 59%
Methane (CH_4)	23 - 28%	0.2 - 0.5%
Hydrogen (H_2)	54 - 59%	1.2 - 2.0%
Oxygen (O_2)	0.03 - 0.8%	0.1 - 0.2%
Hydrocarbons	2 - 3%	-
Calorific power	4000kcal/nm^3	1000kcal/nm^3
Density	0.44kg/nm^3	1.306kg/nm^3

UNIT 5

Skin Pass Mill No. 1 (67")
Purpose: to temper the cold rolled annealed strip (thickness 0.4 - 2.8 mm. width 600 - 1550 mm)

Electric power of 8 MW is established.
Energy consumption:

electric power	- 793 kW
steam	- 0.11 Gcal/hour
water	- 411 m^3/hour; ∂t = 3 - 4°C
compressed air	- 237 nm^3/hour

The steam is used to heat the oils and lubricants.
Operating time - 3,532 hours per year.

UNIT 6

Coil Cut-Up Lines. Rotary Slitting Lines 1 - 5
Purposes: to cup-up wide strip to sheets or to slit it to narrow strip.
Electric power of 4,000 kW is established.
Operating time - 4,500 hours per year

UNIT 7

Cold Strip Mill No. 2 (47")
Purpose: for cold rolling of strips (thickness 0.18 - 0.6 mm. width 500 - 1050 mm)
Electric power of 20 MW is established.
Energy consumption:

electric power	- 5,087 kW
steam	- 4.33 Gcal/hour
oil-in water type coolant	- 1,317 m^3/hour; ∂t = 10 - 20°C
compressed air	- 1653 nm^3/hour

The steam is used to heat the oils and lubricants. Oil-in water type coolant is used to cool the rolls and strip.
Operating time - 5,094 hours per year.

UNIT 8

Continuous Annealing and Process Line 8
Purpose: light annealing of low carbon cold rolled strips (thickness 0.16 - 0.5 mm. width 500 - 1050 mm) in protective atmosphere (6% H_2 94% N_2).
Protective gas expenditure - 800 nm^3/hour.
There are three sections:

entry section (cleaning):
working section (annealing):
exit section (cooling).

The strip heating is performed by 84 radiant tubes with basic and auxiliary burners in each one.

The fuel is deep cleaned coke gas with calorific power of 4,000kcal/nm^3.
Gas medium temperature: 800 - 850°C.
Strip temperature: 600 - 650°C.
The heating in the delay chamber is performed by electric resistors. The working temperature is 75°C.
In the colling chamber (air cooling) the temperature is decreased from 730°C to 430°C. Next the strips are fast cooled (from 430°C to 65°C) in a fast cooling chamber. There are blocks where protective gas circulation is used to cool the strip.
Some additional technical data:

Maximum coke gas consumption	- 1,850 nm^3/hour
Coke gas pressure	- 1,500 mm H_2O
Furnace heat power	- 725,000 kcal/hour
Combustion products volume	- 12,000 nm^3/hour
Combustion products temperature	- 500 - 520°C.

Energy consumption:

electric power	- 1,398 kW
steam	- 1.221 Gcal/hour
water	- 282 m^3/hour
compressed air	- 302 nm^3/hour

Operating time - 6,337 hours per year
There is a project for exhaust gases heat recuperation

UNIT 9

Skin Pass Mill No. 2 (47")
Purpose: to temper the cold rolled annealed strip (thickness 0.18 - 0.6mm. width 800 - 1,050 mm.

Electric power of 5.6 MW is established.
Energy consumption:

electric power	- 1,076 kW
steam	- 0.64 Gcal/hour

The steam is used to heat the oils.
Operating time - 3,558 hours per year.

UNIT 10

Coil Preparation line
Purpose: to prepare the skin-passed coils for tinning.
No data for installed electric power.

UNIT 11

Continuous Electrolitic Tinning Line
Purpose: to tin the cold rolled strip.

Energy consumption:

electric power	- 1428 kW
steam	- 5.3 Gcal/hour
water (mainly for chemical treatment)	- 440 m^3/hour
compressed air	- 371 nm^3/hour

Operating time - 4,494 hours per year

UNIT 12

Continuous Hot-dip Zinc Plating Line
Purpose: for hot-dip zinc plating of cold rolled strips.
There are two furnaces: for preliminary heating and for light annealing or normalizing.
In the preliminary furnace the strips are heated for cleaning from lubricants. To protect the strips from oxidation fuel-air mixture (prop. ratio 0.87) is used. The combustion products contain 4 - 0% H_2 + CO.
The temperature in the furnace space is 1,150 - 1,300°C. The strip temperature is 450 - 650°C.

In the heat treatment furnace the strips are heated delayed and cooled to 455 - 460°C. The fuel-air mixture prop. ratio is 1.15. The fuel is coke oven gas with a calorific value 4000 kcal/hour. Complex gas (4% hydrogen, 96% nitrogen) is used as protective atmosphere.

Some additional technical data for the burners:
Preliminary heating furnace:

Basic burners:

number of units	- 18
coke gas consumption (rate)	- 155 nm^3/hour
gas pressure	- 400 nm H_2O
air consumption (rate)	- 570 nm^3/hour
air pressure	- 510 mm H_2O
heat power	- 620,000 kcal/hour

Auxiliary burners:

number of units	- 18
coke gas consumption (rate)	- 7.5 nm^3/hour
gas pressure	- 450 mm H_2O
air consumption (rate)	- 32 nm^3/hour
air pressure	- 400 mm H_2O
heat power	- 5000 kcal/hour

Annealing furnace:

Basic burners:

number of units	- 76
coke gas consumption (rate)	- 6.35 nm^3/hour
gas pressure	- 70 mm H_2O
air consumption (rate)	- 31 nm^3/hour
air pressure	- 110 mm H_2O
heat power	- 24,540 kcal/hour

Gas medium temperature: 800 - 850°C. There is a waste-heat boiler (steam capacity 5 t/hour).

Energy consumption:

electric power	- 1,113 kW
steam	- 1,272 Gcal/hour
water	- 1,168 m^3/hour
compressed air	- 733.5 nm^3/hour

Operating time - 5,931 hours per year.

The temperature of the exhaust gases after recuperation is approximately 150°C.

UNIT 13

Continuous PVC Plating Line

Purpose: to plating the cold rolled strip-vhit plastic (PVC) material.

There are two drying chambers. Coke gas to entered in the first one, its expenditure is 1250 nm^3/hour to keep temperature of 400°C for gas medium and 240°C for strip. Heat power of this chamber is 800,000 kcal/hour. Air expenditure is 5000 - 700 nm^3/hour. The rate of exhaust gases is 11000 nm^3/hour and the temperature is 750°C.

The second chamber is the same as the first one. Heat power is 14,000,00 kcal/hour. Air expenditure is 17,000 - 19,000 nm^3/hour. The rate of exhaust gases is 3,200 nm^3/hour and the temperature is 750°C. The coke gas expenditure for both chambers is 2200 nm^3/hour and air expenditure is 26,000 nm^3/hour. The rate of exhaust gases is 42000 nm^3/hour.

Operating time is 2,090 hours per year.

UNIT 14

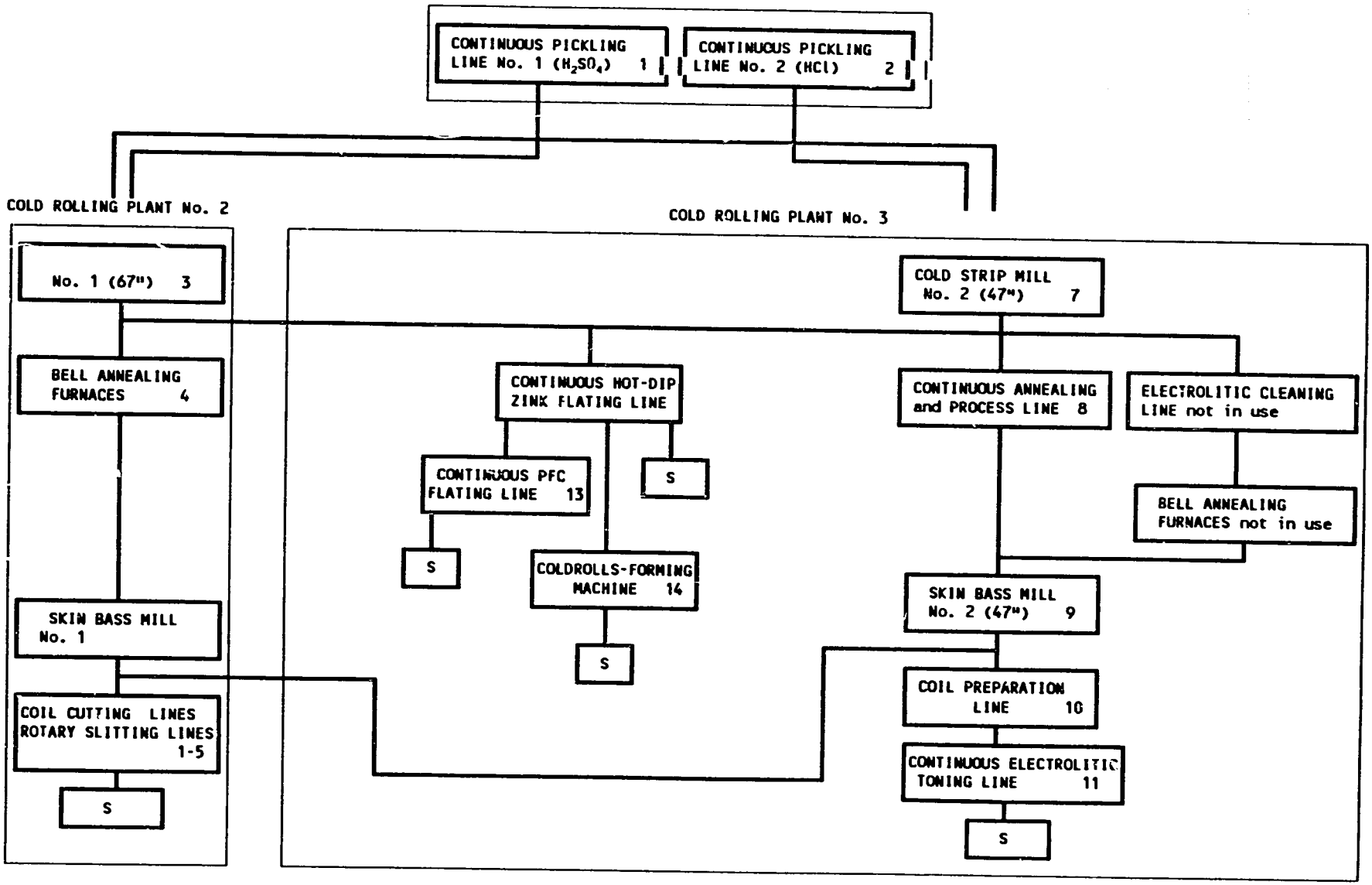
Cold-rolls-forming Machine

Purpose: to produce roll-formed shapes.

Electric power is the main energy expenditure.

UNIT 15 and UNIT 16 are not in use now.

COLD MILL - KREMIKOVTZI - BLACK SCHEME
COLD ROLL PLANT No. 1



APPENDIX VI

EXCERPT OF 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.