PN-ABL-617

ENERGY EFFICIENCY AUDIT REPORT "PHARMACIA" CHEMICAL AND PHARMACEUTICAL INTEGRATED WORKS

Stanke Dimitrov, Bulgaria

PREPARED BY:

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Washington, DC

and

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Sofia, Bulgaria

U.S. EMERGENCY ENERGY PROGRAM FOR EASTERN & CENTRAL EUROPE

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
BUREAU FOR EUROPE
WASHINGTON, DC 20523

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USAID Contract EUR-0015-C-1008-00

May 1992

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LIST OF ACRONYMS

A.I.D.	U.S. Agency for International Development
BTU	British Thermal Unit
GCal	giga-calories
IRG	International Resources Group, Ltd.
kV	kilovolts
KWh	kilowatt hours
lx	lux (lumen per square meter)
lv	levas
psi	pounds per square inch
ROI	return on investment
t	tons
V	volts

ACKNOWLEDGMENTS

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

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

It is IRG's hope that the exchange established through this initiative is maintained and expanded in the future.

PREFACE

In the wake of the political and economic collapse of the Soviet Union, the nations of Central and Eastern Europe confront an energy situation for which there is no historical precedent. Overnight long-standing supply agreements for oil, natural gas and electricity supplies from the Soviet Union have been curtailed or discarded with attendant dramatic increases in the prices of these commodities. In addition, as the veil of secrecy has been lifted in these nations, the devastating legacy of years of neglect of coal and other fossil fuel pollution and an aging, largely unsafe and unregulated nuclear power industry are vital issues that need to be addressed in light of the fundamental structural reform of these Central and Eastern European economies. Democracy for these countries means change amidst great political and economic 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

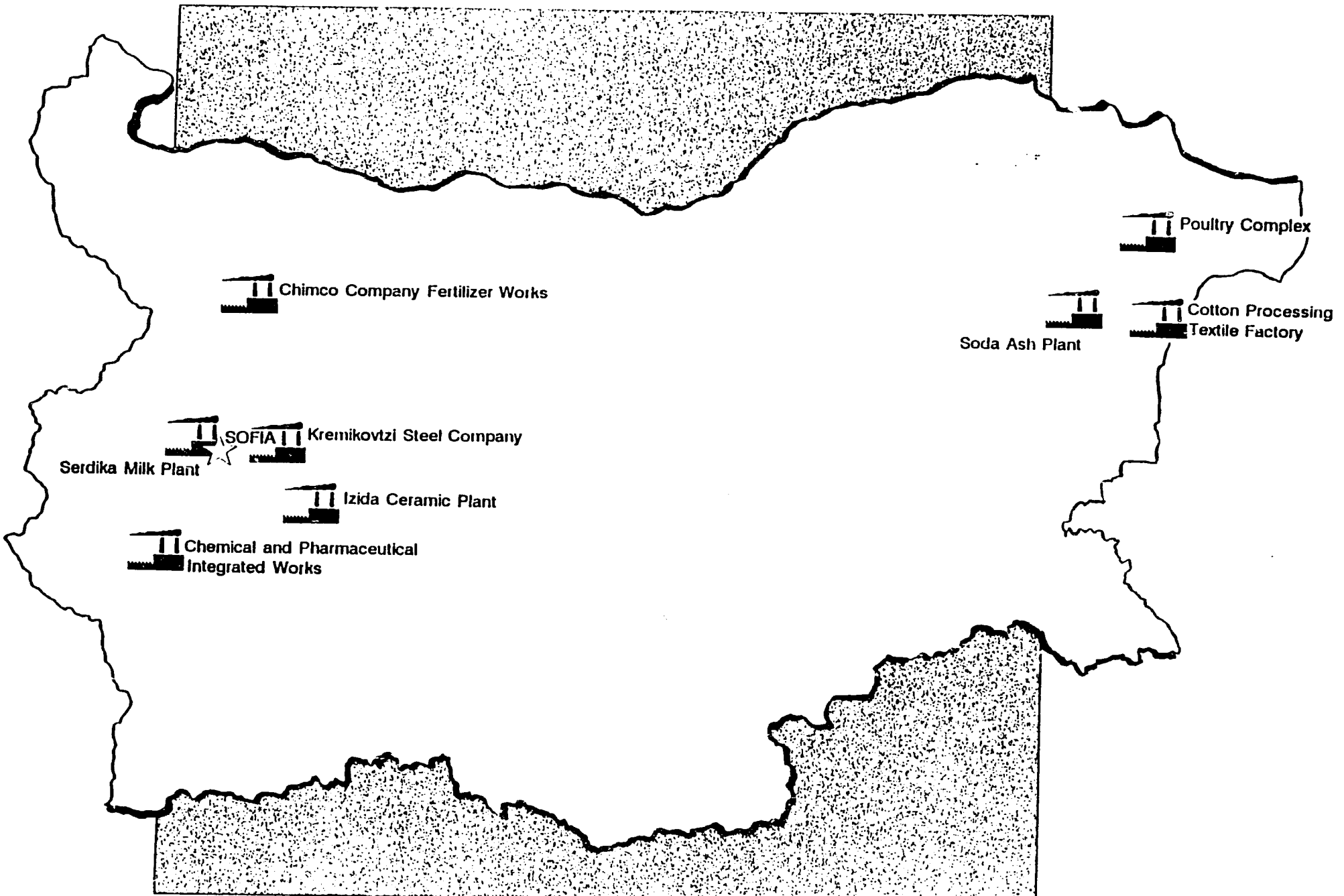


Figure 1. Location of eight industrial plants audited by the IRG team.

Factory

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

The Audit Teams collected data at every plant on the energy costs per unit of production, primarily using plant records, audit measurements, and interviews with plant officials. In some cases, the Audit Teams counselled the plants on the establishment of systems for cost accounting in the plant, particularly where it related to energy costs per unit of output. The Industrial Energy Efficiency activities had tremendous success and generated letters of support from several plant managers.

Program Rationale

While this program was clearly a logical starting point for improved energy use patterns, it is only a beginning. Although all activities under the Industrial Energy Efficiency project were conducted using a relatively small budget for equipment purchases, the energy savings results were significant. Thus, the program demonstrated the tremendous potential for energy savings through low cost and no cost mechanisms. Moreover, these programs represented important energy savings initiatives that were implemented on a timely basis, within a matter of months.

These initiatives should serve as a cornerstone for a new way of approaching energy savings in Bulgaria. They represent the lowest cost and most readily implemented energy savings initiatives available. Furthermore, the energy savings techniques/measures identified and implemented in this Emergency Energy Program should be applicable to other similar facilities and process units throughout Bulgaria. As a result, these low cost techniques for improving energy efficiency, and thereby improving economic efficiency, in industrial facilities, should serve as a model for restructuring energy use in the Bulgarian industrial sector.

The project also highlighted a number of issues that fundamentally affect the ability of industrial entities to solve energy problems. Basic issues such as industrial energy pricing, environmental regulation, legal reforms, corporate organization and management structure, personnel training, and the overall economic environment all affect the ability of industrial concerns to implement energy savings opportunities. Thus, the Industrial Energy Efficiency Improvement project attempted to address issues of micro-level plant organization and management, training, and economic evaluation at each of the plants. In addition, the IRG Team has outlined key macro-level issues which must be addressed by the Government of Bulgaria before comprehensive energy efficiency initiatives are enacted. These issues are addressed in this report as well as in Industrial Profile Report and the Policy and Institutional Analysis Report for Bulgaria, both prepared as part of the Industrial Energy Efficiency Improvement project.

Ultimately, the IRG Team is convinced that the overwhelming potential for energy and cost savings in the Bulgarian industrial sector will provide sufficient incentive for plant managers and industrial executives to actively promote reforms that encourage energy conservation and improved economic efficiency.

1. EXECUTIVE SUMMARY

The Chemical and Pharmaceutical Integrated Works ("Pharmacia") in Stanke Dimitrov produces vitamins, over-the-counter drugs, toothpaste, shampoo, and other goods. Primary energy products used in the plant include fuel oil, electricity, and diesel oil. Processes used in vitamin C production, the tableting workshop, gel workshop, organic preparations workshop, and the energy supply units are the greatest energy consumers at the facility.

The Pharmacia facility, as well as all Bulgarian industry, has been operating in an environment of rapidly increasing energy prices. Specifically, Bulgarian light industry was hit by a tenfold increase in fuel costs during 1990, with similar price increases in 1991. Industry itself appears to have reacted to these rapid changes in limited ways. Hence, there is much room to reduce energy consumption per unit of product.

To address energy inefficiencies at the Pharmacia plant, management initiated a program designed to implement the high-priority projects developed by the Energy Conservation Audit Team of the International Resources Group, Ltd. (IRG). High priority projects included rebuilding the condensate recovery system, improving lighting procedures, installing programs for steam, air, water, and condensate leak repair programs, replacing missing heat and refrigeration insulation, cleaning refrigeration heat exchangers, and installing limited levels of automatic controls on the refrigeration system.

The Projects listed in **Table 1** have a potential savings of more than 3,500,000 leva (lv) per year for a cost of about 230,000 lv. In each case, payback periods are less than one year and have a return on investment (ROI) in excess of 100%.

The Pharmacia plant also has several opportunities to adopt newer technological processes, such as those used in the fermentation industry. Recommendations in this report also include developing training programs in steam theory, refrigeration principles, engineering economics, and energy management techniques. With this type of training, the skills of plant personnel can be improved in a relatively short time.

Results of Emergency Energy Program, Industrial Energy Efficiency

As a contribution to the improvement of energy efficiency in this plant, new equipment and instruments were purchased by IRG through the U.S. Agency for International Development (A.I.D.)-funded Emergency Energy Program. Items purchased included:

- Portable Infrared Thermometer
- Oxygen Analyzers (2)
- Fluorescent Light Fixtures (various)
- Industrial Stethoscope
- Steam Traps (various)
- Pipe Fittings (various)
- Electric Power Monitor
- Centrifuge

More capital intensive recommendations were outlined for the longer term. All recommendations are summarized below.

Table 1. Summary of Opportunities for Energy Savings at the "Pharmacia" Chemical and Pharmaceutical Integrated Works.

I. No Cost/Low Cost Measures Evaluated	Investment (lv)	Energy Savings (KWh/year)	Cost Savings (lv/year)	Payback (years)	Recommend
Rebuild condensate recovery system	100,000	6,896,600 (1st year)	2,000,000 (1st year)	0.1	yes
Install stack gas analyzer and temperature instrumentation	15,000	344,800 (1st year)	100,000 (1st year)	0.17	yes
Repair steam leaks	10,000	1,931,000 (1st year)	560,000 (1st year)	0.08	yes
Eliminate use of direct steam in oil tank cars	-	172,400	50,000	0.1	yes
Improve lighting systems	123,000	517,200 (1st year)	150,000 (1st year)	0.8	yes
Repair steam line insulation	20,000	3,206,900 (1st year)	930,000 (1st year)	0.02	yes
Install smaller recirculating pump for condenser cooling	15,000	431,000	125,000	0 2	yes
Check & clean exchanger surface of condensers	3,500	86,200	25,000	0.08	yes
Install automatic expansion system - 1 stage refrig. station	30,000	258,600	75,000	0.4	yes
Repair refrigeration insulation	6,500	162,100	47,000	0.17	yes
Equip cold storage chamber with thermostatic expansion valve & automatic defrost equipment	10,000	96,600	28,000	0.5	yes
I. Capital Intensive Measures Evaluated					
Replacement of fermentation reactors machine dryers	-	-	-	-	NEI
Cogeneration	-	-	-	-	NEI
TOTAL	230,000	14,103,400	4,090,000		

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

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

2. PLANT BACKGROUND

The Chemical and Pharmaceutical Integrated Works ("Pharmacia") in Stanke Dimitrov (Dupnitza) produces drug substances, drugs, toiletry items (i.e., toothpastes and shampoos) as well as several other goods (organic preparations, veterinary preparations, and essential oils). Plant capacity and production figures for the major products are shown in **Table 2**.

Table 2. Products manufactured at "Pharmacia".

Product	Units of Production	Plant Capacity	Actual Annual Production
Tablets	mln pcs	8,000	6,016
Vitamin "C"	t	300	270
Gel ppns	thou btls	15,000	14,000
Tooth paste	t	10,000	8,295
Cinnarizinum	t	30	24
Shampoos	thou btls	2,000	1,610

Energy products used in the plant are fuel oil, electricity, and diesel oil. The annual consumption levels of fuel oil and electricity are listed in the **Table 3** below. Major consumers of energy (by product) are presented in **Table 4**.

Table 3. Energy consumption of the "Pharmacia".

Year	Fuel oil (t)	Electricity thou Kwh
1989	21,585	27,185
1990	13,850	22,622

Table 4. Energy Consumption by department.

Department	Electricity thou/kWh	Heat (GJ)
Vitamin C	6,600	243,000
Tablet w/shop	1,560	49,000
Gel w/shop	1,950	78,000
Organic ppns w/shop	3,300	125,000
Energy supply units and others	13,775	364

2.1 Boiler Operations

Boilers # 2 and # 3 were each operating at 10 tons (t)/hour on the first day that plant operations were analyzed by the Team. As there was no installed instrumentation for the boilers, the equipment operated with considerable excess air, resulting in low efficiency. At the time of the audit, Team members observed that the damper of Boiler # 3 was partially defective and would not close sufficiently to allow optimal operating conditions. Tests conducted as part of the audit included varying damper positions and analyzing the stack gas. The results of tests on Boiler #2 are presented in **Appendix I**. Tests were conducted on Boilers # 4, # 7 and # 8; results of these analyses are shown in **Appendices II, III, and IV** respectively.

During testing, the stack gas was analyzed at several fuel rates and damper positions to provide operators a guide for more efficient settings until oxygen and temperature measurement equipment could be installed. Results of the audit and subsequent discussions indicated that purchase of such measurement equipment should be a priority in the current environment of rapidly increasing energy/fuel supply costs.

Overall, the boilers appeared to be well maintained, and staff were very cooperative and eager to learn.

2.2 Condensate System

On the first day of the audit, field tests highlighted the fact that little condensate was being returned. Reduced operations and the shutdown of some production lines were the primary reasons for severe reductions in condensate recovery. (Note feed water temperature in **Appendix I**). On the second day of the April audit, field tests revealed that approximately 25 to 28% of the condensate was returned.

Since as the condensate has a potential value of at least 1,700,000 lv per year, the Team conducted in-depth audits of each steam consumption area and developed an appropriate heat balance for each. This analysis suggested that 80% of the condensate could be recovered by adopting and implementing a program to repair and reconstruct the current system. The top three priority items are capital intensive projects that require further analysis and more extensive process changes. Of these, one project was implemented with funding from the U.S. Agency of International Development; this involves the purchase and installation of steam traps and pipe fittings to improve condensate recovery, as well as the procurement of instruments (such as infrared thermometer, industrial stethoscope, centrifuge) designed to detect leaks and other problems within the recovery system.

2.3 Electrical Distribution

The electrical distribution system is currently operated at 20 kV to 400 V, with the power factor well controlled at about 93% (the minimum "no penalty" value). The system was designed redundantly, however so that each department/building has two 20 kV feeds and two transformers (630, 1000 or 1600 kVA). At any one time, only one feed to each department is used. Even given this system, distribution transformers generally operate at under 50% of load capacity. An opportunity exists to move some transformers to reduce internal losses. If new

transformers are purchased, they should be properly sized and should be chosen from among the newer, more efficient transformers now available in Bulgaria.

Currently, there are two lines between the city substation and plant substation; in normal situations, one of the lines is energized and the other serves as a stand-by. Losses for one line are about 330,000 kWh/year or 83,000 lv/year. If both lines were used simultaneously (in parallel) in the future, losses could be reduced to 160,000 kWh/year, generating a cost savings of 40,000 lv annually.

To achieve the above savings, it will be necessary for the plant to provide additional fault protection by installing a differential meter reading system; the cost for this would be 120,000 lv (at 1991 prices) and would have a payback period of about three years. Before implementing a project of this nature, plant management should reassess the payback period in light of 1992 prices, and evaluate the value of project paybacks in the context of other investment alternatives.

2.4 Demand Control

"Pharmacia" monitors total electrical consumption hourly, and maintains records on the same basis. Unfortunately, the day shift begins work at 8:00 A.M., a time which increased energy consumption (due to additional staff on the day shift) overlaps the utility's high-priced morning peak rate' based on the following tariff schedule:

8 - 10 am/6 - 10 pm	- 0.56 lv/kWh (4 c/kWh)
6 - 8 am/10 am - 6 pm	- 0.28 lv/kWh (2 c/kWh)
10 pm - 6 am	- 0.12 lv/kWh (8.6 mills/kWh)

Cost savings to be gained by advancing the shift schedule one-half hour are approximately 672 lv per work day. (based on usage recorded for Monday, April 15, 1991, from 7 to 8 A.M. (1,100 kWh) and 9 to 10 A.M. (2,300 kWh).

Opportunities for reducing or shifting loads to off-peak times were discussed with plant staff. The demand analysis conducted by the Energy Conservation Audit Team caused the plant management to resolve to implement demand control options considered previously but never implemented, and to actively seek this type of opportunity in the future.

2.5 Future Electricity Rates

At the time of the audit, electricity rates were below the incremental new resource costs, and off-peak rates were below the marginal or decremental fuel costs. Also significant was the fact that residential rates were lower than industrial rates, since electric utility prices for residents are still subsidized by the government.

The most important electricity consideration for plant managers is the specter of increasing electricity prices for the future. Until prices for "grid" electricity reflect all costs associated with electricity production and are near "world prices," industrial consumers will continue to operate in a climate of increasing electricity prices. This future risk was discussed

with the management staff of the plant, and they demonstrated awareness of the need to factor this risk into management decisions.

2.6 Cogeneration Prospects

The projected steam load for Pharmacia's plant production rates was approximately 50,000 lbs./hour in the summer and 100,000 lbs./hour in the winter. These rates, using basic economics, would not justify the capital costs of a cogeneration facility; this is particularly true if new boilers are not otherwise required for an existing facility.

However, plant production capacity is two times present demand, and four new boilers (12 T/hr each) were purchased in early 1991 to enable the plant to meet this demand. Three of the boilers were already installed at the time of the audit, and had a total capacity of more than 200,000 lbs/hour. (Assuming over 8,000 hours of operation per year; e.g., three shifts per day, and seven days per week versus the present 4,000 hours per year operation. It also, assumes a market for the products.) Under these conditions, a higher pressure boiler (e.g., 900 to 1,200 psi at superheated temperatures) along with a back pressure or perhaps installation of an extraction/condensing turbine-generator might be justified.

It is well known that energy generation using back-pressure turbine (and assuming an adequate heat sink) can provide electricity at about 4,500 Btu/kWh versus more than 10,000 Btu/kWh (2.52 GCal/kWh) for even the best condensing steam utility plant. Nonetheless, s important to note that a district heating system in Stanke Dimitrov is not currently feasible e to the sprawl of the city, and the fact that most buildings would require extensive and costly modifications to accommodate such a system.

Of course, such an undertaking would require participation by the electric utility and real value of the generated power would have to be near most known new-resource values. Moreover, the prospect assumes the consumption of oil, as a coal-fired plant may have a larger economy of scale.

2.7 Lighting

At the time of the audit, lighting costs accounted for 10% of the total electric power bill in the plant. According to accounting records, 1989 lighting requirements were responsible for 2,718,558 kWh of electricity consumption. Using April 1991 electricity costs (0.25 lv/kWh), the average annual energy cost of lighting would be 680,000 lv/year.

The audit revealed that many lamps were not cleaned or changed until the end of their life, resulting in lighting energy losses of 22% (149,520 lv per year). Such inefficient use of lighting not only has a major effect on plant energy costs, but also affects the production process. For example, it was noted that poor lighting had a significant adverse effect on personnel productivity, as well as high rejection rates for products, adversely affecting quality control. According to most standards for this kind of production activity, lighting levels of over 500 lx are recommended as opposed to the measured level in the Pharmacia facility of 30 lx.

Upon investigation of lighting requirements in Tableting Department No. 1, it was revealed that most lamps were not clean, and 30 to 50% of all lamps were burned out. As a result, lighting intensity within the plant was only 10 to 60 lx. After cleaning and changing lamps in one of the shops, light intensity increased eight times. By comparing the power of lamps in the cleaned versus uncleaned workshops, it was established that energy losses in the uncleaned areas were 80 watts per tube.

To reduce the amount of electricity consumed for lighting, Team members recommended several courses of action. The plant should:

- change to new high efficiency fixtures and/or Ballasts; "Pharmacia" should realize an savings in lighting costs of about 10%.
- replace burned out lamps; the plant should realize higher lighting levels at lower costs based on the measurement and analysis of lighting requirements in the plant.

The total savings from all lighting recommendations would be approximately 150,000 lv in the first year.

2.8 Heat Balances - Steam

A heat balance of the steam system was developed by the Audit Team through the use of the plant's Energy Consumption Limitations plan for 1991 (See **Appendix V**) and by auditing each steam consumption department. Insofar as there was little reliable actual data from measurements (the Team was only able to do spot checks with portable instruments), heat balances are subject to error for specific departments.

The balance of heat losses due to steam leaks, lost condensate, and uninsulated surfaces is shown in **Table 5**.

Table 5. Heat losses, their causes, and cost per year.

Losses	Heat Losses		Losses/Savings lv/year
	GCal/hour	mln BTU/hr	
Steam Leaks	0.415	1.66	560,000
Uninsulated Surfaces	0.690	2.76	930,000
Lost Condensate	1.850	7.40	2,500,000
TOTAL	2.955	11.82	3,990,000

Note: Savings are calculated on the base of fuel price of 1,200 lv/t.

Rough estimates of losses amount to 20.9% of fuel consumption (Mazut) at approximately 16,000 tons per year. Boiler efficiency is about 75%, and the specific heat of fuel is 9.5 GCal/ton.

The heat balance of the factory includes:

- 2 to 4% losses due to steam leakages,
- 10 to 16% losses due to lost condensate,
- 4 to 6% losses due to non insulated surfaces,
- 0.5 to 1 % losses for mazut preheating in rail-way tanks and 2% losses from distribution heating system.

The total amount of losses varies between 18.5 and 29%. At average steam production of 14.25 GCal/hr, the useful energy for plant processes is between 10 and 11.6 GCal/hour, respectively to 15 to 18 tons/hour of steam.

The Energy Conservation Audit Team hypothesized that the heat of evaporization was used in the processes and the enthalpy of the condensate is between 60 - 70 GCal/kg, and that only 25 to 28 % of condensate is returned. If the heat of evaporization is not fully used, expected losses (savings) are much more. This suggests the need for equipment to measure pressure and temperature equipment at the significant steam stations in the plant.

Not withstanding the lack of data, there appear to be several significant steam conservation opportunities that can be reasonably evaluated using economic criteria. These opportunities in several cases improve not only the plant heat utilization, but also have direct impact on condensate recovery. Heat system opportunities include:

- Condensate system reconstruction
- Mazut (fuel oil) receipt and storage system improvements
- Steam leak repairs
- Insulation replacement
- Process design investigations

These opportunities are all significant but certainly the condensate system represents the most important item as, for example, the condensate has a value in the range of at least 1,700,000 lv/year. As mentioned above, it appears that about 80% of the condensate can be economically recovered.

Finally, since improvements in the condensate system, steam leak repair, and insulation replacement are mentioned elsewhere in this report, only improvements to the mazut receipt and storage systems will be described in this section. In cases where accurate float gauges were not installed - and even where oil meters were used - the Audit Team recommended gauging the tanks using the following procedure:

1. Strap the mazut and nafta tanks.

2. Calculate volume from bottom up for every two centimeters, make and mark gauge sticks each 2 cm.

3. Measure the tanks on least at the first of every month; it is able that this procedure be followed daily.

4. Calculate the volume (inventory) in each tank and add oil purchases for the month to arrive at the amount of oil used during the month or daily.

5. Compute oil used per unit, electricity per unit, and cost per unit.

2.9 Heat Balances-Refrigeration

From observations made during the energy audit of the one-stage refrigeration station (See **Figure 2**), it was noted that: insulation was missing from crucial areas; two subcoolers were broken down; there was no automatic load control for the system; and compressors were switched on/off manually. The temperature of evaporation was and the level of the liquid ammonia in all evaporators was regulated by sensors and magnetic valves. Overall, the refrigerating system was very old, with rusty piping around the evaporators. **Figures 2, 3, and 4** show aspects of the system.

The two-stage refrigeration station is used primarily for cold storage of bioproducts. There are two fan evaporators in the cold storage chamber, but no thermostatic expansion valve. There are only two solenoid valves, but they are not wire connected. Defrosting is done manually once a week using heat, as there is no automatic control for a defrost cycle. The two-stage refrigeration station is also equipped with automatic control systems, except for the cold storage chamber.

Inspection of the six condensers showed that the temperature difference between the headers of the inlet and outlet cooling water was about 2 to 3°C. For each condenser, temperature difference varied between 0°C and 6°C, indicating that some condensers did not work properly.

FIGURE 2. SCHEMATIC DIAGRAM OF PHARMACIA'S ONE-STAGE REFRIGERATION SYSTEM

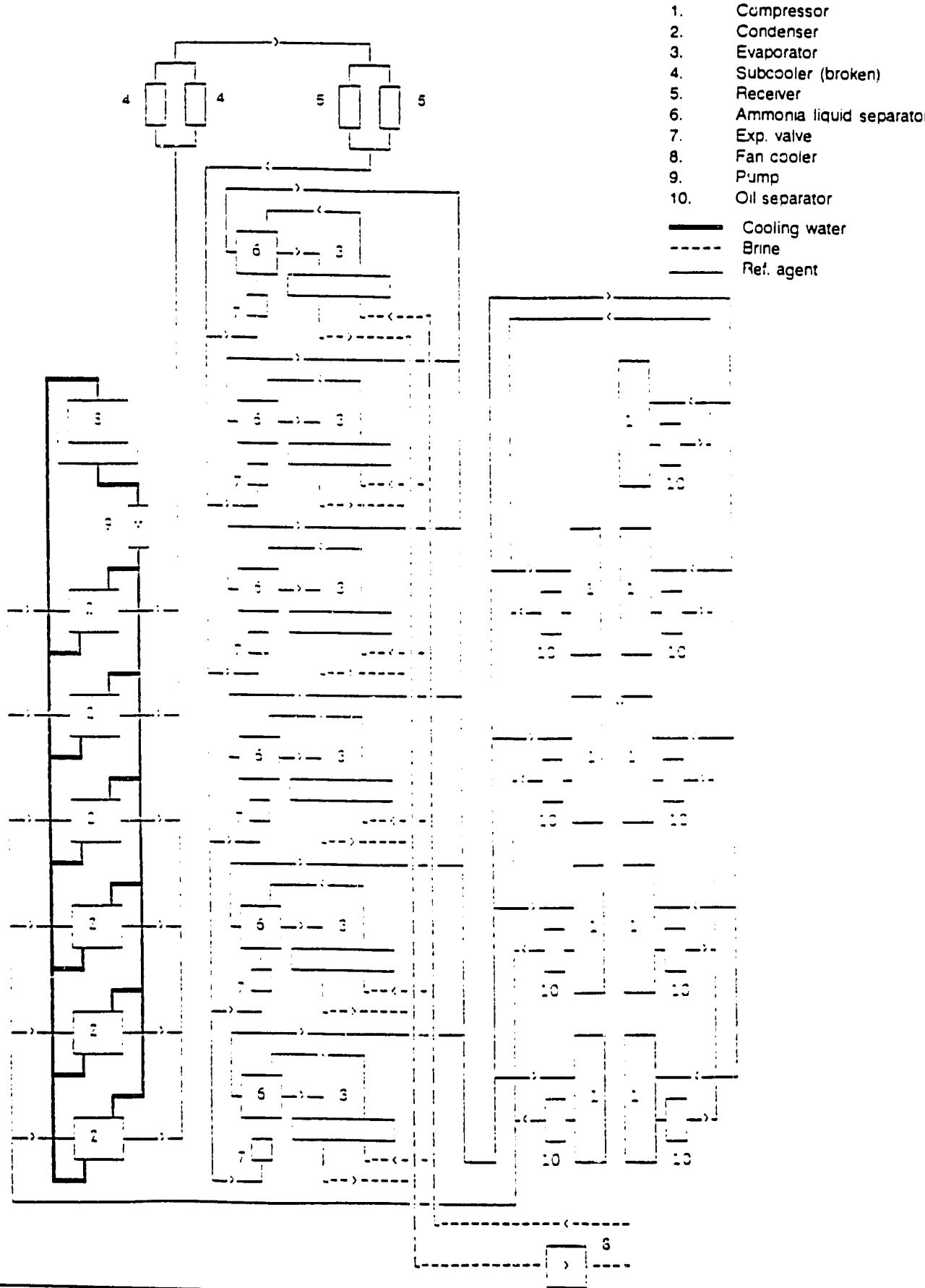


Figure 3. Diagram of the one-stage refrigeration system in its current state (i.e., no automatic control system).

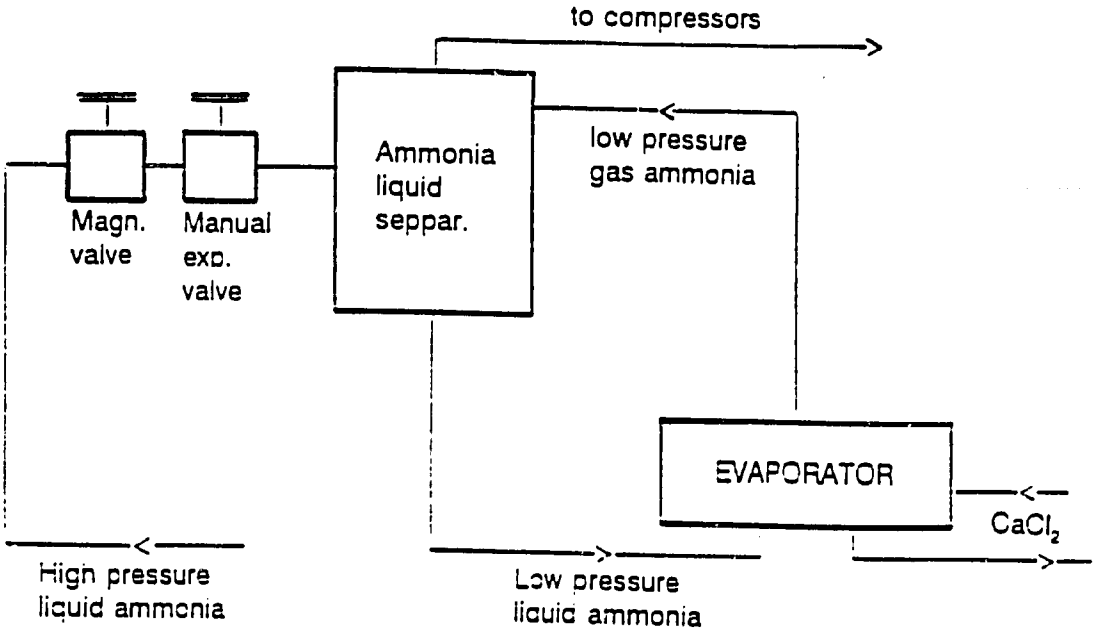
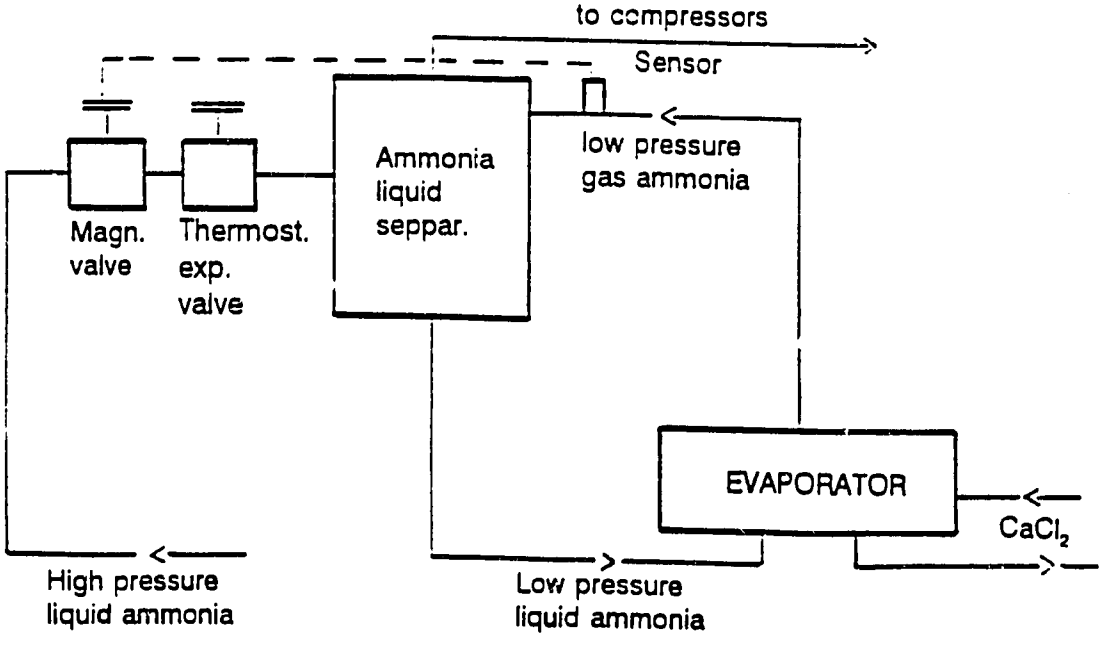


Figure 4. Diagram of the one-stage refrigeration system with an automatic control system added.



3. ENERGY MANAGEMENT

3.1 Energy Management Structure

Prior to the arrival of the Audit Team, energy management was not high priority at "Pharmacia"; and, no formal energy management program had been instituted until that time. Although a list of "Energy Consumption Limitations" had been compiled by the plant in early 1991, there was little awareness within the plant of energy management issues, including knowledge of appropriate technologies, applied expertise in these technologies, understanding of competitive economics, capital for initiating energy conservation measures, and incentives for making significant changes.

However, some energy monitoring had been conducted using electricity and fuel oil invoices along with considered judgements. More extensive quantitative analysis was limited due to the lack of instrumentation. The plant management, by including a large number of individuals in the audit process and cooperating with the Team, demonstrated willingness to institute a comprehensive energy management program. Thus, discussions with plant management emphasized economic justifications for selected instrumentation purchases, along with the development and maintenance of an energy management program.

3.2 Energy Management Seminar

Recognizing the importance of energy management in determining the overall efficiency of industrial energy use, the Energy Conservation Audit Team presented a seminar which addressed a number of energy management issues. Recommendations presented in the seminar were designed by Team members to provide an overall framework for improved energy management and training related to energy efficiency.

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

- steam leaks
- condensate leaks
- insulation opportunities (water, steam, refrigeration)
- electrical opportunities
- lighting
- water leaks
- air leaks
- boiler operations
- refrigeration system analysis

Issues addressed at the seminar were dealt with in more detail at the January 1992 Energy Management Workshop in Sofia, at which a representative of the Pharmacia plant made a presentation. An excerpt of the presentation on Energy Management Practices presented at the January seminar is included as **Appendix IX**.

3.3 Training Requirements

Training requirements for this plant vary by personnel area; however, at a minimum, all plant personnel should receive basic training in energy awareness. Technical and managerial personnel should receive more extensive training in economic and technical areas through seminars, training retreats, and where feasible, outside training courses at technical institutes.

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

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

energy cost accounting - this type of training would be particularly useful if it involved learning practical skills related to the use of 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; and

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.

Refresher courses and subsequent programs for all plant personnel should focus on specifics of the plant's energy management program; key energy waste areas; identification of

energy conservation opportunities and solutions; and energy conservation monitoring and incentive schemes. In addition, training initiatives for managers should address economic issues (with varying degrees of specificity depending on job requirements) including investment evaluation tools, plant profitability, export benefits and principles, and employment issues. Finally, training programs for department heads, engineers, and technical specialists should include thermodynamics (as applied to both steam and refrigeration systems), engineering economics, and detailed energy management techniques.

4. ENERGY EFFICIENCY IMPROVEMENT OPTIONS

Listed below are options for improving energy efficiency use within the plant. Clearly, all of these practices and projects will help conserve energy in the facility. However, given the reality of scarce resources for implementing these projects, the Team made specific recommendations that some of these options be given priority. This prioritization is included in **Section 5**. Nevertheless, this section outlines the wide variety of options that are available for energy efficiency improvement. The ultimate decision regarding implementation of alternative options will depend upon the criteria set by plant management, including acceptable payback periods, and upon the overall corporate strategy.

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

4.1 "No- or Low-Cost" Options

For the purposes of this paper, "no-cost" items refer to projects to be initiated at the expense of the plant in cases where expenditures are involved. Although few of these recommendations are literal "no-cost" propositions, they all are possible to implement within the existing framework of plant expenditures (i.e. leva purchases, improved maintenance, and housekeeping). Local investment and installation labor for low-cost initiatives will be provided by the plant. Hard currency for some of the low-cost items will be available A.I.D. Emergency Energy Program. A summary of purchases is included in **Section 5**. In addition, justification and specifications for these items are included in **Appendix VII.**

1. **Rebuild the condensate recovery system**. This project, which will involve the purchase of steam traps and pipe fittings (some of which will be financed by the Agency for International Development), will require an investment of approximately 100,000 lv, with a savings of 2,000,000 lv in the first year alone. The return on investment (ROI) will be greater than 100%, with a one month payback.

2. **Purchase and install stack gas oxygen and temperature instrumentation and operate the boilers accordingly**. The required investment for this project is 15,000 lv, with an estimated savings of 100,000 lv in the first year. The payback period is two months with an ROI of more than 100%. Some of these instrument purchases will be financed by the Agency for International Development.

3. **Intensify the steam leak repair program**. The cost of this project will be approximately 10,000 lv, with estimated resulting savings of 560,000 lv in the first year. The payback time is one month with an ROI of more than 100%.

4. **Eliminate use of direct steam in oil tank cars**. Apply whatever pressure is available to get deliveries of Mazut <u>only</u> in rail cars that have heating coils in <u>good</u> order. This is a "no cost" investment as defined above, and would have a savings of 50,000 lv/yr. The payback time is one month with a greater than 100% ROI.

5. **Implement lighting improvements. These include:**

   - **Changing to new high efficiency fixtures and/or Ballasts.** The U.S. Agency for International Development will help to finance part of this investment project.

   - **Replacing burned out lamps.** This is a "no-cost" investment as defined above.

   The total cost of all lighting improvements would be approximately 123,000 lv, with a savings of approximately 150,000 lv in the first year. Pay back time is 0.82 years with an ROI of 100%.

6. **Install steam line insulation.** The cost would be approximately 20,000 lv, with savings of 930,000 lv in the first year, a payback period of one month, and an ROI of more than 100%.

7. **Implement refrigeration improvements including:**

   - **Installing a smaller (about 90%) recirculating pump for condenser cooling.** The cost of this project would be 15,000 lv, saving 125,000 lv/year and a ROI of over 100% with payout time of two months.[1]

   - **Checking and cleaning the exchanger surface of poorly functioning condensers.** The cost of this project is 3,500 lv, and it would have savings of 25,000 lv/year, and a ROI of more than 100%, with a payback period of one month.[2]

   - **Install automatic expansion system on the one-stage refrigeration station.** The cost of this project is estimated at 30,000 lv, with estimated savings of 75,000 lv/year. The ROI is more than 100%, with payback time of five months.[3]

   - **Repair refrigeration insulation.** The cost of this initiative would be 6,500 lv, and the project would have savings of 47,000 lv/year. Thus, the project would have a ROI of more than 100 % with payback in two months.

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[1] At 8,000 hours operation the power savings are estimated of 680,000 kWh. The value of the estimated savings is calculated at price of 0.25 lv/kWh.

[2] The Audit Team estimated that the insufficient heat exchange in the condensers increases water expenses proportionally to the unused heat exchange surface. In this case two condensers (from all 6 units) don't operate, or the present additional expenses for electric power consumption are approx. 30%.

[3] The Team assumed that electric power consumption will be reduced by 25% or 300,000 kWh per year in the refrigeration station after installation of an automatic expansion systems.

- **Equip the cold storage chamber with thermostatic expansion valve and automatic defrost equipment.** This project will cost 10,000 lv and yield a savings of 28,000 lv/yr, with a ROI of more than 100% and payout of less than six months.[4]

- **"No Cost" Refrigeration Process Improvements.** In addition to the projects outlined above, the Audit Team recommended a number of maintenance and operation changes (Reference 2) pertinent to refrigeration energy conservation opportunities. These were provided to the seminar participants and include:

  - **Optimize Defrost Cycle.** Set the defrost cycle based on seasonal, humidity, and load requirements;

  - **Purge Non-Condensables.** Remove non-condensables from the refrigeration system at each purge point;

  - **Properly Sequence Compressors.** Manage compressors so that each operates at or near full capacity;

  - **Reduce Condensing Pressure.** Operate refrigeration system at the lowest condensing pressure possible with existing condenser capacity;

  - **Maintain Cooling Tower and related equipment, and treat cooling tower water**; and

  - **Load Management.** Manage both supplementary and product loads.

4.2 Capital-Intensive Options

The following options were discussed with plant management, and initial comments were made concerning each. However, since requisite data was not available for some of these options and feasibility studies had not been conducted, the Team was unable to make a definitive recommendation about these options. The Team recommends, however, that a comprehensive evaluation be made of both the technical and economic aspects of both investments prior to the commitment of any funds.

1. **Reactors** - Consider replacement of present fermentation reactors, investigating state of the art technologies as well as other older models.

[4] The two-stage refrigeration installation operates approximately 5,000 hours per year. The power of the compressor is 75 kW. The Team assumed that after implementation of the above recommendations, a 30% reduction of electric power consumption will be achieved.

2. **Cogeneration** - Review prospects for cogeneration once production and market circumstances require the use of total plant capacity.

5. RECOMMENDATIONS AND CONCLUSIONS

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

5.1 Improved Energy Management

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

In conjunction with improved training, the 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 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 increase), in order to categorically prioritize investment opportunities.

5.2 Improved Operating Practices and Operational Changes

The following recommendations reflect changes in operating practices, housekeeping, and maintenance which can yield significant energy savings with minimal investment cost. These recommendations include focusing attention on lighting, heating, and ventilation for the building, in addition to changes in the operation of the steam boiler plant and the process steam distribution station.

1. **Work to improve condensate recovery** – this is one of the most cost effective ways for this plant to reduce its energy bill.

2. **Prioritize the purchase, installation and use of energy meters, and portable instruments** – this will enable staff to identify energy waste areas, monitor improvements, and provide data for evaluation of energy efficiency investments.

3. **Improve steam systems** – repair steam leaks, eliminate use of direct steam in oil tank cars, and repair or replace insulation for steam lines.

4. **Change lighting systems** – change to new high efficiency fixtures and/or Ballasts and replace burned out lamps.

5. **Implement refrigeration systems maintenance and operational changes** – this includes: 1) installing a smaller (about 90%) recirculating pump for condenser cooling; 2) checking and cleaning the exchanger surface of poorly functioning condensers; 3) installing an automatic expansion system on the one-stage refrigeration station; 4) repairing refrigeration insulation; 5) equipping the cold-storage chamber with thermostatic expansion valves and automatic defrost

equipment; 6) optimizing the defrost cycle; 7) purging non-condensables; 8) properly sequencing compressors; 9) reducing condensing pressure; 10) maintaining cooling tower and related equipment, and treat cooling tower water; and 11) instituting a load management program.

5.3 Recommended Capital Investments

Equipment Purchased Under the Emergency Energy Program:

1. **IR Thermometer** — The portable infrared thermometer will identify damaged insulation or heat losses from other sources throughout the plant. The cost of the item was $437; the estimated savings from this instrument are expected to be more than $1,200 per year.

2. **Oxygen Analyzer** — These items will monitor excess air in the combustion process. The cost of the item was $952, with savings estimated at over $2,600 per year.

3. **Fluorescent Lights** — More efficient fluorescent lights will replace some of the burned out fixtures within the plant, achieving a higher level of light at a lower energy consumption rate. The cost for these fixtures was $8,197 and savings are estimated to be approximately $10,000 per year.

4. **Industrial Stethoscope** — The industrial stethoscope will check for steam trap leakages. The cost of this item was $451, with the savings valued at $4,200 per year.

5. **Steam Traps** — High quality US-made steam traps will improve steam utilization within the plant and avoid large energy losses associated with steam leaks and faulty steam traps. This investment cost $8,435, but its energy savings are valued at nearly $80,000.

6. **Pipe Fittings** — Pipe fittings will be used along with the steam traps to improve steam utilization within the plant. This investment cost $5,148, and will save an estimated $55,900 of energy expenses per year.

7. **Power Monitor** — The electric power monitor will monitor electric energy use throughout the plant, where in-situ meters are not available, and will help energy managers to identify energy waste areas, monitor improvements, and provide data for evaluation of

investments. This item cost $5,870 and will result in an estimated savings of $9,600.

8. **Centrifuge** — This will be used to improve monitoring of plant processes. Cost of the item was $582.

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

5.4 Other Recommended Projects

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

1. Install the following equipment:
   - In-situ oxygen analyzers for all four boilers, with a moveable recording meter;
   - Temperature meters for stack gas measurements.
2. Investigate reliability and maintainability of flow meters for Mazut. Follow-up with recommendations as appropriate.
3. Repair/replace the condensate system in stages, making all necessary investments in addition to the investments made under the Emergency Energy Program.
4. Calibrate boiler metering equipment.
5. Refine instructions and boiler operation procedures
6. Implement flow meter investigation results.

APPENDIX I

STATE COMPANY "PHARMACIA"

STACK GAS ANALYSIS - BOILER #2: (old type)

Position	Unit	1	2	2	2
Date:	4-13-91				
Time		9:58	10:24	10:27	10:47
Oil Pressure	kg/cm^2	19	20	19	17
Combustion Eff.	%	79.7	81.0	80.8	80.5
Ambient Temp	°C	19	24	24	26
Stack Temp	°C	144	145	145	149
OxYgen	%	6.0	1.9	2.8	3.7
Carbon Monoxide	PPM	39	1834	1264	497
Carbon Dioxide	%	6.9	8.8	8.5	8.1
Combustible Gases	%	0.00	0.00	0.00	0.00
Excess Air	%	35	9	13	18
Oxides of N	PPM	0	0	0	0
Sulfur Dioxide	PPM	730	1439	1263	863

Conditions:

1. Closed damper to pos. 1 from 5 positions (1 fully closed; 5=fully opened).
2. Closed damper to pos. 3 from 5 positions.
3. Fuel in computer was 19,360 Btu/lb versus 16,500 to 17,000 as estimated for Mazut.
4. No condensate was returned. The feed water temperature was 6°C (when condensate was returned the temperature was approximately 20°C)

APPENDIX II

STATE COMPANY "PHARMACIA"

STACK GAS ANALYSIS - BOILER #4 (KM-12; old type)

Position	Unit	1	1	1
Date:	4-15-91			
Time		11:35	11:44	11:49
Oil Pressure	kg/cm^2	12	18	20.5
Combustion Eff.	%	76.4	76.9	77.6
Ambient Temp	°C	25	25	25
Stack Temp	°C	195	202	204
Oxygen	%	7.0	4.4	3.3
Carbon Monoxide	PPM	46	80	101
Carbon Dioxide	%	6.5	7.7	8.2
Combustible Gases	%	0.03	0.07	0.04
Excess Air	%	44	23	17
Oxides of N	PPM	0	0	0
Sulfur Dioxide	PPM	8	169	219

Conditions:

1. Damper missing (broken).
2. The boiler was found to work best at an oil pressure of 12 kg/cm^3.
3. Fuel in computer was 19,360 Btu/lb versus 16,500 to 17,000 as estimated for Mazut.
4. No condensate was returned; the feed water temperature was 6°C.

APPENDIX III

STATE COMPANY "PHARMACIA"

STACK GAS ANALYSIS - BOILER #7 (PKM 12; old type)

Position	Unit	1	1	2	3
Date:	4-15-91				
Time		10:38	10:44	11:02	11:07
Oil Pressure	kg/cm^2	3	5	3.8	4.2
Combustion Eff.	%	72.8	76.5	77.4	78.8
Ambient Temp	°C	23	24	25	25
Stack Temp	°C	201	222	206	198
Oxygen	%	11.2	4.9	4.4	1.6
Carbon Monoxide	PPM	0	8	37	51
Carbon Dioxide	%	4.6	7.5	7.7	9.0
Combustible Gases	%	0.00	0.00	0.00	0.00
Excess Air	%	101	24	24	7
Oxides of N	PPM	0	0	0	0
Sulfur Dioxide	PPM	12	189	232	282

Conditions:

1. Closed damper to pos. 9 from 9 positions (1 = fully closed, 9 = fully opened).
2. Closed damper to pos. 6.5 from 9 positions.
3. Closed damper to pos. 6.8 from 9 positions.
4. The boiler was found to work best at an oil pressure of 3 kg/cm^3.
5. Fuel in computer was 19,360 Btu/lb versus 16,500 to 17,000 as estimated for Mazut.
6. No condensate was returned; the feed water temperature was 6°C.

APPENDIX IV

STATE COMPANY "PHARMACIA"

STACK GAS ANALYSIS - BOILER #3: (PKM-12 Old type)

Position	Unit	1	2	2
Date:	4-15-91			
Time		9:33	9:44	10:13
Oil Pressure	kg/cm^2	3	4	5
Combustion Eff.	%	75.5	76.5	77.8
Ambient Temp	°C	22	22	23
Stack Temp	°C	198	193	204
Oxygen	%	7.9	5.1	2.2
Carbon Monoxide	PPM	5	10	283
Carbon Dioxide	%	6.1	7.4	8.7
Combustible Gases	%	0.04	0.11	0.05
Excess Air	%	53	28	11
Oxides of N	PPM	0	0	0
Sulfur Dioxide	PPM	593	1079	1005

Conditions:

1. Closed damper to pos. 5 from 9 positions (1 = fully close, 9 = fully opened).
2. Closed damper to pos. 7 from 9 positions.
3. The boiler was found to work best at an oil pressure of 3 kg/cm^3.
4. Fuel in computer was 19,360 Btu/lb versus approx. 16,500 to 17,000 as estimated for Mazut.
5. No condensate was returned. The feed water temperature was 6°C.

APPENDIX V

ENERGY CONSUMPTION LIMITATIONS - 1991
STATE COMPANY "PHARMACIA"

	Electric Power kWh		Steam (t/hr)		Water cu m/day		Gases (no. of m^3/hr)	
Department	Day rate	Peak rate	Winter	Summer	Drinking	Industrial	Air	Nitrogen
1. Tabletting 1	80	80	3.4	1.6	198.0	-	1500	-
2. Tabletting 2	320	320	3.1	1.2	190.0	420	1100	-
3. Vitamin C	580	485	10.5	6.5	250.1	900	4000	35
4. El.Ch.Ox-low vltg	120	100	0.1	-	15.0	-	-	-
5. Synthesis 1	70	55	4.5	2.5	166.0	180	100	15
6. Synthesis 2	75	60	4.0	2.0	35.0	55	100	10
7. Synthesis 4	70	55	4.1	2.2	30.0	45	100	15
8. Synthesis 5	65	50	3.0	1.2	150.0	80	120	10
9. Organic Prod.	100	80	4.2	1.8	40.0	230	50	20
10. Gel Prep.	120	100	2.5	1.2	645.0	32	120	-
11. Tooth Paste	50	50	2.1	1.0	40.0	192	150	-
12. Steam Boilers	220	180	0.2	-	1.0	1150	-	-
13. Nitrogen St.	70	50	0.1	-	1.5	12	-	-
14. Refrig. St.	330	260	0.2	-	1.5	200	-	-
15. Tech. Compress.	235	235	0.1	-	0.5	510	-	-
16. Water Recycling	160	100	0.1	-	1.0	-	-	-
17. Store Prod.	25	25	0.5	-	4.5	-	10	-
Goods	15	15	-	-	0.5	-	-	-
18. Wells	140	120	0.6	-	28.0	-	-	-
19. Admin. &	25	25	2.0	1.1	1.0	-	-	-
Canteen	10	10	1.1	0.5	1.0	-	-	-
20. Pumping St. 1	50	10	0.1	-	1.0	30	-	-
21. Pumping St. 2	25	15	0.5	0.1	10.0	-	-	-
22. Two Stag. Refrig.	25	20	0.4	-	3.0	-	-	-
23. Laboratory Bldg.	120	100	0.6	0.1	10.0	6	-	-
24. Engineer Bldg.								
25. Mach Repair Plant								
Total	3100	2600	48.0	23.0	1824.6	4042	7350	105

Note: Excluding electrical power, all other limits are defined according to project estimations, pressure, pipe diameters, and statistical data.

APPENDIX VI

Meeting
April 12, 1991 Friday
State Company Pharmacia

Name	Position	Affiliation
Norbert Methven	Engineer	International Resources Group
Christian Spassov	President	Ecotechproduct
Ivan Nickolov	Computers & Heating	Ecotechproduct
Emil Chickekliev	Heating & Refrigeration Engineer	Ecotechproduct
Svetla Razmova	Inspector of Energy consumption	Energy Department
Emil Nikolov	Inspector of Energy consumption	Energy Department
Valery Krastev	Inspector of Energy consumption	Energy Department
Bojan Tsanev	Deputy Director	Pharmacia Comp.
Stamenko Karachorsky	Chief Power Engineer	Pharmacia Comp.
Timko Rainov	Power Engineer	Pharmacia Comp.
Plamen Slavov	Power Engineer	Pharmacia Comp.
Alexander Begov	Chief Electric Substation	Pharmacia Comp.
Krum Panaitotov	Chief Steam Boiler Station	Pharmacia Comp.
Snejana Boitcheva	Technol. Chief "Univers." 1	Pharmacia Comp.
Michail Lazov	Mech. Eng. "Univers." 1	Pharmacia Comp.
Alexander Ahtchiev	Depart. Chief "Univers." 2	Pharmacia Comp.
Vladimir Rakidjiiski	Power Eng. "Univers." 2	Pharmacia Comp.
Nicolai Kostadinov	Power Eng. "Univers." 4	Pharmacia Comp.
Georgi Grantcharov	Power Mech. "Univers." 5	Pharmacia Comp.
Snejana Angelova	Depart. Chief "Univer." 5	Pharmacia Comp.
Ani Dimitrova	Depart. Chief "Tablett." 2	Pharmacia Comp.
Ljudmil Nestorov	Mech. Eng. "Tablett." 2	Pharmacia Comp.
Nina Kraleva	Power Eng. "Tablett." 2	Pharmacia Comp.
Blagoi Orozov	Power Eng. "C vitamin"	Pharmacia Comp.
Asen Radenkov	Mech. "C vitamin"	Pharmacia Comp.
Peter Ushev	Depart. Chief "Organopr."	Pharmacia Comp.
Snejana Stanoeva	Mech. "Organopr."	Pharmacia Comp.
Verter Atanasov	Mech. "Gel Prep."	Pharmacia Comp.

Meeting
April 13, 16 and 17 1991 Saturday, Tuesday and Wednesday
State Company Pharmacia

Name	Position	Affiliation
Norbert Methven	Engineer	International Resources Group
Christian Spassov	President	Ecotechproduct
Ivan Nickolov	Computer Specialist	Ecotechproduct
Emil Chickekliev	Heating & Refrigeration Engineer	Ecotechproduct
Svetla Razmova	Inspector of Energy consumption	Energy Department
Emil Nikolov	Inspector of Energy consumption	Energy Department
Valery Krastev	Inspector of Energy consumption	Energy Department
Stamenko Karachorsky	Chief Power Engineer	Pharmacia Comp.
Timko Rainov	Power Engineer	Pharmacia Comp.
Alexander Begov	Chief Electric Substation	Pharmacia Comp.
Krum Panaitotov	Chief Steam Boiler Station	Pharmacia Comp.

Meeting
April 15, 1991 Monday
State Company Pharmacia

Name	Position	Affiliation
Norbert Methven	Engineer	International Resources Group
Christian Spassov	President	Ecotechproduct
Ivan Nickolov	Computer Specialist	Ecotechproduct
Emil Chickekliev	Heating & Refrig. Eng.	Ecotechproduct
Svetla Razmova	Inspector of Energy consumption	Energy Department
Emil Nikolov	Inspector of Energy consumption	Energy Department
Valery Krastev	Inspector of Energy consumption	Energy Department
Simeon Georgiev	Director	Pharmacia Comp.
Stamenko Karachorsky	Chief Power Engineer	Pharmacia Comp.
Timko Rainov	Power Engineer	Pharmacia Comp.
Alexander Begov	Chief El. Substation	Pharmacia Comp.
Krum Panaitotov	Chief Steam Boiler Station	Pharmacia Comp.

Meeting
April 18, 1991 Thursday
State Company Pharmacia

Name	Position	Affiliation
Norbert Methven	Engineer	International Resources Group
Christian Spassov	President	Ecotechproduct
Ivan Nickolov	Computers & Heating	Ecotechproduct
Emil Chickekliev	Heating & Refrig. Eng.	Ecotechproduct
Svetla Razmova	Inspector of Energy consumption	Energy Department
Emil Nikolov	Inspector of Energy consumption	Energy Department
Valery Krastev	Inspector of Energy consumption	Energy Department
Simeon Georgiev	Director	Pharmacia Comp.
Bojan Tsanev	Deputy Director	Pharmacia Comp.
Stamenko Karachorsky	Chief Power Engineer	Pharmacia Comp.
Timko Rainov	Power Engineer	Pharmacia Comp.
Plamen Slavov	Chief El. Substation	Pharmacia Comp.
Alexander Begov	Chief Steam Boiler Station	Pharmacia Comp.
Krum Panaitotov	Technol. Chief "Univers." 1	Pharmacia Comp.
Snejana Boitcheva	Mech. Eng. "Univers." 1	Pharmacia Comp.
Michail Lazov	Depart. Chief "Univers." 2	Pharmacia Comp.
Alexander Ahtchiev	Power Eng. "Univers." 2	Pharmacia Comp.
Vladimir Rakidjiiski	Power Eng. "Univers." 4	Pharmacia Comp.
Nicolai Kostadinov	Power Mech. "Univers." 5	Pharmacia Comp.
Georgi Grantcharov	Depart. Chief "Univer." 5	Pharmacia Comp.
Snejana Angelova	Depart. Chief "Tablett." 2	Pharmacia Comp.
Ani Dimitrova	Mech. Eng. "Tablett." 2	Pharmacia Comp.
Ljudmil Nestorov	Power Eng. "Tablett." 2	Pharmacia Comp.
Nina Kraleva	Power Eng. "C vitamin"	Pharmacia Comp.
Blagoi Orozov	Mech. "C vitamin"	Pharmacia Comp.
Asen Radenkov	Depart. Chief "Organopr."	Pharmacia Comp.
Peter Ushev	Mech. "Organopr."	Pharmacia Comp.
Snejana Stanoeva	Mech. "Gel Prep."	Pharmacia Comp.
Verter Atanasov		Pharmacia Comp.

APPENDIX VII

EQUIPMENT SPECIFICATIONS AND JUSTIFICATIONS FOR PURCHASE OF EQUIPMENT

"PHARMACIA" CHEMICAL AND PHARMACEUTICAL INTEGRATED WORKS

All consumable items and critical spare parts must be provided for two years usage. Two sets of operating and maintenance manuals are required. The equipment must be rugged and proven for the service desired. Metric units are to be used unless otherwise specified. 220 V, 50 hertz power is available. Units should be complete and ready for installation with all required equipment. Quotations should provide complete installation sketch and description of all equipment to be supplied.

1. **Portable Infrared Temperature Measuring Instrument** -- to be used in conjunction with the Flue Gas Analyzer and the Oxygen Analyzer to assess stack emissions, help minimize emissions, and to affect the most efficient air/fuel mixtures. By installing oxygen and temperature instrumentation, boilers will operate more efficiently. The infrared temperature measuring device also will be able to provide necessary measurements associated with rebuilding the condensate recovery system. Dickson Company model IR-550 or equivalent is recommended.

2. **Oxygen Analyzer** -- to be used in conjunction with the Infrared Temperature Measuring Instrument to analyze stack gas emissions, to help minimize emissions, and affect efficient air/fuel mixtures. By installing oxygen and temperature instrumentation, boilers will be able to operate more efficiently. Davis Instruments Model BC 108101 or Universal Enterprises Model C5A or equivalent is recommended.

3. **Replacement Oxygen Sensors** -- to provide replacement sensors for the oxygen analyzer ensuring the effective operation of this instrument in the future. This would facilitate the analysis of stack emissions. By installing oxygen and temperature instrumentation, boilers will be able to operate more efficiently. Davis Model BC 108927 or Universal Enterprises Model AO51 or equivalent are recommended.

<u>For items 1 - 3:</u>

Estimated annual energy savings:	344,800 KWh in first year
Estimated cost savings:	100,000 levs ($6,666) in first year
Estimated cost:	15,000 levs ($1,000)
Estimated payback:	two months

4. **Industrial Stethoscopes** -- to be used with other appropriate equipment in support of work to rebuild the condensate recovery system and achieve a higher level of energy efficiency. Davis Instruments is a representative vendor.

5. **Thermostatic Steam Trap** -- To be used to replace faulty steam traps as part of an overall strategy to rebuild the condensate recovery system and yield a higher level of energy

efficiency. 1 inch 152 NPT, 1" 152 Internal Kit and 1" 152H Internal Kit in Stainless Steel where available. Yarway or Armstrong or equivalent recommended.

6. **Unibody Disc Traps with Strainer** --To replace traps as part of an overall strategy to rebuild and maintain the condensate recovery system. 3/4" 721 NPT, 3/4" 721 Internal Kit, 3/4" 721 Blowdown kit, 1" 721 NPT, 1" 721 Internal Kit, 1" 721 Blowdown Kit. Yarway or Armstrong Models or equivalent recommended.

7. **Unibody Variable Orifice** -- To be used as part of an overall strategy to rebuild and maintain the condensate recovery system. 3/4" 741L NPT, 3/4" 741A Internal Kit, 3/4" 741B Internal Kit, 3/4" 741C Internal Kit, 3/4" 741D Internal Kit, 3/4" 741 Blowdown Kit, 1" 741L NPT, 1" 741A Internal Kit, 1" 741B Internal Kit, 1" 741C Internal Kit, 1" 741D Internal Kit, 1" 741 Blowdown Kit. Yarway or Armstrong Models or equivalent recommended.

8. **Pipe Fittings** -- To be used as part of a strategy to rebuild and maintain the condensate recovery system. 3/4" Unions, 1" Unions, 3/4" x 6" Nipples, 1" dia x 12" Nipples, 3/4" NPT Dies, 1" NPT Dies, Die Wrench/hande, 3/4" Strainer Y-type w/stainless steel woven strainer, 1" Strainer y-type w/ stainless steel woven strainer, 3/4" tees, 1" tees, 3/4" gate valves, 1" gate valves, 3/4" swing check valves, 1" swing check valves. American Building Supply is a representative vendor.

<u>For items 4 - 8 (plus teaching tools listed below):</u>

Estimated annual energy savings:	6,896,600 KWh
Estimated cost savings:	2,000,000 levs ($133,333)
Estimated cost:	100,000 levs ($6,665)
Estimated payback:	one month

9. **Energy Efficient Fluorescent or Metal Helide Lighting Luminaries** -- designed for Tabletting Department (4 rooms), 75 Footcandles. The system will include 30 fixtures (220 v/50 hz), 60 spare tubes (lamps) and 10 spare ballasts (or electronics). Fluorescent lighting is more energy efficient than the current lighting system and will have a positive effect on worker productivity and product quality.

Estimated annual energy savings:	517,241 KWh
Estimated cost savings:	150,000 levs ($10,000)
Estimated cost:	20,000 levs ($1,333)
Estimated payback:	0.2 years

10. **Electric Power Energy Monitor with Sensor** -- The monitor and related equipment (220 V. and 400 V., 50 hertz listed below) would help to improve energy efficiency in plant refrigeration by monitoring energy use more accurately and preventing unnecessary energy losses. Davis Instruments Models MC 293345 or EM-KWDR 51350 or equivalent are recommended.

11. **Digital Recorder** -- Davis Instruments DRO Model or equivalent for use with above monitor.

12. **Digital Printer** -- Davis Instruments DP-100 or equivalent for use with above monitor.

13. **Power Supply** -- Davis Instruments Model or equivalent with 220 V., 50 hertz.

14. **Recording Paper** -- Davis Instruments or equivalent for use with above monitor.

15. **Spare Inking Supply** -- Davis Instruments or equivalent for use with above monitor.

For items 10 - 15:

Estimated annual energy savings:	517,000 KWh/year
Estimated cost savings:	125,000 levs/year ($8,333)
Estimated cost:	15,000 levs ($1,000)
Estimated payback:	two months

TEACHING TOOLS

1. **Video tapes** -- educational materials principles of operating steam traps, trouble-shooting steam traps, steam trap repairs, air in steam, guidelines for steam efficiency, solving water hammer puzzle, and a comparison of disc versus bucket steam traps. These videos, available through Armstrong Machine Works would be used with the above video equipment as teaching tools designed to complement efforts to rebuild and maintain condensate systems and repair steam leaks.

2. **Overhead Projector** -- projector with high intensity position and three spare lamps. 220 volts, 50 hertz. Lanier Presentation Systems or equivalent recommended. To be used by the Committee on Energy as a teaching device in support of work to rebuild and maintain the condensate system and repair steam leaks, contributing to the overall energy efficiency of the plant.

3. **Transparency Film** -- Transparency Film 8 1/2 x 11" for use with plain paper copiers. 3M Model PP2200 or equivalent is recommended. The transparencies will be used with the overhead projector as part of a teaching strategy designed to support the rebuilding and maintenance of the condensate system and the repair of steam leaks.

4. **Projection Screen with Retractable Floor Stand** -- Approximately 42" x 42" screen. A teaching tool to be used by the Committee on Energy that will complement activities designed to rebuild and maintain the condensate system and repair steam leaks.

Items 1-4:

Estimated energy savings	see above
Estimated cost	$2,800

APPENDIX VIII
ADDITIONAL CHARTS

ELECTRICAL OPPORTUNITIES Tabletting Department № 1

Date 04.15.91

Area "PHARMACIA"

	Location (Be Specific)	Comments *	Tag No.	Type **	Watt / HP	No.	Repair Costs $	Savings $/Yr***	RC %
	(A) Cleaning and replacement of lamps in Tabletting shop № 1							(LV/Yr)	
0.									
1.	Engine compartment	indoor		FL	3600	30	x14 (LV) 420	594	
								110600	
	The plant can economize ~22% of expenses for lighting including cleaning and changing of lamps							110600	
	(B) Replacement of ballast of lamp with more efficently								
1.	Engine compartment	indoor		FL	3600	30	(30 LV) 900	270	
	There is a possibility for 10% decrease in power of lamps. The plant can economize:							33980	
	(C) Replacement of pumps with more efficently								
1.	Engine compartment	indoor		FL	3600	30	1440	1080	
	There is possibility for 40% decrease in power of lamps. The plant can economize:							135800	

* Indicate whether it is inside or outdoor lighting.
** For type show MV = mercury vapor, HPS = high pressure sodium, INC = incandescent, and MH = metal halide.
*** Unless actual HP is known, multiply nameplate HP rating by 1 HP costs.

Data collected by: Emil Nikolov

INSULATION OPPORTUNITIES

In the space

Date 04 15 1991
Area Pharmacies pl.

	Location (Be Specific)	Comments *	Tag No.	Length **	Wid. **	Dia. **	Repair Costs $	Savings $/Yr	RC %
9.		st. t = 120°C	0.78	5		250	51	7700	
10.	H st. Pumps station	cond tank	12.40	1.20	2.0	1200	187	5000	
11.	H st Universal-5	st t = 140°C	11.30	6		600	734	20200	
		st t = 140°C	2.19	2		350	142	4000	
		cond tank	11.25	5	1.5	1500	731	11000	
12	Tablet shop-2	cond tank	2.51	1		800	163	4300	
		cond	1.5	6		80	97	4000	
		cond	0.94	3		100	61	2600	
13	Universal shop 4	cond tank	12.24	3		1300	796	15800	
		cond	1.88	6		100	122	5200	
		cond	1.13	2		180	74	2400	
14	Universal shop 2	st t = 120°C	0.31	1		100	20	860	
		st t = 120°C	3.51	14		80	228	9400	
		st t = 120°C	3.76	2		600	244	6700	
		st t = 120°C	1.50	8		60	97	4200	
		cond	7.03	28		80	457	18900	
		cond	0.75	3		80	49	2000	
		cond tank	6.12	15		1300	398	8700	
15	Tablet shop-1	st t = 125°C	0.62	1		200	40	1350	
		st t = 125°C	0.78	2.5		100	51	2200	
		st t = 125°C	0.50	2.0		80	32	1300	
		st t = 125°C	1.96	5.0		125	127	4800	
		cond	1.57	10.0		50	102	4300	
		cond	0.94	3.0		100	61	2600	
		cond	2.00	8.0		80	130	5400	
		cond	0.37	2.0		60	24	770	
		cond	0.50	4.0		40	32	1350	
		cond	0.40	1.0		125	26	960	
	heat exchanger	st/w	3.14	2.0		500	204	5800	
	heat exchanger	st/w	13.20	2.5		900	858	18600	
		TOTAL					6338	184390	

* Indicate what it is: tank, pipe, duct, etc.
** Show all dimensions in feet, except show pipe diameter in inches.

For pipe, annual cost (multiply by 2 for outside items).
For flat surfaces, annual cost (multiply by 2 for outside items).

→ 19701 557000

~ 20,000 · 560,000 LV

Tot. 3/3

cpw/0212/c25-2
2C 02/12/86

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INSULATION OPPORTUNITIES

In the space

Date 04 15 1991
Area Pharmacies pl.

	Location (Be Specific)	Comments *	Tag m²	Length **	Wid. **	Dia. **	Repair Costs $	Savings $/Yr	RC %
1	Boiler station	st t = 154°C	20.41	13	500		1327	37500	
		st t = 154°C	4.4	3.5	400		286	8430	
		st t = 154°C	4.4	7	200		286	9400	
		st t = 154°C	6.6	21	100		429	18200	
		st t = 154°C	5.76	15	80		245	10100	
2,	H.St. Experimental shop	st t = 140°C	5.02	2	800		326	8700	
		st t = 140°C	0.94	2	150		61	2100	
3,	H.St Universal shop - 1	cond. tank	17.8	2	1200	2	312	7000	
4,	H.St Laundry	st t = 120°C	1.88	10	60		122	5300	
		st t = 120°C	0.94	6	50		61	2600	
		st t = 120°C	0.75	6	40		49	2000	
		st t = 120°C	0.39	5	25		25	700	
		cond tank	2.85	1.3	700		185	5000	
5.	H.St Laboratory building	st T = 140°C	0.31	1	100		20	850	
		st t = 140°C	0.87	4	70		56	2100	
	heat exchanger	st-w t = 53°C	5.02	2	800		326	8600	
		st t = 140°	0.31	2	50		20	870	
6.	H.St. Vitamin "C" shop	st t = 110°C	1.57	2	250		102	3000	
		st t = 110°C	1.88	4	150		122	4200	
	Pilli Hatm	st t = 127°C	2.57	3	273		167	5200	
	Pilli Zatm	st t = 127°C	0.47	1	150		31	1060	
	Turbo heat exchangers	st t = 120°C	3.53	8.5	450		230	6600	
		cond t = 105°C	2.26	12	60		147	5200	
		cond t = 105°C	5.02	16	100		326	13800	
		cond t = 105°C	5.02	8	200		326	10800	
7.	H.St nitric station	st t = 110°C	0.25	1	80		16	670	
		cond. tank	4.88	1	800	0.8	42	3200	
		cond	1.25	8	50		81	3460	
8,	H.St. Organic preparation shop	st t = 120°C	20.1	8	800		1306	34700	
		st t = 120°C	4.4	4	350		286	8100	
		st t = 120°C	2.26	18	40		147	7000	
			131 m²				9365	236450	

* Indicate what it is: tank, pipe, duct, etc.
** Show all dimensions in feet, except show pipe diameter in inches.

For pipe, annual cost (multiply by 2 for outside items).
For flat surfaces, annual cost (multiply by 2 for outside items).

cpw/0212/c25-3
2C 02/12/86

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INSULATION OPPORTUNITIES Steam & Cond.

In open

Date 04.15.1991
Area Pharmaceutical pl

	Location (Be Specific)	Comments *	Tag No.	Length **	Wid. **	Dia. **	Repair Costs $	Savings $/Yr	RC %
1	Boiler st - by-pass	st. t = 140°C	15.38	14		350	1000	28300	
2	deviation line for PE1	st. t = 140°C	2.26	9		80	147	6100	
3	In front of Un st -1	st t = 135°C	1.1	1		350	71	2000	
		cond	2.35	5		150	153	5300	
4	dev. for laundrus	st t = 120°	0.54	7		25	35	1000	
5	dev. for laboratory building	st t = 140°	1.17	3		125	76	2900	
		st t = 140°C	0.61	3		65	40	1700	
		st t = 140°C	0.25	2		40	16	670	
		cond	0.23	3		25	15	600	
6	dev. for Vitamin "C" shop	st t = 140°C	4.1	6		250	306	9200	
7	dev. for metric st	st t = 140°C	0.75	3		80	49	2500	
		cond	0.47	3		50	30	1300	
8	dev. for CR	st t = 120°C	0.7	7		32	45	1700	
9	dev. for refr st	st t = 120°C	3.26	13		80	212	8800	
		cond	0.47	3		50	30	1300	
10	Main line for Un -5 from the Boiler st	st. t = 120°C	0.94	1		300	61	1850	
11	dev. for organic preparation shop	st t = 120°C	3.92	5		250	255	7700	
12	dev. for shop "Lisa"	st t = 120°C	10.1	10		80	653	27000	
13	tube for tablet shop-2	st t = 135°C	5.38	35		250	382	11600	
		cond t = 80°C	1.63	6.5		80	106	4800	
14	Main line for Un 2,4	st t = 135°C	5.02	8		200	326	10800	
15									
							3998	136170	

m^2

62 m^2

* Indicate what it is: tank, pipe, duct, etc.
** Show all dimensions in feet, except show pipe diameter in inches.

For pipe, annual cost (multiply by 2 for outside items).
For flat surfaces, annual cost (multiply by 2 for outside items).

CONDENSATE LEAKS

Date 04.15.1991
Area Pharmaceuticals

Location (Be Specific)	Comments	Tag No.	* GPM	Repair Costs $	Savings $/Yr	RC %
H.St. Tablet shop-1 [t/h]	no reason	2,89	1.36	—		
H.St. Vitamin "C"-shop [t/h]	the main condensate line is broken down in winter	9.1	5.52	27720		
H.St. Universal shop-4 [t/h]	—"—	3.485	1.87			
H.St Universal shop-2 [t/h]	no reason	3.4	1.7	—		
H.St nitric station [t/h]	no reason	0.085	—	—		
H.St Refrigerator station [t/h]	no reason	1.7	—	—		
H.St Storage - breakdown of condensate line	the pumps can't operate	0.425	—	12000		
H.St Pump station-1	no pumps			8000		
	no condensate	1.7	0.935	13000		
H.St Pump station-2	el. supply	0.935	0.425	9000		
H.St laboratory building	the pumps are broken	0.425	0.085	8000		
H.St engineering building	—"—	0.34	—	8000		
Bu the Organic preparation shop	breakdown of the main condensate line	0.5	0.5	13720		
H.St experimental shop	no pumps	0.425	—	8000		
H.St Laundry	no pumps	0.17	—	8000		
	t/h	25.58	12.4	68,172	1071200	
					664144	

The condensate leaks are 57% in winter or 56.6% in summer

The costs from condensate leaks are in winter 1071200 and 664144 lei in summer or 1735344 lei/yr

* all condensate returned at 55 psig values.

For 12 months leaks, 1 GPM = .

cpw/0212/c25-5
2C 02/12/86

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STEAM LEAKS

Date 04.15.1991
Area Pharmacia

Location (Be Specific)	Comments	Tag No.	* Size	Repair Costs Lv	Savings Lv/Yr
In front of the Universal shop-1	Breakdown	3/4"	S	48 Lv	225000
	breakdown	3/4"	M	48 Lv	60000
In front of the experimental shop	flange of valve	1m	M	30 Lv	60000
H. st. experimental shop	flange of valve	1m	W	30 Lv	12000
H st Universal shop-1	—//—	3m	W	90 Lv	36000
	—//—	1m	M	30 Lv	60000
H.st laundry	—//—	2m	W	60 Lv	24000
	—//—	1m	M	30 Lv	60000
H st laboratory building	—//—	3m	M	90 Lv	180000
Vitamin "C" shop 5 - breakdown	valve 3/4"	1m	M	615 Lv	60000
H.st organic preparation	flange of valve	3m	W	90 Lv	36000
H st Universal-5 - breakdown	valve D=200mm		S	485 Lv	225000
	gland of valve	2m	W	60 Lv	24000
H st Universal-4-	flange-valve	1m	W	30 Lv	12000
	gland of valve	1m	M	30 Lv	60000
H st Universal-2	flange of v	1m	W	30 Lv	12000
boiler station	flange of v	6m	W	180 Lv	72000
In front of the oil tanks - parallel	breakdown				
steam lines of oil lines	tube-1/2"	8m	M	86 Lv	480000
	—//—	1m	S	23 Lv	225000
	broken down				
	valve-3/4"	2m	M	123 Lv	120000
TOTAL				1501,5	2043,00

* Can use the following code for leak size: W = wisp, M = moderate, S = severe.

For 12 months leaks, wisp = 228000 Lv moderate = 1140000 Lv severe = 675000 Lv

1060 kgm/hr

690,000 Kcal/hr

Sigs

Lv/yr

Cost

cpw/0212/c25-4
2C 02/12/86

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REFR. STATIONS.

INSULATION OPPORTUNITIES

Date 04.15.1991
Area PHARMACIA ST. DIMITROV

Location (Be Specific)	Comments *	Tag No.	Length **	Wid. **	Dia. **	Repair Costs $	Savings $/Yr	RC %
EVAPORATORS - 6 units. : t_s = - 13.5								
NON INSULATED SURFACE			A = 3.2 m^2			416	6000	
NH_3 pipes : t_s = - 13.5 °C								
Refr. station	pipe : A = 0.314 m^2		2.5		0.04	41	480	
— " —	— " — ; A = 2.45		12.00		0.065	318	3000	
— " —	— " — : A = 3.68		4.5		0.259	476	3800	
$CaCl_2$ pipes : t_s = - 11.2 °C								
Distr. set	pipe : A = 2.68 m^2		15.00		0.057	348	3750	
— " —	pipe : A = 1.36 m^2		4.00		0.108	177	2000	
— " —	— " — : A = 1.84 m^2		4.50		0.130	239	1800	
— " —	— " — : A = 1.96 m^2		2.50		0.250	255	1900	
— " —	— " — A = 2.10		1.30		0.370	273	1890	
— " —	— " — A = 30.4		23.00		0.42	3952	23000	
TOTAL A = 49.9						Rep. Costs = 6500 · Sav. = 47613		

* Indicate what it is: tank, pipe, duct, etc.
** Show all dimensions in feet, except show pipe diameter in inches.

For pipe, annual cost (multiply by 2 for outside items).
For flat surfaces, annual cost (multiply by 2 for outside items).

Data collected by:
Christian Spassov

cpw/0212/c25-2
2C 02/12/86

APPENDIX IX
ENERGY MANAGEMENT PRACTICES: A BRIEF REVIEW

"ENERGY MANAGEMENT PRACTICES" EXCERPT OF PRESENTATION

BY MR. BARRY TUNNAH AT THE ENERGY MANAGEMENT WORKSHOP IN SOFIA, BULGARIA (JANUARY 1992)

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 / 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.

FIGURE 2. SCHEMATIC DIAGRAM OF PHARMACIA'S ONE-STAGE REFRIGERATION SYSTE

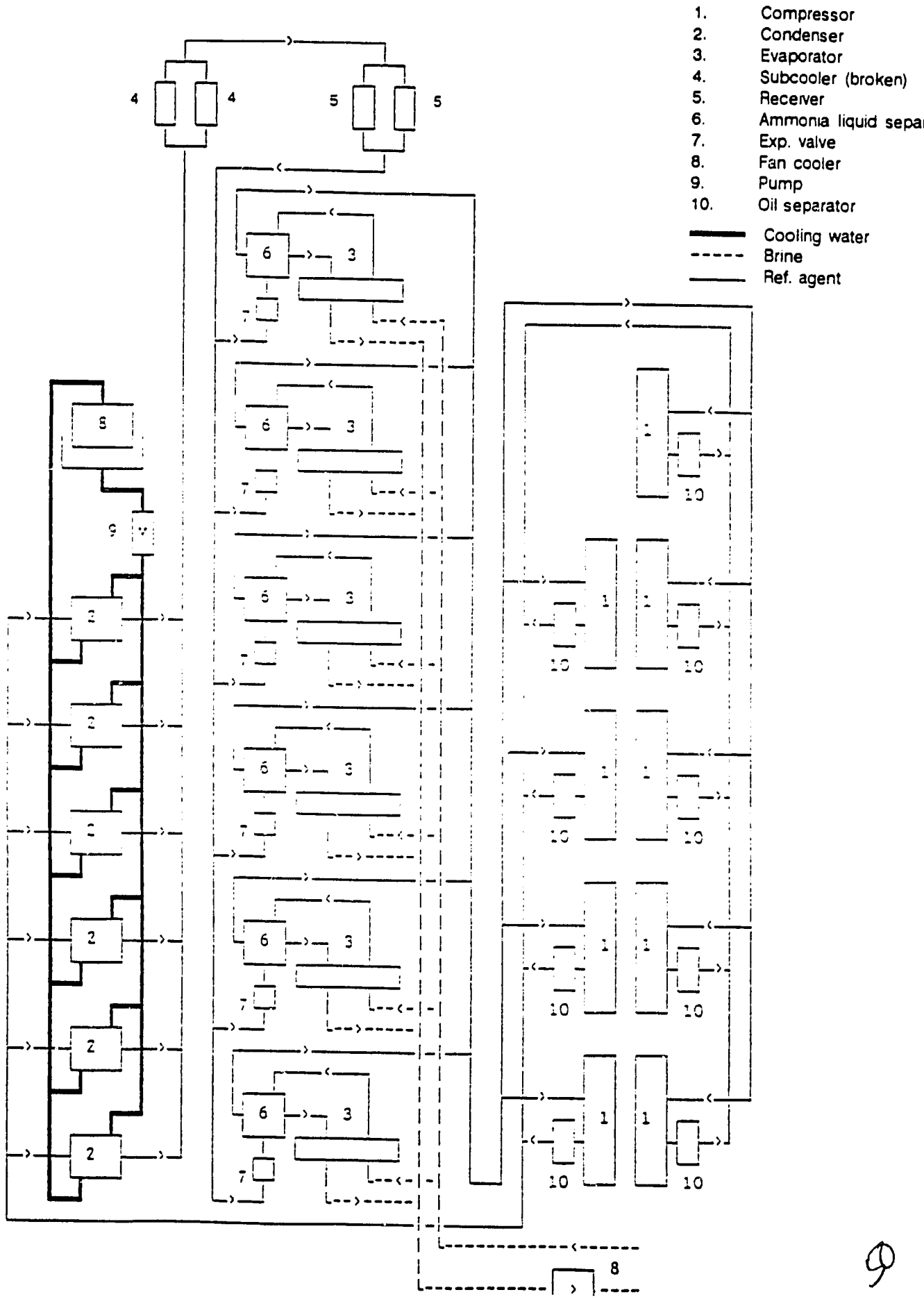

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Figure 3. Diagram of the one-stage refrigeration system in its current state (i.e., no automatic contrc system).

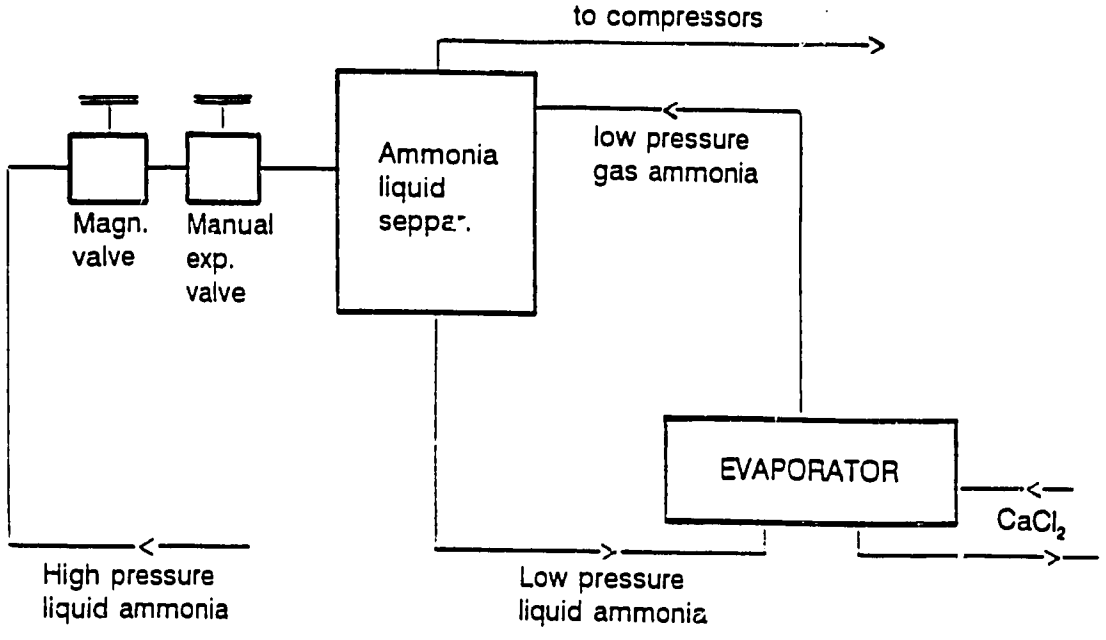
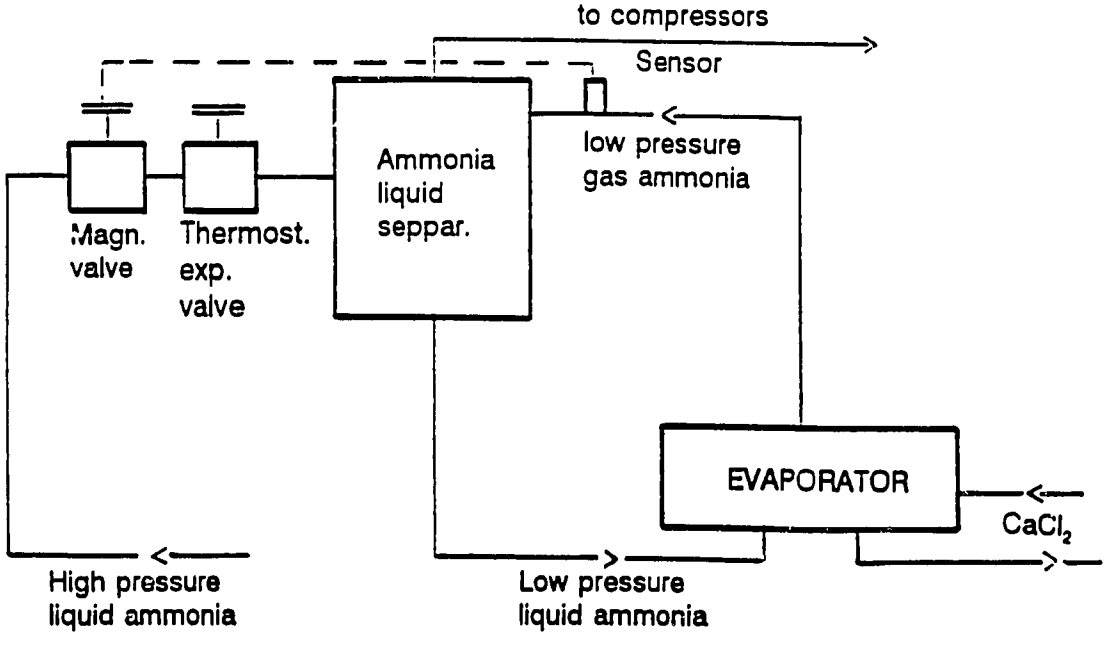
Figure 4. Diagram of the one-stage refrigeration system with an automatic control system added.