INDUSTRIAL ENERGY EFFICIENCY AUDIT REPORT

BUCHAREST MILK PROCESSING ENTERPRISE
Bucharest, Romania

JANUARY 1992

PREPARED BY: **RESOURCE MANAGEMENT ASSOCIATES OF MADISON, INC.**
Madison, WI

and

INSTAPART
Bucharest, Romania

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

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
BUREAU FOR EUROPE
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ENERGY & INFRASTRUCTURE DIVISION
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i. Eastern Europe Industrial Energy Efficiency Program

The countries of Eastern Europe face unprecedented changes both in their political and economic systems. To aid in the transition to market economies, the U.S. Agency for International Development (USAID) designed the Eastern Europe Emergency Energy Program. Resource Management Associates of Madison, Inc. (RMA) is the technical assistance contractor for the Industrial Energy Efficiency Component (IEEC) of the program in Romania.

The Industrial Energy Efficiency Component was designed to address the problems of industrial energy efficiency with a short term program aimed at the immediate needs of industry. The program involves three main activities:

1. To identify and implement cost-effective low-cost/no-cost energy improvements, with an emphasis on oil savings.

2. To conduct energy audits and transfer energy auditing and management techniques, including financial and economic analysis.

3. To provide energy auditing and/or energy efficiency equipment to implement the program objectives, improve energy management, and identify additional energy efficiency opportunities.

The IEEC program deliverables consist of plant audit reports, a policy and institutional analysis report, an industry profile report, and the in-country audits, training, and equipment delivery and installations. The tasks are being carried out by a team of energy specialists and policy analysis experts in four different phases:

- Phase One: Screening - During this phase the plants to be audited will be identified, and a specific plan to implement the following phases developed and put in place.

- Phase Two: Industrial Plant Energy Audit/Training - A team of energy specialists will arrive in-country and perform a detailed energy audit at the eight selected industrial sites. They will identify short-term energy efficiency measures, develop recommendations to implement these measures, demonstrate and train plant personnel on auditing techniques, and demonstrate financial and economic methodologies for justifying energy improvement projects. Additional equipment will be ordered for Phase Three.

- Phase Three: Implementation - The recommendations identified in Phase Two will be implemented, evaluated, and modified as necessary. Additional training will be provided and the final energy efficiency equipment turned over to the host country.

- Phase Four: Analysis of Factors - This phase will analyze the factors that make up energy efficiency management and investment decision making. Recommendations for policy reform and options for enhanced energy management will be identified and a program for implementation suggested.

Energy monitoring and testing equipment will be turned over to the Romania industrial sector and the Government of Romania (GOR). The GOR will be provided with analysis and recommendations for further energy efficiency measures.

ii. Executive Summary

An energy audit was conducted for the Bucharest Milk Processing Plant, located in the city of Bucharest, Romania during the week of March 25 to 29, 1991. The audit was conducted as part of the Industrial Energy Efficiency component of the USAID Emergency Energy Program. A summary of the findings were presented to the facility management, and representatives from the Romanian Agency for Energy Conservation, the Romanian Ministry of Industry, and the US embassy. The summary presentation took place on Friday, March 28, 1991.

The audit and the subsequent analysis were primarily focused on the energy intensive electrical and thermal systems. However, during the audit, substandard process equipment, operating methodologies, and the facility technical staff interactions became worthy of consideration. The following are the highlights of these observations:

1. Energy Efficiency Component

Three low-cost measures with a relatively high return on investment were selected for evaluation. The analysis steps and the assumptions are given in Appendix B. The savings associated with these measures are also shown in Section 4.0. These are:

- Recover heat from ammonia refrigerant
- Insulate exposed low pressure refrigerant pipe
- Return condensate from the pasteurizers.

These measures, if implemented, would reduce the plant's gas consumption by about 6.5% and reduce the annual natural gas bill by about 784,000 lei/yr ($22,000/yr). The reduction in electricity would be over 2% which is equivalent to 295,477 lei/yr ($8,366/yr).

2. Short-Term Energy Management Equipment Recommendations

In accordance with the USAID program guidelines, a limited budget is available for the provision of energy efficiency equipment. The complete specifications and purchase justification for this equipment is given in Appendix A, and listed below:

A. A natural gas flow meter

B. A saturated steam flow meter

C. A portable battery operated combustion analyzer

D. A hand-held battery operated digital thermometer.

The total expected cost for the above items is $10,200.

3. Long-Term Recommendations

Four relatively high cost measures were also identified which need further evaluation. Due to time constraints, no analysis was carried out to show the cost and savings calculations. However, past experience and practices elsewhere indicate attractive return on investment and reduction in energy consumption through implementation of these measures. A list of these measures, which are described more fully in Section 4.0, follows:

- Convert the naturally operated cooling tower in the Uzina Refrigerator #1 (see plot plan in Appendix C) to a forced cooling tower, by adding cooling tower blowers.

- Install automatically controlled valves at the discharge of the ammonia compressors. Float the discharge pressure with ambient air or cooling tower water temperatures.

- Link the boiler steam pressure, natural gas flow, and combustion air. This automatic control would not only save energy but also protect the boiler and ensure a safe boiler operation. Consideration should also be given to installing an oxygen trim analyzer.

- Install a three level conductivity probe for controlling the steam drum level. Interlock the drum level with the boiler feedwater valve.

4. Two major manufacturing and construction problems were identified as requiring correction. These are:

A. The Ice Cream Cone Manufacturing/Baking Process

About 40 to 50% of the baked waffle cones are rejected because of defects and poor quality. Immediate consideration needs to be given to modifying tooling, mixing, ingredients, and/or baking oven temperature controls. This will not only reduce the material waste but will also cut down the natural gas consumption by about 40 to 50% (20 to 30 m^3/hr or 700-1050 cu ft/hr).

B. The Ice Cream Freezer Storage

The loading dock needs to be enclosed to prevent excessive air infiltration and ice formation. The insulation on the structure should be increased. Metering data and subsequent data analysis indicate excessive refrigeration load is being used in the ice cream manufacturing and storage areas. The cooling load would need to be reduced about 40% to 50% (175 kW) to make this area comparable to modern refrigerated warehouses.

5. It appears the facility technical staff are very capable technically. However, they lack authority to initiate the needed process equipment improvements or to implement low-cost energy conservation measures.

Implementation Phase

The implementation phase of the audit involved a return trip to the facility to expedite the implementation of the Audit Team's recommendations. All equipment provided to the Bucharest Milk Plant was portable, so the main focus of the visit was on training the staff on the use of the equipment. The Draft Audit Report was reviewed with plant staff, and a plan for using the equipment was developed.

1.0 Plant Description

1.1 General

The Bucharest Milk Processing Enterprise is located in Bucharest, Romania. The plant has the capacity to process over 600,000 liters/day (160,000 gal/day) of raw milk for bottled milk, butter milk, powdered milk, cheese, yogurt, and ice cream products. Presently, the plant is operating at about 50% capacity.

The manufacturing facility consists of two plants, a fresh milk products plant and the ice cream manufacturing plant. The supporting facility consisted of steam generation (three boilers and water treatment equipment), two refrigeration plants (compressors and cooling towers), a pumping station, and several warehouses/machine shops.

The fresh milk plant includes a bottling facility, a laboratory, and the process equipment for producing the milk products. The ice cream plant manufactures various brands of cream, has freezer storage, manufactures waffle ice cream cones, and is equipped with three natural gas operated baking ovens.

The plant is similar to only three other milk processing plants in Romania. However, the refrigeration equipment, refrigeration compressors, and natural gas operated ovens is typical of process equipment used throughout the industry.

1.2 Organization

The key plant staff member with whom the Audit Team consulted is Mr. Gheorghe Petica, Chief Mechanical Engineer.

The plant organizational chart, given in Appendix D, illustrates in detail the various operating departments and key personnel.

It appears that key personnel lack the authority to make decisions for long-term renovation, energy management, or modernization. Alternatively, the Agency for Energy Conservation and the Ministry can not authorize common plant preventive maintenance and renovation projects for productivity, product quality, and the energy utilization improvement.

1.3 Operation

The facility operates 24 hours a day, 7 days per week. During the audit visit, the plant was operating at 50% capacity; the reduction was due to a shortage of raw materials.

The facility employs about 2675 people, of which 52 are engineers, 23 are in marketing, 46 are technicians, and the rest are clerical and manufacturing personnel. It appears that staff reduction is underway to cut down operating costs.

1.4 Electrical

The facility is directly connected to the RENEL (Romanian Electricity Company) power grid via five (5) kVA transformers. The transformers feed 380/220 V electricity to the plant electrical distribution grid. The monthly average demand, average energy consumption, electricity unit cost, and the annual electricity bill are shown in *Table 1* of Section 2.0. The power demand ranges from a low of 325 kW in December (holidays) to a high of 1219 kW in August. Most of this power increase is due to the hot weather and high refrigeration load for milk and ice cream products. It is estimated that over 800 kW is required to operate the refrigeration systems during the month of August.

1.5 Thermal

Process steam is generated by the plant's three boilers to meet the maximum steam requirement of 15 metric tons/hr. The three 10 metric ton/hr boilers are Romanian-built and were installed in 1976. They use natural gas, and generate saturated steam at pressures ranging from 8 to 15 bar.

During the combustion test, the steam pressure was found to be 8 bar and the temperature was measured at 175 °C. Only one boiler was operating during the test.

The boilers are of the water tube type, and are equipped with economizers. The combustion air is preheated with steam externally before being blown into the combustion chamber. Air and fuel are mechanically linked, with manual control of the linkage. Steam drum level control is also manual.

There is continuous and intermittent blowdown, with a heat recovery system for the continuous blowdown. No condensate is returned to the system. Make-up water is therefore supplied at the steam consumption rate.

The three boilers feed steam into a common header. From the header, steam is supplied at three different pressures. The main header pressure is 8.0 bar. This is reduced to 4.8 bar and then to 2.0 bar, to be supplied to lower pressure applications.

All the steam used within the plant is used in the fresh milk products plant. This includes bottle sterilization and heating of the pasteurizers. Steam is also sold to an adjacent facility at a rate of about 1 metric ton/hr, for 462 lei/Gcal ($13.20/Gcal).

1.6 Heating

District hot water is used for heating the facility. A consumption profile is also shown in the *Table 1* of Section 2.0.

1.7 History of Energy Efficiency Measures

There appear to have been no energy efficiency measures implemented in recent years.

2.0 Plant Energy Profile

2.1 Summary

The summary of the energy profile is illustrated in *Figure 1.* It can be seen that electric consumption and water consumption remain high for all ranges of production, while natural gas decreases with increasing production over 50%. Consumption of hot water for heating occurs only in the winter months.

2.2 Electrical

The demand and energy consumption peak during the summer months is primarily due to over 50% refrigeration load. The monthly energy requirements, the energy unit cost and annual cost are shown in *Tables 1 and 2.* The electric consumption as a function of production (energy intensity) is illustrated in *Figure 2.* From this graph, it can be seen that electric consumption remains high regardless of production quantities, while there is a slight downward trend for increasing production rates over 50%. This can probably be attributed to high recycle rates on some energy consumption equipment. It should be noted that the current plant operating level of 50% production is almost the highest energy intensity point on the graph, thus the highest cost operating point.

2.3 Natural Gas

Natural gas is primarily used for the three 10 metric tons/hr capacity boilers. In addition, three ice cream cone dryers use natural gas. Based on name plate data of the dryers, only about 7% of the plant's natural gas is being used in the dryers. The total consumption, monthly consumption, total cost, and unit cost is also shown in *Table 1.* The natural gas consumption as a function of production (energy intensity) is illustrated in *Figure 3.* From the graph it can be seen that natural gas energy intensity declines steadily above 50% for increasing production. This would also indicate a higher rate of thermal energy production is being maintained even at lower production levels, thus wasting energy.

It is reported that about one metric tons/hr of saturated steam at 8-13 bar (116-188 psi) is sold to the adjacent manufacturing plant. This is small compared with the plant average use of 15 metric tons/hr.

2.4 City Water

The facility purchases water from the city at a unit cost of 4.0 lei/m^3. The monthly consumption and the annual cost is also given in *Tables 1 and 2.* The consumption is relatively flat. It is reported that the there is no waste water treatment. The waste water is discharged to the sewer and a great potential for water pollution exists.

2.5 Hot Water Heating

During heating season, the facility purchases hot water from the District at a unit cost of 505 lei/Gcal ($3.60/MBTU). As shown in *Table 1*, the heating season is about six months.

Summary:
The annual utilities cost is now about 32.1 million lei/yr ($916,245/yr). Electricity and natural gas are predominant, followed by city water and hot water, respectively.

Table 1. Typical Annual Utilities Profile

Months 1989	Electricity (10^3 kWh)	Average Demand (kW)	Natural Gas (10^3 m^3)	Water (10^3 m^3)	Hot Water (Gcal)	Total Products (Metric Tons)
JAN	450	625	272	119	688	3966
FEB	498	692	200	109	538	3520
MAR	585	813	268	105	497	5257
APR	578	803	338	120	181	4678
MAY	743	1032	304	67	0	5103
JUN	711	988	348	114	0	4642
JUL	761	1057	392	119	0	4216
AUG	878	1219	373	118	0	3194
SEP	832	1156	426	114	0	3679
OCT	854	1186	486	115	0	4272
NOV	656	911	457	115	275	4540
DEC	234	325	465	115	596	4112
Total	7780	900	4329	1330	2775	51179
unit cost	1.7		2.8	4	505	
	lei/kWh		lei/m^3	lei/m^3	lei/Gcal	

Table 2. Annual Cost

Electricity	13.2 million Lei/yr
Natural Gas	12.1 million Lei/yr
City water	5.32 million Lei/yr
Hot water	1.40 million Lei/yr
Annual utilities cost	32.1 million Lei/yr
Annual utilities cost (official)	$ 916,245

Note: 35 lei/$ was used in calculations

Figure 1. Utilities Profile

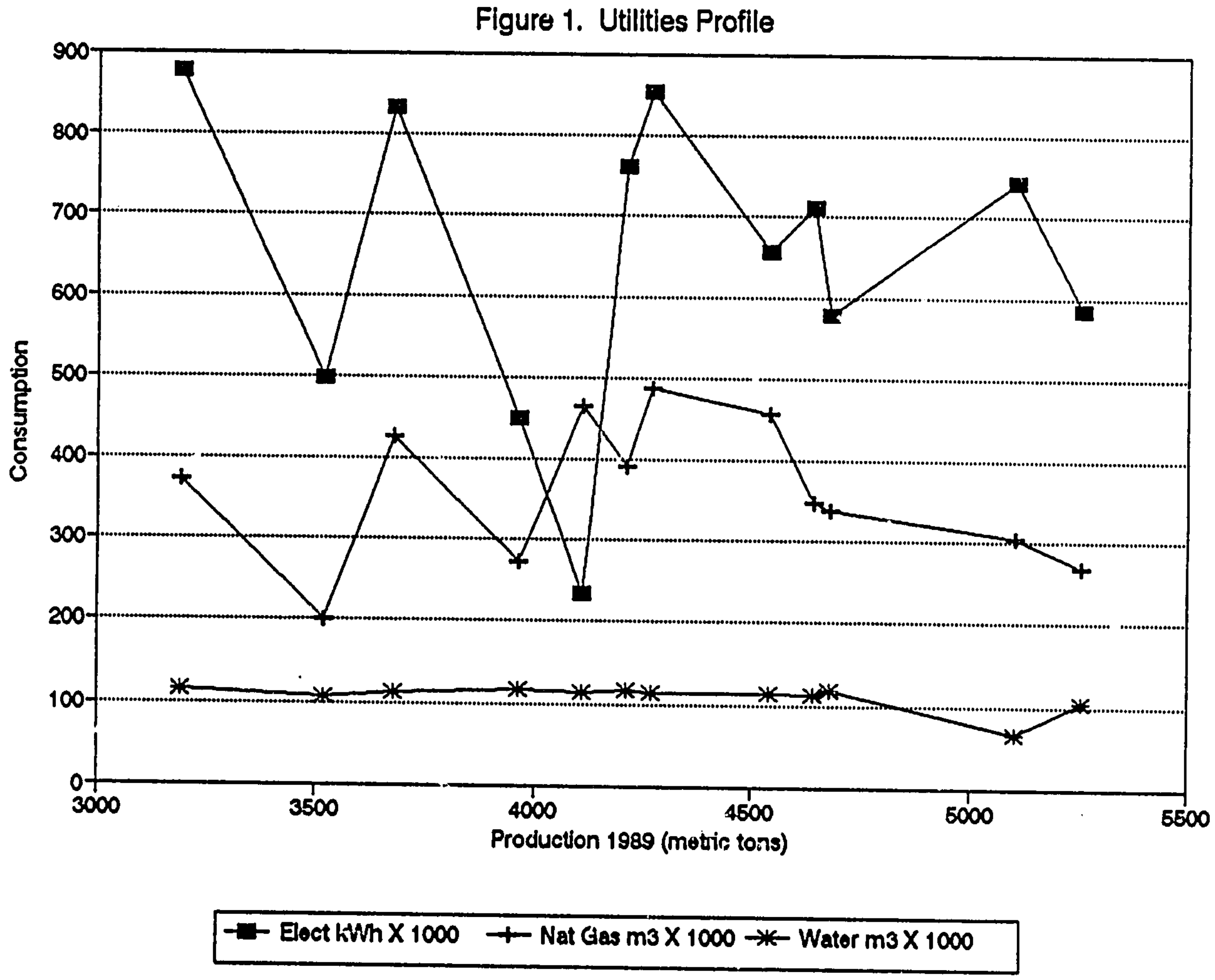


Figure 2. Electricity Energy Intensity

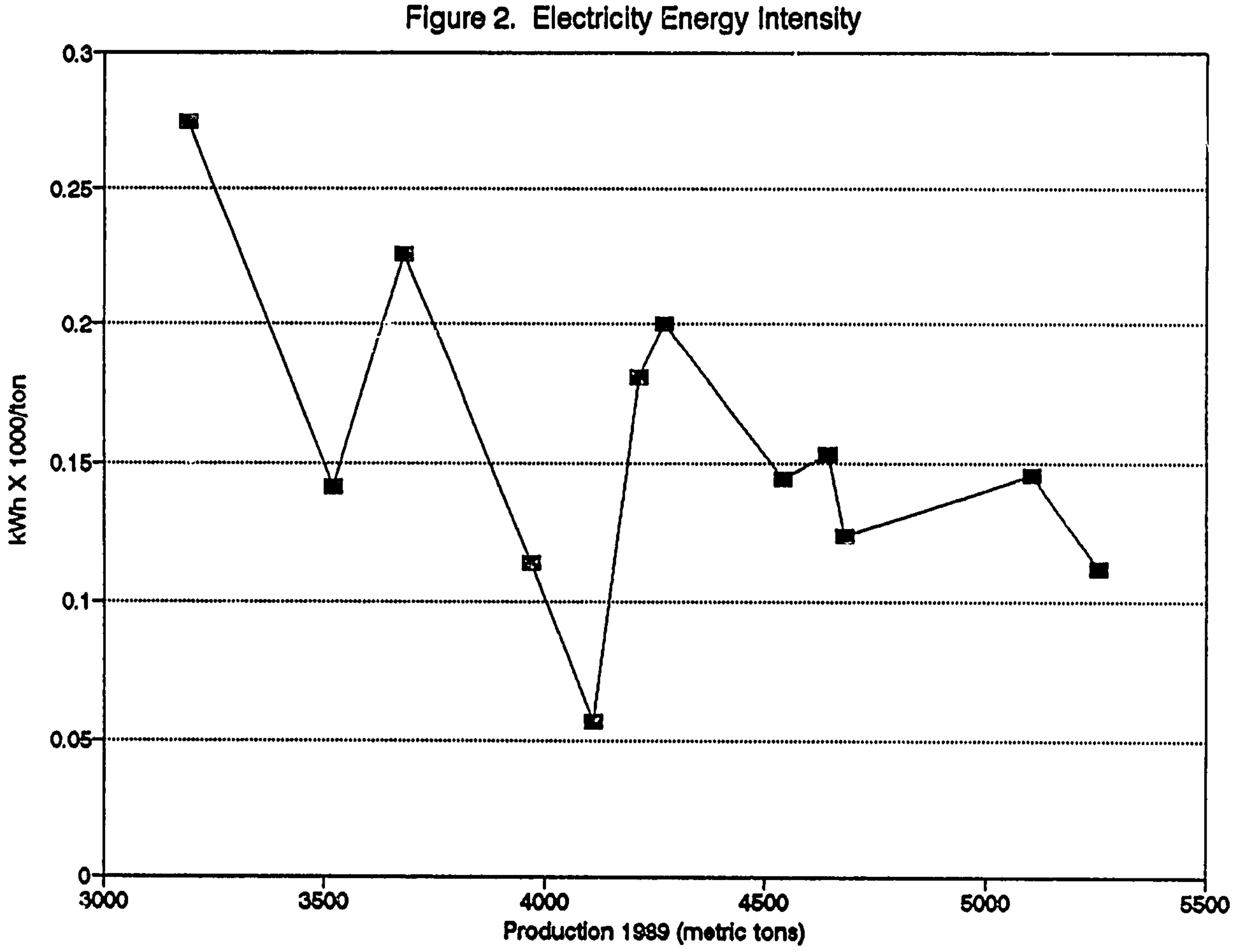
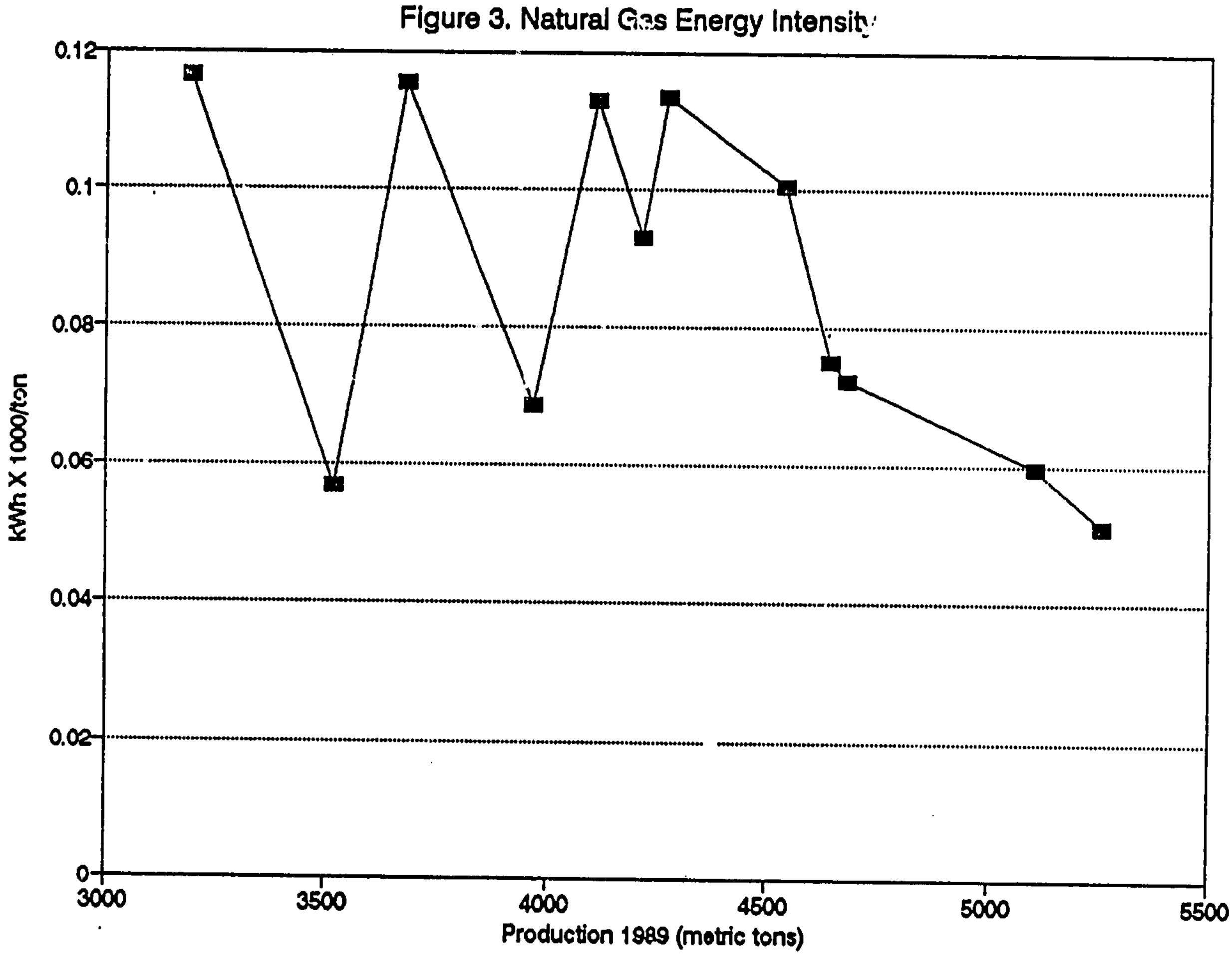


Figure 3. Natural Gas Energy Intensity



3.0 Audit Description

3.1 Summary

In accordance with the USAID scope of work, a pre-audit site visit was made to the facility by the Energy Efficiency Component Team Leader. Discussions were held with the key plant management personnel, and potential energy conservation equipment and areas were identified for the subsequent energy audit. The following areas were identified:

- Power factor measurement for ammonia compressors
- Survey of boiler control and combustion analysis
- Metering arrangement for in-plant energy and material balance
- Ice Cream freezer storage defrost system
- Ice Cream manufacturing shop suction lines insulation
- Low pressure Ammonia tank insulation
- Naturally operated cooling tower for one of the refrigeration plants
- Ice cream cone reject issues
- Pasteurizer-plate heat exchanger leak

The Audit Team then spent one week at the facility gathering data and identifying potential energy efficiency measures that could be adopted. A general walk-through audit of the energy intensive processes and potential problem areas was made to identify energy conservation measures.

A portable combustion analyzer was used to test one boiler which was in operation. A power factor meter and a multi-meter were used to measure the power factor and voltage draw of two randomly chosen ammonia compressors (12 compressors were operating). A clamp-on ammeter was used to measure the current draw of all ammonia compressors, cooling pumps, and blowers.

3.2 Boiler Test Results

A total of five combustion tests were performed on one boiler. At the time of the test, the boiler was operating at 8 bar (116 psi) pressure, supplying saturated steam to the facility. The boiler is a Romanian-made water tube design, with a single natural gas burner. Combustion air is forced from outside, and has a steam air preheater. At the discharge of the boiler, an economizer is installed to recover energy.

Two combustion tests were performed on the discharge of the boiler, and two other tests were performed on the discharge of the economizer. These four combustion tests were performed with no change to the air or fuel damper and valve. The fifth test was performed after reducing the combustion air, to demonstrate the effect of excess air on thermal boiler efficiency. The data for the boiler test and efficiency results are shown in *Table 3*.

- The boiler efficiency reading is relatively good. As demonstrated, the efficiency can be increased by either manually adjusting or automatically setting the excess air for a compromised oxygen content.

- Since boiler control is manual, a hand-held combustion analyzer and training of the boiler operator to obtain an acceptable oxygen and excess air content will improve the boiler efficiency by 4-5%.

3.3 Ammonia Refrigeration System Test Results

The power factor and voltage data for two randomly chosen compressors is also tabulated at the bottom of *Table 3.* The current readings of all operating compressors, cooling tower pumps, and blowers are shown in *Table 4.*

Table 4 also shows the cooling coils rating which was obtained from the two refrigeration plant operators. The average power factor (0.77), measured for two compressors and the measured voltage (364 volts) were used in conjunction with the current data, measured with clamp-on ammeter, to determine the power draw of each compressor and total power draw of the entire plant refrigeration system. The only electrical loads not included for refrigeration were liquid ammonia pumps and cooling coils fans which are relatively insignificant.

Table 3. Test Measurement Results

A. Boiler Measurements

The combustion analyzer was used to pull samples from two locations: at the discharge of the boiler and at the discharge of the economizer. The boiler has an air preheater which uses steam. No correction was made for the higher combustion air temperature. The temperature probe of the combustion analyzer is defective, and hence the efficiency data is inaccurate. Based on excess air (analyzer) and temperature reading from a digital thermometer, the efficiency is calculated as follows:

Discharge of the Boiler

Test #	O_2 (%)	CO_2 (%)	Excess Air (%)	Temperature (°C)	Efficiency (%)
1	9.7	6.4	76.0	290.0	73.4
2	10.4	5.9	89.0	288.0	72.3
3*	7.6	7.6	49.0	273.0	76.9
4	9.5	6.5	75.0	193.0	79.7
5	10.0	6.2	82.0	193.0	79.3

Since excess air was higher than normal, the air damper was slightly closed and the test was repeated.

B. Power Factor and Voltage Measurements

Two refrigeration compressors (a two stage and a single stage) were randomly chosen to perform the test. The results are tabulated below:

Compressor Stage	Power Factor	Voltage (volts)	Current (amps)	Actual Power (kW)	Nominal Power (kW)
Two	0.5-0.85	364	70-88	33.6	55
Single	0.86	364	82	44.4	55

Result: The power factor of the compressors need to be improved by replacing or increasing more capacitance in the motor circuit.

Table 4. Refrigeration Load Calculation

The refrigeration cooling is supplied by two refrigeration plants. The Uzina Frig #1 is used to supply cooling to fresh products such as milk, yogurt, cheese and some very low temperature cooling to ice cream storage areas. The Uzina Frig #2 is used primarily for ice cream manufacturing, processing and storage.

During the site visit, (Tuesday March 26, 1991, outdoor temp about 7°C), four compressors were running (#9, #16, #14, and #12). The PF meter and multi meter were used to find the average voltage and power factor. Also, a clamp-on ammeter was used to measure the current draw of each compressor. The results are as shown below:

Uzina Frig. #1

Average Volt: 364
Average Power Factor: 0.77

Area Served	Compressor (#)	Suction (°C)	Load kcal	Current amp	Power kW
Fresh	9	-1	200000	125	61
Produce	10	-1	100000	130	63
Freezer	14	-35	150000	68	33
Warehouse	12	-35	150000	65	32
Total			600000	388	188

The three natural cooling towers draw a total of 150 amps.
This corresponds to 73 kW.
The 600,000 kcal/hr corresponds to about 198 metric tons.
This results in a 0.91 kW/metric ton usage, which is quite good.

Uzina Frig. #2

Average Volt: 364
Average Power Factor: 0.77

Area Served	Compressor (#)	Suction (°C)	Load kcal	Current amp	Power kW
	4	-33	common	68	33
	11	-33	400000	70	34
	9	-33	150000	65	32
	6	-45	150000	65	32
	10	-45	30000	63	31
	12	-45	common	65	32
	7	-33	common	65	32
	5	-33	common	70	34
Total			730000	531	257

(Table 4 continued)

The forced cooling tower at this plant uses three cooling tower blowers and three cooling tower water pumps.

Measurements showed the following:

	Blowers	Pumps
Current (amps)	81	80
Power (kW)	39	39
Total Power: 78		

The 730,000 kcal/hr corresponds to 241 metric tons resulting in a 1.07 kW/metric ton. Experience would suggest that this value is too low. A value of 1.20 kW/metric ton is more reasonable.

In summary, the compressors are operating reasonably well. The natural cooling tower needs to be converted to forced, and more than 50% of the refrigeration load is wasted by poor insulation and construction.

Summary results:

- As shown in *Table 3*, the power factor for one compressor was low, and the second one needed to be raised to the 90% range.

- The kW/metric ton or kW/kcal rating of all compressors is very good. This is due to two-stage operation and intercoolers.

- A booster and high stage arrangement for very low temperatures (-33 to -45 °C) would further improve the rating. This could be considered as a long-term refrigeration renovation.

- The naturally operated cooling tower should be converted to forced. The inefficiency of the naturally operated system is quite evident from the power data. The Uzina # 2 (forced cooling tower) has about 21.7% more cooling load and uses only 7% more power on the tower. The cooling water consumption becomes increasingly high during summer months due to high ambient temperature, further increasing the impact of the cooling tower inefficiency.

4.0 Summary Results

4.1 Short-Term Recommendations

The site survey, observation of the equipment in operation, and discussion with plant operating staff has resulted in the identification of a number of energy conservation opportunities. If implemented, these short term measures would result in the following savings:

A. Heat recovery from the hot ammonia refrigerant

Natural gas savings:	246,789 m^3/yr
Energy savings:	$1.74X10^9$ kcal/yr
Cost savings:	691,010 lei/yr

B. Prevent ice build on the piping (assumed 100 m^2 of surface)

Power demand reduction:	20 kW
Energy savings:	173,810 kWh/yr
Cost savings:	295,477 lei/yr

C. Return Condensate from pasteurizers

Natural gas savings:	33317 m^3/yr
Energy savings:	$2.34X10^8$ kcal/yr
Cost savings:	93288 lei/yr

If these three short-term recommended measures are implemented, the total estimated savings are:

Thermal annual energy saving	$1.974X10^9$ kcal/yr
Thermal annual cost saving	784,298 lei/yr
Percentage annual savings	6.5%
Electrical annual energy saving	173810 kWh/yr
Electrical annual bill reduction	295,477 lei/yr
Percentage annual savings	2.2%

Other short-term energy savings opportunities include:

- Use of a strip curtain on the ice cream storage door.
- Reduction of the ice cream rejected through better quality control. Only one dryer may be needed instead of three.
- Recirculation of the cooling water from the compressor's oil

4.2 Long-Term Recommendations

A detailed analysis of the savings was not made for long-term energy recommendations due to time constraints. These recommendations are based on prior experience, available equipment, electronic controls, and operating methodologies:

- The cooling load used to maintain the ice cream at temperature -33°C to -45 °C (-27 °F to -49 °F) is about 50% higher than a comparable facility built in the U.S. This is due to poor insulating materials, relatively high infiltration rates, and leaky doorways with no buffer zone in the loading area. This load ranges from 250 kW in the winter to 450 kW in the summer.

- The Ice Cream fabrication shop needs to be maintained at about 7 °C (45 °F). This reduces the refrigeration load for the ice cream products. The present practice of letting the room temperature float is very costly.

- The cooling tower in the Uzina Frig #1 should be converted to forced cooling with interlock control to shut down the water pumps first and then the cooling tower blowers sequentially. Similar interlock control need to be installed in the Uzina Frig #2. A forced cooling tower can also be used to lower the temperature of the water from compressor oil coolers.

- The refrigeration compressor discharge valve needs to be regulated automatically with cooling water or ambient air temperatures. The existing hand value discharge pressure adjustment is unreliable and inefficient.

- The boiler air blower, the natural gas valve and steam pressure need to be linked automatically. For more efficient operation, an oxygen trim system will complement this control package nicely and very efficiently. The existing air/fuel mechanical linkage is generally unreliable and inefficient.

- A conductivity probe for steam drum level control is needed. The sensor having high, low, and normal output should be linked to the boiler feedwater valve for safe and reliable operation.

- Investigate using steam from the existing boilers for domestic hot water and heating. This requires hot water circulating pump(s), a properly sized expansion tank, a steam to hot water heat exchanger (preferably a condenser such that the steam condensate can be returned to the dearator). The cost of the equipment with the existing Romanian labor rate can not be too expensive. Since the plant sells steam to the neighboring plants for 460 lei/Gcal and buys hot water for heating for 505 lei/Gcal, the economics and the payback of implementing this measure under the existing circumstances may prove attractive.

Install three circuit hot gas defrost control. This automatic hot gas defrost system is to be installed on three ice cream storage cooling coils with a common control panel and timers. This system will prevent excessive ice formation on the coils and improve the efficiency of the cooling system.

4.3 Replication Potential

Storage of food products by refrigeration is just beginning in Romania. Grocery stores and refrigerated warehouses will soon be using the same refrigeration methods as the Milk Processing Enterprise. The new technologies, refrigeration control, automatic hot gas defrost, floating head pressure, and cooling tower control interlocks discussed with the facility staff will be applicable not only to milk processing facilities in Romania but also to future industrial/commercial refrigeration in Romania.

4.4 Pricing Policy Issues

It appears that the plant management is heavily regulated by various GOR Ministry agencies. These government entities may not always be cognizant of the need for more efficient energy utilization when enacting energy pricing policies.

A review of the existing organization chart indicates multi and duplicate functions. The major users of energy are not in the main stream of the existing organization.

The plant technical staff are not always aware of how energy is being wasted. Heavy industrial equipment that may run on recycle, thus wasting energy, is ignored while obvious small energy users are controlled This apparent lack of priorities is due in part to lack of adequate monitoring equipment, and in part to lack of up-to-date energy technology. The best energy pricing/policy issues for the Bucharest Milk Processing Enterprise may not produce any positive results as long as the cited situations are not changed. However, with some organizational changes and the participation and motivation of the key personnel, the following may produce results:

A. Penalize the plant for operating under 0.90 power factor.

B. Provide shared saving incentives for the plant to reduce consumption by 10%. This may require low-cost equipment. However, it will generate a good number of ideas and the motivations.

C. Provide incentives for production managers to submit weekly or monthly production schedules. This will give the supporting utilities (refrigeration plants, boiler room operators) the information they need to schedule their equipment to meet the load.

4.5 Energy Conservation Equipment for Immediate Installation

After review of the facility monitoring, metering, and energy conservation equipment and given the limited budget allocated for the purchase of equipment, it was decided to recommend the following (detailed specifications are contained in Appendix A):

1. A Natural Gas Flow Meter

   This meter is specified to meter and totalize the incoming natural gas flow.

2. A Saturated Steam Flow Meter

   This meter is specified to have three flow elements for monitoring all three boilers steam output. A main monitoring station will be designated for the digital display.

3. A Portable Battery Operated Combustion Analyzer

   This combustion analyzer will allow the boiler operator to routinely check the combustion products. Guidelines will be issued to the operators for operating the boiler in the excess air ranges for optimum efficiency.

4. A Hand-Held Digital Thermometer

   This thermometer will allow the operator to measure the furnace temperature, the steam temperature, the hot boiler exterior temperature, and the temperature of the condensate.

The equipment specification, names of suppliers, and operating conditions are included in Appendix A as well as a brief justification for recommending this equipment. This equipment is intended for the following energy management and awareness opportunities:

A. Provide energy and material balance tools for the three boilers. With known natural gas and steam flow rates, boiler jacket and stack gas temperatures, an accurate material and energy balance becomes possible. This combustion-related equipment will provide awareness and energy conservation if the boiler control, combustion burner, or combustion control begins to malfunction.

B. The automatic hot gas defrost for industrial refrigeration not only saves energy but also reduces the product waste. Presently, water is being sprayed on cooling coils for defrost. The sprayed water appears to be freezing on the floor because of poor drainage. This water freezing requires additional cooling which is considered to be waste. The manual spray, if not kept consistent, provides inadequate cooling which may result in not only inefficient cooling but also a softer ice cream product.

5.0 Plant Organization

5.1 Plant Organization Description

The existing organizational chart is shown in *Figure 4*. It illustrates the entire management and organizational structure in detail. It shows a great deal of duplication between the Militari (Fresh Milk Products) and the ice cream manufacturing sections.

Under present organizational structure, the facility engineering office (Mechanic Chief) is responsible for all energy related issues and conservation projects. Surprisingly, the facility's major energy users, such as the refrigeration and thermal (boilers) plants, do not report to the Mechanic Chief. These major energy users report to production managers who may or may not have any interest in the energy conservation projects.

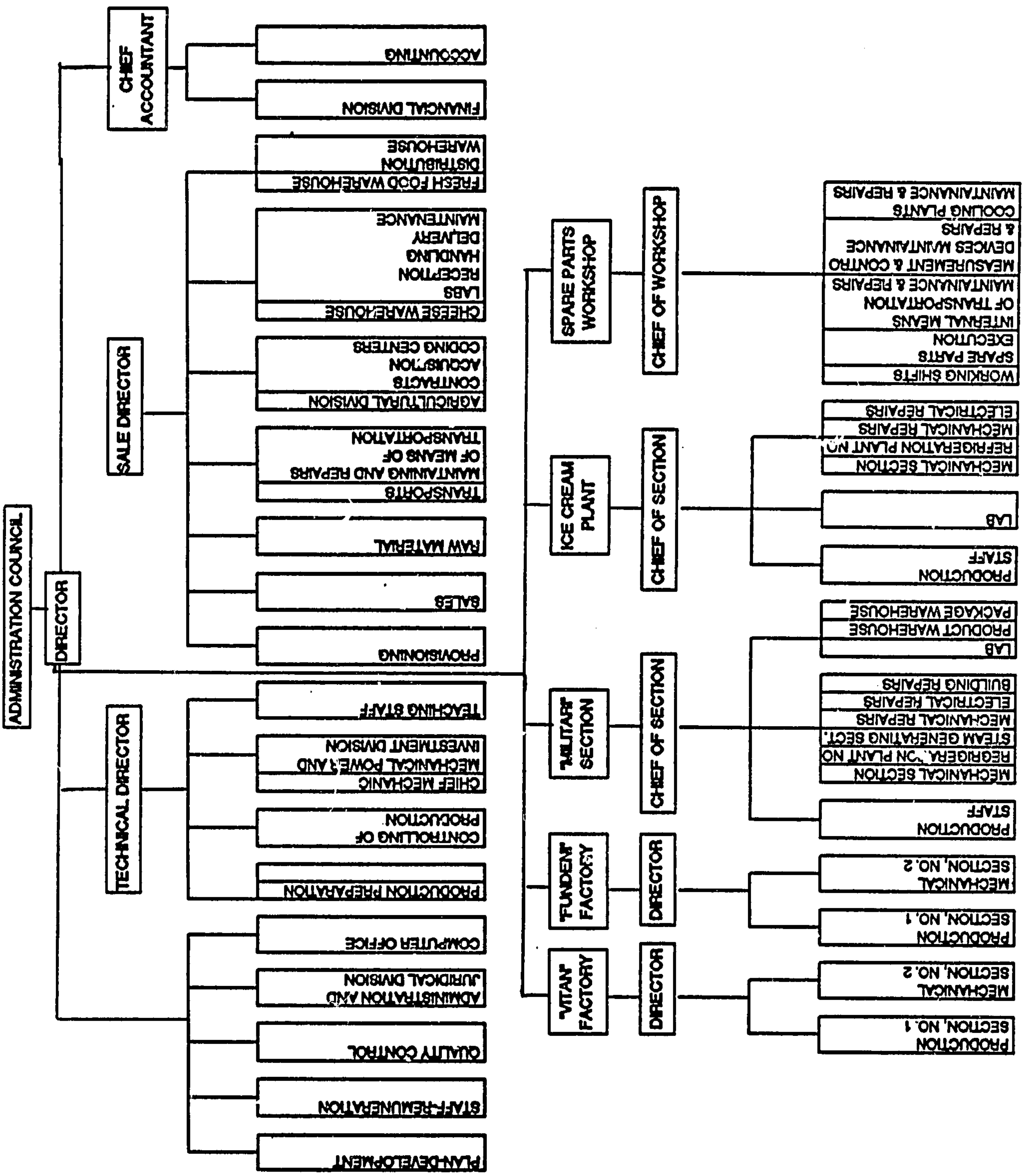
It is believed that any energy related projects and energy conservation issues initiated by the major energy user departments will never reach the office of the Mechanic Chief because of lack of interest and too many levels of management approval.

Because of this, restructuring the organization is recommended, not only for implementation of energy conservation concepts but also for energy user motivation for initiating low-cost/no-cost energy management measures.

5.2 Recommendations

A simplified organizational chart, illustrating major departmental functions, to be adopted for the Bucharest Milk Processing Enterprise, is illustrated in *Figure 5*. Under this organizational structure, an energy conservation staff, operating at the same level as facility's major energy users, is recommended. The energy conservation manager along with the major energy user managers; namely electrical, refrigeration plants, and thermal system, report to the Mechanic Chief who will report to the technical director. The advantage of this recommended organization is that the facility engineer (Mechanic Chief) is directly in communication with the major energy users as well as the energy conservation manager. Any energy conservation projects approved by the Mechanic Chief are expected to be implemented.

Figure 4. Plant Organizational Chart



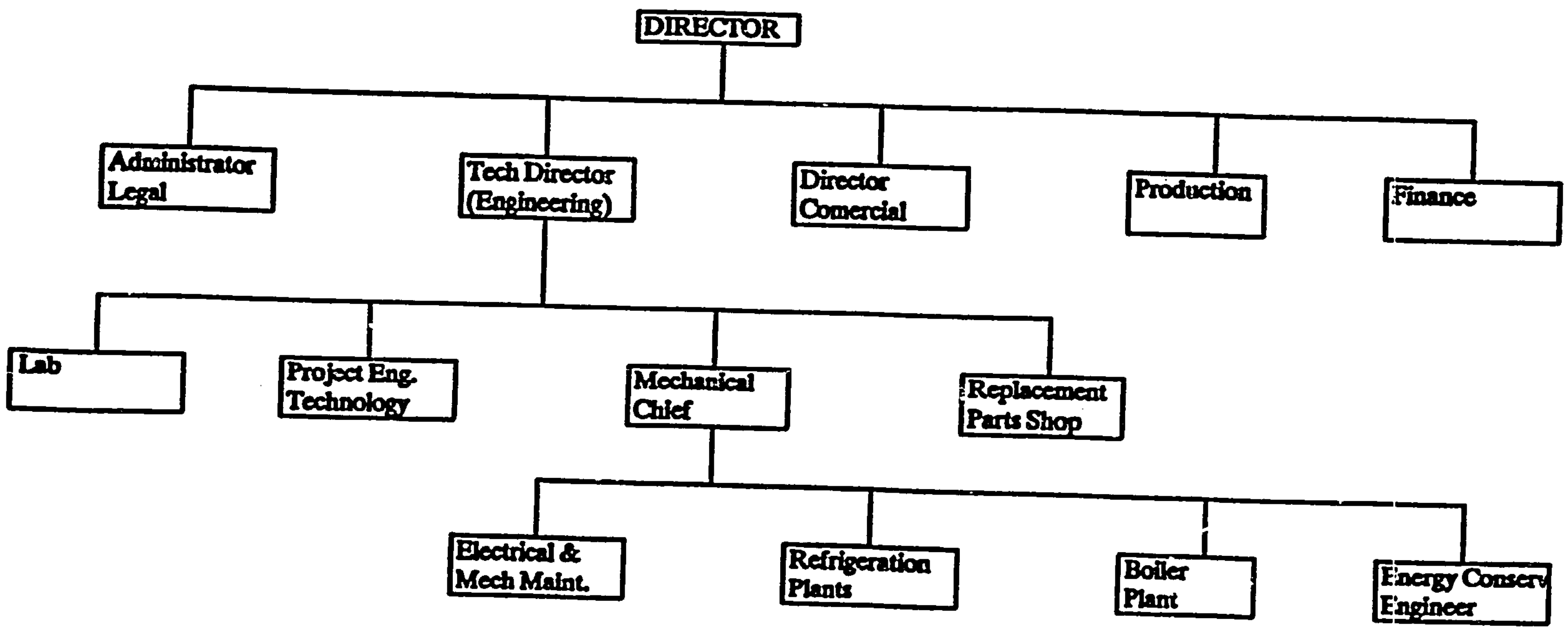


Figure 5. Simplified Organizational Chart

6.0 Implementation Phase

6.1 Summary

The Bucharest Milk Processing Plant received a digital thermometer, a portable combustion analyzer, and a natural gas flow meter. The steam flow meter is scheduled to be delivered as soon as it arrives at Bucharest. The operation of the equipment was demonstrated and explained as clearly as possible at the plant. The facility has another milk processing plant at Fundeni. The management arranged a half day tour of this plant. The plant is considerably smaller than the Bucharest plant and is well managed. Following are the highlights of the tour at the Fundeni milk processing plant:

- Plant capacity is 140,000 liter per day. Milk available for processing is 60,000 liter per day.
- The plant produces bottled milk, yogurt, cream, cream cheese, cheese and other dairy products.
- The plant has three 4 metric ton/hr horizontal kettle-type boilers. Two boilers operate when the plant is at full capacity.
- Boiler control is semi-automatic and boilers are well maintained.
- There is no combustion test equipment. Air/fuel ratios are adjusted manually.
- The two-stage refrigeration compressors are similar to those used in the Bucharest plant.
- The cooling tower is a natural air circulation type, similar to the cooling tower of Frig #1 in the Bucharest plant.
- Over 80% of condensate is returned, considerably more than the Bucharest plant.

From operational, process equipment, and control stand point, the Bucharest and Fundeni plants need to evaluate and improve system performance with the following priorities:

- Refrigeration - Over 50% of the plant's electrical energy use is for refrigeration. A 25% to 50% reduction of this can be achieved by the combination of proper equipment, insulation and renovation. A significant amount of electrical energy can be saved by preventing frost formation on the bare pipes either by installing better insulation or increasing the suction pressures the compressors use for medium temperature refrigeration. The natural air circulation cooling towers in both plants need to be evaluated for possible conversion to forced air circulation.

Thermal Systems - The mechanical air/fuel linkage, the pressure difference sensor for steam drum level control, and visual combustion air adjustment are a few sources of energy waste. These need to be replaced and the boilers need to be tested with a boiler combustion analyzer and adjusted for optimum efficiency.

Some of the existing management do not realize the necessity of producing quality products at a competitive cost and continue to operate in isolation. For the Milk Enterprise to remain competitive as the Romanian economy moves toward a free market, organization restructuring will be needed to reduce the number of managers and increase the productivity and efficiency at the plant production level.

6.2 In-Country Draft Audit Report Review

The review process was conducted with two company personnel and an Engineer Inspector from the Agency Resource Conservation Energy (ARCE) of Romania. The two representatives from the Bucharest Milk Plant could not comment much because of the unfamiliarity with the prior work. As a result a great deal of time was spent comparing the present plant organization with the organizational structure recommended in the report. They concluded that the existing organizational structure developed through years of effort is superior. Upper management resistance to the proposed changes may forestall their implementation.

The energy conservation opportunities presented in the report were discussed item by item. These include the loss of significant energy in the ice cream warehouse, ice cream manufacturing, natural cooling tower, and refrigeration heat recovery recommendation. The refrigeration heat recovery recommendation is the one most likely to be implemented in the near future.

6.3 Energy Efficiency Measures Adopted by the Facility

None of the energy conservation measures were adopted. The refrigeration heat recovery measure may be implemented, pending available funding from company officials.

6.4 Management Results

As mentioned above there will not be any management restructuring. Restructuring must be initiated by outside authorities rather than within the existing organization.

6.5 Implementation Plan

6.5.1 Equipment

Operation of the digital thermometer and the portable combustion analyzer operation was briefly discussed. Both were tested on one of the boilers and key operation functions were described. By the completion of the plant visit, the fixed gas flow meter had arrived at the plant, although the shielded wire and the long bolts were missing. The boiler operators were planning to use metric bolts and nuts if they do not receive the original bolts. A schematic was prepared to show approximate installation dimensions for the meter and the peripheral equipment.

We discussed using fixed and portable equipment for boiler energy and material balances. The operators were planning to prepare a data log sheet to record the test data for boiler analysis and correction when if becomes required.

6.5.2 Management

As mentioned above no changes in the management structure are planned.

6.6 Expected Energy Savings

The facility uses about 8 metric tons/hr saturated steam at an average steam pressure of about 10 bar. Use of this equipment may result in a 2% savings. This corresponds to about 13.4 m^3/hr of natural gas. Annual savings are calculated at 80,000 m^3 of natural gas assuming operation of 6,000 hr/yr. This results in about 720 Gcal/yr of energy savings.

Appendix A
Energy Conservation Equipment Specification/Purchase Justification.

A1. Equipment Specification

After a plant survey and subsequent discussion with the plant operation personnel, it was found that the facility does not have any metering equipment to perform routine energy and material balance on the flow of natural gas (energy entering the boilers) and steam generation rate (energy leaving the boilers). Because of this, it was decided to specify and recommend the purchase of the following metering equipment for routine energy and material balances on the steam generation system. In addition, a three circuit hot gas defrost control system was also recommended because of heavy ice formation on the evaporation coils and manual operation contributing to significant energy losses.

1. Natural Gas Turbine Flow meter

Type	Insertion
Fluid	Natural Gas
Range	400-1600 m^3/hr
Normal	1000 m^3/hr
Pipe OD/ID	159/150 mm
Temperature	20°C
Pressure range	1200-5000 mm H^2O
Compensator	Masstrol or equivalent
Capability	Compensated flow in m^3/hr, totalizer, and 4-20 mA output.
Electrical	220 V AC, 50 hz

The total cost estimated approximately $3,800.

2. Saturated Steam Flow Meter

The plant has three boilers and needs to measure the steam output. Three flow elements and transmitters need to be installed in three steam pipes. The output need to be fed to a panel with a selector switch. A common panel for three flowmeters needs to be designed and commissioned for final installation.

Type	Insertion or orifice plate
Fluid	Saturated steam
Range	5-10 metric ton/hr
Normal	8 metric ton/hr
Pipe OD/ID	159/150 mm
Temperature	saturated, varies with pressure
Pressure range	8-15 bar
Compensator	Masstrol or equivalent
Capability	Compensated flow in metric ton/hr, totalizer, and 4-20 mA output.
Electrical	220 V, 50 hz

The approximate cost is $5,100.

3. A Portable Combustion Analyzer

A battery operated hand-held combustion analyzer is needed. The analyzer shall be equipped with the following digital readings:

** Temperature of the stack.
** % of stack losses.
** % of combustion product; CO_2, O_2, and excess air.
** dual fuel capability, Natural gas and fuel oil # 6.
** Re-Chargeable battery.
** Battery charger for 220 Volt and 50 Hertz power.

The approximate cost is $675.

4. Hand-Held Battery Operated Digital Thermometer.

A portable thermometer capable of reading temperature from 0 to 1100°C. is needed. The thermometer may be dual range for a reasonable accuracy covering the entire temperature range. With the meter the following is needed:

** Two type K thermocouple leads for fluid measurement.
** Two type K thermocouple leads for surface measurement.
** One type K thermocouple lead with ceramic beads at hot junction for high temperature (combustion products at 2000 °F)
** Rechargeable battery.
** Battery charger for 220 Volt and 50 Hertz electricity.

Note: The battery charger in part 4 may combined with the charger in part 5.

The approximate cost is $475.

A2. Equipment Purchase Justifications.

We are recommending purchase of the following equipment:

A-- Boiler and steam related equipment:

1-- A Natural Gas Flowmeter	$3,800
2-- A steam flowmeter(3 flow elements)	$5,100
3-- A hand- held combustion analyzer	$675
4-- A hand-held digital thermometer	$475
Total for combustion related equipment, excluding installation and commissioning.	$10,050

Justification

To perform an energy and material balance around the boiler, one need to measure the fuel input rate, the steam output rate, the steam pressure/temperature, temperature of incoming fuel, temperature of incoming combustion air, stack gas analysis, temperature of the incoming boiler feed water, and the boiler exterior surface temperature. Some of the measurements may be duplication, however, they are used for cross checking. The combustion related equipment is recommended to enable the operator to perform the energy and material balance periodically. This also enables the facility to determine any peculiarities in generation or fuel consumption. The calculations below use the combustion analyzer result assuming other losses remain unchanged.

Billing history indicates the facility used over 4.3 million m^3 of natural gas in 1989. The combustion test results, presented in the report, indicates at least a 4% stack loss reduction by using the combustion analyzer and adjusting the excess air. Using the 4% reduction in gas consumption the following results:

Annual gas consumption	4,000,000 m^3/yr
Reduction in consumption	4%
Reduction in gas consumption	160,000 m^3/yr
Natural gas cost	2.8 Lei/m^3
Annual cost saving	448,000 lei/yr
Annual cost saving (official)	12,800 $/yr
Equipment cost	$10,050
Simple payback	10 months

Appendix B
Energy Conservation Sample Calculations.

Energy Conservation Calculations:

A. Refrigeration Heat Recovery

Since the plant operates the boiler year-round, it is recommended that the treated make-up water be preheated, using only the superheated portion of the Ammonia refrigerants. Calculation steps are as follow:

Refrigeration load (439 metric tons)	1.33 million kcal/hr
Suction to second stage	-15 °C
Average discharge pressure	12 bar
Calculations show superheat temperature	112 °C
Calculations show the enthalpy diffe. of	323 kcal/kg
Calculations show the refrigeration flow of	4118 kg/hr
Calculation the enthalpy diffe. superheat	49 kcal/kg
This results in a heat recovery of	201,765 kcal/hr
Operating hours per of	8,600
Annual waste heat recovery of	1.74 billion kcal/yr
Natural gas heating value	8,900 kcal/m^3
Boiler efficiency	79%
This results in a natural saving of	246,789 m^3/yr
Natural gas price	2.8 lei/m^3
Natural gas cost saving will result	691,010 lei/yr
The management estimated equipment cost of	550,000 lei
This will result in a payback of	0.80 yr
If we assume calculations accuracy 50%, the payback period increases to	1.8 yr

The implementation of this measure should be considered immediately.

B. Prevent Ice Buildup on Suction Lines

There are many pipes and tanks maintained about -30 to -40 °C. These vessels and the connecting pipes need to be re-insulated because of the following:

1. The existing insulation is very porous and has high conductivity and is not suitable for very low temperature applications.
2. In order to defrost, warm water had been sprayed; and consequently the existing insulation is wet and very conductive.

The energy loss per square meter is calculated as a guide for economic analysis. One can measure the total square meter of the pipes in the ice cream shop and in the Uzina #2 refrigeration plant to determine the overall cost impact.

Assume the following:

The ice surface temperature is	-25 °C
Add new insulation to have surface temperature of	15 °C
Assume average room temperature	20 °C

Note: Insulation thickness depends on surface and clearance available. In some areas about 30 cm of insulation with a conductivity value of 0.036 W/m/K may be needed.

Calculations show ice surface u-value is	17.9 $W/m^2/K$
The heat loss per square meter is then calculated as	806 W/m^2
Calculations show the insulation surface U-value	28.3 $W/m^2/K$
The heat loss per square meter is then calculated as	142 W/m^2
The net heat loss reduction, therefore is	664 W/m^2
This heat loss corresponds to	571 kcal/hr/m^2

Now, assume 100 square meters of the pipings need to be insulated.

The heat loss reduction is	57118 kcal/hr
As indicated the compressor (kW/metric ton=139)	
Or kW per 3,024 kcal/hr is 1.07 kW.	
This results in power reduction of	20 kW
8,600 hour per year operation, this results in	173,810 kWh/yr
1.7 lei/kWh electricity cost, this results in	295,477 lei/yr
A 30 cm thick insulation costs about	1,600 lei/m^2
Installation cost and labor	400 lei/m^2
This results in a total insulation cost of	200,000 lei
The payback for this repair is	0.68 yrs
Assume the calculation is inaccurate by 50%	
The payback then becomes less than	1.4 yr

This calculation indicated immediate re-insulation of all exposed vessels and pipings for preventing ice formation.

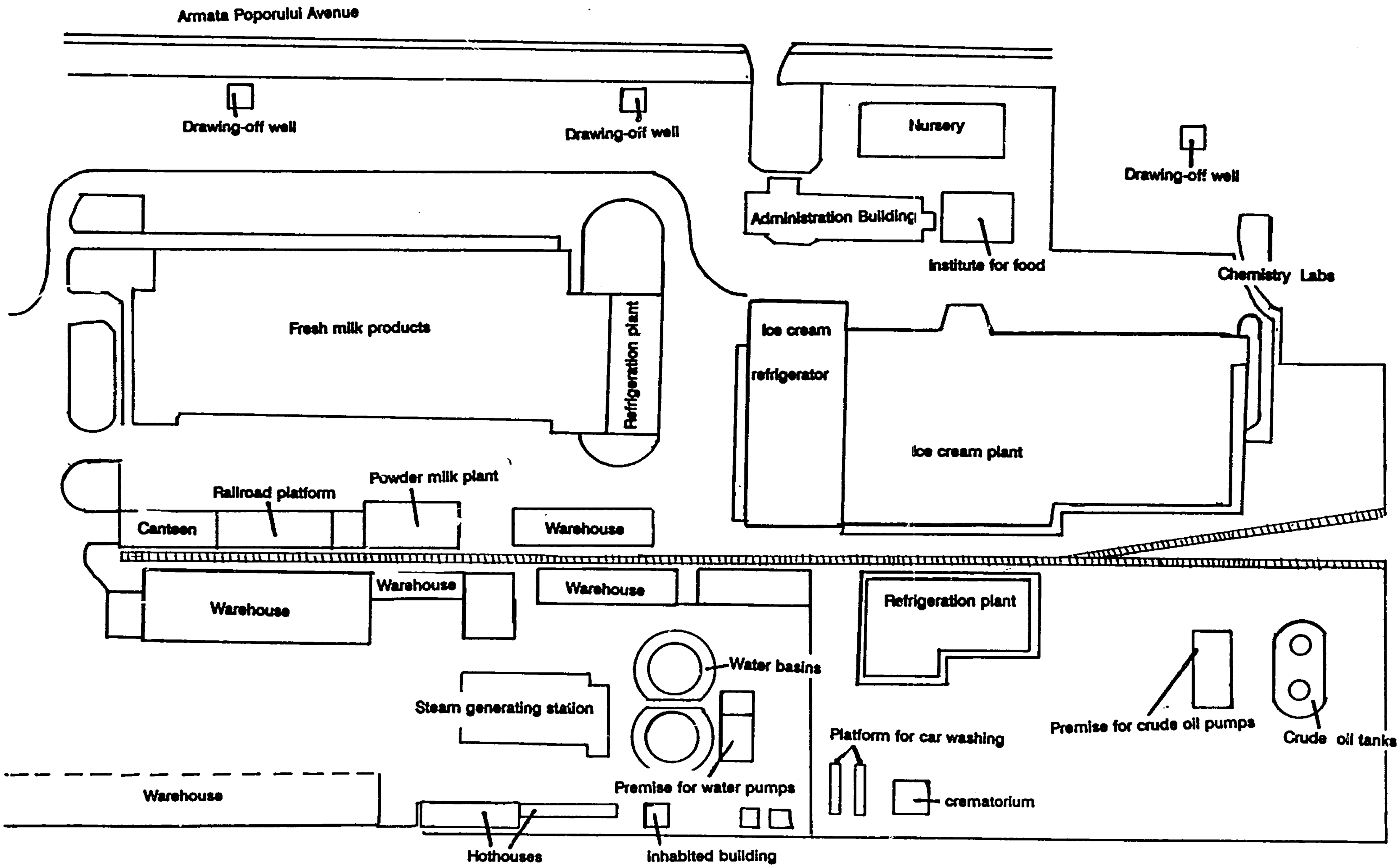
C. Return Condensate from Pasteurizer Area

It is reported that the condensate from pasteurizer can not be returned because of leaks. We would like to show the energy loss and justify the cost of the repair or some equipment replacement.

Annual condensate loss	2,100,000 kg/yr
The pressure is	1 bar
Enthalpy of the condensate is	121.6 kcal/kg
Make-up water has enthalpy of	10.0 kcal/kg
The condensate energy loss is	2.34E+08 kcal/yr
Boiler efficiency is	79.0%
Natural gas heating value is	8,900 kcal/m^3
The natural gas saving becomes	33,317 m^3/yr
Natural gas cost is	2.8 lei/m^3
Cost saving is	93,288 lei/yr
Each new pasteurizer costs (local currency)	75,000 lei
Total equipment (3 pasteurizers) cost	2225,000 lei
Payback for returning the condensate is	2.4 yr

Note: The equipment cost is an estimate. All three pasteurizers may not need to be replaced. Also, the pasteurizers cost (plate heat exchangers) may be considerably cheaper than the cost estimated. It is recommended to investigate the actual cost and implement the condensate leak repairs.

Appendix C
Plot Plan



Plot Plan: Bucharest Milk Processing Enterprise

Appendix D
List of Abbreviations

List of Abbreviations

AC = alternating current
amps = amperes
atm = atmosphere = 14.696 pounds per square inch
bar = 100,000 pascals = 14.504 pounds per square inch
BTU = British thermal unit
cfm = cubic feet per minute
cm = centimeter = 0.3937 inches
cm^2 = square centimeter = 0.155 square inches
CO = carbon monoxide
CO_2 = carbon dioxide
DC = direct current
°C = degree Celsius T[°C] = 5/9*(T[°F] - 32)
°F = degree Fahrenheit
°R = degrees Rankine T[°R] = T[°F] + 460
eff = efficiency
ex air = excess air
Gcal = gigacalorie = 1 billion calories = 3.968 million BTU
GJ = gigajoules = 1 billion joules
gph = U.S. gallons per hour
gpm = U.S. gallons per minute
GWh = gigawatt hours = 1 billion watt hours
H_2 = hydrogen
H_2O = water
H_2SO_4 = sulfuric acid
hectare = 10,000 square meters = 2.471 acres
hectoliter = 100 liters = 26.42 U.S. gallons
Hg = mercury
hr = hour
Hz = hertz = cycles per second
J = joules
K = Kalvin
kcal = kilocalories = 1 thousand calories = 3.968 BTU
Kcs = 29.77/$1 US
kg = kilogram = 2.2046 pounds
Kgcc = 7,000 kcal = 27,776 BTU
kJ = kilojoules = 1 thousand joules = 0.947813 BTU
km = kilometer = 0.621 miles
kN = kilonewton = 1 thousand newtons
kPa = kilo pascals = 1 thousand pascals = 0.14504 pounds per square inch
kV = kilovolts = 1 thousand volts
kVA = kilovolt-amperes
kVAr = kilovars = 1 thousand volt-amperes (reactive)
kW = kilowatt = 1 thousand watts
kWh = kilowatt hour = 1 thousand watt hours
lbs = pounds
liter = 0.2642 U.S. gallons = 0.03531 cubic feet

m	= meter = 39.37 inches
m^2	= square meter = 10.76 square feet
m^3	= cubic meter = 35.31 cubic feet
mA	= milliampere = 0.001 amperes
metric ton	= 1 thousand kilograms = 1.1023 U.S. tons
mg	= milligrams
min	= minute
MJ	= megajoules
mm	= millimeter = 0.03937 inches
MPa	= 1 million pascals = 145.04 pounds per square inch
MVA	= megavolt-amperes
MW	= megawatt = 1 million watts
MWh	= megawatt hours = 1 million watt hours
NG	= natural gas
nm	= nanometer
Nm^3	= cubic meters at standard conditions of temperature and pressure (20°C and 1 atmosphere)
NO_X	= nitrogen oxide
O_2	= oxygen
P	= pressure
PC	= personal computer
PF	= power factor
ppm	= parts per million
psi	= pounds per square inch
psig	= pounds per square inch (gauge)
R	= thermal resistance
s	= second
SO_2	= sulfur dioxide
sq ft	= square feet
Tcal	= teracalorie = 1 trillion calories = 3.968 billion BTU
T	= temperature
V	= volts
VArs	= volt-amps (reactive)
VSD	= variable speed drive
W	= watts
yr	= year