PN-ABL-043
76720

# INDUSTRIAL ENERGY EFFICIENCY AUDIT REPORT

## PULP AND PAPER FACTORY
Braila, 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
WASHINGTON, D.C. 20523

PN-ABL-043

# INDUSTRIAL ENERGY EFFICIENCY AUDIT REPORT

## PULP AND PAPER FACTORY
Braila, Romania

JANUARY 1992


**PREPARED BY:** RESOURCE MANAGEMENT ASSOCIATES OF MADISON, INC.
520 University Avenue
Suite 300
Madison, WI 53703
(608) 283-2880

and

INSTAPART
Sos. Catelu nr. 9
Bloc PM 62, Sc 1, Ap. 12, Et 2
Bucharest III
Romania
40-48-388388



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

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
BUREAU FOR EUROPE
OFFICE OF DEVELOPMENT RESOURCES
ENERGY & INFRASTRUCTURE DIVISION
WASHINGTON, D.C. 20523

USAID Contract EUR-0015-C-1006-00

## Table of Contents


i. Eastern Europe Industrial Energy Efficiency Program . . . . . 1

ii. Executive Summary . . . . . 3

1.0 Plant Description . . . . . 5
- 1.1 General . . . . . 5
- 1.2 Organization . . . . . 5
- 1.3 Plant Operation . . . . . 6
- 1.4 Electrical System . . . . . 6
- 1.5 Thermal System . . . . . 6
- 1.6 Black Liquor . . . . . 7
- 1.7 Steam Generation . . . . . 7
- 1.8 History of Energy Efficiency Measures . . . . . 8

2.0 Plant Energy Profile . . . . . 9
- 2.1 Electrical . . . . . 9
- 2.2 Natural Gas . . . . . 9
- 2.3 Plant Water . . . . . 13
- 2.4 Black Liquor . . . . . 13
- 2.5 Steam Generation . . . . . 13

3.0 Audit Description . . . . . 16
- 3.1 Summary . . . . . 16
- 3.2 Boiler Test Results . . . . . 16
- 3.3 Summary . . . . . 18

4.0 Summary of Results . . . . . 19
- 4.1 Short-Term Recommendations . . . . . 19
- 4.2 Long-Term Recommendation . . . . . 20
- 4.3 Replication Potential . . . . . 22
- 4.4 Pricing Policy Issues . . . . . 22
- 4.5 Energy Conservation Equipment for Immediate Installation . . . . . 23

5.0 Plant Management/Organization . . . . . 25
- 5.1 Description of Plant Organization . . . . . 25
- 5.2 Recommendation . . . . . 25

6.0 Implementation Phase . . . . . 26
- 6.1 Summary . . . . . 26
- 6.2 In-Country Review of Draft Audit Report . . . . . 27
- 6.3 Energy Efficiency Measures Adopted by the Facility . . . . . 27
- 6.4 Management Results . . . . . 28

6.5 Implementation Plan . . . . . 28
6.6 Expected Energy Savings . . . . . 30

## List of Tables

Table 1. 1988 Energy Consumption and Generation Profile . . . . . 11
Table 2. Boilers Identification and Nameplate Data . . . . . 12
Table 3. 1989 Steam Generation Profile . . . . . 15
Table 4. Boiler Measurement Results . . . . . 17

## List of Figures

Figure 1. Energy Profile . . . . . 10

## List of Appendices

Appendix A
Energy Conservation Equipment Specifications

Appendix B
Energy Conservation Calculations

Appendix C
Organizational Chart

Appendix D
Photographs

Appendix E
List of Abbreviations

## 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 industrial energy efficiency audit was conducted for the S.C. CELHART DONARIS S.A., located near the city of Braila, Romania. The audit covered a one week period from March 18 to March 22, 1991.

The survey and the subsequent analysis was primarily focused on the electrical and thermal systems. However, during the survey, process equipment, operating methodologies, and the facility technical staff interactions also became noteworthy of consideration. The following is a summary of the audit team findings:

1. Two energy intensive areas have been identified as feasible for energy efficiency measures, as follows.

   a. The facility is reported to require an average rate of 25,000 $m^3$/hr water. This water is pumped from the Donaris river, located several kilometers from the plant, and treated for plant use. The connected load for the three treatment stations and distributions is 13 MW. This load is about 16% of the total plant demand and appears to be excessive. The manual operation of choking the discharge valve of the pumps and horizontal transportation of the water with no vertical reservoir and hydraulic head are major contributors to the system inefficiency. One should investigate vertical storage tanks and level switches for automatic pump operation. A load reduction of at least 25% is possible. In order to determine the load and flow fluctuations of the pumps, a portable analyzer, an ultrasonic flow meter, and a portable computer with software for downloading capability are recommended.

   b. Steam is being generated in the Craft central (11 boilers) and recovery boilers (5 to 6 boilers) and then transported relatively long distances via large pipelines to major consumers, especially the pulp plant. At the present time, due to the plant operating at 50% capacity and 50% over design, a significant amount of steam energy is being lost. A significant portion of this energy could be saved if production scheduling and fast response communication tools between users and producers could be established. With proper scheduling, equipment control integration, and faster communication between the two plants, a 15% to 25% steam energy saving is possible.

2. The facility technical staff seem very capable. The organization and management appear to be very willing to undertake process equipment improvements and energy management opportunities. However, they do not have adequate financial resources and technical expertise in some specific technologies, material science, and control/instrumentation. The audit team spent over 50% of the time discussing and presenting new technologies, electronic controls, and equipment capable of performing in a harsh and corrosive environment.

Three low-cost measures with relatively high return were selected for evaluation. The analysis and assumptions are given in Appendix B and a summary result is shown in Section 4.1.

Long-Term Recommendations

Nine 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 benefit trade-offs. However, past experience and practices elsewhere indicate attractive paybacks and reduction of energy consumption for similar measures. A brief description of these measures is given in Section 4.2.

Short-Term Energy Management Equipment Recommendations

In accordance with the USAID program guidelines, a limited budget is available to recommend and specify energy management and conservation equipment. The specifications and purchase justifications for the equipment is given in Appendix A. A summary with purchase justification is also shown in Section 4.5.

Follow-Up Actions

The following action items are also recommended:

1. The digester requires a load cell for energy and material balance. The load cell should be installed at the bottom of the digester and with instrumentation to show the reaction rate as a function of time. It is recommended that several suppliers be contacted to obtain the necessary information, prices, brochures and specific applications.

2. The pneumatically operated valves in the digester control circuit fail repeatedly. This is due to the corrosive and high temperature environment. These valves should be replaced with new ones according to the following specifications: pipe diameter 200 mm, temperature 180 °C, and valve pn25.

3. The black liquor in the two recovery boilers (#4 and #5) requires chemical analysis to determine the combustibility limit of the black liquor to prevent flame blow out. It is recommended that a combustibility test be conducted by a qualified laboratory.

Implementation Phase

The implementation phase of the audit involved a return trip to the facility to facilitate the installation and use of the equipment. Training on portable equipment was provided for the plant staff. The draft audit report was reviewed. Fixed energy efficiency equipment purchased by the project was installed. Finally, a utilization plan was developed for the equipment.

## 1.0 Plant Description

### 1.1 General

The S.C. Celhart Donaris S.A. is a pulp and paper manufacturing facility, located approximately 10 kilometers from the city of Braila, Romania. The plant was built in 1960 to process river weeds for pulp which was used to manufacture low grade cardboard. The plant was later upgraded to process birch trees for wood pulp and writing/typing paper. At the time of the audit, the plant production output had been reduced to about 50% capacity, primarily due to the shortage of natural gas, fuel oil, and electric power from the RENEL power grid. This plant is representative of seventeen other facilities around the country.

The entire facility is located in a three hectare area. It consists of two manufacturing plants (pulp and paper), a central power station, and other support facilities such as recovery boilers, a water treatment facility, and connecting pipelines for utilities and electrical conduits.

The pulp plant uses machines for birch wood debarking, wood chipping, and finally the Craft technology for dissolving pulp and pulp production. At the opposite end of the pulp plant, there is a paper making machine (Supercalendar), a steam heated paper dryer, and paper packaging. The audit team had only enough time to briefly examine the dryer and one of the digesters (there are 11 digesters in total).

The paper plant manufactures paper using the pulp from the pulp plant, and performs quality inspection and packaging.

### 1.2 Organization

The key plant staff assisting the audit team were:

| | |
|---|---|
| Mr. Nicolae Mocanu | Technical Director, Technical Department |
| Mr. Nicolae Mitu | Engineer Manager, Paper Mill |
| Mr. Valeriv Diaconescu | Chief of Automation |
| Mr. Constantin Ghenoiu | Chief Mechanical/Energy |
| Mr. Lucian Giurgiu | Engineer, Energy/Thermal System |
| Mr. Georgica Stan | Engineer, Resource Ministry |
| Mr. Petre Ciobanu | Engineer, Energy Conservation Agency |

The plant organizational chart, included in Appendix C, illustrates in detail the various operating departments and key directors.

The organization appears to be cohesive with a sense of cooperation. The facility problems and technical issues are well known and discussed frequently. Plant staff are aware that process equipment and controls fabricated internally may not solve the technical challenges facing Romanian industry.

## 1.3 Plant Operation

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

The facility used to employ about 10,000 people. It is reported that about 10% to 15% were technical engineers and technicians. Presently, the plant employment is reported to be about 8,000 people. Further staff reduction may be necessary if plant production can not be increased.

## 1.4 Electrical System

The facility is directly connected to the RENEL power grid via four (110) kV substations and automatic switching to accept the excess power from the facility steam turbine generators. The facility steam turbine generators are capable of generating a total of 162 MW. Plant staff need to optimize the operation of multiple generators and boilers. Because of this, a fixed power analyzer and a steam flow meter flow compensator is recommended to be installed on boiler #31 and the 50 MW steam turbine/electrical generator, which uses the superheated steam from boiler #31. The performance rating information from this metering arrangement will provide significant operating characteristics and will assist in the operation of other steam turbine generators.

## 1.5 Thermal System

Superheated and saturated steam is generated by the plant's 16 boilers. Eleven of the boilers are in the Craft Central power station. The other five are recovery boilers located in various areas near the production of black liquor, wood chips, and other combustible by-products. The following are pertinent information regarding the boilers in the Craft Central power station:

- All are Romania built boilers, installed in 1960 or later.
- Only two of the boilers, #31 and #24 were tested.
- Boiler #31 is a 420 metric ton/hr boiler which uses oil. It supplies steam at 540 °C and 140 bar.
- Boiler #24 is a 150 metric ton/hr boiler which uses gas. It supplies steam at 540 °C and 140 bar.
- Combustion blower: outside, preheated with stack gas.
- Equipped with economizer.
- Type: water tube.
- Air/fuel is mechanically linked.
- Steam drum level control is manual.
- The mechanical air/fuel linkage is changed manually.
- Continuous and intermittent blowdown.
- Continuous blowdown is equipped with heat recovery system.
- About 80% of the condensate is returned.

- Steam sale to the adjacent chemical plant is not known accurately.
- Steam sale average price is 680 lei/Gcal.

The following are pertinent information regarding the recovery boilers:

- Recovery boiler #5 was made by Combustion Engineering of Canada. It is an 80 metric ton/hr liquor/gas boiler that supplies steam at 435 °C and 40 bar.
- Recovery boiler #4 is German made. It is a 28 metric ton/hr liquor/gas boiler that supplies steam at 435 °C and 40 bar.
- The recovery boiler #6 uses wood chips and is not operating. It is a 10 metric ton/hr boiler that would supply steam at 250 °C and 17 bar.
- Recovery boiler #5 has a superheater tube problem. Because of this, its steam is not being used in the steam turbine generator.
- Both recovery boilers are using steam atomizers.
- The black liquor burned in boilers #4 and #5 varies in composition during day to day operations. It contains a concentration of non-combustibles that fluctuates significantly. The plant staff do not have the equipment to analyze this.
- Other recovery boilers and boilers could not be visited because of time constraints.

## 1.6 Black Liquor

Black liquor is separated from the pulp process and is used in two recovery boilers for generating medium pressure steam for steam turbine generators. Since black liquor contains non-combustibles and fluctuates during the process, the boiler operation becomes very unreliable. Accurate chemical analysis is needed to prevent flame blow out, pumping failure, and combustion nozzle plugging. Because of this, plant staff requested that a U.S. supplier of chemical analysis equipment be located by the audit team.

## 1.7 Steam Generation

The reported data for steam generation is very incomplete. Various assumptions have been used to fill in the missing data. The average monthly generation for all boilers and corresponding estimating assumptions are discussed in Section 2.5. The steam generation profile does not show any specific trend. This may be due to incompleteness of the reported data and the assumptions made to arrive at these data.

## 1.8 History of Energy Efficiency Measures

It appears that no energy efficiency measures have been initiated in recent years. This may be due to lack of financial resources and technical expertise. There are many opportunities which were identified by the audit team, which are briefly outlined in the summary section. However, to perform a thorough economic and technical assessment, considerable capital is needed.

## 2.0 Plant Energy Profile

Plant energy consumption for 1988 is shown in *Figure 1* and *Table 1*. Data consists of monthly consumption of natural gas, fuel oil #6, and black liquor by-products from the pulp process; and the monthly cost of the natural gas and fuel oil. The total energy liberated (energy in) and the energy in the flow of the generated steam (energy out) is also given. This results in a monthly energy conversion (fuel to steam conversion) ratio of 70%, which is very good, if the steam flow measurement is correct. From *Table 1*, the following energy related information can also be summarized:

- Heating value of the natural gas is 8,900 kcal/$m^3$.
- Heating value of the fuel oil #6 is 10,369 kcal/kg.
- Heating value of the black liquor is 3,200 kcal/kg.
- Natural gas consumption peaks during summer months.
- Fuel oil consumption peaks during winter months.
- Black liquor production is relatively constant with the exception of the month of April, which may be reported incorrectly.
- Unit cost for natural gas is 2.8 lei/$m^3$.
- Unit cost for #6 fuel oil is 4,700 lei/metric ton.
- Average unit cost (gas & oil) 336 lei/Gcal.
- Water and sewer expenses 37 lei/$m^3$.
- The fuel cost (natural cost and fuel oil) is 1.872 billion lei/yr.
- Over 79% of the fuel cost is for natural gas and the balance is for fuel oil.

### 2.1 Electrical

The facility has 7 steam turbines capable of generating a total of 162 MW of electricity. The steam turbine generators and the corresponding connected boilers are shown in *Table 2*. The facility is connected to RENEL in four substations to import/export electricity via automatic switching.

The power demand of the facility and the power generated by the facility steam turbine generators are shown in *Table 1*. As can be seen, the facility 1988 average annual consumption was 81 MW. In the same year, the average power generation of the facility generators was only 79 MW. This indicates that the plant electric consumption and generation is only 50% of the capacity. Operating electrical equipment at 50% part load generally results in poor energy utilization and efficiency.

### 2.2 Natural Gas

The facility has 16 boilers generating steam at various pressures and temperatures. The high pressure (140 bar) and medium pressure (37 bar) steam is primarily used for steam turbine electric generators. Steam at various lower pressures is extracted from the turbines and combined with steam from the low pressure boilers for domestic and export use. The boilers' capacity, operating characteristics, turbine generator rating, steam extraction, and

*Figure 1. Energy Profile*

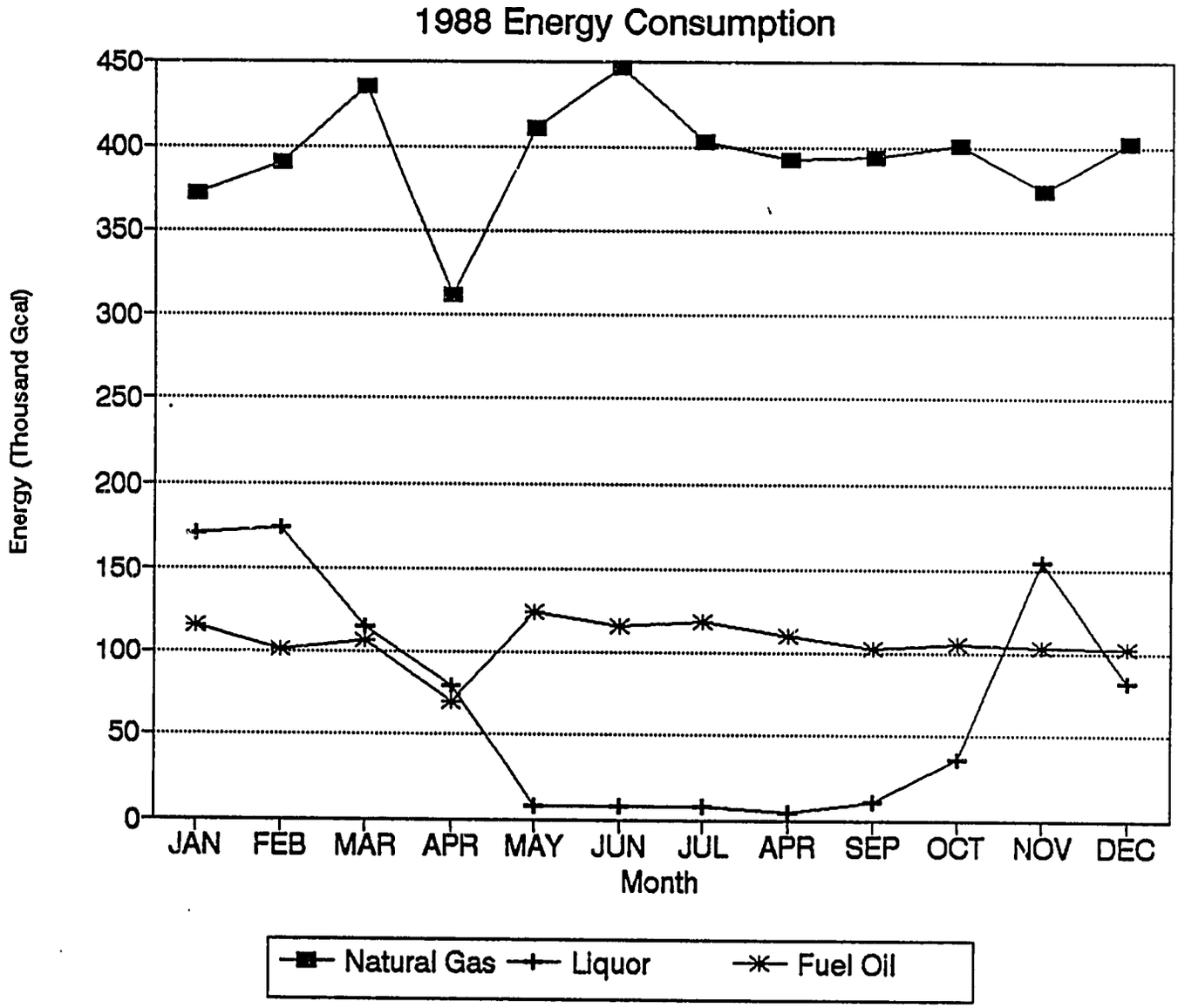


*Table 1. 1988 Energy Consumption and Generation Profile*

| MONTH 1988 | N. Gas thousand m3 | F.Oil metric ton | Liquor metric ton | Eff. % | N.Gas Million lei | F.Oil Million lei |
|---|---|---|---|---|---|---|
| JAN | 41773 | 16479 | 36104 | 71.20 | 117 | 77 |
| FEB | 43883 | 16808 | 31456 | 67.16 | 123 | 79 |
| MAR | 48839 | 11096 | 33224 | 65.71 | 137 | 52 |
| APR | 34935 | 7615 | 21676 | 65.44 | 98 | 36 |
| MAY | 46088 | 755 | 38644 | 69.55 | 129 | 4 |
| JUN | 50168 | 735 | 36052 | 68.95 | 140 | 3 |
| JUL | 45255 | 750 | 36968 | 68.28 | 127 | 4 |
| AUG | 44092 | 404 | 34204 | 69.35 | 123 | 2 |
| SEP | 44264 | 963 | 32034 | 70.12 | 124 | 5 |
| OCT | 45023 | 3409 | 32644 | 70.95 | 126 | 16 |
| NOV | 42054 | 14912 | 32244 | 74.00 | 118 | 70 |
| DEC | 45209 | 7853 | 32024 | 79.74 | 127 | 37 |
| TOTAL | 531583 | 81779 | 397264 | 70 | 1488 | 384 |

| TOTAL 1988 | N.Gas Gcal | F.Oil Gcal | Liquor Gcal | Tot.In Gcal | Tot.Out Gcal | Elect. Gen. MW | Elect Consum. MW |
|---|---|---|---|---|---|---|---|
| JAN | 371821 | 170864 | 115533 | 658218 | 468655 | 95 | 85 |
| FEB | 390603 | 174275 | 100659 | 665537 | 447004 | 92 | 83 |
| MAR | 434716 | 115050 | 106317 | 656083 | 431115 | 86 | 86 |
| APR | 310956 | 78957 | 69363 | 459277 | 300541 | 59 | 64 |
| MAY | 410229 | 7828 | 123661 | 541718 | 376775 | 64 | 83 |
| JUN | 446545 | 7621 | 115366 | 569533 | 392705 | 88 | 78 |
| JUL | 402815 | 7776 | 118298 | 528889 | 361109 | 76 | 85 |
| AUG | 392463 | 4189 | 109453 | 506105 | 350960 | 75 | 84 |
| SEP | 393994 | 9985 | 102477 | 506456 | 355108 | 74 | 81 |
| OCT | 400750 | 35347 | 104461 | 540557 | 383768 | 81 | 78 |
| NOV | 374323 | 154617 | 103181 | 632120 | 467766 | 87 | 83 |
| DEC | 402405 | 81425 | 102477 | 586307 | 467544 | 75 | 82 |
| TOTAL | 4731620 | 847934 | 1271245 | 6850799 | 4803050 | 79 | 81 |

Summary:

| | | |
|---|---|---|
| Unit cost for natural gas | 2.8 | lei/m3 |
| Unit cost for fuel oil #6 | 4700 | lei/metric ton |
| Average cost (oil & gas) | 336 | lei/Gcal |

(1) Efficiency is defined as total energy input to the steam generators vs. useful energy out.

(2) The economic analysis of projects designed to reduce overall plant thermal energy consumption should use an energy cost based on an average of the costs of natural gas and #6 fuel oil, weighted to reflect the relative consumption of these two fuels. Calculating from the above table, this cost is found to be 336 lei/Gcal.

## *Table 2. Boilers Identification and Nameplate Data*

| Boiler # | Fuel Type | Capacity metric ton/h | Temp C | Press. bar | Gen. MW | Extracted Steam Pressure bar |
|---|---|---|---|---|---|---|
| 11 | Gas/Oil | 45 | 450 | 37 | 6.0 | 11,7 |
| 12 | Gas/Oil | 45 | 450 | 37 | 6.0 | 11,7 |
| 21 | Gas | 150 | 540 | 140 | 25.0 | 11,7 |
| 22 | Gas | 150 | 540 | 140 | 25.0 | 11,7 |
| 23 | Gas | 150 | 540 | 140 | 25.0 | 11,7 |
| 24 | Gas | 150 | 540 | 140 | 25.0 | 11,7 |
| 41 | Gas/Oil | 105 | 250 | 17 | 0.0 | 7,28,40 |
| 42 | Gas/Oil | 105 | 250 | 17 | 0.0 | |
| 43 | Gas/Oil | 105 | 250 | 17 | 0.0 | |
| 31 | Oil | 420 | 540 | 140 | 50.0 | |
| Total | | 1425 | | | 162 | |

Recovery Boilers

| Boiler # | Fuel Type | Capacity metric ton/h | Temp C | Press. bar |
|---|---|---|---|---|
| 1 | Waste | 25 | 435 | 40 |
| 2 | Waste | 25 | 435 | 40 |
| 3 | Waste | 25 | 435 | 40 |
| 4 | Liquor/gas | 28 | 435 | 40 |
| 5 | Liquor/gas | 80 | 435 | 40 |
| 6 | Wood chips | 10 | 250 | 17 |
| Total | | 193 | | |

Note:

1--Combustion test was conducted on boiler #24 and #31.

2--The recovery boiler # 6 was not operating during the plant visit.

3--The recovery #5 , made by CE Canada, has mechanical problem with the superheater tubes.

4--The two black liquor recovery boilers are connected with boilers #11 and # 12 to supply steam to steam turbines.

Purchase electricity

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| RENEL: | 2 | Lei/kWh | at | 35 | lei/$ | = | $0.0571/kWh |
| Steam sale: | | | | | | | |
| Gas | 315 | lei/Gcal | at | 35 | lei/$ | = | $9.00/Gcal |
| Oil | 453 | lei/Gcal | at | 35 | lei/$ | = | $12.94/Gcal |

the fuel type for combustion are shown in *Table 2*. Because of the time constraint, the audit team only tested two of the boilers and briefly discussed the operation of the two black liquor recovery boilers.

## 2.3 Plant Water

The water for plant use is pumped from the Donaris river and treated in three stages of separation, decantation, and filtration. The average use is reported to be about 25,000 $m^3$/hr. The cost of the treatment and sewer charge is reported to be about 37 lei/$m^3$.

A survey of the final treatment station indicates the connected pumping load is excessive. This is due to manual operation; transporting and pumping water horizontally from station to station; and manually adjusting the discharge valves to meet the demand fluctuation. A quick count of the pumps operating during the survey shows the following:

- 6 pumps, each with connected load of 800 kW.
- 3 pumps, each with connected load of 1,250 kW. One operates and the other two are spare.
- 6 pumps, each with connected load of 630 kW.
- 10 pumps, each with connected load of 320 kW.

A total of 23 pumps were operating, with a connected power draw of about 13,030 kW. This load for pumping 25,000 $m^3$/hr plant water is excessive and should be evaluated for alternative pumping schemes and possible automation.

## 2.4 Black Liquor

The monthly black liquor production from pulp operation is given in *Table 1*. It is reported that the heating value is about 3,200 kcal/kg. The black liquor by-product rate is relatively flat with the exception of April, which may be due to reporting error.

## 2.5 Steam Generation

The monthly steam generation at various pressures and temperatures for all four steam plants and recovery boilers is shown in *Table 3*. The Central Craft plant, consisting of CET1, CET2, CET3, and CET4, generates steam for various process uses and steam turbine generators. This steam, and in some cases the extracted steam from turbines, is combined with the steam generated from the recovery boilers to meet the total plant utilization.

The reported data for steam generation is not complete. Because of this, data for missing months are estimated based on the available information and generation rate given for other months. Relevant assumptions are included in *Table 3* for clarifications.

No definitive trends or conclusions can be drawn from this data. This is due to the various assumptions made to complete the data. However, it appears that winter steam generation is about 30% higher than summer generation. This may be due to plant heating, or poor quality of pipe insulation, or a combination of both.

*Table 3. 1989 Steam Generation Profile*

| MONTH 1989 | CET1 Boilers | CET2 Boilers | CET3 | CET4 | CET Total | RECOVERY Boilers |
|---|---|---|---|---|---|---|
| --- | 11,12 | 21,22, 23,24 | 31 | 41,42,43 | All 10 Boilers | 1,2,3,4,5 |
| | *Tons | Tons | **Tons | ***Tons | Tons | #Tons |
| J | 48786 | 414076 | 177973 | 149392 | 790227 | 52704 |
| F | 58317 | 364505 | 181526 | 144075 | 748423 | 52704 |
| M | 44718 | 411577 | 119837 | 177096 | 753228 | 52704 |
| A | 40200 | 284881 | 82242 | 109001 | 516324 | 52704 |
| M | 46126 | 365265 | 8154 | 132794 | 552339 | 52704 |
| J | 43124 | 366886 | 7938 | 134199 | 552147 | 52704 |
| J | 43389 | 348890 | 8100 | 146789 | 547168 | 52704 |
| A | 47185 | 367775 | 4363 | 139742 | 559065 | 52704 |
| S | 43234 | 350021 | 10400 | 116912 | 520567 | 52704 |
| O | 41655 | 371928 | 36817 | 131716 | 582116 | 52704 |
| N | 36304 | 384282 | 161050 | 135606 | 717242 | 52704 |
| D | 34611 | 327450 | 84812 | 109729 | 556602 | 52704 |
| TOTAL | 527649 | 4357536 | 883213 | 1627051 | 7395449 | 632448 |

Tons in the above table refers to metric tons of steam generation.

* Data for boiler #7 is not available for seven months. This was estimated based on the data given for other 5 months.

** Data for boiler #31 is not available for 11 months. This was estimated based on fuel oil data.

*** Data for boiler #43 is also not available for 6 months. This also was estimated based on the data given for other six months.

\# No data was available for recovery boilers. This was estimated based on 80% load factor and 50% availability.

Also note the following:

1. Water consumption for the entire plant is reported to average about 25,000 $m^3$/hr. This value is used with no substantiation.

2. Water treatment and sewer charge is reported to be about 37 lei/$m^3$.

3. The average steam sales to the adjacent chemical plant is reported to average about 680 lei/Gcal.

## 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 audit team Leader. Discussions were held with the key plant management personnel, and potential energy efficiency improvements were identified for the subsequent energy audit. The following areas were identified:

- Combustion controls
- Paper machine steam control
- Steam and fuel metering
- Power factor correction
- Pipe insulation

The audit team spent one week in this facility gathering data and identifying potential energy efficiency measures that could be adopted. A general walk-through of the facility was made to identify energy efficiency opportunities.

Because of the size of the facility, it was decided to focus on the thermal and electrical systems. Meetings with the facility technical staff were held to discuss the thermal, electrical systems, and the associated controls. These meetings were scheduled with various groups during the five days of the plant audit. During these meetings, the short-term equipment requirements and many long-term energy management opportunities were identified.

A portable combustion analyzer was used to perform the combustion test on two randomly chosen boilers. Boiler #24, which is natural gas fired, and boiler #31, which is fired with #6 fuel oil, were chosen.

The electrical audit equipment could not be used because of high voltage applications.

### 3.2 Boiler Test Results

A total of nine combustion tests were performed on the two boilers (Boiler #24 and Boiler #31). The operating conditions and rated design data are shown in *Table 2*. The combustion air is forced from outside and is preheated with boiler exhaust gas. The preheater is installed at the discharge of the economizer to further reduce the stack temperature.

Two of the combustion tests were performed on the discharge of the boilers. The remaining tests were performed on the discharge of the economizer. The results of these tests are tabulated and shown in *Table 4*. Some of the tests were repeated by slightly closing the air damper or opening the fuel valve in order to reduce the excess air and improve combustion efficiency.

## *Table 4. Boiler Measurement Results*

Measurement results:
A-- Boiler
The combustion analyzer (Enerac 2000) was used to pull samples from two randomly chosen boilers at two locations in two consecutive days.
The boilers have air preheaters installed at the discharge of the economizer.
No correction was made for the higher combustion air temperature. The temperature probe of the combustion analyzer was defective, hence the effeciency data is inaccurate. Based on excess air (analyzer) and temperature reading from a digital thermometer, the calculated stack losses along with stack gas analysis are shown below.
Boiler #24 is a natural gas operated boiler, generates superheated steam at 140 bar and 540 C for a 25 MW steam turbine.
Boiler #31 is a fuel oil # 6 operated boiler, generates superheated steam at 140 bar and 540 C for a 50 MW steam turbine.

| Date | | Discharge of the boiler | | | | |
|---|---|---|---|---|---|---|
| 3/19/91 | | | | | | |
| Boiler # | Test # | Oxygen | Carbon Dioxide | Excess Air | Temp | Efficiency |
| -- | -- | % | % | % | C | % |
| #24 | 1 | 4.8 | 9.1 | 20.0 | 450.0 | 71.3 |
| #31 | 2 | 7.2 | 11.0 | 52.0 | 550.0 | 54.8 |

| Date | | Discharge of the economizer | | | | |
|---|---|---|---|---|---|---|
| 3/18/91 | | | | | | |
| Boiler # | Test # | Oxygen | Carbon Dioxide | Excess Air | Temp | Efficiency |
| -- | -- | % | % | % | C | % |
| #24 | 3 | 14.0 | 3.5 | 204.0 | 250.0 | 65.6 |
| #24 | 4 | 14.1 | 3.9 | 186.0 | 250.0 | 67.3 |
| Since excess air is higher than normal, the air damper was slightly closed and test was repeated. | | | | | | |
| #24 | 5 | 13.3 | 4.3 | 158.0 | 250.0 | 69.4 |
| #31 | 6 | 8.0 | 10.5 | 56.0 | 350.0 | 65.6 |
| #31 | 7 | 8.4 | 10.0 | 64.0 | 64.0 | 62.7 |
| 3/19/91 | | | | | | |
| #24 | 8 | 4.9 | 9.0 | 28.0 | 250.0 | 80.4 |
| #31 | 9 | 8.8 | 9.7 | 67.0 | 350.0 | 59.3 |

## 3.3 Summary of Test Results

A summary of the test results is as follows:

Data from boiler #31 (fuel oil #6) indicates this boiler was consistently operating with acceptable excess air range and combustion efficiency during both days of testing. The combustion efficiency data is an estimate based on temperature data obtained from the plant boiler control room.

The excess air for boiler #31 should be further reduced so that stack losses fall below 15%. Since the boiler is controlled manually, and since boiler output may fluctuate, this may not be possible. To experiment and optimize the boiler stack losses, an accurate and reliable combustion analyzer is needed.

Excess air was high for boiler #24 in the first day of data collection. An attempt was made to close the combustion air damper and some improvement was observed. However, data obtained in the second day appeared to be very good.

One may suggest various reasons for improved efficiency of the boiler #24 in the second day of testing; one being the improper linkage between fuel valve and air damper. This was quite evident since the air linkage was tied to a steel beam. Second, the improved efficiency may be due to the low fire, high combustion chamber negative pressure, and the consequence of high infiltration.

In summary, the boilers are well maintained, operators are well trained, and with the available combustion monitoring equipment the operation is reasonably efficient. Further fine tuning and efficiency improvements are possible with the proper combustion testing equipment.

## 4.0 Summary of Results

### 4.1 Short-Term Recommendations

As indicated earlier, the audit was coordinated with the plant technical staff and directors to exchange ideas and to provide technical assistance. The plant technical staff were found very capable and competent. Three low-cost/no-cost measures were identified which will demonstrate energy conservation opportunities. The projected cost of these measures is low, and the payback is within one year. Detailed calculations are shown in Appendix B and are summarized below:

Plant Steam Leaks

| | |
|---|---|
| Number of leaks | 25 |
| Equivalent leak diameter | 6 mm |
| Energy losses | 2761 Gcal/yr |
| Unit cost | 336 lei/Gcal |
| Cost savings | 0.93 million lei/yr |

The observations of the audit team indicate that 25 or more steam leaks can easily be located. The cost savings shown here is representative of achievable savings, and needs to be verified in the implementation phase.

Condensate Leak

| | |
|---|---|
| Number of leaks | 30 |
| Equivalent leak diameter | 2 mm |
| Condensate pressure | 6 bar |
| Energy losses | 1,616 Gcal/yr |
| Unit cost | 336 lei/yr |
| Cost savings | 0.54 million lei/yr |

The above numbers demonstrate the energy and cost impacts of allowing condensate to leak through the pump seals, valve packing, and pipe joints.

Steam Pipe Insulation

| | |
|---|---|
| Pipe diameter | 400 mm |
| Saturated steam pressure | 17 bar |
| Pipe exterior temperature | 200 °C |
| Calculated energy losses | 3,516 kcal/hr/m |
| Insulation thickness | 50 mm |
| Calculated energy losses | 144 kcal/hr/m |
| Reduction in heat losses | 3,372 kcal/hr/m |
| Assume pipe length | 100 m |
| Assume operating hours | 8,600 hr/yr |
| Annual energy savings | 3.87 billion kcal or 3,870 Gcal |
| Unit fuel cost | 336 lei/Gcal |
| Annual cost reduction | 1.30 million lei/yr |

Much of the existing insulation on large diameter steam pipelines is damaged or removed for repair work. These exposed pipelines need to be re-insulated. The total pipe length, diameter, and surface temperature are not known accurately enough to determine the total energy loss. The calculations presented here and in Appendix B are intended to demonstrate the cost penalty.

## 4.2 Long-Term Recommendations

No analysis was done regarding long-term energy related issues due to time constraints. The following recommendations are based on prior experience, applicability of electronic controls for faster response, and the operating methodologies discussed with the plant technical staff.

A. Electronic Air/Fuel Mixing - Currently all 16 boilers are operating with mechanical air/fuel mixing with manual indicators. Newer electronic mixing technology provides for better mixing and accurate proportioning, which consequently results in a higher combustion efficiency. The facility needs to implement new controls gradually during scheduled maintenance shutdown.

B. Electronic Boiler Control System - All 16 boilers are equipped with manual air/fuel ratio and poor linkage to steam flow or pressure. Manual adjustment and human judgement contributes to poor boiler efficiency, unscheduled boiler blowoffs, and steam pressure/flow fluctuations. Linking the air/fuel ratio to an oxygen trim (stack oxygen analyzer) controller and setting the steam flow or pressure to lead via an electronic four element control package is recommended. This packaged control system would eliminate the operators' guess work and prevent unnecessary energy losses.

C. Steam Drum Level Control - The steam drum level controller needs to be upgraded and replaced with conductivity sensors. The present differential pressure cell arrangement does not respond as well as the conductivity probe.

D. Boiler Blowdown Control - The boiler blowdown control also needs to be upgraded and replaced with conductivity probes for maintaining the specified and recommended solid concentration in the boiler.

E. Combustion Blower Analysis for Boiler #31 - The forced and induced combustion blowers (800 kW and 500 kW motors, respectively) appear to be too large for boiler #31. This may be due to a smaller duct size in the economizer and air preheater sections requiring a higher static pressure. This requires static pressure measurement and analysis for determining the cause for the higher power requirement.

F. Superheated Temperature Control - Superheated temperature control is done manually by pumping the deaerator water directly into superheated steam. This method of superheater temperature control is commonly called "attemperator". Great difficulties were reported in maintaining the desired temperature due to: manual valve setting; inaccurate/slow response control; constant change in air/fuel ratio causing changes in superheated temperature; and large thermal inertia and the lack of predictive feedback control. Because of space limitations, attempts should be made to modify the existing attemperator to function properly. This can be done by fixing the air/fuel ratio and operating the boiler at as constant a load as possible. One should make sure the spray nozzles have a pressure difference of 2.5 to 3.0 bar for fogging and water dispersion into steam prior to the temperature control station.

G. Improved Systems for Efficient Operation Below Design Capacity - Steam pipelines, process equipment, thermal systems, and electrical equipment are designed for 100% capacity. The thermal and electrical energy losses account for 10% to 15% of the design output. At the present time, the plant is operating at about 50% capacity. Since much of the equipment is not modularized, the system losses are 20% to 30%, which is the outside range of the manufacturing norm. Attempts should be made to integrate some of the equipment operation and shut down or unload other energy intensive equipment.

H. Scheduling and Communications - Observations indicate a significant amount of thermal and electrical energy being lost by a lack of production scheduling (especially at 50% capacity) and slow communications between the pulp and paper plants and the Central Craft power station. Observations also indicated a constant steam blow off boiler drums, dearators, and relief valves. The use of two way radios and pagers needs to be investigated. Production scheduling between two manufacturing plants and the power generating station needs to be coordinated. This, along with some control and equipment operation integration, may result in a 20% to 25% savings in thermal energy and a 10% to 15% savings in electrical energy.

I. Water Supply System - The water supply, treatment, and purification systems uses excessive power to deliver water from the Donaris river to the plant. This is mainly due to water being transported horizontally with no vertical storage and head. When demand decreases, the operator closes the discharge valve. This method of water supply system results in poor pump performance and costly operation. It is recommended that the application of water tower and automatic level control be investigated.

### 4.3 Replication Potential

All Romanian-made water tube boilers are manually controlled. The potential application for boiler, combustion, and boiler feed water treatment technology/equipment, as well as oxygen trim analyzer control interlock is excellent. The usefulness of this control-related equipment needs to be demonstrated for reliable operation and control in several selected sites.

Many pieces of equipment are old, poorly designed, and incompatible with the harsh process environment and high temperature. The constant equipment failures are affecting plant output. The application of pneumatic or electrically actuated valves, with alloy seat for the high temperature and corrosive environment in the pulp digester plant, needs to be demonstrated. Magnetic or ordinary pumps for pumping black liquor have excellent application for demonstration, and potential for application throughout the Romania paper and pulp industry.

### 4.4 Pricing Policy Issues

The company appears to have a reasonably good electrical generating contract with RENEL, such that the surplus electricity production is automatically transferred to the RENEL power grid. However, the cost differential between buying electricity from RENEL and selling it back is high. The electrical and thermal transaction between RENEL and the adjacent chemical company is reported as:

| | |
|---|---|
| Purchased Electricity from RENEL | 2.0 lei/kWh |
| Sold to RENEL Grid | 0.9 lei/kWh |
| Sold to Adjacent Chemical Plant | 1.50 lei/kWh |
| Cost to Generate | 0.6 lei/kWh |
| | |
| Steam Sold to Adjacent Chemical Plant | 680 lei/Gcal |
| Composite Steam Cost from Billing History | 706.8 lei/Gcal |

## 4.5 Energy Conservation Equipment for Immediate Installation

A review of the facility monitoring, metering, and energy conservation equipment indicates a need for the following monitoring, metering and control systems. The detailed specifications for this equipment are given in Appendix A. Listed below are estimated costs, and projected savings for the recommended equipment.

Combustion and Thermal Related Equipment

| | |
|---|---|
| Portable combustion analyzer (Enerac 2000)<br>Estimated cost | $5,300 |
| Oxygen trim control with 4-20 mA output for boiler #31<br>Estimated cost | $3,900 |
| Infrared temperature sensor<br>Estimated cost | $2,200 |
| Hand held digital thermometer<br>Estimated cost | $700 |
| Total Estimated Cost | $12,100 |

The equipment will be used to monitor the oxygen level in boiler #31 and provide stack gas analysis tools for all 16 boilers. With this equipment, it should be possible to reduce the stack losses in boiler #31 by at least 2% and #24 by at least 4%, assuming the following:

| | |
|---|---|
| Boiler # 31 Capacity | 420 metric tons/hr |
| Load Factor | 80% |
| Efficiency Improvement | 2% |
| Operating Hours | 6000 hr/yr |

Other operating parameters are assumed to be as shown in *Table 2*.

Calculations show over 11,000,000 lei/yr cost reduction, which at 35 lei/$, corresponds to less than a one month payback.

## Performance Monitoring Equipment

| | |
|---|---|
| Steam flow meter compensator for Boiler #31<br>Estimated cost | $1,500 |
| Steam turbine generator power analyzer for Boiler #31<br>Estimated | $5,200 |
| Portable power analyzer for end-use metering<br>Estimated cost | $3,300 |
| PC computer software to be used with portable analyzer<br>Estimated cost | $3,000 |
| Portable ultrasonic flow meter to be used with analyzer<br>Estimated cost | $7,700 |
| Total Cost for Performance Monitoring Equipment | $20,700 |

The recommended equipment will provide a tool for determining the performance of the 50 MW steam turbine (connected to boiler #31), and to monitor the concurrent kW draw and water flow rate of the 13 MW water supply system. Fifty percent of the equipment will be used to determine the performance (kcal/kWh) of the 50 MW steam turbine generator. It is expected that when accurate performance data becomes available, and when this performance is compared with efficient turbine generators, attempts will be made to correct the inefficiency. If one assumes a 0.5% improvement, this corresponds to over 3,000,000 lei/yr savings, which results in about 3 months payback.

The remaining electrical equipment is for end-use metering of not only water supply pumps but also other low voltage electrical equipment. The portable analyzer and the associated equipment were not used during the audit, but it is expected that they will be used to identify electrical equipment which is performing inefficiently.

Process Related Equipment (digester level control)
Estimated cost $1,000

The purpose of the digester level control is to demonstrate Programmable Logic Control (PLC) capability to control the temperature of the digester as a function of digesting time. At present, a significant amount of live steam is lost due to condensate tank level malfunctioning. By establishing a temperature profile of the digester and with PLC control, no steam will be entering the condensate tank. If this system functions as described here, the payback is estimated to be less than one month.

## 5.0 Plant Management/Organization

### 5.1 Description of Plant Organization

The plant organizational chart is illustrated in Appendix C, which shows the entire management organization in detail. The technical, economic, business, and marketing directors report to the company chief officer. Production, utilities, and maintenance managers report directly to the technical directors, who participate in the overall company decision making process. During the site survey, the audit team had daily meetings with the technical director to outline the schedule and arrange meetings and discussions with utility managers. The utility managers would seek support from the production, maintenance, thermal, electrical, or instrumentation personnel to present and discuss various energy, control, and process equipment issues and concerns.

During the site audit, it was found that the managers making decisions for energy related issues were very receptive to ideas, willing to undertake responsibilities, and internally cohesive. It appears the managers realize technological shortcomings of the equipment available in Romania and have a good knowledge and understanding of the equipment available abroad.

Various feasibility studies are needed to demonstrate the economic advantages of the new systems and controls versus the existing equipment and methodologies. If the studies prove further investment to be economically attractive, it is felt that the plant management will proceed with implementation.

### 5.2 Recommendations

It appears the organizational structure is well situated for executing programs found to be beneficial to the company. However, identifying energy conservation concepts, analyzing the trade-offs, and demonstrating the investment rate of return is found to be beyond the capability of the present management. Therefore, we recommend that a corporate level energy management department be established. The corporate energy management department head should report to the technical director and directly interact with production, utilities, and maintenance managers. The corporate energy management staff should include personnel experienced in energy, fuel, and combustion processes, and have an academic background in thermodynamics, fluid flow, heat and mass transfer, and energy engineering.

## 6.0 Implementation Phase

The implementation phase of the audit involved a return trip to the facility from July 29 to August 2 of 1991. During this phase the main objective was to facilitate the installation and use of the equipment that was purchased for the facility based on the previously discussed recommendations. The distribution of the equipment to the site was performed by the Romanian Ministry of Industry. A representative from the Ministry was also involved during the activities of this phase. The key elements of this phase were:

1. Distribution of portable measuring instrumentation;
2. Training for plant staff;
3. Installation of fixed energy efficiency equipment;
4. Review of the draft audit report with plant staff;
5. Monitoring of equipment performance;
6. Discussion of past and future energy conservation efforts; and
7. Development of a specific plan for equipment utilization.

A draft of the audit report containing sections 1.0 through 5.0 was provided to the Ministry and plant staff for their review prior to the site visit.

### 6.1 Summary

Most of the portable equipment was received and distributed by the Ministry before the end of the implementation phase. The ultrasonic flowmeter and the portable combustion analyzer were not available during the site visit. Ministry representatives at the site were Mr. Cristea and Mr. Stan. The primary plant contact was Mr. Valeriu Diaconescu, Chief of Automation. Training on the available equipment was completed for plant staff that would use the equipment. Demonstrations of the power analyzing equipment included the "down loading" of power data collected to the EPSON PC. Software on the computer was demonstrated, including techniques on developing audit reports and project justification.

Two permanently installed pieces of equipment for the plant were an oxygen sensor, transmitter, and analyzers for one of the boilers, and the compensating processor for steam flow measurements. These items were scheduled to be installed at the facility, but had not arrived prior to the site visit. INSTAPART, a private engineering firm, is responsible for ensuring proper installation and commissioning of the equipment. During part of the site visit, INSTAPART participated in determining the most appropriate location for the oxygen sensor and the compensating processor. Other installation factors were discussed to minimize complications during installation. Mr. Mihai Georgescu of INSTAPART was also

trained on the proper use and application of the ultrasonic flowmeter at the GRIRO and South Power Plant facili' ' ;o that he can assist with the use of the flowmeter.

The draft audit report was reviewed with Mr. Diaconescu. He felt in general that the report was useful and that it provided a service in summarizing their primary energy concerns. He did not find any inaccuracies in the report. The plant is planning to take the recommended steps to improve their energy efficiency. The equipment implementation plan, developed by Mr. Diaconescu, outlines the method and frequency with which the equipment will be used to reduce energy use.

## 6.2 In-Country Review of Draft Audit Report

The draft audit was reviewed with Mr. Diaconescu. He could not identify any inaccuracies in the energy profile figures or the energy savings calculations. He felt that the report was accurate in its emphasis on determining energy use and increasing energy efficiency. He said the biggest problem is securing capital to meet these needs. For example, large energy losses result from inadequate insulation on the steam piping system. The lack of adequate insulation and a lack of funds available to purchase more insulation are barriers to project completion. This is a perfect example of how energy is wasted because money is only available for projects that are essential to keep the plant functioning.

The most useful part of the audit report was the estimate of energy losses and information on automatic controls. While Mr. Diaconescu agreed with most of the recommendations, he felt that, due to the "transition period" between government ownership and privatization, some of the recommendations will not be realized until the future. However, they will continue to work toward implementation of many of the recommendations.

Mr. Diaconescu was interested in obtaining more information on U.S. combustion control equipment, including information on manufacturers and on how the controls work. He was also interested in a more detailed description of the recommendation regarding linking the air-fuel ratio to oxygen levels and steam pressure. Literature was provided from U.S. sources and manufacturers which addressed many of these questions.

## 6.3 Energy Efficiency Measures Adopted by the Facility

The plant is presently changing to an automatic system to control superheated steam temperature in boiler #22. The Romanian-made control system uses a processor that utilizes the instantaneous steam temperature and the rate of change of temperature to determine the proper amount of water to inject into the steam. This control can reduce energy use by minimizing the amount of "attemperating" water sprayed into the steam, thereby maintaining the highest level of superheat appropriate.

A new natural gas distribution system has been installed to facilitate accurate and automated monitoring of gas consumption. The orifice plate flow meters that will be installed on various branches of the piping system will eventually tie into a central

monitoring and control system. This will be very helpful in developing energy balances on the gas burning systems. They are also planning to monitor electric use for different areas of the plant.

The audit report recommended investigation of the benefits of purchasing two way radios and pagers. This would increase communication between areas in the plant and reduce the energy lost due to varying production schedules. In the past, Romanian-made radios were used, but these did not work as well as expected. Mr. Diaconescu indicated they intend to buy some pagers and are interested in more information on available models.

The recommendation regarding the water pumping system was viewed to be appropriate. A feasibility study is required to determine new technologies available for lowering the cost of water treatment and pumping requirements, which may include a water tower. The feasibility study should also investigate the control of water flow in this proposed system through valves or variable speed drive equipment, and determine the best pump and motor for maximizing efficiency. A similar feasibility study should be performed for the digester. The feasibility studies would likely need to be done by an outside consulting firm, since the plant staff does not have access to the new technologies.

### 6.4 Management Results

No significant changes in the management structure were made since the initial audit. In the draft audit report, it was suggested that a corporate-level energy management department be established. Because the company is still in the transition to privatization, changes in the management structure to facilitate the adoption of projects based on maximizing energy efficiency and minimizing payback have not yet been made.

At present, Mr. Diaconescu and Mr. Luciun Giurgiu are responsible for identifying and justifying energy conservation measures. For larger and more complex projects, higher level management determines the appropriate action to be taken. For large projects, the payback may be in the five to ten year range.

### 6.5 Implementation Plan

At the initial meeting of the implementation phase, we requested that the staff develop a utilization plan for the equipment provided as part of the project. During equipment training, we discussed how the instruments might best be utilized. The staff developed the following plan:

1. Hand-held Digital Thermometer
   - Estimate insulation efficiency at accessible locations (tanks, pipes).
   - Check closing of steam, hot water and hot liquid valves.
   - Check against Romanian instruments already in place.

   The apparatus will be used daily.

2. Digital Heat Spy

- Determine temperature of pipes, etc., that are not accessible.
- Measure temperature inside recovery boiler.
- Assist in heat loss study on piping network.
- Quick estimate of fluid temperature inside pipe.

The apparatus will be used weekly or as required.

3. AC Power Analyzer

- Compare actual motor performance against performance specifications; determine if phases are balanced.
- Analyze performance of distribution station for a group of equipment and address power factor correction problems.
- Monitor air dryers for instruments and compressors to compare against other types and determine the need for replacement.
- Analyze pump efficiency using AC power analyzer and controlotron flow meter.
- Monitor fans for boiler forced draft system.

The power analyzer will be used continuously.

4. Portable Combustion Analyzer (Enerac)

- Check combustion of boilers at least once per week and take corrective action as necessary.
- Develop database of boiler performance at various loads.

5. Ultrasonic Flowmeter (Controlotron)

- Monitor pump flow to determine pump efficiency.
- Check other flow meters.

6. Computer (Epson 386)

- Assist in analysis of motor performance testing, pump efficiency analysis, fan performance analysis, and database development for boiler combustion tests.
- Create own application software such as database for pressure losses and heat losses in piping network.

All instrumentation will be kept in the office of the Chief of Automation. The automation section has personnel in every major area of the plant.

Photographs of some of the equipment are in Appendix D.

## 6.6 Expected Energy Savings

The expected energy savings are based on earlier estimates of energy savings and the equipment utilization plan listed above. The use of the combustion analyzer is expected to increase boiler efficiency by 5% to 8%; the oxygen sensor should increase the boiler efficiency by about 8%; and the compensating processor for steam flow is expected to reduce steam use by 3%. Since the power analyzer, ultrasonic flow meter, and the PC computer will be used on many projects, it is impossible to quantify their effect on plant efficiency.

# APPENDIX A
## Energy Conservation Equipment Specifications

Short-Term Recommendations

1. COMBUSTION ANALYZER ($5,300)

- Portable Analyzer
- RS-232 Port/Phone compatible
- 220 Volt/50 Hz
- $SO_2$ sensor

The combustion analysis indicated that the efficiency of the boilers could be significantly increased. Our estimate is that boiler efficiency can be increased 5 to 8 percent by using a combustion analyzer to determine the actual excess air during operation. For example, boiler #24 used 97.8 million cubic meters of gas in 1989. If efficiency of this boiler was increased by 5% the savings would be 4.9 million $m^3$ or (at 2.8 lei/$m^3$) 13.7 million lei per year.

2. OXYGEN SENSOR AND TRANSMITTER ($3,900)

- Fixed Sensor
- 4-20 mA signal

The first step in automatic control of combustion air or automatic oxygen trim is to measure and transmit accurate oxygen concentration in the stack gas. We propose that an oxygen sensor be installed in the stack of boiler #31 and integrated with a 4 to 20 mA signal. This signal will be transmitted to the computerized monitoring system which is being installed on boiler #31. This would provide the largest boiler with continuous stack gas readings for oxygen and allow more informed and accurate control of this boiler. In addition, it would provide a significant step toward using their new computer system to automatically control excess air.

At 70% load, the estimated consumption of oil for boiler #31 is 39,000 kg/hr. At 4,000 hours per year of operation in this condition, the total consumption of oil would be 156,000 metric tons of oil. The average monthly consumption from boiler #31 is 9,230 metric tons/month, which would correspond to 111,000 metric tons/year. The savings from a continuous oxygen sensor reading is estimated at 8%. This would be an estimated savings of 8,900 metric tons of oil or 42 million lei per year.

3. INFRARED TEMPERATURE SENSOR ($2,200)

- Hand held Digital Temperature Sensor
- Temperature range: 0 to 1000 °C

There were many pipes observed that would benefit from increased insulation. The best instrument to use for quick and accurate determination of surface temperatures of pipes and other vessels is an infrared temperature sensing "gun". From the additional information on temperatures that this sensor will provide, it will be very easy for the plant personnel to make the calculations to determine the economic justification of adding insulation.

4. HAND HELD DIGITAL THERMOMETER ($700)

- Digital Thermometer
- Surface Probe
- Immersion Probe
- Gas Probe

The digital thermometer should provide capability for measuring surface and fluid temperatures to 1000 °C. This instrument will allow determination of existing sensor accuracy as well as temperature information for improved control and justification for process changes.

5. COMPENSATING PROCESSOR FOR STEAM FLOW ($1,500)

- Flow Computer
- Pressure: 110 to 140 atmospheres
- Temperature: 520 to 540 °C
- Max. Flow: 420 metric tons/hr

The present measurement of steam flow from the boiler to the turbine is not compensated for varying pressures and temperatures. Therefore, an accurate steam flow cannot be measured. A processor, such as a "Masstrol", would compensate flow readings from their orifice plate flow measuring device with regards to different pressures and temperatures. This would allow the balance of energy related to the boiler to be accurately measured and the overall efficiency quantified. With this knowledge, the steam production efficiency could be increased by an estimated.

The associated energy cost savings attributed to the information available from the infrared temperature sensor, the hand held digital thermometer, and the compensating processor for steam flow could easily save 3% of their steam use. The annual steam production is 6.6 million metric tons. A three percent savings would mean 198,000 metric tons of steam saved, or about 78 million lei in reduced fuel costs.

6. POWER ANALYZER ($5,200)

- Max. Power: 50 MW
- Max. Voltage: 12 kV
- Nominal Current: 4129 amps
- 50 Hz $\pm$ 5%
- Power Factor Measurement
- Stationary

The power analysis equipment that they use is not as accurate as presently available equipment. In addition, the equipment that is used is not capable of storing data. This data history is an important aspect in determining inefficiency and maintenance requirements. Savings from a power analyzer for measuring volts, amps, and reactive power would be about 2% to 4%. We propose that one such meter be installed on their 50 MW power

generator. The annual production of electricity from this system will be about 288,000 MW. An annual savings of 2% would mean a savings of 5,760 MWh or a savings of 11 million lei.

7. PORTABLE ULTRASONIC FLOW METER ($7,700)

- Primarily for Water Flow Measurements
- Max. Flow: 32,000 cubic meters/hour

This meter will primarily be used to perform a feasibility study analysis on the pumping system that is presently used in water treatment and distribution system.

8. PORTABLE POWER ANALYZER ($3,300)

- Max. Voltage: 600 volts
- Max. Current: 1000 amps
- Memory (one week, with 15 min. readings)
- Measure: volts, amps, VArs, power factor, power
- Ability to download to PC/spreadsheet
- Hard copy printout

This power analyzer will be used to measure loads on electric end-use equipment and address power factor problems. One of the main projects will be with the water distribution pumping system.

9. PORTABLE PC COMPUTER WITH PRINTER ($3,000)

- Laptop 386 computer
- Lotus Software
- Letter quality printer

The main use of the portable PC will be to download data from the power analyzer and the combustion analyzer to facilitate analysis. Software will be available to manipulate the data to perform technical and economic justification for energy conservation projects.

# APPENDIX B
## Energy Conservation Calculations

Energy Conservation Calculations: STEAM PIPE INSULATION

Large number of steam pipes are transporting steam from Central Kraft center to Paper/Pulp plants. The insulation on some of the steam pipes either are damaged or removed for repair.

A sample calculation is shown below to demonstrate the savings associated with insulating the lareg diameter (400 mm) pipes which are transporting steam over 500 meter distance.

Following is given :

| | | | |
|---|---|---|---|
| Pipe diameter | = | 400 | mm |
| Saturated steam pressure | = | 17 | bar |
| Pipe exterior Temperature | = | 200 | C |
| Average outdoor temp. | = | 20 | C |
| Heat transfer coefficient | = | 18 | W/m2 K |
| Calculations show heat losses to be | = | 3516 | Kcal/hr m |

Now assume the following:

| | | | |
|---|---|---|---|
| Insulation thickness | = | 50 | mm |
| Insulation thermal conductivity | = | 0.036 | W/m K |
| Heat transfer coefficient | = | 0.6 | W/m2 K |
| Calculations show heat losses to be | = | 144 | Kcal/hr m |
| Net heat loss reduction (savings) | | 3372 | Kcal/hr m |
| Operating hours | = | 8600 | hr/yr |
| Annual saving | = | 2.90E+07 | Kcal/yr m |
| Assume 100 meter of the bare pipes | = | 100 | m |
| Boiler efficiency | = | 75 | % |
| Annual savings | = | 3.867E+09 | Kcal/yr |
| Composite fuel cost | = | 336 | lei/Gcal |
| Annual cost saving | = | 1.30E+06 | lei/yr |

Note:
Past experience shows the payback falls within one year.

Energy Conservation Calculations: STEAM LEAK

The plant has large number steam leaks. These leaks are through the pipe joints, traps, blow-off joints, and leaky shut off valves.
In order to show the significance and economic impact of these leaks, below are the assumptions and corresponding evaluations:

Assume the following:

| | | | |
|---|---|---|---|
| No. of leaks | = | 25 | -- |
| Equivalent leak diameter | = | 6 | mm |
| Saturated steam pressure | = | 10 | bar |
| Average velocity of the leak | = | 34 | m/s |
| Saturated steam density | = | 5.7 | kg/m2 |
| Steam flow leakage rate | = | 0.5 | metric ton/hr |
| Enthalpy of saturated steam | = | 664.1 | Kcal/kg |
| Enthalpy of the city water | = | 12.8 | Kcal/kg |
| Annual rate energy loss | = | 2761 | Gcal/yr |
| Average cost | = | 336 | lei/Gcal |
| Annual cost | = | 927696 | lei/yr |

At this time the number of leaks and the size of the leaks are not known. One can easily find 25 steam leaks.

Energy Conservation Calculations: CONDENSATE LEAK

The Plant has a large number of condensate leaks. Thses leaks are through valves packing, pumps seal, corroded pipes, leaky valves, & etc.

One can easily find more than 30 leaks.

Assume the following:

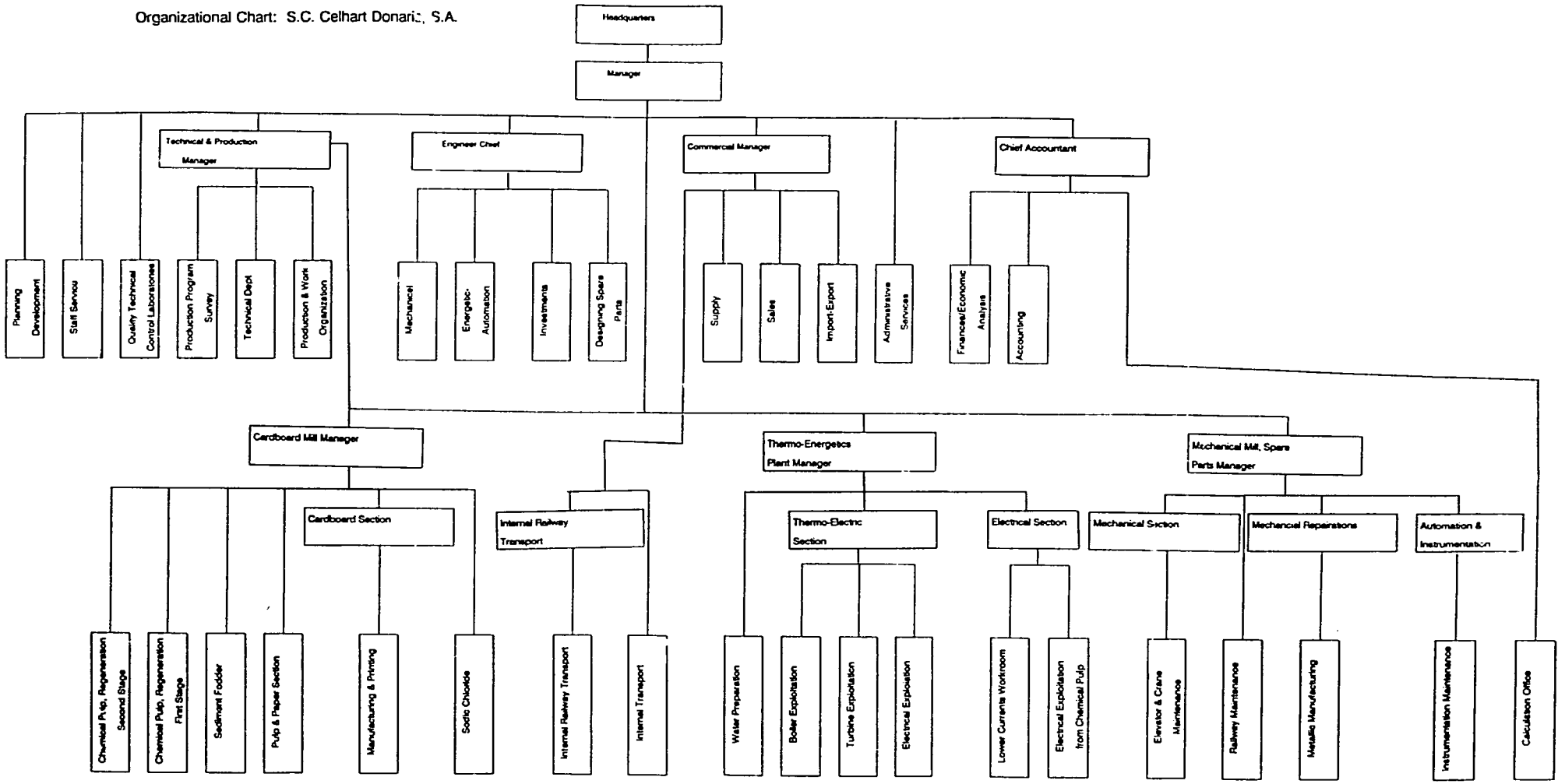
| | | | |
|---|---|---|---|
| No. of leaks | = | 30 | -- |
| Equivalent leak diameter | = | 2 | mm |
| Saturated H2O pressure | = | 6 | bar |
| Average velocity of the leak | = | 4 | m/s |
| Water density | = | 902 | kg/m3 |
| Water flow leakage rate | = | 1.2 | metric ton/hr |
| Enthalpy of the hot water | = | 166.4 | Kcal/kg |
| Enthalpy of the city water | = | 12.8 | Kcal/kg |
| Annual rate energy loss | = | 1616 | Gcal/yr |
| Average cost | = | 336 | lei/Gcal |
| Annual cost | = | 542976 | lei/yr |

Note: The cost does not include cost of pumping , water treatment, and sewer charge.

Note also , this is a demonstration of how a 2 mm water leak and 30 leaks can be very costly. Experience shows attractive payback for repairing condensate leaks.

# APPENDIX C
## Organizational Chart

Organizational Chart: S.C. Celhart Donaric, S.A.



# APPENDIX D
## Photographs

1. With the power analyzer Mr. Diaconescu and other facility personnel measure the actual load on a 200 kW water pump.

2. Mr. Diaconescu uses a power analyzer to monitor water pump.

# APPENDIX E
## 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 |
| MCal | = megacalorie = 1 million calories |
| 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 |