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# ENERGY EFFICIENCY AUDIT REPORT

## PRAGOLAKTOS DAIRY PLANT
Prague, Czechoslovakia

JANUARY 1992


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

and

ENERGOPROJEKT
Prague, Czechoslovakia



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

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

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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

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## i. Executive Summary

The countries of Eastern Europe face unprecedented changes in both 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 of the program in Czechoslovakia. RMA was provided valuable assistance by two in-country subcontractors: 1) Stredisko pro Efektivni Vyuzivani Energie (SEVEn), in the plant selection and in-country logistics; and 2) Energoprojekt in the audit and equipment installation work.

Czechoslovakia faces severe energy problems including uncertain oil supplies, pollution from coal, and questions about the future of nuclear energy. The Czechoslovakian industrial sector has experienced large increases in energy prices, the latest in January, 1991. At the same time, the country embarked upon a fundamental economic structural reform. The US Agency for International Development established the Industrial Energy Efficiency Program to help mitigate the impacts of increased energy costs on the industrial sector by providing technical support through energy audits and economic support through purchase and installation of energy conservation equipment in selected representative industrial plants.

Results of the Pragolaktos energy audit show that there are many short-term, low-cost, and no-cost energy conservation opportunities (ECOs). The major opportunities are in improving maintenance, repairing existing equipment and improving control equipment. It is estimated that twenty percent of the present 233,000 gigajoules (GJ) of combined steam and electric energy consumption for this plant could be saved by such measures. The recommended measures for thermostatic heating control valves and computer controlled heating supply water temperatures implementation, with USAID funding, will reduce energy consumption by about 7,000 GJ or about three percent of present consumption. The recommended measures have wide applicability and should be replicable at many sites within Czechoslovakia.

Based on the results of the plant energy audit, specifications were prepared for installation of thermostatically controlled space heating, control of heating water temperatures, provisions for scheduling of temperatures in office and residential areas, and for replacement of flow control valves in cooling tower, condenser water and ice-water pumping circuits. A local equipment supplier, under supervision of Energoprojekt, was selected to install the energy efficiency improvements and provide training to plant staff. The installation was completed in September 1991.

## ii. Description of Energy Efficiency Program

Czechoslovakia's industrial sector is well developed and contains many large and heavy industries. However, there are many medium size industries within the country that consume a large percentage of the industrial energy used. Many of these industries are made up of multiple companies and plants within the country, making them ideal targets for industrial energy audit work because of high potential replication. Many of these medium-size plants are quite viable, but have not yet implemented energy conservation activities.

Increases in energy prices to equivalent world prices have put additional pressures on industrial firms to conserve energy. Changes within the economic system (increasing energy prices, privatization, etc.) will necessitate increased energy efficiency and reduced energy intensity of production. The Industrial Energy Efficiency Program will train Czech managers and engineers in energy efficiency measures and practices, as well as in energy management. This training will demonstrate the benefits of energy conservation and illustrate the advantages of making all employees aware of energy waste.

The Industrial Energy Efficiency Program is based on four distinct tasks:

1. Industrial plant screening
2. Industrial plant energy audit
3. Policy analysis
4. Implementation.

Fifteen industrial plants were screened and eight were selected to be audited. Criteria used in this selection included:

- opportunity for energy savings (with a focus on oil savings)
- potential replicability of energy saving options in similar plants or systems
- future viability of the plant in the changing economy
- size of the plant
- other activities such as joint ventures or other bi-lateral aid projects.

The energy audit activity, described in detail in this report, determined the overall energy efficiency of the plant, which was used to identify no/low-cost equipment opportunities with short-term payback. An assessment was made of the technical and management capabilities and capital investment decision-making processes regarding energy conservation applications. Preparation of equipment specifications and other documents required for procurement of U.S. equipment or materials completed the audit.

In the implementation phase, equipment specified in the energy audit was procured, cleared through customs, and delivered to the plant. Also, requirements for installation of the material were identified. Where possible, this was done by plant personnel, or alternatively, by CSFR contractors. Following installation, the effectiveness of the energy conservation application was evaluated.

## 1.0 Plant Description

Name: Pragolaktos Dairy plant
Address: Ceskobrodska 1174, 198 00 Prague 9
Contacts: Mr. Karel Majer, Director of Technology
Phone: 71 81 51
FAX: 83 87 05
Product: 88 million liters milk, 18 million liters ice cream and 7.5 million liters of yogurt annually.
Plant size: 513 employees, 10 buildings, more than 33,000 square meters.
Date of Plant Commissioning: 1981

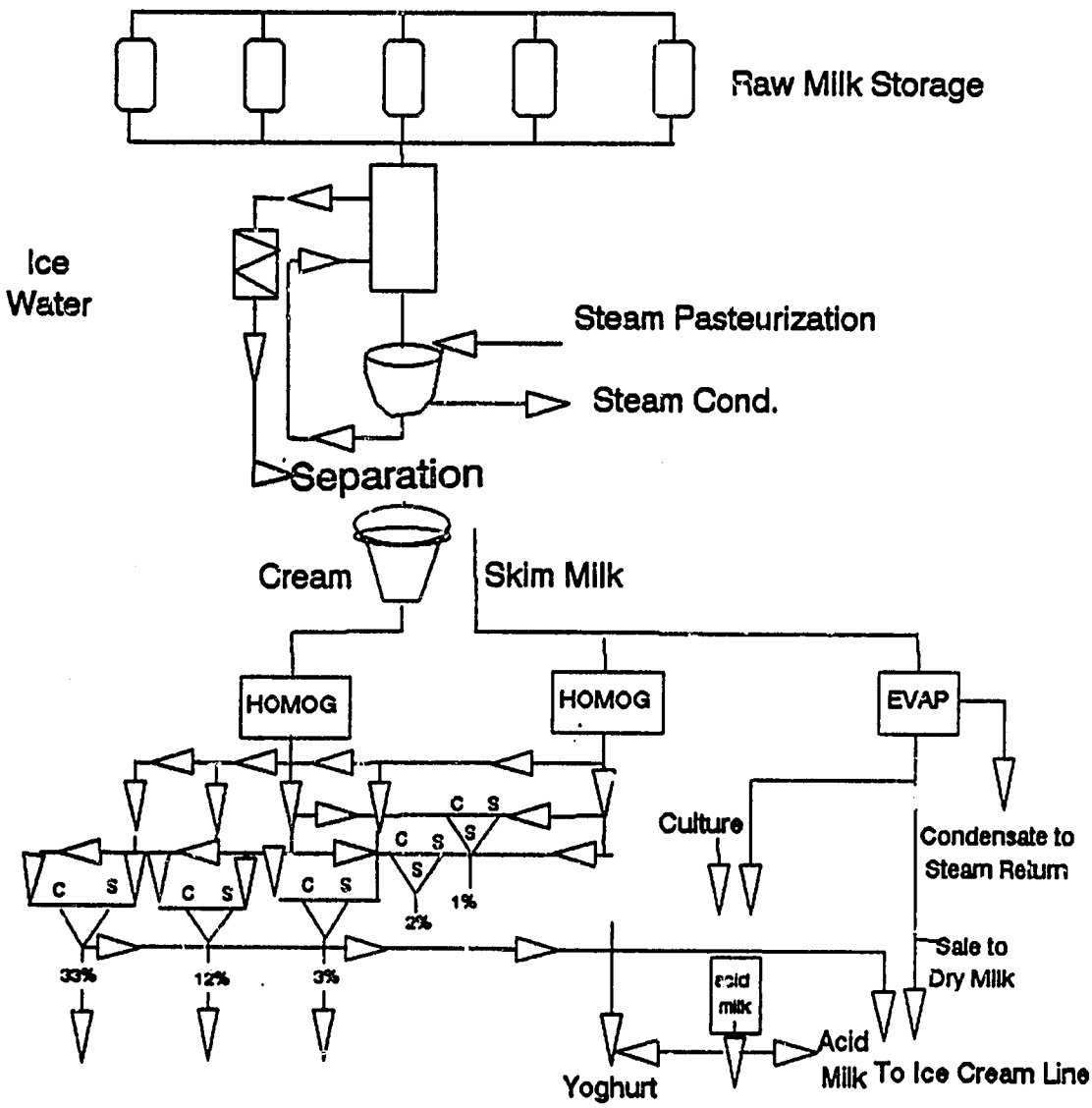
Electric Energy: demand: 2,500 kW,
consumption: 12,000,000 kWh
self generation capacity: none
refrigeration load: 4.3 MCal installed

Steam Requirements: method of supply: District steam system
average demand: 10 metric tons/hour temp. 180 °C
pressure: 1.0 Mpa
annual use: 190,000 GJ

Process Description:

Raw milk is received by tanker trucks from various dairy farms. Milk is refrigerated to 5 °C at the farm, but the tankers are uninsulated and milk must be cooled again. Cold raw milk is stored in refrigerated tanks before entering the processing line. The first process step, *Figure 1*, is pasteurization where the milk is heated to 90 °C. The pasteurized milk is then cooled, first in a heat exchanger by the cold milk entering the pasteurizer, then by ice water. The milk then enters a centrifugal separator where most of the butter fat is removed. The two separator exit streams are cream with a fat content greater than 35%, and skim milk which is less than 1 percent fat. Both flow streams, cream and skim milk, then enter homogenizers which break up fat particles to sizes that will no longer separate. The two streams then enter one of three standardization stations where cream (fat) is added to the skim milk to create one of three standardized milks: whole milk with 3 percent fat, 2 percent, and 1 percent milks. Each of these products are again homogenized before packaging for shipment. Some skim milk is used with the remaining cream to produce two grades of cream, 33 percent fat and 12 percent fat. The remaining skim milk goes to a two stage vacuum evaporator where the water content is reduced. Some skim milk is cultured to produce acidified milk and various yogurts, with cream added. Evaporated milk and the remaining cream is sent to the ice cream plant, with the exception of a minor amount of both, which is sold to other dairies.

*Figure 1. Milk Process*



## 2.0 Plant Energy Profile

Plant energy usage for 1990 is presented in *Table 1*. Costs in *Table 1* are based on costs as of March 1, 1991. Production is down 35% in the first quarter of 1991 due to economic effects of Czechoslovakia's transition to a free market economy and use in 1991 will likely be down also. *Figure 2*, Annual Energy Use, presents the energy use in gigajoules (GJ) graphically. *Figure 3*, Annual Energy Costs, shows the annual cost of energy. *Figure 4*, Energy Use Distribution, is an approximate distribution of annual energy use by end use in the plant. Maximum and average 24 hour electric demand profiles are presented in *Figure 5* for typical summer days, and average and maximum demand for typical winter days in *Figure 6*. There is a small seasonal effect of approximately 200 to 300 kW.

*Table 1. Plant Energy Usage for 1990*

| | ENERGY USE | | ENERGY COSTS (Kcs) | | ENERGY COSTS ($) | |
|---|---|---|---|---|---|---|
| MONTH | KWH | STEAM (GJ) | KWH | STEAM | KWH | STEAM |
| JAN | 882,800 | 15,058 | 778,824 | 2,157,501 | $28,259 | $78,284 |
| FEB | 879,000 | 19,408 | 777,570 | 2,682,546 | 28,214 | 97,335 |
| MAR | 1,028,000 | 21,569 | 826,740 | 2,943,378 | 29,998 | 106,799 |
| APR | 974,500 | 16,200 | 809,085 | 2,295,340 | 29,357 | 83,285 |
| MAY | 1,053,000 | 14,200 | 834,990 | 2,053,940 | 30,297 | 74,526 |
| JUN | 1,069,400 | 13,350 | 840,402 | 1,951,345 | 30,494 | 70,804 |
| JUL | 1,013,300 | 14,172 | 821,889 | 2,050,560 | 29,822 | 74,403 |
| AUG | 1,149,600 | 11,500 | 866,868 | 1,728,050 | 31,454 | 62,701 |
| SEP | 960,600 | 15,500 | 804,498 | 2,210,850 | 29,191 | 80,220 |
| OCT | 1,062,900 | 15,445 | 838,257 | 2,204,212 | 30,416 | 79,979 |
| NOV | 1,005,200 | 18,400 | 819,216 | 2,560,880 | 29,725 | 92,920 |
| DEC | 895,124 | 17,932 | 782,891 | 2,504,392 | 28,407 | 90,871 |
| YEAR | 11,973,424 | 192,734 | 4,438,730 | 23,602,994 | $161,057 | $856,422 |

Energy use pattern is dominated by production levels. However, some discussion with plant personnel indicated that the increase in steam consumption in January through March of 1990 was normal due to increased ice cream production and storage, in anticipation of high ice cream consumption in the spring and summer. The consumption of all products was down from that expected, and ice cream production was expected to be cut back in April through June. Some recovery of consumer demand was experienced in the latter months of 1990 but had not recovered to previous subsidized levels.

*Figure 2. Annual Energy Use*

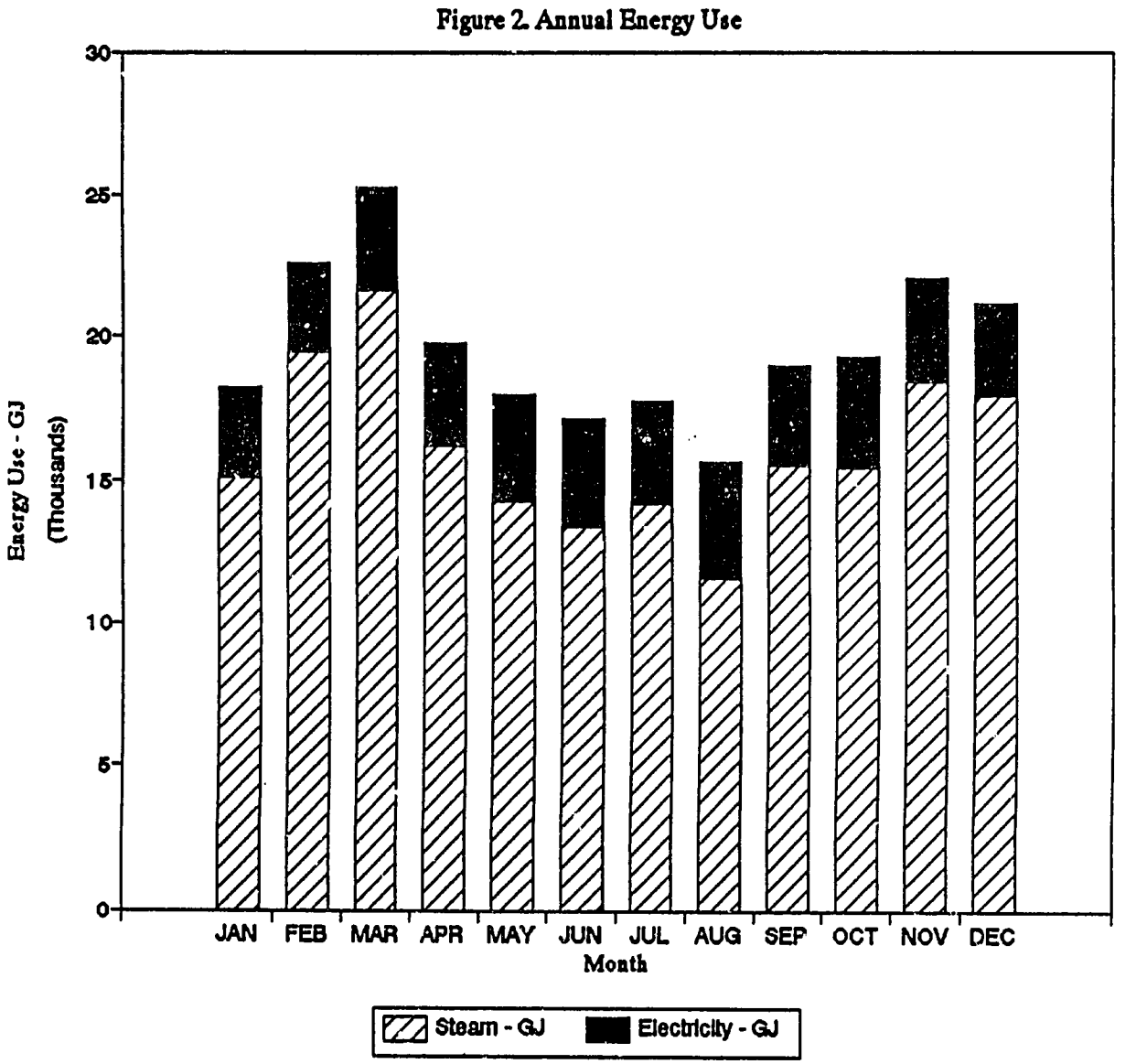


*Figure 3. Annual Energy Costs*

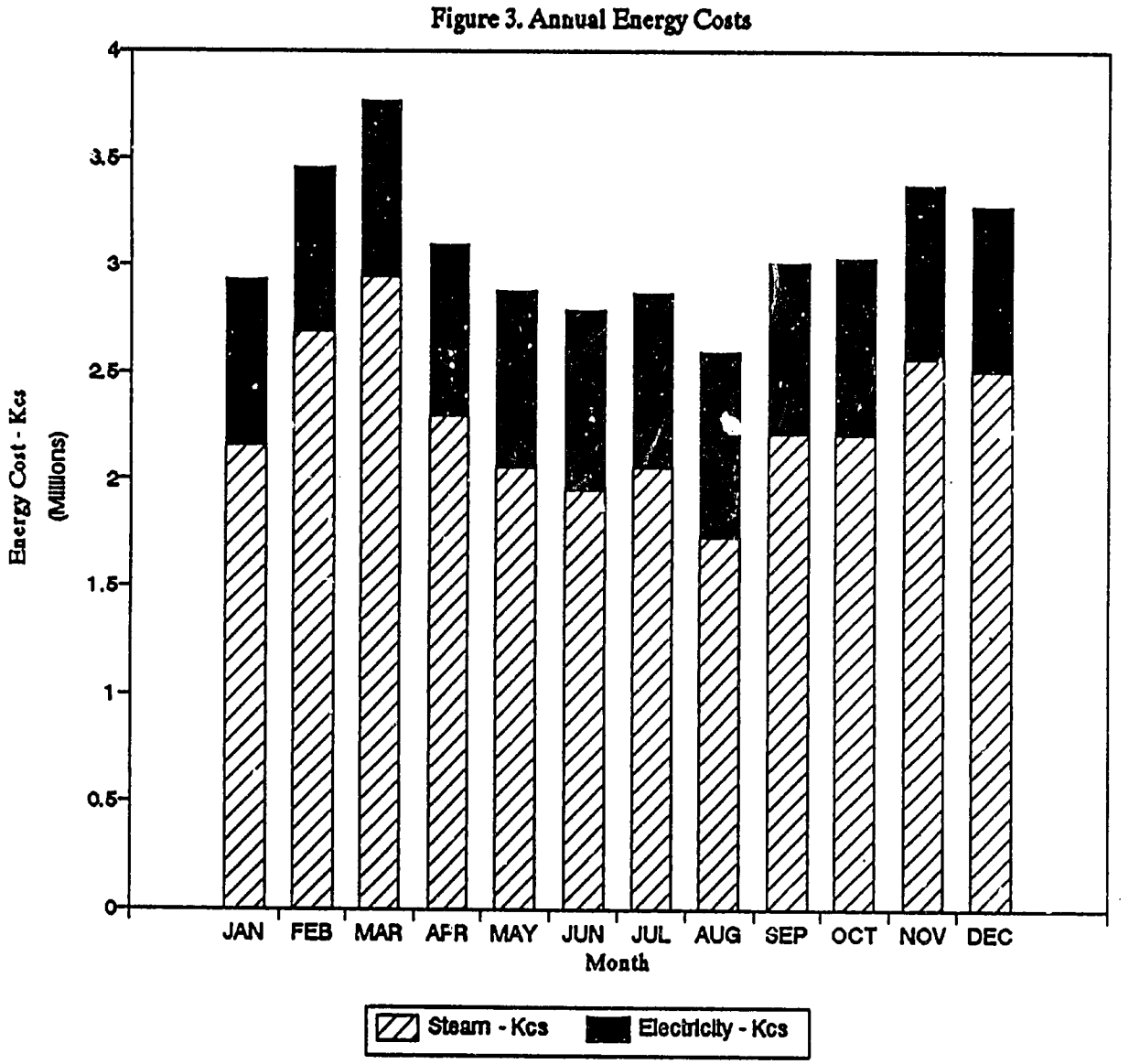


*Figure 4. Energy Use Distribution*

**Figure 4. Energy Use Distribution**

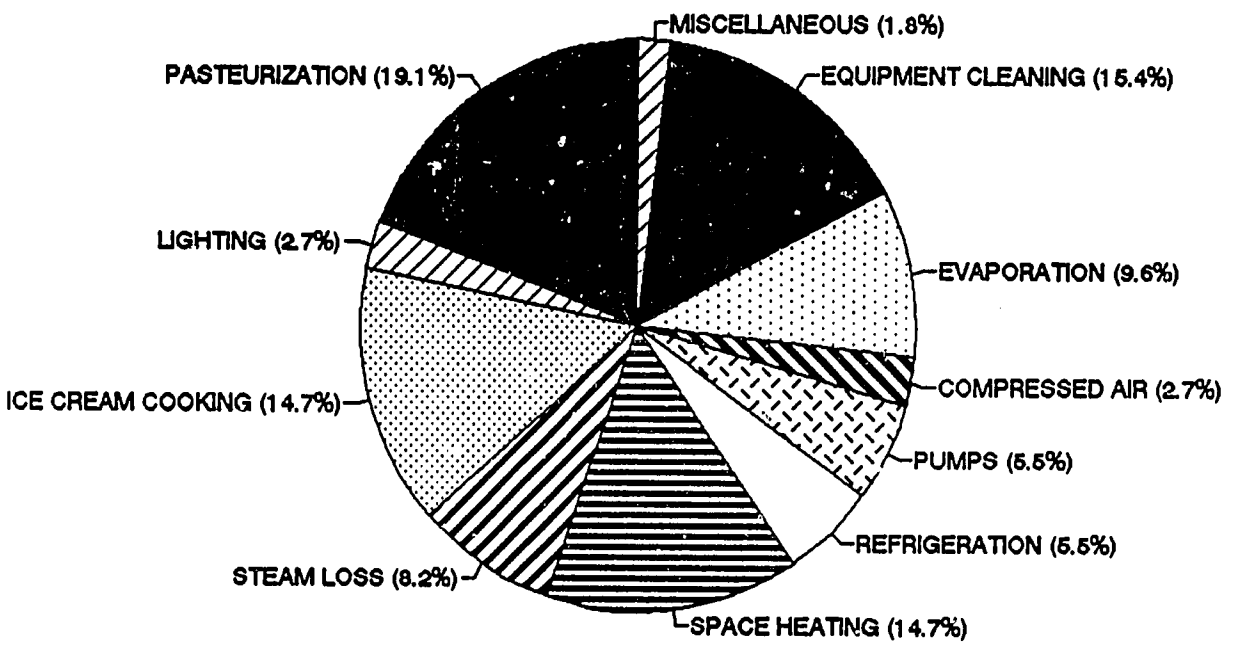


*Figure 5. Average and Maximum Summer Demand*

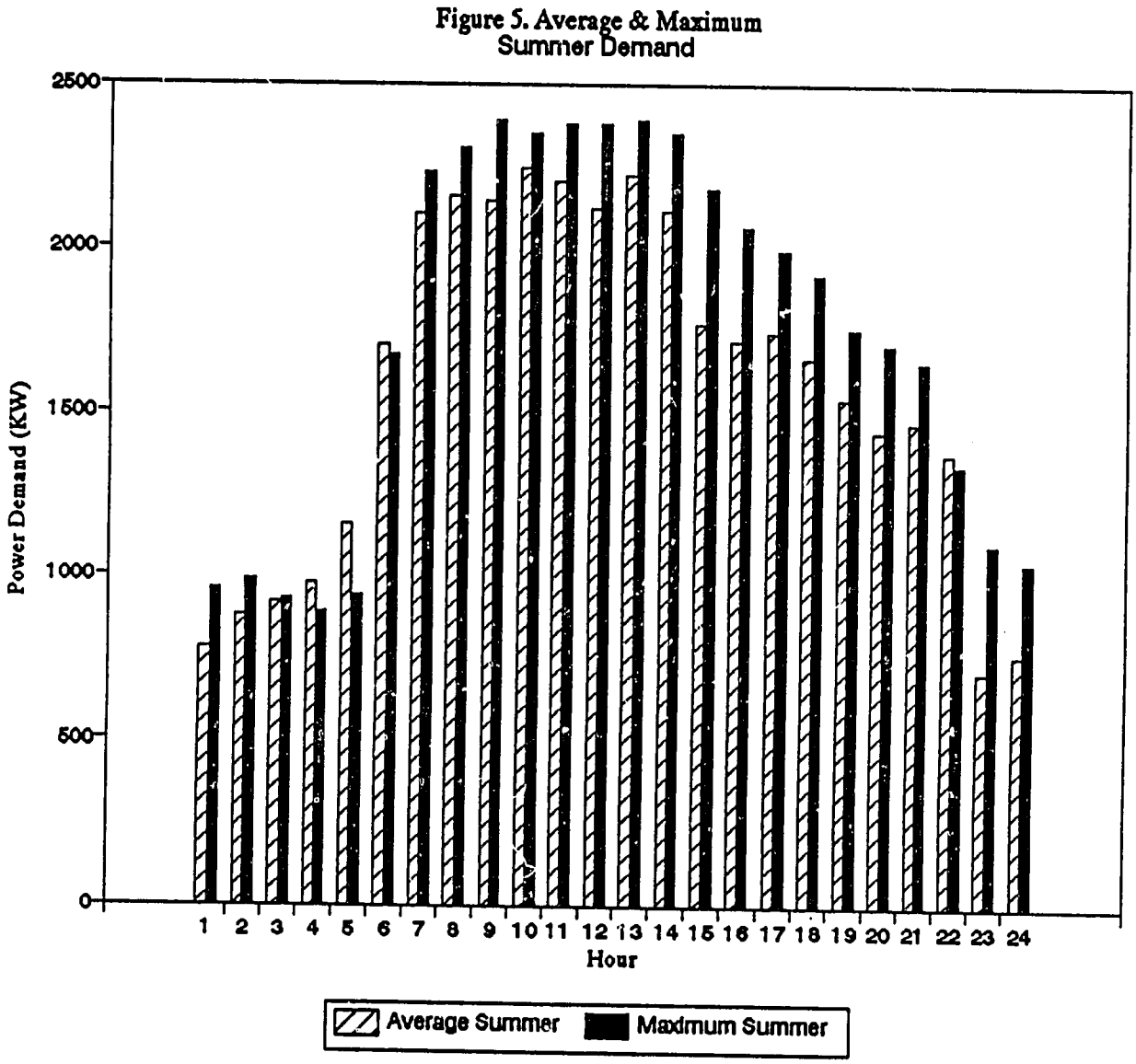
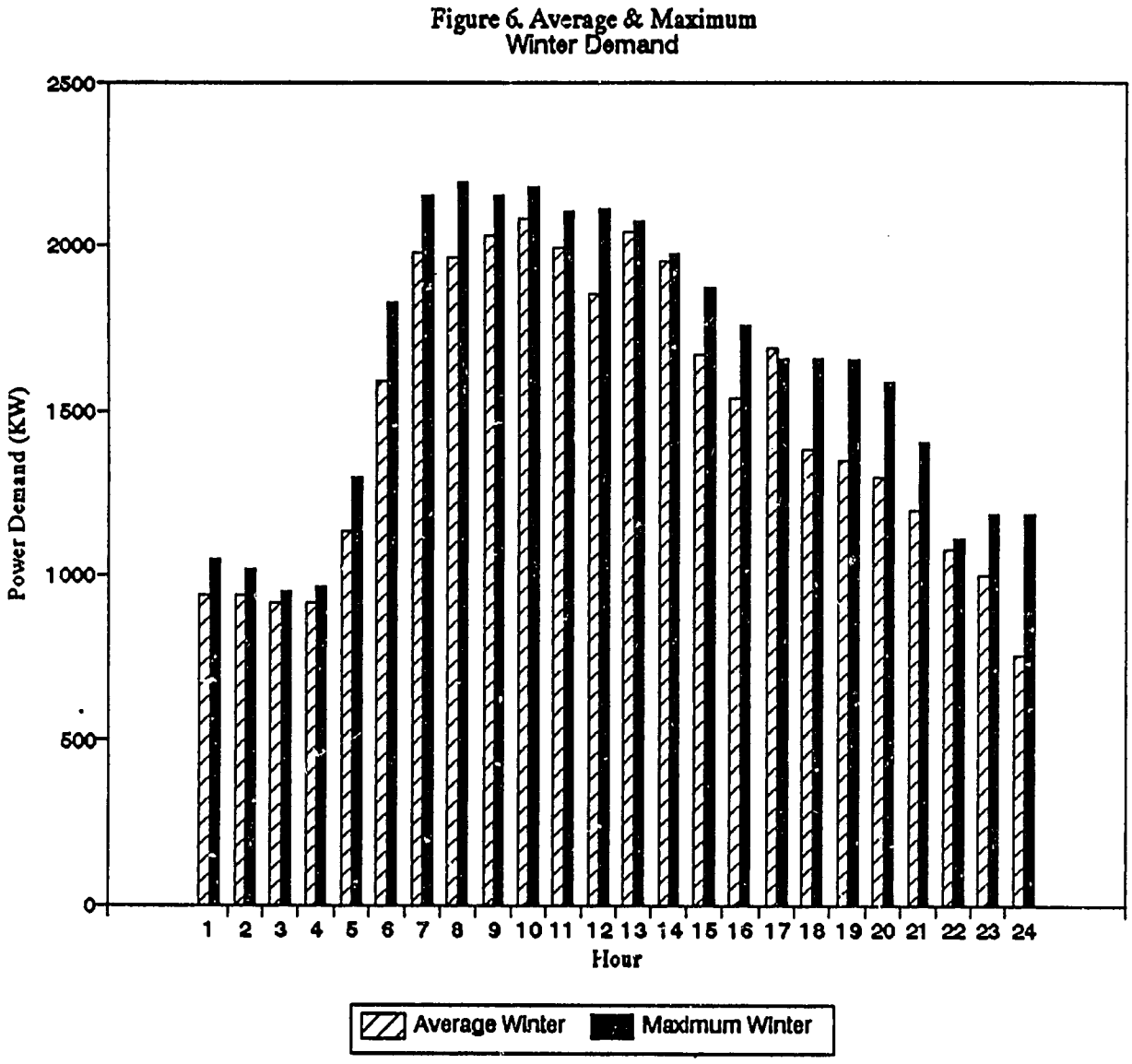


*Figure 6. Average and Maximum Winter Demand*



## 3.0 Audit Description

Two members of the audit team surveyed the plant during the period of March 11-15, 1991. The plant was toured on Monday, various measurements were taken on Tuesday and plant personnel interviewed. The audit team found that the plant technical personnel were well qualified and aware of increasing energy costs. Awareness of the costs of neglected maintenance and energy wastes was less evident. Some examples are:

1. In the main steam distribution center, both main pressure reduction valves were leaking badly and had been for some time. The auditors were unable to determine a schedule for repair of this severe leak, which is wasting an estimated 0.38 GJ/hr, 3,328 GJ/year, or 402,784 Kcs/year at 121 Kcs/GJ.

2. In the central pumping station all of the active pumps had severe packing leaks. One ice-water pump was estimated to be leaking over 20 liters per minute. Using nominal pumping energy and refrigeration equipment performance figures, this results in average losses of 2 kW/hr, or 17,520/year (5,781 Kcs/year). Considering that the cost of seal replacement should not exceed 1,350 Kcs and 2 hours labor, this should be an immediate priority repair.

3. Flow control valves (check valves) were leaking badly on several operating pumps. Operators had to close isolation valves manually prior to shutting pumps down to prevent back flow through idle pumps. Consequently, pumps were kept running for many more hours than was necessary. If new valves were installed and kept in repair, it was estimated that one each of the ice-water, warm water (cooling tower), and condenser pumps could be shut down for one half of the year. This results in a savings of 493 MWh/yr or 163,000 Kcs/yr.

4. Problems with the automatic control of condenser pumps, i.e., controlling pumps by condenser head pressure, had led to abandoning the automatic controls and using manual scheduling of pumps. Since this was exacerbated by the problems outlined above with flow control valves, no estimate of cost was made.

*Table 2. 1990 Aggregate Production*

| | SUMMER | | WINTER | |
|---|---|---|---|---|
| HOUR | AVERAGE | MAX | AVERAGE | MAX |
| 1 | 780 | 960 | 940 | 1050 |
| 2 | 877 | 990 | 940 | 1020 |
| 3 | 920 | 930 | 920 | 950 |
| 4 | 980 | 890 | 920 | 970 |
| 5 | 1160 | 940 | 1135 | 1302 |
| 6 | 1700 | 1670 | 1593 | 1825 |
| 7 | 2100 | 2226 | 1977 | 2150 |
| 8 | 2155 | 2305 | 1960 | 2190 |
| 9 | 2140 | 2390 | 2027 | 2150 |
| 10 | 2243 | 2350 | 2080 | 2180 |
| 11 | 2200 | 2380 | 1990 | 2100 |
| 12 | 2115 | 2380 | 1850 | 2110 |
| 13 | 2220 | 2390 | 2040 | 2070 |
| 14 | 2112 | 2350 | 1950 | 1972 |
| 15 | 1765 | 2180 | 1670 | 1870 |
| 16 | 1710 | 2060 | 1540 | 1757 |
| 17 | 1740 | 1990 | 1690 | 1660 |
| 18 | 1662 | 1915 | 1387 | 1660 |
| 19 | 1540 | 1750 | 1350 | 1657 |
| 20 | 1440 | 1702 | 1300 | 1590 |
| 21 | 1470 | 1650 | 1200 | 1410 |
| 22 | 1375 | 1340 | 1000 | 1115 |
| 23 | 710 | 1100 | 1080 | 1190 |
| 24 | 760 | 1040 | 1000 | 1190 |

## 4.0 Summary of Results

The audit revealed many opportunities for energy conservation. It is estimated that at least 20 percent of the present 233,000 GJ annual energy use could be saved by low-cost, no-cost measures. Two energy conservation opportunities (ECOs) recommended for demonstration implementation, from among the opportunities identified, will save 5,300 to 7,000 GJ per year, or three percent of the plant's annual consumption.

### 4.1 Recommended Energy Conservation Opportunities for Demonstration

1. Installation of an automatic temperature control system for space heating in the Administration building. This system will include computerized control of inlet heating water temperature based on outside air temperature, and 220 thermostatically controlled valves for individual radiators (presently, radiators in the administration building are controlled by manually controlled valves). In addition, control valves and programs will be installed to allow setting back temperatures in office areas during night and weekend periods while maintaining temperatures in the employee housing areas and change areas.

   Estimated annual energy savings (steam): 3,800-5,300 GJ
   Estimated annual cost savings: 460,000-640,000 Kcs ($15,500-$21,700)
   Estimated cost: 945,000 Kcs ($32,000), plus cost sharing by Plant in form of installation labor.
   Estimated Payback: 1.5-2 years

2. Installation of flow control valves on cooling tower and condenser water pumps. Present check or flow control valves leak and allow water to flow back through the pumps. Because of this, pumps run longer than they would normally since the plant personnel must close manual pump isolation valves in order to shut down a pump. New flow controls will allow personnel to shut pumps down whenever load allows.

   Estimated annual energy savings (electricity): 493 MWh
   Estimated cost savings: 163,000 Kcs ($5525)
   Estimated cost: 110,200 Kcs ($3,700)
   Estimated Payback: 0.7 years

### 4.2 Summary of Recommended No/Low-Cost Energy Conservation Measures.

1. Space Heating

   Current Condition: All space heating is controlled only by manual valves, e.g. "on or off", and if a space is over heated, windows are opened. None of the heated areas are controlled by thermostats.

Short Term Recommended Energy Conservation Opportunities:

a. thermostatic control of all heated space.
b. close windows during heating periods.
c. lower temperature during nighttime and other periods of inactivity.

Long-term Recommended Energy Conservation Opportunities:

a. Installation of Computer Central Control systems.

2. Steam Distribution System

Current Condition: Steam distribution system has been under-maintained and includes numerous leaks, faulty insulation, lack of insulation, and inoperable steam traps. Plant plans to renovate steam piping within the 1991 - 1993 period due to corrosion and scaling of pipes.

Short-Term Recommended Energy Conservation Opportunities:

a. repair steam leaks.
b. repair/replace steam traps.
c. replace wet insulation.
d. install/repair pipe insulation.

Long-Term Recommended Energy Conservation Opportunities:

a. Up-grade pipe insulation to "economic thickness".

3. Ice Water Distribution

Current Condition: Large portion of ice water lines are exposed to high humidity and high temperature due to their proximity to steam leaks and condensate tanks. Ice water lines are uninsulated, and atmospheric water vapor is continuously condensed on the lines. Hence, the ice water is subjected to higher sensible and latent heat loads than necessary.

Short-Term Recommended Energy Conservation Opportunities:

a. Ventilate areas with high heat/humidity to reduce sensible and latent loads on ice water pipes. Example: areas near steam distribution room, pasteurization area, and ice cream cooking area.

Long-Term Recommended Energy Conservation Opportunities:

a. Insulate ice water lines to "economic thickness".

4. Lighting

Current Condition: Lighting is manually controlled and under maintained. Day lighting is available in many areas but artificial lighting is used regardless of ambient light levels. Almost all lighting is either fluorescent or high intensity discharge (HID), with a minor amount of incandescent lighting.

Short-Term Recommended Energy Conservation Opportunities:

a. clean luminaries.
b. replace burned out lamps.
c. disconnect unused lamps/ballasts.
d. turn off lights in areas with day lighting.
e. clean/increase transparency of skylights.
f. reduce lighting levels in some halls and office areas.

Long-Term Recommended Energy Conservation Opportunities:

a. replace existing lighting with high efficiency lamps, luminaries, ballasts, and/or different light sources, e.g., replace high bay fluorescent lighting with high pressure sodium lights.
b. conduct lighting survey and adjust lighting levels accordingly.
c. install automatic lighting controls.
d. design lighting levels for tasks ("task lighting").

5. Compressors/Chillers/Pumps:

Current Condition: Equipment is 12 years old, based on 20 year old technology and under maintained.

Short-Term Recommended Energy Conservation Opportunities:

a. Install check valves on pumps for cooling tower water, condensing water and ice water to prevent back flow.

Long Term Recommended Energy Conservation Opportunities:

a. Install variable speed pump controls on one cooling tower and one condenser pump to better match pumping capacity to cooling load.
b. Install computerized control for cooling system.
c. Replace electric motor compressor drives with high efficiency motors or replace compressors and motors with screw compressors with improved coefficients of performance. Modern screw compressors are well suited to ammonia service and offer improved full and part load performance.
d. Compressor discharge temperatures are nearly 100 °C. Heat exchangers could be installed to heat domestic hot water and hot water for equipment cleaning.

6. Cold Rooms

Current condition: The insulation of cold rooms is in good repair except for small areas where condensation was observed on outside walls. Entrance and shipping doors are left open for excessive periods, causing inflow of warm/moist air, thereby increasing sensible and latent cooling loads.

Short-Term Recommended Energy Conservation Opportunities:

a. repair plastic door curtains.
b. minimize humidity in areas adjacent to cold rooms.
c. install automatic doors.
d. institute stricter manual control on door openings.

Long-Term Recommended Energy Conservation Opportunities:

a. Up-grade/repair insulation in cold rooms.

7. General/Administrative

Current condition: The plant has identified an "Energy Manager", however this function does not yet include responsibility for energy conservation. Personnel are not trained in energy conservation technologies, but are eager to learn. Management is aware of the need for energy conservation and is willing to support a continuing program.

Short-Term Recommended Energy Conservation Opportunities:

a. Assign direct responsibility for energy conservation; estimated level of effort- 0.5 person year.
b. Initiate an Energy Management Program for entire facility.
c. Obtain/use test equipment for checking operating performance of energy consuming equipment.
d. Train plant personnel in energy conservation procedures.
e. Conduct energy conservation awareness program for all employees.
f. Assign maintenance personnel full time to repair and upgrade of present equipment to efficient operation. Estimated level of effort - 2 person years.

Long-Term Recommended Energy Conservation Opportunities:

a. Include energy costs in "cost center" accounting; give cost centers credits for successful energy conservation.
b. Maintain continuing Energy Management Program.

## 5.0 Implementation Evaluation

Dates visited: July 23 and 24, 1991
Contacts: Ing. Kartel Major and staff of the Energetics Department.
Objectives of visit:

1. Evaluate the status of the Demonstration Projects.
2. Assist in the preparation of the presentation for the August 13, 1991 Seminar.
3. Evaluate the status of other energy conservation measures undertaken by Pragolaktos.

Status of the Demonstration Project

The objective of the demonstration project was to reduce the space heating requirements of the Administration Building by installing a computer controlled steam supply system and thermostatic control valves on radiators throughout the building. The mixing valves are shown in Picture 1 in Appendix E.

During joint meetings with Pragolaktos and Johnson Controls, Inc. (JCI), the equipment supplier, the following items were defined and, where necessary, agreement was obtained from all parties:

1. JCI has delivered all items ordered to Pragolaktos or has them stored in the Prague office of JCI for immediate delivery. To facilitate delivery of imported equipment, JCI had paid the outstanding duty taxes and, depending on the resolution of responsibility for payment of duty taxes, JCI will bill either Pragolaktos or RMA.

2. Pragolaktos will begin electrical and piping work in preparation for installation of the JCI control system July 29, 1991 and complete the work by August 12, 1991.

3. JCI will begin installation of the control system on August 12, 1991 and complete the work by August 19, 1991. During the same period, Pragolaktos will install the thermostatic control valves on the radiators throughout the building.

4. JCI will provide training on the computer control system and demonstrate its operation for one manager and two operators during the week of September 9, 1991. The training period will 3-5 days, as required, and JCI will provide a "refresher course" during the start of the heating season (late October).

5. It was understood by all parties that Pragolaktos will receive a one-year warranty on all parts supplied by JCI (including the computer) and a one-year service policy from JCI; the effective start date of the warranty will be the date of completion of installation by JCI.

6. Upon successful completion of installation of the computer control system by JCI, Pragolaktos will send a letter of completion to RMA via SEVEn.

7. Upon request, Pragolaktos has offered to supply information regarding the performance of the heating control system during the 1991-1992 heating season to RMA.

## Preparation for the Seminar

The Pragolaktos presentation for the industrial efficiency workshop was outlined with the proposed speaker, and the presentation was prepared. A schedule was agreed upon for participation on the workshop. It was agreed that SEVEn will also assist in the preparation of materials for the Pragolaktos presentation.

## Status of Energy Conservation Measures Undertaken by Pragolaktos

Pragolaktos stated they had carefully considered all the energy conservation measures recommended by the audit team, and have either completed implementation of such measures or have made plans for their implementation. These measures are in addition to the stated demonstration project and are to be funded totally by Pragolaktos.

Examples of major measures undertaken by Pragolaktos are:

1. Planned for 1991-1992 - Installation of automatic data acquisition of energy use and automatic control of processes. The computer system provided under the demonstration project will be used for these additional functions. These additional uses will not interfere with the primary function of the computer to control space heating in the Administration building.

2. Planned Spring 1992 - Install new steam pressure reduction stations to better match steam pressures to process requirements.

3. Completed in July, 1991 - Replacement of cooling towers with an energy efficient design, including two-speed fan motors and semi-automatic controls.

4. Completed in August, 1991 - Repair of pipe insulation.

5. Completed in August, 1991 - Replacement of plastic strip door closures for cold rooms and repair of automatic door closers.

6. Planned for Fall, 1991 - Installation of "air lock" door systems for freezer rooms.

7. Planned for Spring, 1992 - Installation of a new space cooling system for the milk packaging hall, using chilled water from existing chillers.

8. Completed in August, 1991 - Apply solar reflective window coatings to south facing windows in the Administration building. Since the space is not air conditioned, this measure will help reduce the future need for energy for cooling, and hence, is an energy avoidance measure.

9. Planned for Fall, 1991 - Installation of energy efficient high intensity discharge (HID) lighting in the milk processing hall.

10. Planned for Fall, 1991 - Changes in the management organization to strengthen the role of energy management, including the inclusion of energy costs in operating cost centers. Recommendations for organizational changes will be prepared by an outside consulting firm under contract.

It is clear from the actions completed and planned by Pragolaktos that the recommendations presented by the audit team were well received and stimulated numerous energy conservation projects. Whereas the sum total of energy savings can not be quantified at this time, it is believed that the energy conserving measures identified will result in energy savings of 15-20%.

Final Note

The installation of the energy efficiency improvements was completed in September 1991, and training was provided in October 1991.

# APPENDIX A
## Specifications for ECO Demonstrations

Appendix A. Specifications for Space Heating Controls of Building 03 - Administration and Apartments.

Purpose: Reduce space heating energy consumption by controlling heating requirements and temperatures, Building 03.

Suggested Supplier: Johnson Controls, International Division.

Contact: Dan Mach
Jenecska 5
160 00 Praha 6 - Dolni Liboc
Tel. 02 - 36 61 21
Fax 02 - 36 61 21

Equipment Description:

1. Control Station: PC computer (CS-9100)
   Interface rack (DRG16)
2. Controllers: 5 Stations (DC-9100)
3. Field equipment: sensors, valves, actuators, etc.
4. Services: engineering, installation, programming, commissioning, training of plant personnel, including operational manuals.
5. Thermostatic control units for application to existing radiators, approximately 380 units with manual temperature adjustment. To be quoted with and without field installation.

All above items: stated warranty, delivery schedule, and complete costs delivered on site.

# APPENDIX B
## Specifications for Cooling Tower Valves

Appendix B. Specifications for Cooling Tower Valves

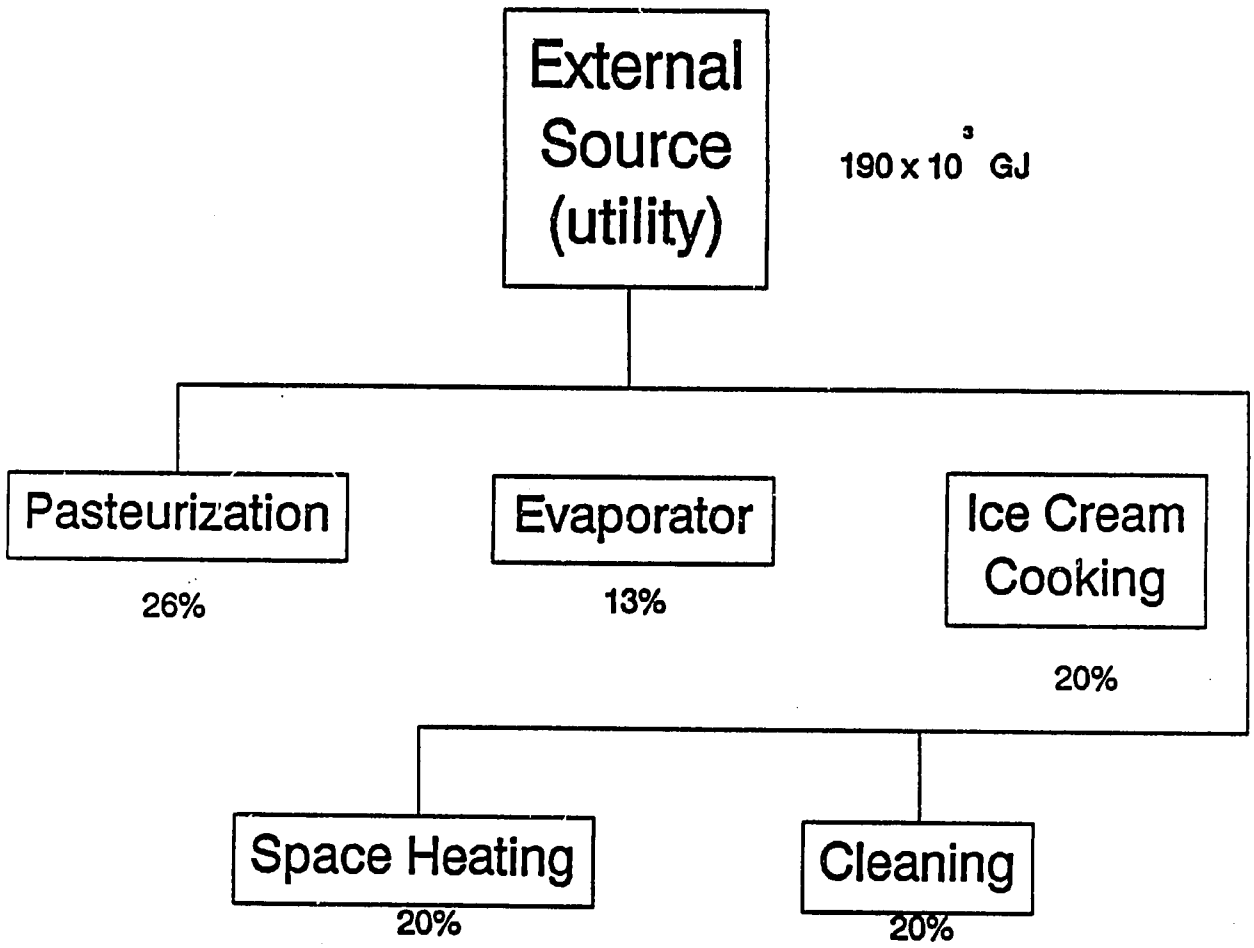
Purpose: Improve performance of cooling tower system by installation of flow control valves on cooling tower pumps to allow periodic shutdown of pumps during periods of low cooling demands.

Suggested supplier: Johnson Controls
International Division
Contact:
Equipment Description:

1. 8 Valve units, to match existing cooling tower equipment. To be installed by plant personnel; contractor to furnish material and installation instructions. Quote to include delivered cost and delivery schedule.

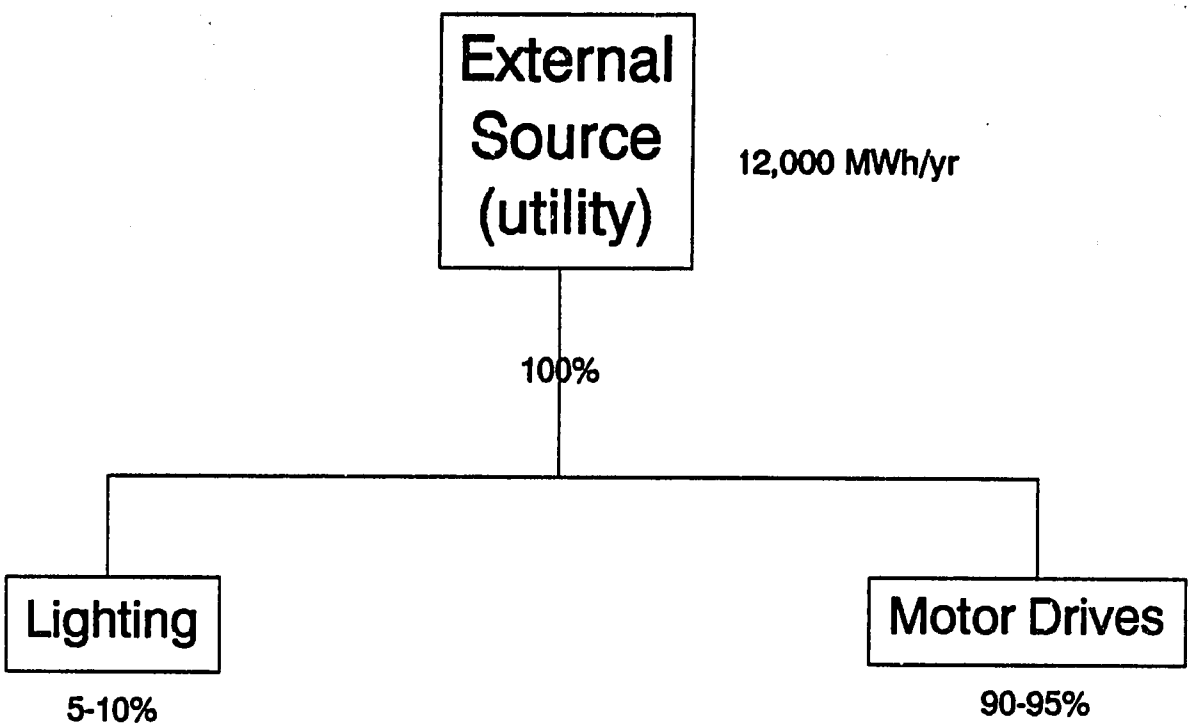
# APPENDIX C
## Steam Flow Diagram

## Steam Flow Diagram



# APPENDIX D
## Electrical Flow Diagram

## Electrical Flow Diagram



# APPENDIX E
Photograph

1. Mixing valves to control the temperature of the hot water supply for apartments. From left to right: Dan Mach (Johnson Controls, International Division), William Dries (RMA), B. Malek (Energoprojekt) and Karel Majer (Director of Technology at Pragolaktos).

# APPENDIX F
## 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[°F] = 9/5 T[°C] + 32 |
| °F | = degree Fahrenheit |
| °R | = degrees Rankine = T[°F] = T[°R] + 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 |
| 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 = 146.96 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 = 0.03532 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 |
| MCal | = megacalorie = 1 million calories |
| 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 = 146.96 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 |
| 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 |
| yr | = year |