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# ENERGY AUDIT REPORT
# FOR
# TEXTILES CONTINENTAL S.A.
# GUAYAQUIL, ECUADOR

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and

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Consultants Financed by

United States Agency for International Development (U.S. AID)


November 1984

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## FOREWORD

This audit report is part of an Industrial Energy Conservation Program undertaken by the Institute Nacional de Energia (INE), with the cooperation of La Escuela Superior Politecnica del Litoral (ESPOL).

This multi-phase program was launched by INE in association with the U.S. Agency for International Development in 1984. The program includes, in these initial stages, extensive training of young engineers in the basics of energy management principles and practices, including on-site training in energy audit techniques.

The major objective of Phase I is to develop the energy auditing skills necessary to be able to implement a nationwide program of industrial energy conservation.

This report details the findings of an energy audit conducted at Textiles Continental S.A. during September 1984. The plant was selected to participate in the training program based on its suitability for auditing, relevance to the Ecuadorian industrial sector, and the willingness of the plant management to open the plant to the training program.

The energy-consuming systems examined during the audit are common to many industrial plants. It is envisioned that similar audit evaluations can be conducted in other industrial facilities in Ecuador, resulting in major conservation savings.

**ACKNOWLEDGEMENTS**

The energy audit detailed in this report was performed under a program sponsored jointly by the following organizations:

Instituto Nacional de Energia, Quito, Ecuador

La Escuela Superior Politecnica del Litoral, Guayaquil, Ecuador

The Bureau for Science and Technology, U.S. Agency for International Development, Washington, DC

U.S. AID Mission to Ecuador, Quito, Ecuador

Technical assistance was provided by consultants from Hagler, Bailly & Company, Washington, DC and Reliance Energy Services, New York, New York.

We would like to express our appreciation to the management of Textiles Continental S.A. for allowing their plant to be used for training purposes.

This report details savings from reducing energy consumption at Textiles Continental S.A., Guayaquil, Ecuador. Savings estimates are based on the findings of an energy audit training program conducted under the joint auspices of INE, ESPOL, and USAID in September 1984.

The training program began with a classroom session, lasting 4 days. The purpose of this session was to instruct course participants in the use of portable instrumentation and in the data collection and test procedures. During 5 days of site work, the participants were responsible for testing the wide range of equipment in the plant, including the boiler and ancillary systems, chilled water and environmental control systems, and plant process equipment.

The balance of the training program was held in the classroom and consisted of the analysis of the collected data, formulation of energy conservation strategies, and calculation of the savings possible by implementation of the recommended measures. This session lasted a further 7 days.

The energy savings discussed in detail in this report can be achieved by implementation of projects and strategies identified during the course of the audit and data analysis.

To identify the areas where improvements in energy utilization are possible, the plant was analyzed in the following manner:

A visual inspection of the plant was conducted to familiarize the participants with the basic layout of the plant and to identify the most obvious sources of waste. This was followed by the collection of readily available energy related data.

This Preliminary Energy Audit (PEA) included collection of the following types of information:

- Energy use by fuel type and source delivered
- Energy costs
- Inventory of major energy-consuming equipment in the plant
- Operating schedules for major departments in the plant

- Details on current energy management program
- Information on energy conservation projects being considered, underway, or previously implemented.

The PEA data was used to develop a plan for the instrumented testing of major energy-consuming plant equipment. The equipment was tested to determine the level of energy waste and the amount of energy that could be usefully recovered.

To ensure full audit coverage of the plant, the plant was divided into a number of discrete areas. Each audit team wa responsible for conducting tests in each of the areas. The areas were:

- Boiler plant, steam distribution, and condensate return systems
- Chilled water plant, distribution, and space conditioning systems
- Lighting systems
- Compressed air systems
- Electrical distribution and motors
- Spinning and weaving operations
- Finishing operations.

These areas comprise the major process and service departments within the plant.

Analysis of the data collected enabled identification of the potential for energy conservation. This was followed by the formulation of strategies to achieve the energy savings. Each strategy was then further analyzed to estimate the implementation cost required to achieve the savings. The analysis of implementation cost and projected energy cost savings then allowed the development of an energy conservation action plan.

The major findings and recommendations of the study are described in the following paragraphs.

Textiles Continental S.A. is engaged in the production of wool and wool blend fabrics for use in apparel and home furnishings. The plant produces thread from raw fiber and then weaves the thread into the raw textiles. A number of wet and dry finishing operations are employed to produce the final product.

The plant was built in the early 1970s and is located on the outskirts of Guayaquil. Approximately 260 persons are employed at the plant. Production has been curtailed somewhat due to a lack of product demand.

Three major fuels are consumed by Textiles Continental. Electricity is used primarily for motors and drives. Bunker oil is fired in a central boiler plant to produce steam for process use and for generation of chilled water in two steam absorption chillers. Diesel oil is used to fire two thermal fluid boilers; the thermal fluid is used exclusively in two finishing operations. A total thermal equivalent of 78,146 GJ was consumed in the year 1983, corresponding to a cost of S/15,129,929. The breakdown by fuel type is indicated in the table below:



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| Energy sources | Percent of energy | Percent of energy cost |
|---|---|---|
| Electricity | 10.6 | 54.4 |
| Bunker oil | 64.2 | 27.3 |
| Diesel oil | 25.2 | 18.3 |
| | **100.0** | **100.0** |

Textiles Continental does not currently have an energy management program established. It is recommended that either the chief engineer or the plant electrical engineer be appointed energy coordinator for the facility and be responsible for a number of activities, including:

- Development of a data base of energy-related information, including:
  - major energy-consuming equipment
  - energy consumption and cost data
  - production and environmental data
- Monitoring of energy use in the facility through the procurement, installation, and use of additional instrumentation, including:
  - boiler combustion test equipment
  - electric consumption/demand meters to be installed in each operating department
  - fuel oil meters for each steam and thermal fluid boiler
  - stethescopes and thermocouple for testing steam traps
  - humidity meter to test moisture content of fabrics being dried in the stenter
- Development of plant norms for minimum energy use in each process within the facility and establishment of operating procedures to conform to these norms
- Commencement of an employee energy awareness program through meetings with department heads and supervisors and training of plant personnel.

During the on-site audits, a number of areas where energy savings could be achieved were identified. Analysis of the savings potential for all of these items, along with their costs of implementation, allowed the conservation measures to be grouped into three categories:



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- Recommended energy conservation measures
- Energy conservation measures not recommended
- Items requiring further study.

Recommended energy conservation measures are those with simple payback periods of less than 8 years on an individual basis. When grouped together, the 11 items identified have an aggregate payback period of 1.4 years at current energy prices. These items account for a total energy savings of 9,525 GJ, or 12.2 percent of 1983 energy consumption; this is equivalent to cost savings of $1,780,176, or 11.8 percent of 1983 energy costs. These measures are summarized in Exhibit 1 and described in the paragraphs below.

Boiler plant utilization can be improved by installation of boiler sequencing controls (lead-lag controls). Currently, three of the four boilers are kept on-line at any one time, with the fourth boiler down for maintenance. All of the boilers operate at low to mid fire. An analysis of the steam demand indicates that two boilers are sufficient to meet steam requirements: one boiler at high fire and the other at mid-fire. Installation of lead-lag controls will allow two boilers to operate at their optimum levels, reducing the requirement for a third boiler to be on-line.

Steam and condensate pipework in the plant is poorly insulated, with large runs of uninsulated pipework observed. Insulation of the pipework will reduce excessive heat losses and further reduce boiler load. While savings for insulation of steam and condensate pipework have been calculated individually, combining these measures yields an aggregate payback period of 3.1 years.

Steam leaks and clean condensate sent to drain represent energy losses that require a minimum of effort to eliminate.

The aggregate savings for these five items is 8,738 GJ (over 55,000 gallons), equivalent to $719,836, or 17.4 percent of 1983 consumption and cost for bunker oil. Taken as a group, these items have an aggregate payback period of 2.6 years based on current bunker oil prices.

The electric utility serving Textiles Continental plans to impose a power factor penalty on those industrial users having a power factor below 0.95. While installation of additional capacitors to raise plant power factor from the current 0.91 to the "safe" level of 0.95 will not save energy, the penalty would amount to approximately $360,000 annually. It is recommended, therefore, that additional capacitors be installed.

Compressed air leaks are easily repaired and represent sources of energy waste that can easily be avoided. A regular compressed air system inspection and repair program should be established at Textiles Continental.

In the area of air conditioning, it was noted that process area space conditioning systems draw return air from unconditioned areas. Eliminating the return air from the service corridor between the plant and offices and installing plastic

Exhibit 1

Summary of Savings for Recommended Measures

| Item | Energy data | | | | Cost data | |
|---|---|---|---|---|---|---|
| | Energy saved (GJ) | Cost saved (sucres) | % of savings | | Total cost | Payback years |
| | | | Energy | Cost | | |
| 1. Improvement in steam boiler utilization | 903 | 74,389 | 9.5 | 4.2 | 500,000 | 6.7 |
| 2. Insulation of steam pipework | 4,853 | 399,790 | 51.0 | 22.5 | 993,300 | 2.5 |
| 3. Insulation of condensate pipework | 638 | 52,558 | 6.7 | 3.0 | 401,784 | 7.6 |
| 4. Repair of steam leaks | 2,319 | 191,039 | 24.3 | 10.7 | minimal | immediate |
| 5. Improved condensate return | 25 | 2,060 | 0.3 | 0.1 | minimal | immediate |
| 6. Increased power factor | -- | 359,109 | -- | 20.2 | 444,500 | 1.2 |
| 7. Repair compressed air leaks | 105 | 96,250 | 1.1 | 5.4 | minimal | immediate |
| 8. Eliminate return air from service corridor | 566 | 518,835 | 5.9 | 29.1 | 200,000 | 0.3 |
| 9. Eliminate return air from main corridor | 66 | 60,500 | 0.7 | 3.4 | 20,000 | 0.3 |
| 10. Remove ballasts | 24 | 22,000 | 0.3 | 1.2 | minimal | immediate |
| 11. Insulate thermal fluid tank | 26 | 3,646 | 0.2 | 0.2 | 7,150 | 2.0 |
| **Totals** | **9,525** | **1,780,176** | **100.0** | **100.0** | **2,566,734** | **1.4** |

strips to reduce air circulation between the areas will reduce the amount of air required for cooling and humidification. This will in turn reduce the power requirements of the seven rooftop air handling units. A similar strategy is proposed for the office air conditioning fan coil unit. Return air should be provided from the conditioned space rather than from the unconditioned office area corridor.

Lighting levels have been reduced in the plant by allowing fluorescent bulbs to burn out without replacing them. The ballasts serving those fixtures, however, are live and continue to consume electricity. Since the reduced lighting levels doe not appear to affect productivity, it is recommended that the unnecessary ballasts be disconnected.

The aggregate savings for these five items is 761 GJ (over 200,000 kWh), equivalent to S/1,056,694, or 9.2 percent and 12.8 percent of 1983 electricity consumption and cost, respectively. Taken as a group, these items have an aggregate payback period of 0.6 years, based on current electricity prices.

Finally, insulation of the thermal fluid overflow tank will reduce heat loss from the tank, resulting in diesel oil energy savings of 26 GJ (over 175 gallons) equivalent to S/3,646. This is equivalent to 0.1 percent of 1983 diesel oil consumption and cost, with a payback period of 2.0 years based on current diesel oil prices.

Several additional energy conservation measures have been identified but are not recommended due to their extended payback periods, even taking into consideration proposed and expected increases in Ecuadorian energy prices.

The first of these measures is oxygen trim control for the steam boilers. While this measure can save 603 GJ (3,800 gallons of bunker oil) annually, based on current boiler operating practice, the implementation cost is estimated to be S/4,800,000, resulting in a simple payback period of nearly 100 years. Even if bunker oil prices increase to current world prices, the payback period exceeds 10 years.

The second measure is installation of a cooling tower filtration system to reduce contamination of chiller condenser water. While this measure can save 827 GJ (230,000 kWh) annually, the implementation cost is estimated at S/2,000,000, resulting in a simple payback period of nearly 30 years at current electricity prices. Electricity prices are not expected to increase at the same rate as petroleum-based fuels due to the large dependence on hydroelectric generation, and the payback period for this measure will not drop significantly.

The final item in this group is heat recovery from stenter exhaust air to preheat incoming air. This measure can save 375 GJ (2,565 gallons of diesel) annually; the implementation cost of this measure is estimated at S/3,000,000. The simple payback period is nearly 60 years. Again, the projected increases in diesel oil prices will not result in a reasonable payback period for this measure.

The final group of items consists of those requiring further study. The first item in this group is replacement of existing steam absorption chillers with more efficient electric centrifugal chillers. While a substantial energy saving can be achieved, the cost differential between petroleum-based fuels and electricity results in a net additional cost of S/350,000 annually. The table below reflects the effect of increasing bunker oil prices on savings and payback period. This calculation assumes that electricity prices remain at current levels; if electricity prices increase with petroleum fuel prices, the payback periods will increase as the energy cost savings decrease.

| Cost of bunker oil (sucres/gallon) | Energy cost savings (sucres) | Simple payback (years) |
|---|---|---|
| 13.00 | (349,550) | -- |
| 20.00 | 1,179,046 | 29.3 |
| 30.00 | 3,362,713 | 10.3 |
| 40.00 | 5,546,724 | 6.2 |
| 50.00 | 7,730,391 | 4.5 |
| 60.00 | 9,914,058 | 3.5 |
| 70.00 | 12,097,725 | 2.9 |
| 80.00 | 14,281,392 | 2.4 |

Further study is required for this measure to predict, with some reliability, the near-term energy prices in Ecuador for industrial users.

The second item in this group involves increasing feedwater temperature by isolating hot and cold discharges that currently are fed back into the condensate return system. The study involves an analysis of the existing condensate return system to determine requirements for controls, valves, piping, and storage vessel sizing to recover the cold discharge.

Because of the limited time available, it was not possible to conduct this study at the time of the on-site visit.

As a first step in implementating the recommended measures, an action plan has been developed. The plant is shown in Exhibit 2 and is based on the relative cost benefits and ease of implementation of the measures identified.

Exhibit 2

Implementation Action Plan

| Item | Time frame | Action required |
|---|---|---|
| Appoint energy coordinator | Immediate | Recruit in-house coordinator, either chief engineer or electrical engineer |
| Procure additional instrumentation | Immediate | Purchase and install (as necessary) new instrumentation; establish test procedures and scheduling |
| Energy monitoring program | On delivery of new instrumentation | Commence testing program and energy monitoring program; develop standards for stenter operation |
| Employee awareness program | Immediate | a. Obtain support of department heads and superior personnel<br>b. Inform plant operators of importance of energy<br>c. Train operators, especially boiler plant personnel, in energy-efficient use of equipment |
| Repair steam leaks | Immediate | a. Begin regular steam system surveys to identify leaks<br>b. Repair leaks on weekends when plant is idle |
| Repair compressed air leaks | Immediate | a. Begin regular compressed air system surveys to identify leaks<br>b. Repair leaks on weekends when plant is idle |
| Remove ballasts from unused fluorescent fixtures | Immediate | Remove ballasts from unnecessary fluorescent fixtures; make sure lighting levels are sufficient for safe operation of equipment |
| Improve condensate return | Immediate | a. Identify locations where clean condensate is sent to drain<br>b. Extend lines into condensate return system |

Exhibit 2 (continued)

Implementation Action Plan

| Item | Time frame | Action required |
|---|---|---|
| Eliminate return air from service corridor | Immediate | a. Obtain heavy gauge plastic stripping to block off entrances into process area and install<br>b. Block off return air grilles located in corridor |
| Eliminate return air from main corridor | Immediate | a. Obtain and install grilles in walls between offices and machine room<br>b. Block off door louvres<br>c. Reduce use of electric air conditioners |
| Increase plant power factor | 2 months | Obtain and install additional capacitors to increase power factor to 0.95 before utility increases penalty |
| Insulation of thermal fluid overflow tank | 4 months | Purchase and install insulation |
| Insulation of steam and condensate pipework | 4 months | a. Identify missing insulation<br>b. Contact local suppliers<br>c. Purchase materials<br>d. Install using in-house labor or local contractor |
| Improvement of steam boiler utilization | 6 months | a. Contact local suppliers for quotes on 4 boiler lead-lag control system<br>b. Purchase and install controls<br>c. Operate two boilers instead of three |
| Replace steam absorption chillers with electrical systems | 2 months | a. Conduct study of increases in bunker oil prices and electricity prices to determine whether it will be economically viable to make conversion<br>b. Implement if study indicates favorable conditions |

Exhibit 2 (continued)

Implementation Action Plan

| Item | Time frame | Action required |
|---|---|---|
| Conduct study of feasibility of isolating cold discharge from condensate return system | 4 months | a. Identify all areas where cold discharge is returned to condensate system<br>b. Measure quantities<br>c. Determine where modifications to condensate return system are required and size of storage vessel<br>d. Determine cost of modification<br>e. Implement if economically feasible |

## 1.1 INTRODUCTION

Reliance Energy Services has produced this report as part fulfillment of our contract with USAID to provide energy audit training to Ecuadorian engineers. This report summarizes energy conservation opportunities identified during an energy audit training program conducted at Textiles Continental S.A. in Guayaquil, Ecuador during September 1984. Data collected during the field work has been used to estimate energy savings that can be achieved by implementation of the measures recommended.

The energy audit training program was conducted in the following manner:

The Ecuadorian engineers received instructions in energy audit techniques in classroom sessions conducted at ESPOL in early September 1984. A total of 14 engineers participated in the classroom portion of the training program; all were involved in the plant portion of the training as well.

To collect the necessary information in the textile plant to complete this report, the participants were split into three teams. Each team was under the guidance of a USAID consultant.

The three teams followed a systematic approach through which data concerning the energy utilization performance of the plant was collected. The initial step consisted of the conduct of a visual inspection and collection of readily available energy-related data. This Preliminary Energy Audit (PEA) permits identification of major energy-consuming systems that can be evaluated using portable instrumentation during the Detailed Energy Audit (DEA).

To evaluate the energy performance of the plant, it was broken down into a number of discrete processes and service areas:

- Boiler plant, steam distribution and condensate return systems
- Chilled water plant, distribution, and space conditioning systems
- Lighting systems
- Compressed air and motors
- Electrical distribution systems
- Spinning and weaving operations
- Finishing operations.

Each of the three teams carried out instrumented tests in the above areas, and it is from analysis of the data collected in those tests that this report has been prepared.

Each major energy-consuming system is tested as part of a Detailed Energy Audit to determine its relative energy efficiency and to determine energy cost reduction opportunities.

An important part of the energy audit process is the interviewing of plant personnel to establish procedures, schedules, and operating details. During the Detailed Energy Audit, personnel from the following departments were interviewed by the participants in the training program:

- Plant engineering
- Operations and maintenance
- Production
- Quality control
- Plant services.

Hagler, Bailly & Company and Reliance Energy Services would like to thank the management of Textile Continental S.A. for allowing the use of its plant for training purposes.

## 1.2 PLANT DESCRIPTION

Textiles Continental S.A. is located on the outskirts of Guayaquil. The company is engaged in the production of textiles for use in the manufacture of apparel and home furnishings. Final products consist of finished textiles comprised of wool, synthetic materials, or blends. A brief process description follows.

Raw materials, in the form of processed fibers (wool, rayon, and polyester), are formed into thread through combing, drawing, spinning, winding, and warping operations. Some sizing is also accomplished, although this depends on the requirements of the final product.

In the weaving department, the yarn is woven into rolls of cloth. From the weaving department, the cloth passes on to the dyeing and finishing department. The actual processes employed to finish the cloth depend on the final product requirement. The plant is capable of performing a number of wet and dry finishing operations, including dyeing, washing, aging, drying, and resin finishing.

The plant consists of one major building, which includes the processing departments, boiler room, chilled water plant, and administrative offices. A separate building houses an employee dining room, which was not included in this audit.

The plant was built in 1972 and 1973. With the major exception of a number of new looms, most of the equipment in the facility was installed during the construction of the facility.

Textiles Continental employs 260 persons.

## 1.3 OPERATING SCHEDULES

The operation of the textile plant is broken into a number of process and service areas. While the operation of the factory as a whole is 24 hours per day, 5 days per week (8:00 a.m. Monday through 8:00 a.m. Saturday), individual operating schedules for the process and service departments are shown in the table below:

| Department | Hours per day | Days per week |
|---|---|---|
| Boiler plant | 17.0 | 5 |
| Chilled water plant | 15.0 | 5 |
| Spinning | 24.0 | 5 |
| Weaving | 24.0 | 5 |
| Finishing | 16.0 | 5 |
| Winding/warping | 24.0 | 5 |
| Inspection | 8.0 | 5 |
| Pre-spinning | 22.5 | 5 |
| Air handling units | 17.0 | 5 |
| Compressed air | 17.0 | 5 |

Normal shift times are 0800 to 1600 hours, 1600 to 0000 hours, and 0000 to 0800 hours, and are of 8 hours duration. The boiler plant and chilled water plant commence operations at least 1 hour before normal first shift start-up time to allow availability of steam chilled water at the start of the production day. Meal times are staggered to eliminate lost production time. The factory operates an average of 50 weeks per year.

## 1.4 PRODUCTION DATA

Textiles Continental S.A. is engaged in the production of finished textile products for apparel and home furnishings. These textiles are produced from wool and/or synthetic materials. The table below presents production statistics for the various plant departments.

| Department | Period | Production | Units |
|---|---|---|---|
| Spinning | 6/83-5/84 | 160,253 | kilograms |
| Weaving | 1/84-8/84 | 772,963 | meters |
| Finishing | 1/83-12/83 | 968,579 | meters |
| Finishing | 1/84-8/84 | 615,135 | meters |

## 1.5 ENERGY CONSUMPTION AND COSTS

The tables below show the energy consumption by fuel type for the year 1983. The costs shown are those that would be incurred by applying the current marginal costs to the actual consumption of fuels and electric energy during that period. Marginal energy costs are those in effect during the third quarter of 1984.

**Consumption and Costs**

| | Units | Consumption | Annual cost (sucres) | Percent of total cost |
|---|---|---|---|---|
| Electricity | kWh | 2,292,400 | 7,564,920 | 50.0 |
| Peak demand | kW | 840 | 665,280 | 4.4 |
| Bunker oil | gal | 317,818 | 4,131,634 | 27.3 |
| Diesel oil | gal | 135,029 | 2,768,095 | 18.3 |
| | | | 15,129,929 | 100.0 |



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**Thermal Equivalents**

| | Equivalent consumption | Marginal energy cost (sucres/GJ) | Percent of total consumption |
|---|---|---|---|
| Electricity | 8,253 | 916.67 | 10.6 |
| Bunker oil | 50,152 | 82.38 | 64.2 |
| Diesel oil | 19,741 | 140.22 | 25.2 |
| | 78,146 | | 100.0 |

**Conversion to GJ**

| | | |
|---|---|---|
| Electricity | - | 0.0036 x kWh |
| Bunker oil | - | 0.1578 x gal |
| Diesel oil | - | 0.1462 x gal |

Electricity is purchased from Empresa Electrica Regional Guayas-Los Rios, under the I-2 rate schedule. The current marginal cost for electricity is S/3.30 per kilowatt hour, inclusive of all adjustments. In addition, there is a demand charge of S/60 per kilowatt per month. A power factor penalty is included in the tariff for industrial users with power factor of less than 0.90; since Textiles Continental maintains power factor above this level, no penalty is incurred. It should be noted, however, that the utility plans to impose a power factor penalty on those users with a power factor below 0.95; this will be implemented in the near future.

Both bunker and diesel oil are purchased from Corporation Estatal Petrolera Ecuatoriana (CEPE). The current cost of diesel oil is S/20.50 per gallon, while that of bunker oil is S/13.00 per gallon. These prices include all delivery and handling charges.

## 1.6 MAJOR ENERGY SYSTEMS

Energy is consumed by several major systems and processes in the plant. A listing of the major energy systems is presented in Appendix 3 of this report. Electricity is used primarily for motive power, compressed air, and lighting. Bunker oil is consumed in a steam boiler plant to produce steam for process use and for generation of chilled water in a steam absorption chilled water plant. Diesel oil is used

primarily for firing a thermal fluid boiler which supplies heat to several processes; diesel oil is also used to power an emergency diesel-electric generator.

The boiler plant is comprised of four identical firetube boilers, each rated at 200 hp, producing steam at a working pressure of 90 to 115 psi. Steam is used for process heating and for generation of chilled water.

Chilled water is produced in a central plant consisting of two steam absorption chillers, each rated at 227 tons. Each chiller is served by an individual cooling tower, located on the roof above the chilled water plant. The cooling towers are cross-connected, allowing either tower to serve either chiller. Chilled water is used exclusively for maintaining temperature and relative humidity conditions in the spinning and weaving sections of the plant. A small amount of chilled water is used to air condition the office areas.

The chilled water is supplied to a series of seven air handling units, which are located on the factory roof. Each of the air handling units cools air by an evaporative process using the chilled water. In addition, each air handling unit is fitted with a steam reheat coil; these are no longer used and have been valved off. Air conditioning of the office and administrative areas is provided by a single fan coil unit, which uses a conventional chilled water coil; this unit operates on 100 percent return air from the offices.

Compressed air is produced by four air compressors, located in the boiler house. Three of these are reciprocating piston compressors; the fourth is a screw compressor. This latter air compressor is not working. In addition to the central compressed air plant, a number of smaller air compressors are situated in the finishing department.

Diesel oil is consumed primarily by two thermal fluid boilers located in the finishing department. These boilers heat Marlotherm S to temperatures in excess of 300°F to perform drying and resin finishing of a range of fabrics.

Diesel oil is also used in two diesel-electric generators located in the boiler house. These generators are water cooled and are used only when normal electric utility service is interrupted. Each of the generators is rated at 568 kW for continuous service, and 625 kW for intermittent operation.

The main use of electricity is for the motors and drives associated with process equipment in the prespinning, spinning, weaving, and finishing departments.

The following sections summarize the findings of the energy audit.

## 2.1 ENERGY MANAGEMENT PROGRAM

Textiles Continental S.A. does not currently have a formal energy management program established. Although energy use by the boilers and electrical systems is monitored on a regular basis, this information appears to be collected for information purposes only. No further use is made of the collected data.

## 2.2 ENERGY UTILIZATION

### 2.2.1 Boiler Plant

The boiler plant consists of four four-pass firetube boilers, manufactured by Cleaver Brooks. The boilers are rated at 200 hp each, and are rated to operate at 150 psi. Actual operating pressure is in the range of 90 to 115 psi. In normal operation, three of the four boilers are on-line at any one time, with the fourth boiler shut down for maintenance. Duty is changed on a monthly basis. In a normal work week, the boilers are fired at 0000 hours Monday and operate through to 0000 hours Tuesday. During the rest of the week, the boilers are fired for 17 hours per day, from about 0700 to 0000 hours. The boilers are shut down for the weekend at 0000 hours Saturday.

Each boiler is fitted with a single pressure jet burner, which fires bunker oil utilizing air atomization. The burners are of the spill and return variety, with the return oil sent back to the fuel oil storage tank. Since this oil has already been heated prior to passage to the burner, it is recommended that the fuel oil system be modified to return the hot oil to the oil feed line before it enters the heat exchanger. Fuel oil is obtained from CEPE (Corporation Estatal Petrolera Ecuatoriana) and stored in two fuel oil tanks located outside of the boiler house. The tanks and fuel oil delivery lines are steam heated to facilitate transport of oil to the boilers. In addition, the bunker oil is further heated in steam heated heat exchangers prior to atomization in the burner; each boiler has an individual heat exchanger.

The boiler plant is in generally good condition, with a high level of maintenance evident. The operation of the boilers is generally good, considering that a high degree of manual control is employed. This can be seen in the summary of boiler combustion efficiency tests, presented in the table below:

**Summary of Boiler Combustion Efficiency Tests**

| Boiler | Boiler combustion efficiency at firing rate | | | |
|---|---|---|---|---|
| | Low | Medium | High | Average |
| 1 | 85.4 | N/A | 86.6 | 86.1 |
| 3 | 88.8 | 85.4 | 86.6 | 86.6 |
| 4 | 88.1 | 84.1 | 86.7 | 86.3 |

Boiler number 2 was not in operation at the time of the plant visit. It should be noted that the boilers in service were found to be operating predominantly at low to middle fire. Overall boiler plant efficiency was found to be 82.2 percent, allowing for blowdown and radiation losses.

Although the boilers have automatic controls for air/fuel ratio, these appear to require adjustment. At the present time, air/fuel ratio is often set manually by the boiler operator after observation of the boiler stack for smoke. In addition, the current boiler controls require that all three of the boilers fire at the same rate to meet the steam demand. Savings can be achieved by conversion of the present controls to lead-lag or sequential controls. In this case, it is possible that only two of the boilers need be kept on-line at a time as the boilers were observed to operate predominantly at mid-fire.

Make-up water is supplied to the boiler in two ways. Part of the make-up water comes directly from a water treatment plant located outside of the boiler house. The balance of the make-up water, which is supplied regardless of feedwater requirements, is obtained in the finishing department. In this area, treated water is used for process cooling and discharged directly to the condensate return system. While this conserves treated water, the temperature throughout the condensate return system is lowered since this discharge cooling water is not very hot. It is recommended that this cooling water be isolated from the condensate return system and stored in a separate tank for use as make-up water as required.

Part of the effect of this cooling of the return condensate is to cause the water temperature within the feedwater tank to be too low. The temperature measured was below 80°C. At such a low temperature, oxygen cannot be eliminated from the feedwater, and boiler damage due to corrosion may occur. It is recommended that the feedwater tank be insulated or, as an alternative, that the feedwater tank be replaced by a deaerator.

Boiler total dissolved solids (TDS) levels were found to be excessive in all three operating boilers. Although the boiler TDS level is monitored by the boiler operators using an electric conductivity meter, this meter was found to be badly out of calibration. The meter was recalibrated against the two TDS meters in Reliance Energy Services' test kits, and the boiler room supervisor was instructed

to begin a specific program to reduce TDS to more acceptable levels. This program required blowing down the boilers more frequently and for longer periods than normally practiced until the blowdown was maintained in the 2,700 to 3,000 ppm total dissolved solids range.

The boiler house staff carry out water quality tests on a daily basis, which is to be commended. It is recommended, however, that additional testing be carried out on a regular basis. Textiles Continental should procure boiler combustion efficiency instrumentation; either a chemical kit, or an electronic efficiency indicator. Tests should be carried out at least once each shift to indicate proper operation of air/fuel ratio control. At the same time, flue gas smoke content, an indicator of incomplete combustion, should be monitored using a True-spot smoke tester. Instrument suppliers are listed in Appendix 27.

Finally, it is recommended that the boiler operators undergo additional training. This recommendation should not be interpreted as a criticism of the boiler room staff. While the staff operate the boilers to a high standard at the present time, additional training will allow more efficient boiler operation.

### 2.2.2 Steam Distribution and Condensate Return System

Steam is distributed from the boiler house via three steam distribution lines. Two of these supply the chiller plant, while the third supplies the dyeing and finishing areas. Steam is distributed at boiler pressure to the point of use. In the case of the chillers, steam pressure is reduced in a pressure reducing station to 0.67 bar.

Condensate is returned to a cistern located outside of the boiler house. An additional cistern for collection of condensate from the finishing department is located outside of the finishing department. This condensate also includes cooling water that is discharged directly into the condensate lines.

The steam and condensate system is in a generally good state of repair with few leaks observed. However, the distribution and return systems are poorly insulated, with long runs of uninsulated pipework observed throughout the plant. Although steam traps were found to be in good condition, a steam trap maintenance program with regular steam trap testing and repair should be instituted.

The cooling water that is discharged into the condensate return system is chemically treated water. While it is a good idea to reuse this water as boiler feed, the manner in which this is currently accomplished leaves much to be desired. The cooling water is discharged to the condensate return system at a much lower temperature than the condensate, causing an overall reduction in condensate return temperature. The cooling water should be isolated from the condensate return and collected in a separate tank to be used as boiler make-up water as required.

In addition, hot condensate was found to be discharged to drain in several areas in the plant; this clean condensate should be returned to the boiler.

### 2.2.3 Electrical Systems

Electrical power enters the textile plant in an area adjacent to the boiler house. Incoming service is reduced to 230 volts for distribution through the plant in two substations located in this area. Plant power factor is maintained at 0.91 by two banks of automatic switching capacitors.

Electrical metering is provided by a utility-supplied meter, located on the incoming power panel.

In addition to the utility supply, the textile plant maintains two diesel-electric generators with a combined capacity of 1,136 kW. These are cooled by two cooling towers located outside of the plant. The generators are used only during periods when utility electric service is not available. Electric utility tariffs prohibit industrial cogeneration. Supplemental electric meters, located on the distribution panels, meter electricity production by the diesel generator.

Electricity is used primarily for motors and drives within the plant.

The electric utility is planning to change the power factor penalty portion of the tariff by imposing the penalty on users with a power factor below 0.95. Textiles Continental should seriously consider increasing capacitor capacity to maintain 0.95 power factor.

### 2.2.4 Compressed Air Systems

Compressed air is generated in four compressors located in the boiler house. Compressors 1 and 2 are identical 10 hp Automan reciprocating compressors, capable of producing 42 cubic feet per minute of compressed air at 171 psi. Compressor 3 is a 15 hp Quincy reciprocating compressor; compressor details are not available as the nameplate had been removed. All three of these compressors were in operation at the time of the site visit; the compressors operate under sequence control. Compressed air was being produced at 110 psi.

The fourth compressor is a relatively new Ingersoll-Rand rotary screw machine using a 25 hp motor. This machine is capable of producing 100 cubic feet per minute of compressed air at 100 psi and incorporates an air dryer. This compressor was not operating owing to a continual malfunction.

Several small compressors are located in the plant, supplying particular process equipment, especially in the finishing department.

A number of compressed air leaks were identified during the site survey. These leaks should be repaired. Because of the difficulty in locating compressed air leaks at times when the plant is operating, it is recommended that a program be instituted to check for leaks during weekend periods when the plant does not normally operate.

### 2.2.5 Chilled Water Plant and Distribution Systems

Chilled water is produced in two Carrier 227 ton steam absorption chillers. The chillers are located in a room on the north side of the plant. Heat is rejected by two Marley 20 hp forced draft cooling towers located on the roof directly above the chillers. The cooling towers are intended to serve individual chillers; however, the condenser water piping is arranged such that the condenser water from either chiller may be routed to either cooling tower.

Chilled water is used primarily for space conditioning (cooling and humidification) in seven air handling units which are described below. An additional fan coil unit is used for office area comfort cooling.

The chilled water is pumped to the seven air handling units, which are also located on the roof above the plant. Cooling and humidification is achieved by spraying the chilled water into the air stream. The chilled water is recovered by a mist eliminator and returned to a reservoir located in the chiller room.

Chilled water temperature is controlled manually by the chiller operators. An economizer control of chilled water temperature, based on outside air temperature, did not appear to be functional.

The chillers are in fair condition. At the time of the plant visits, they were not operating normally due to the failure of one of the chilled water pumps.

Because of the presence of foreign matter in the air, chilled water returned to the reservoir is contaminated by textile dust. While a filter is present at the reservoir for removal of this material, it was found to be shut down at the time of the site visit. The condition of the chilled water reservoir should be monitored regularly by the chiller operator and the filters used more frequently. Foreign matter in the chilled weater can cause fouling of the chiller and chilled water distribution system.

In general, the chilled water distribution system was found to be in good condition. Because of the presence of wind blown dust and dirt in the area of the cooling towers, a condenser water filtration system may be required. This dirt and dust can foul condenser tubes in the chiller, causing a drop in efficiency.

### 2.2.6 Space Conditioning Systems

As noted previously, cooling and humidification of the spinning and weaving areas of the plant is provided by a series of seven Carrier Rotospray air handling units located on the roof. Details of these units are provided in the table below:

| Air handling unit | Service | Fan hp | Fan cfm | Cooling capacity (tons) |
|---|---|---|---|---|
| 1 | Spinning | 40 | 47,000 | 96.5 |
| 2 | Spinning | 25 | 32,000 | 41.0 |
| 3 | Spinning | 25 | 32,000 | 41.0 |
| 4 | Spinning | 25 | 32,000 | 41.0 |
| 5 | Spinning | 25 | 32,000 | 41.0 |
| 6 | Weaving preparation, storage | 30 | 32,000 | 65.0 |
| 7 | Weaving | 40 | 47,000 | 100.0 |

The air handling units are provided with return and fresh air dampers. While the units are capable of motorized damper control, these motors were never fitted. Consequently, the air handling units are manually controlled and operate with 100 percent return air. Temperature and humidity control for the spaces served is provided by thermostats and humidistats located in those areas. These controls were found to be inoperative. In addition, the air handling units are fitted with steam coils for reheating of discharge air; these coils are valved off and not used.

Return air is supplied back to the air handling units through a series of floor mounted grilles. These feed into a series of seven return air plenums located under the floor of the plant.

At the time of the site visit, the chiller plant was not operating correctly, resulting in space temperatures and humidities that did not conform to the standard conditions required in the plant. These are summarized in the table below:

| | Standard conditions | | Measured conditions | |
|---|---|---|---|---|
| Location | Temperature | Relative humidity | Temperature | Relative humidity |
| Spinning department | 75°F | 68% | 75°F-78°F | 69%-87% |
| Weaving preparation | 75°F | 68% | 78°F | 68% |
| Weaving department | 75°F | 68% | 80°F | 68% |

These measurements indicate that it may be possible to operate the facility at temperatures and humidities that would allow the reduced use of the chiller plant.

In addition, depending on outside and inside air conditions, it may be more economical to operate the air handling units with a cooling coil rather than a spray. Because of the abnormal operation of the air handling units at the time of the site visit, however, this measure cannot be quantified, although it deserves further study.

A portion of the return air is provided from the service corridor, located between the process departments and the office and shop areas. This corridor is open to the outside through entranceways at either end, and to air circulation through the unconditioned shops. It is recommended that this corridor be isolated from the conditioned process areas by the installation of doors. The return air ducts located in the corridor should then be blocked off. This will reduce the cooling load on the air handling units and allow a reduction in the amount of air to be moved.

The dyeing and finishing areas are not air conditioned and are separated from the spinning and weaving departments by a double door vestibule. At various times during the plant visit, employees were found to be cooling themselves in the finishing departments by opening both sets of vestibule doors and standing in the breeze. This practice should be discouraged by plant management. Employee comfort cooling in the finishing department can be provided more economically by the installation of spot air blowers located near machine operator stations.

Comfort cooling in the office areas is provided by a fan coil unit located in a small machine room. Air is distributed to the offices by two main ducts. Return air is provided primarily by natural flow through the main corridor into the louvered door of the machine room. This return air is supplemented by a grille located in the wall between the machine room and the adjacent office. Comfort cooling is supplemented by a number of through-the-wall electric air conditions located in the offices and exhausting into the service corridors.

At the time of the site visit, it was observed that an employee had partially blocked off the through-the-wall return grille to the machine room. Since the main corridor is not air conditioned and picks up a substantial heat gain through solar insolation and air infiltration from the outdoors, it is recommended that a new return air duct be installed in the office areas and that air return by natural air flow be eliminated. This may allow the elimination of the use of the electric air conditioners except during extreme temperature/humidity conditioners.

### 2.2.7 Lighting Systems

Lighting in the plant is provided primarily by 8 foot fluorescent tubes mounted two per fixture. These tubes are of standard wattage but are grooved to permit increased light output. Lighting in the drying and finishing departments is provided by mercury vapor bulbs. Office area lighting is provided by 4 foot fluorescent tubes.

A lighting survey of the plant indicated that most areas are underlit, compared with published recommended illumination levels for textile plants. This has apparently caused no problems in the performance of processing operations. The low light levels have been achieved primarily by allowing luminaires to burn out without replacement. It is recommended, however, that ballasts serving these fixtures be disconnected to increase energy savings.

### 2.2.8 Spinning and Weaving Departments

The spinning and weaving departments use electric energy to produce raw textiles from raw material fibers. In the spinning areas, the fibers are formed into threads by a number of mechanical operations. In the weaving department, these threads are formed into the textile matrix, again by mechanical means.

The operations in these departments were examined, and no major observations were noted. All equipment appeared to be operating within normal limits. It should be noted, however, that at the time of the site visit, a number of looms were not in operation owing to a lack of product demand.

### 2.2.9 Dyeing and Finishing Departments

The dyeing and finishing departments process the raw textiles into the finished goods for shipping. A number of processing operations are available, the sequence of which depends on the requirements of the final product.

The finishing department can process the raw textiles in a number of preparatory steps: singeing, shearing, pressing, and washing. Dyeing is accomplished in jiggers or jet dyeing vessels. Drying is accomplished by mechanical and thermal processes. No fabric printing capability exists in the plant.

During the site visit, particular attention was given to the stenter. This machine uses a hot thermal fluid (Marlotherm S) generated in an adjacent thermal fluid boiler to dry or fix fabrics. The thermal fluid passes into a number of stenter zones, and air is circulated around the fabric. The hot air from the stenter is exhausted to the atmosphere. It was observed that this hot air could be used as a source of heat recovery for preheating incoming air to the stenter.

It was also observed that instrumentation for control of the stenter was not available. It is recommended that incoming and leaving fabric moisture content be monitored by means of a moisture detector, and that standards be established for stenter throughput rate and thermal fluid temperature to optimize energy use.

In other areas of the finishing department, it was observed that hot waste liquors are discharged directly to drain. Because of time constraints, it was not possible to measure the quantity and temperature of these streams. It is recommended, however, that further study be made of the potential for waste heat recovery from these streams.



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In the paragraphs above, mention was made of the practice of discharging cooling water into the condensate return system. As noted there, this practice should be eliminated since the temperature of the condensate return is reduced substantially.

## 3.1 ENERGY MANAGEMENT

As noted above, the plant does not currently have an established energy management program. In the paragraphs below, a recommended program is described.

### 3.1.1 Structure

The textile plant should appoint an energy coordinator for the facility. This person would be responsible for all energy-related activities in the facility. It is recommended that either the chief engineer or the plant electrical engineer be given this position. His duties as energy coordinator would be to first develop and maintain a data base of energy-related information, including:

- Major energy-consuming equipment
- Energy consumption and cost data
- Production and environmental data.

His second responsibility would be to monitor the use of energy in the facility. To accomplish this, the plant should acquire additional instrumentation and test equipment, as described below:

- Boiler test kit, including either a chemical or electronic flue gas analyzer, thermocouples, and a smoke tester. Boilers should be tested at least daily to verify that optimum combustion efficiency is being achieved

- Additional electric consumption/demand meters to be installed in each plant department to monitor the use of electricity within the plant

- Steam meters to monitor the use of steam by the chillers and the various process departments and equipment

- Fuel oil meters to monitor the consumption of bunker and diesel oil by the steam and thermal fluid boilers

- A portable thermocouple/temperature indicator and stethoscope to test the proper operation of steam traps

- A portable humidity meter (to replace the inoperative meter owned by the plant) to test moisture content of fabrics being dried in the stenter to prevent overdrying.

Availability of test equipment is indicated in Appendix 27.

### 3.1.2 Monitoring

Using the instrumentation described above, an energy monitoring program can be established. The purpose of this program is to:

- Establish plant norms for energy use within the facility
- Take corrective measures when energy use exceeds the norms.

As an example, the stenter currently is not instrumented, leading to the potential for overdrying. Instruments will allow the establishment of operating practices which ensure that product quality is maintained while using the minimum amount of energy in the processing.

In addition, regular test procedures of equipment and systems in the plant should be established. Steam traps should be tested at least monthly to ensure proper operation. Boilers, as noted above, should be tested at least daily to ensure that optimum combustion efficiency is obtained.

### 3.1.3 Awareness

Employee awareness of the importance of energy should be a major portion of the plant energy management program. This awareness can be achieved by three activities:

- Regular meetings with department heads and supervisors to encourage them to find ways to reduce energy use by more efficient operating practices

- An employee awareness program consisting of posters and information posted around the plant encouraging their cooperation in reducing energy waste

- Training of boiler operators in the efficient and safe operation of boiler systems.

It is important to realize that the full cooperation and participation of everyone in the plant is necessary to achieve the goal of energy conservation. This spans the range from plant management to equipment operators.

## 3.2 ENERGY UTILIZATION

Energy savings shown have been developed on the basis of existing production levels and operating schedules. Cost savings have been calculated on the basis of marginal costs in effect during the third quarter of 1984.

### 3.2.1 Measures with Simple Paybacks Under One Year

The following recommendations for energy cost reduction measures have simple payback periods of less than 1 year at current energy prices.

**Repair of Steam Leaks**

A number of steam leaks were identified during the site visit. These leaks should be repaired as soon as possible. In addition, a regular program of steam system inspection should be instituted to locate faults and schedule their repair in an expeditious manner.

Energy savings: 2,319 GJ/year
Cost savings: $191,039/year
Cost of implementation: minimal
Simple payback period: immediate
Appendix: 13
Fuel saved: bunker oil
Implementation status: recommended.

**Improved Condensate Return**

Clean condensate was observed being sent to drain in the finishing department. The drain was located adjacent to an existing condensate return line. It is a relatively simple matter to extend the existing drain line to feed into the condensate return system.

Energy savings: 25 GJ/year
Cost savings: $2,060/year
Cost of implementation: minimal
Simple payback period: immediate
Appendix: 14
Fuel saved: bunker oil
Implementation status: recommended.

**Repair of Compressed Air Leaks**

A number of compressed air leaks were identified during the site visit. These should be repaired as soon as possible. In addition, it is recommended that a

regular compressed air distribution system maintenance program be instituted. This would involve an inspection of the compressed air system on weekends when the plant is shut down, and air leaks can be located by sound.

Energy savings: 105 GJ/year
Cost savings: $96,250/year
Cost of implementation: minimal
Simple payback period: immediate
Appendix: 16
Fuel saved: electricity
Implementation status: recommended.

**Eliminate Return Air from Service Corridor**

Return air for the seven air handling units serving the production areas is provided partially from the unconditioned service corridor that separates the main process areas from the offices and shops. Elimination of the return air from this area will reduce the volume of air moved through the air handling units, with a reduction in fan motor power requirements. This measure can be implemented by sealing the return air vents in the corridor and by placing plastic strips in the openings between the process area and the corridor. The plastic strips will permit ready access between the areas and reduce air infiltration between them.

Energy savings: 566 GJ/year
Cost savings: $518,835
Cost of implementation: $200,000
Simple payback period: 0.4 years
Appendix: 19
Fuel saved: electricity
Implementation status: recommended.

**Eliminate Return Air from Main Corridor**

Return air for the air handling unit serving the office areas is brought from the front office corridor, which is not air conditioned. The heat gain in this area causes the fan coil unit to operate at higher capacity than necessary. It is recommended that the louvered doors into the corridor be sealed and that air be returned to the fan coil unit directly from the conditioned space. This can be done by installing return air grilles in the walls of the office areas to allow conditioned air to flow back to the fan coil unit. Implementation of the measure should allow the elimination of the use of through-the-wall electric air conditioners in the office areas.

Energy savings: 66 GJ/year
Cost savings: $60,500/year
Cost of implementation: $20,000
Simple payback period: 0.3 years

Appendix: 20
Fuel saved: electricity
Implementation status: recommended.

**Remove Ballasts from Unused Fluorescent Fixtures**

In many areas, fluorescent lights have been allowed to burn out. This has achieved an overall reduction in plant illumination levels without apparent detrimental effects on product quality. It is recommended that fluorescent ballasts be removed from the fixtures as the ballasts consume energy even when the tubes are not live.

Energy savings: 24 GJ/year
Cost savings: $/22,000/year
Cost of implementation: minimal
Simple payback period: immediate
Appendix: 21
Fuel saved: electricity
Implementation status: recommended.

### 3.2.2 Measures with Simple Paybacks Over One Year

The following recommendations for energy cost reduction measures have simple payback periods greater than 1 year at current energy prices.

**Improvement in Steam Boiler Utilization**

The current practice in the textile plant is to operate three boilers at a time at mid-fire. Analysis of steam requirements indicate that individual boiler capacity is sufficient to allow operation of one boiler at high fire and one boiler at mid-fire to meet the plant steam demand. It is recommended that boiler sequencing controls be fitted to allow operation in this fashion. Savings will be achieved primarily by reduction in boiler radiation losses.

Energy savings: 903 GJ/year
Cost savings: $/74,389/year
Cost of implementation: $/500,000
Simple payback period: 6.7 years
Appendix: 8
Fuel saved: bunker oil
Implementation status: recommended.

**Oxygen Trim Control for Steam Boilers**

Improved fuel/air ratio control provided by an oxygen trim system will improve boiler efficiency by about 1 percent. This device monitors oxygen levels in the

flue gases and adjusts boiler combustion air and fuel inputs to provide minimum excess air levels for good combustion. One control unit is required for each boiler.

Energy savings: 603 GJ/year
Cost savings: $/49,675/year
Cost of implementation: $/4,800,000
Simple payback period: 96.6 years
Appendix: 9
Fuel saved: bunker oil
Implementation status: not recommended.

**Insulation of Steam Pipework**

Steam pipework in a number of plant areas was found to be uninsulated. Insulation of this pipework will result in substantial savings.

Energy savings: 4,853 GJ/year
Cost savings: $/399,790/year
Cost of implementation: $/993,300
Simple payback period: 2.5 years
Appendix: 11
Fuel saved: bunker oil
Implementation status: recommended.

**Insulation of Condensate Pipework**

Large areas of the condensate return system were found to be uninsulated, causing a substantial reduction in condensate temperature. These lines should be insulated to reduce heat loss.

Energy savings: 638 GJ/year
Cost savings: $/52,558/year
Cost of implementation: $/401,784
Simple payback period: 7.6 years
Appendix: 12
Fuel saved: bunker oil
Implementation status: recommended.

**Increased Overall Plant Power Factor**

The utility serving the textile plant plans to increase the power factor penalty currently imposed to cover those customers with a power factor below 0.95. The addition of capacitors to the existing power factor control systems will allow the plant to avoid a substantial penalty in 1985.

Energy savings: nil
Cost savings: S/359,109/year
Cost of implementation: S/444,500
Simple payback period: 1.2 years
Appendix: 15
Fuel saved: none
Implementation status: recommended.

**Cooling Tower Filtration**

To reduce the level of suspended solids in the condenser water, it is recommended that a cooling tower filtration system be installed. The filtration system will remove air-borne dust and dirt that may deposit on the condenser surface, causing fouling of the condenser.

Energy savings: 827 GJ/year
Cost savings: S/68,128/year
Cost of implementation: S/2,000,000
Simple payback period: 29.4 years
Appendix: 18
Fuel saved: bunker oil
Implementation status: not recommended.

**Insulation of Thermal Fluid Boiler Overflow Tank**

The thermal fluid boiler overflow tank is not insulated, resulting in excessive heat loss. Insulation of this tank is recommended.

Energy savings: 26 GJ/year
Cost savings: S/3,646/year
Cost of implementation: S/7,150
Simple payback period: 2.0 years
Appendix: 24
Fuel saved: diesel oil
Implementation status: recommended.

**Heat Recovery for Stenter Air Preheating**

Hot exhaust air from the stenter can be used to preheat incoming air by passing the air through a heat exchanger. This measure requires installation of two heat exchangers (one for each exhaust duct), two incoming air blowers, and the associated ductwork.

Energy savings: 375 GJ/year
Cost savings: S/52,583/year
Cost of implementation: S/3,000,000

Simple payback period: 57.1 years
Appendix: 26
Fuel saved: diesel oil
Implementation status: not recommended.

## 3.3 PROJECTS REQUIRING FURTHER STUDY

Several projects have been identified that require further study.

### Increase Feedwater Temperature

Boiler feedwater is provided at 76°C, which is too low to permit removal of oxygen from the feedwater. This can result in corrosion of boiler tubes. To implement this measure, a major renovation of the condensate return system is required to isolate hot and cold discharges. A feasibility study is required to identify all of the sources of cold discharge and their quantities and to specify the control systems required and size of the cold discharge storage vessel.

Energy savings: 1,298 GJ/year
Cost savings: S/106,929/year
Appendix: 10
Fuel saved: bunker oil
Implementation status: requires further study.

### Replacement of Steam Absorption Chillers by Electrical Systems

The existing steam absorption chillers were found to be operating at a particularly low efficiency. Replacement by electric centrifugal chillers with similar capacity will result in net energy savings, but operating costs will be increased due to the difference in unit energy prices of fuel and electricity. In addition, an increase in peak electric demand will be incurred by conversion to an electric system. Because the economics of this item are highly dependent on the relative cost of energy, it is recommended that a feasibility study of this measure be undertaken.

Energy savings: 31,266 GJ/year
Increased demand: 363 kW
Increased cost: S/349,550
Cost of implementation: S/34,559,800
Appendix: 17
Fuel saved: bunker oil
Fuel use increased: electricity
Implementation status: requires further study.

Appendix 1.1

Summary of Savings for Recommended Measures

| Item | Energy data | | | | Cost data | |
|---|---|---|---|---|---|---|
| | Energy saved (GJ) | Cost saved (sucres) | % of savings | | Total cost | Payback years |
| | | | Energy | Cost | | |
| 1. Improvement in steam boiler utilization | 903 | 74,389 | 9.5 | 4.2 | 500,000 | 6.7 |
| 2. Insulation of steam pipework | 4,853 | 399,790 | 51.0 | 22.5 | 993,300 | 2.5 |
| 3. Insulation of condensate pipework | 638 | 52,558 | 6.7 | 3.0 | 401,784 | 7.6 |
| 4. Repair of steam leaks | 2,319 | 191,039 | 24.3 | 10.7 | minimal | immediate |
| 5. Improved condensate return | 25 | 2,060 | 0.3 | 0.1 | minimal | immediate |
| 6. Increased power factor | -- | 359,109 | -- | 20.2 | 444,500 | 1.2 |
| 7. Repair compressed air leaks | 105 | 96,250 | 1.1 | 5.4 | minimal | immediate |
| 8. Eliminate return air from service corridor | 566 | 518,835 | 5.9 | 29.1 | 200,000 | 0.3 |
| 9. Eliminate return air from main corridor | 66 | 60,500 | 0.7 | 3.4 | 20,000 | 0.3 |
| 10. Remove ballasts | 24 | 22,000 | 0.3 | 1.2 | minimal | immediate |
| 11. Insulate thermal fluid tank | 26 | 3,646 | 0.2 | 0.2 | 7,150 | 2.0 |
| **Totals** | **9,525** | **1,780,176** | **100.0** | **100.0** | **2,566,734** | **1.4** |

Appendix 1.2

Summary of Savings for Recommended Measures

| Item | Energy data | | | | Cost data | |
|---|---|---|---|---|---|---|
| | Energy saved (GJ) | Cost saved (sucres) | % of savings | | Total cost | Payback years |
| | | | Energy | Cost | | |
| 1. Improvement in steam boiler utilization | 903 | 74,389 | 8.0 | 3.8 | 500,000 | 6.7 |
| 2. Oxygen trim | 603 | 49,675 | 5.3 | 2.6 | 4,800,000 | 96.7 |
| 3. Increase feedwater temperature** | 1,298* | 106,929* | -- | -- | ** | ** |
| 4. Insulation of steam pipework | 4,853 | 399,790 | 42.8 | 20.5 | 993,300 | 2.5 |
| 5. Insulation of condensate pipework | 638 | 52,558 | 5.6 | 2.7 | 401,784 | 7.6 |
| 6. Repair of steam leaks | 2,319 | 191,039 | 20.5 | 9.8 | minimal | immediate |
| 7. Improved condensate return | 25 | 2,060 | 0.2 | 0.1 | minimal | immediate |
| 8. Increased power factor | -- | 359,109 | -- | 18.4 | 444,500 | 1.2 |
| 9. Repair of compressed air leaks | 105 | 96,250 | 0.9 | 4.9 | minimal | immediate |
| 10. Replace absorption chillers** | 31,266* | (349,550)* | -- | -- | 34,559,800* | -- |
| 11. Cooling tower filtration | 827 | 68,128 | 7.3 | 3.5 | 2,000,000 | 29.4 |
| 12. Eliminate return air from service corridor | 566 | 518,835 | 5.0 | 26.6 | 200,000 | 0.4 |
| 13. Eliminate return air from main corridor | 66 | 60,500 | 0.6 | 3.1 | 20,000 | 0.3 |
| 14. Remove ballasts | 24 | 22,000 | 0.2 | 1.1 | minimal | immediate |
| 15. Insulate thermal fluid tank | 26 | 3,646 | 0.3 | 0.2 | 7,150 | 2.0 |
| 16. Stenter waste heat recovery | 375 | 52,583 | 3.3 | 2.7 | 3,000,000 | 7.0 |
| Totals | 11,330 | 1,950,562 | 100.0 | 100.0 | 12,366,734 | 6.3 |

*Not included in totals.
**Requires further study.

Appendix 2.1

Summary of Savings by Fuel Type for Recommended Measures

| Fuel | Annual savings | GJ savings | Cost savings (sucres) |
|---|---|---|---|
| Electricity | 211,389 kWh | 761 | 1,056,694 |
| Bunker oil | 55,374 gallons | 8,738 | 719,836 |
| Diesel oil | 178 gallons | 26 | 3,646 |
| | | 9,525 | 1,780,176 |

**Conversion to GJ**

Electricity: 0.0036 x kWh
Bunker oil: 0.1578 x gallon
Diesel oil: 0.1462 x gallon.

Appendix 2.2

Summary of Savings by Fuel Type for All Measures

| Fuel | Annual savings | GJ savings | Cost savings (sucres) |
|---|---|---|---|
| Electricity | 441,111 kWh | 1,588 | 1,124,822 |
| Bunker oil | 59,195 gallons | 9,341 | 769,511 |
| Diesel oil | 2,743 gallons | 401 | 56,229 |
| | | 11,330 | 1,950,562 |

Conversion to GJ

Electricity: 0.0036 x kWh
Bunker oil: 0.1578 x gallon
Diesel oil: 0.1462 x gallon.

Appendix 3

Inventory of Major Energy-Consuming Equipment

**Steam Boilers and Ancillaries**

| | | |
|---|---|---|
| Steam boilers (4) | each | 200 hp capacity |
| Feedwater pumps (4) | each | 5.5 kW |

**Compressed Air**

| | | |
|---|---|---|
| Central compressors (4) | total | 45.5 kW |

**Chilled Water System/Environmental System**

| | | |
|---|---|---|
| Steam absorption chillers (2) | each | 227 tons |
| Cooling towers (2) | each | 20 hp |
| Chilled water pumps (2) | each | 50 hp |
| Condenser water pumps (2) | each | 15 hp |
| Rotospray air handling units (2) | each | 40 hp |
| Rotospray air handling units (5) | each | 25 hp |
| Office air handling unit (1) | (estimated) | 5 hp |

**Pre-Spinning**

| | | |
|---|---|---|
| Mixer | | 3.75 kW |
| Combing machines (2) | | 2.95 kW |
| Combing machines (2) | | 3.90 kW |
| Vacia tacho (1) | | 3.75 kW |
| Autoriyulador (1) | | 5.15 kW |
| Preparatia (2) | each | 3.75 kW |
| Preparadora (1) | | 14.3 kW |
| Spinning machines (7) | each | 21.17 kW |

**Spinning**

| | | |
|---|---|---|
| Vaporizor (1) | | 7.4 kW |
| Coning machine (1) | | 8.0 kW |
| Doubling machine (1) | | 3.0 kW |
| Twisting machine (4) | each | 30.0 kW |

Appendix 3 (continued)

Inventory of Major Energy-Consuming Equipment

**Winding/Warping**

| | | |
|---|---|---|
| Warping machine (1) | | 8 kW |
| Sizing machine (1) | | 12.7 kW |
| Winding machine (3) | each | 4.1 kW |
| Cleaner (1) | | 8.0 kW |

**Weaving**

| | | |
|---|---|---|
| Looms (76) | total | 140 kW |

**Dyeing and Finishing**

| | | |
|---|---|---|
| Jet dyeing (2) | each | 57.5 kW |
| Autoclave (1) | | 20.0 kW |
| Bobbin dryer (1) | | 55.0 kW |
| Sucsosa (1) | | 20.0 kW |
| Stenter (1) | | 121.6 kW |
| Lisadora (1) | | 17.4 kW |
| Shearing machine (1) | | 9 kW |
| Press (1) | | 5.5 kW |
| Dekatur (1) | | 25 kW |
| Washer (1) | | 13.5 kW |
| Jigger (1) | | 3.5 kW |
| Condenser (1) | | 26.0 kW |

**Thermal Fluid Baler**

| | | |
|---|---|---|
| Konus thermal fluid boilers (2) | | |
| Circulating pumps (4) | | N/A |

**Electric Generators**

| | | |
|---|---|---|
| Diesel-electric generators (2) | each | 568 kW* |
| Cooling towers for generators (2) | | N/A |
| Cooling water pumps (2) | | N/A |

*Continuous load. Intermittent load rating = 625 kW.

Appendix 4

Steam Boiler Details

Location: Boiler House

Note: Data presented below is typical for all four boilers.

**Boiler data**

| | |
|---|---|
| Manufacturer: | Cleaver-Brooks |
| Year installed: | 1972 |
| Type: | Fire-tube, 4 pass |
| Rating: | 200 hp |
| Medium raised: | Steam |
| Operating pressure: | 115 psi nominal (90-115 psi actual) |

**Boiler data**

| | |
|---|---|
| Fuel fired: | Bunker oil |
| Manufacturer: | Cleaver-Brooks |
| Year installed: | 1972 |
| Type: | Pressure jet |
| Draft: | Forced |
| Atomization: | Air |
| Burner control: | Automatic/manual |
| Draft control: | Automatic/manual |

Appendix 5

Steam Boiler Combustion Tests

Boiler #1

| | Low | Medium | High |
|---|---|---|---|
| Firing rate | | | |
| Percent $CO_2$ | 9.5 | 9.0 | 13.6 |
| Percent $O_2$ | 9.1 | 10.5 | 5.5 |
| Smoke number | 2 | 3 | 5-6 |
| Stack temperature: degree (F) | 363 | N/A | 412 |
| Combustion air temperature (F) | 87.5 | 87.5 | 95.5 |
| Feedwater temperature (F) | 169 | 169 | 169 |
| Pressure psig | 90 | 95 | 115 |
| Draft - in w.g. | -.25 | -1.3 | -2.2 |
| Losses in flue gas (%) | 14.6 | N/A | 13.4 |
| Combustion efficiency (%) | 85.4 | N/A | 86.6 |

Boiler #3

| | Low | Medium | High |
|---|---|---|---|
| Firing rate | | | |
| Percent $CO_2$ | 14.3 | 11 | 14 |
| Percent $O_2$ | 3.5 | 6.4 | 3.3 |
| Smoke number | 8 | 3.5 | 4.33 |
| Stack temperature: degree (F) | 325 | 401 | 437 |
| Combustion air temperature (F) | 99 | 99 | 100 |
| Feedwater temperature (F) | N/A | N/A | N/A |
| Pressure psig | N/A | N/A | N/A |
| Draft - in w.g. | N/A | N/A | N/A |
| Losses in flue gas (%) | 11.2 | 14.6 | 13.7 |
| Combustion efficiency (%) | 88.8 | 85.4 | 86.3 |

Appendix 5 (continued)

Steam Boiler Combustion Tests

Boiler #4

| | Low | Medium | High |
|---|---|---|---|
| Firing rate | | | |
| Percent $CO_2$ | 13 | 9.6 | 14.5 |
| Percent $O_2$ | 5.6 | 7.8 | 1.65 |
| Smoke number | 8 | 3.25 | 4 |
| Stack temperature: degree (F) | 343 | 412 | 428 |
| Combustion air temperature (F) | 99 | 96 | 94 |
| Feedwater temperature (F) | 154 | 151 | 149 |
| Pressure psig | N/A | N/A | 110 |
| Draft - in w.g. | N/A | N/A | N/A |
| Losses in flue gas (%) | 11.9 | 15.9 | 13.3 |
| Combustion efficiency (%) | 88.1 | 84.1 | 86.7 |

Appendix 6

Water Tests and Estimate of Blowdown

The results shown are average for the tests completed during the audit.

| TDS levels measured | ppm measured |
|---|---|
| Mixed condensate and cooling water | 300 |
| Condensate from chillers | 25 |
| Entrance to feedwater tank | 50 |
| Feedwater | 100 |
| Makeup water | 125 |

At entrance to feedwater tank:

$$300\ (X) + 25\ (1 - X) = 50$$

$X = 9$ percent (mixed condensate and cooling water)
$1 - X = 91$ percent (condensate from chillers)

Within feedwater tank:

$$50\ (X) + 125\ (1 - X) = 100$$

$X = 33$ percent (condensate, mixed condensate/cool water)
$1 - X = 67$ percent (make-up water)

Therefore, the feedwater is composed of:

67 percent fresh make-up water
30 percent condensate
3 percent mixed condensate and cooling water

**Blowdown Calculations**

| | | |
|---|---|---|
| Blowdown (average) TDS for three boilers | = | 4,717 ppm (A) |
| Feedwater TDS | = | 100 ppm (B) |
| Percent make-up water | = | 67 percent (C) |

Blowdown rate = (B X C) / (A - B) = (100 x 0.67) / (4,717 - 100)
= 0.0145 kg blowdown/kg steam

$$\text{Percentage blowdown loss} = \frac{\text{Heat content in blowdown}}{\text{Heat needed to raise steam}}$$

Appendix 6 (continued)

Water Tests and Estimate of Blowdown

**Data**

| | | |
|---|---|---|
| Feedwater temperature | = | 76°C |
| Boiler pressure (average condition) | = | 105 psi (7 bar) |
| Make-up water at 36°C | = | 150.4 kJ/kg |
| Boiler efficiency (combustion) | = | 86.3 percent |
| Fuel input to boilers | = | 50,152 GJ/year |
| Heat content of steam at 7 bar | = | 2,769.1 kJ/kg |
| Heat content of feedwater | = | 317.5 kJ/kg |
| Heat content of water at 7 bar | = | 721.4 kJ/kg |
| Heat added to feedwater in boiler | = | 2,769.1 - 317.5 = 2,451.6 kJ/kg |

$$\text{Estimated steam generation per year} = \frac{\text{Fuel input to boiler x boiler efficiency}}{\text{heat required to raise 1 kg steam}}$$

$$= \frac{(50,152)\ (.863)\ (1,000,000)}{(2,451.6)}$$

$$= 17,654,257 \text{ kg/year.}$$

Blowdown = (0.0145) kg/kg steam) X (17,654,257 kg steam) = 255,987 kg/year.

Heat content of blowdown = 721.4 - 150.4 = 571 kJ/kg.

$$\text{Percent blowdown loss} = \frac{\text{(Heat content in blowdown)}}{\text{(heat input to boiler)}}$$

$$= \frac{(571)\ (255,987)\ (100)}{(50,152)\ (1,000,000)}$$

$$= 0.3 \text{ percent.}$$

Appendix 7

Steam Boiler Efficiency

**Estimate of Radiation Loss**

Radiation loss at MCR = 1.5 percent

Average boiler load = 40 percent

Radiation loss = 1.5/0.4 = 3.75 percent.

**Net Boiler Plant Efficiency**

| | | |
|---|---|---|
| | 100.0% | |
| less | 13.7% | (stack loss from Appendix 5) |
| less | 0.3% | (blowdown loss from Appendix 6) |
| less | 3.8% | (radiation loss from above) |
| | 82.2% | Net Boiler Efficiency |

Appendix 8

Improvement in Steam Boiler Utilization

## Data

| | | |
|---|---|---|
| Percent make-up water used | = | 67 percent |
| Feedwater TDS level | = | 100 ppm |
| Boiler fuel consumption | = | 50,152 GJ/year |
| Boiler plant efficiency (overall) | = | 82.2 percent |
| Current radiation loss | = | 3.8 percent |
| Boiler plant hours of operation | = | 4,000 (production hours) |
| Heat content of feedwater | = | 317.5 KJ/kg |
| Heat content of steam at 7 bar | = | 2,768.1 KJ/kg |
| Boiler operating capacity | = | 200 hp (each) |

## Assumptions

Boiler TDS level will be reduced to 3,000 ppm.

## Calculations

### Energy Savings

New blowdown rate (at 3,000 ppm)

$$= \frac{(\text{\% make-up water})\ (\text{feedwater TDS})}{(\text{blowdown TDS} - \text{feedwater TDS})}$$

$$= \frac{(67)\ (100)}{(3{,}000 - 100)}$$

$$= 2.3 \text{ percent.}$$

Steam generation (annual)

$$= \frac{(1 - \text{\% blowdown})\ (\text{boiler fuel})\ (\text{boiler efficiency})\ (10^6)}{(\text{heat required to generate 1 kg steam})}$$

$$= \frac{(1 - 0.023)\ (50{,}152)\ (0.822)\ (10^6)}{(2{,}768.1 - 317.5)}$$

$$= 16{,}435{,}473 \text{ Kg/year.}$$

Appendix 8 (continued)

Improvement in Steam Boiler Utilization

Average steam load

$$= \frac{\text{Annual steam production}}{\text{annual hours of operation}}$$

$$= \frac{16,435,473}{4,000}$$

= 4,109 kg/hr = 262 hp

Assume one boiler operating at full load and one boiler operating at mid-load.

**Radiation Loss After Rescheduling**

Lead boiler = (1.5%)/(1.00) = 1.5%
Lag boiler = (1.5%)/(0.50) = 3.0%.

Weighted average radiation loss = 2.0%.

Savings due to reduction in radiation loss =
3.8% - 2.0% = 1.8%.

Annual fuel savings

= (0.018) (50,152) = 903 GJ/year.

**Cost Savings**

= (GJ/year) (Sucres/GJ)

= (903) (82.38)

= S/74,389 per year.

**Cost of Implementation**

This strategy can be achieved by fitting sequencing controls to the boilers at a cost of S/500,000.

Appendix 8 (continued)

Improvement in Steam Boiler Efficiency

**Simple Payback**

$$= \frac{\text{Cost of implementation}}{\text{annual savings}}$$

$$= \frac{500{,}000}{74{,}389}$$

$$= 6.7 \text{ years.}$$

**Energy savings = 903 GJ/year**
**Cost savings = S/74,389/year**
**Cost of implementation = S/500,000**
**Simple payback period = 6.7 years.**

Appendix 9

Oxygen Trim Control for Steam Boilers

## Assumption

Fuel/air ratio control will improve boiler plant efficiency by 1 percent.

## Data

Boiler efficiency = 82.2 percent
Boiler fuel use = 50,152 GJ/year.

## Calculations

**Energy Savings**

$$= \frac{\text{(New efficiency - old efficiency)}}{\text{(new efficiency)}} \text{ (boiler fuel use)}$$

$$= \frac{(0.832 - 0.822)}{(0.832)} (50,152)$$

= 603 GJ/year.

**Cost Savings**

= (GJ/year) (Sucres/GJ)

= (603) (82.38)

= S/49,675/year.

**Cost of Implementation**

The cost of implementation is estimated at S/1,200,000 per boiler, for a total of S/4,800,000.

Appendix 9 (continued)

Oxygen Trim Control for Steam Boilers

**Simple Payback**

$$= \frac{\text{Cost of implementation}}{\text{annual savings}}$$

$$= \frac{4{,}800{,}000}{49{,}675}$$

$$= 96.6 \text{ years.}$$

**Energy savings = 603 GJ/year**
**Cost savings = S/49,675/year**
**Cost of implementation = S/4,800,000**
**Simple payback period = 96.6 years.**

Increase Feedwater Temperature

Energy savings can be achieved by increasing feedwater temperature to 95°C.

**Data**

Feedwater temperature = 76°C (current)

Annual steam generation = (16,435,473 kg/year (Appendix 8) (after reduction of boiler TDS to 3,000 ppm)

Boiler efficiency = 82.2 percent.

**Calculation**

**Energy Savings**

Enthalpy difference between feedwater at 76°C and feedwater at 95°C = 79 kJ/kg.

Energy savings

$$= \frac{\text{(Steam production) (enthalpy difference)}}{10^6}$$

$$= \frac{(16,435,473)\ (79)}{10^6}$$

= 1,298 GJ/year.

**Cost Savings**

= (GJ/year) (Sucres/GJ)

= (1,298) (82.38)

= S/106,929 per year.

Increase Feedwater Temperature

**Cost of Implementation**

The cost of implementation includes a major renovation of the condensate return system, including control valves and a cold discharge storage vessel. Because of the complex nature of this measure, a feasibility study is required.

**Energy savings = 1,298 GJ/year**
**Cost savings = $106,929/year.**

Appendix 11

Insulation of Steam Pipework

**Assumption**

Reduction in heat loss from bare pipe by insulating = 90 percent.

**Data**

Boiler plant hours of operation = 4,600 hours/year

Boiler plant efficiency = 82.2 percent

Uninsulated pipework details: see table attached.

**Calculations**

**Energy Savings**

$$= \frac{\text{(Heat loss coefficient) (length) (hours/year) (0.90)}}{\text{(boiler efficiency) } (10^6)}$$

Boiler plant to chillers

$$= \frac{(2{,}383)\ (76)\ (4{,}600)\ (0.90)}{(0.822)\ (10^6)}$$

= 912 GJ/year.

Finishing department to chillers

$$= \frac{(2{,}383)\ (50)\ (4{,}600)\ (0.90)}{(0.822)\ (10^6)}$$

= 600 GJ/year.

Appendix 11 (continued)

Insulation of Steam Pipework

Spinning department to chillers

$$= \frac{(2{,}511)\ (25)\ (4{,}600)\ (0.90)}{(0.822)\ (10^6)}$$

= 316 GJ/year.

Boiler plant to finishing department

$$= \frac{(2{,}383)\ (252)\ (4{,}600)\ (0.90)}{(0.822)\ (10^6)}$$

= 3,025 GJ/year.

Total savings

= 4,853 GJ/year.

**Cost Savings**

= (GJ/year) (Sucres/GJ)

= (4,853) (82.38)

= S/399,790 per year.

**Cost of Implementation**

The cost of implementation is estimated as follows:

| Pipe diameter | Length required | Unit cost | Total cost |
|---|---|---|---|
| 100 mm | 160 m | S/1,923/m | S/307,680 |
| 150 mm | 260 m | S/2,637/m | S/685,620 |
| | | | $/993,300 |

Appendix 11 (continued)

Insulation of Steam Pipework

**Simple Payback Period**

$$= \frac{\text{Cost of implementation}}{\text{annual savings}}$$

$$= \frac{993,300}{399,790}$$

$$= 2.5 \text{ years.}$$

**Energy savings = 4,853 GJ/year**
**Cost savings = S/399,790 per year**
**Cost of implementation = S/993,300**
**Simple payback period = 2.5 years.**

Uninsulated Steam Pipework Details

| Location | Length (m) | Diameter (mm) | Temperature (°C) Ambient | Temperature (°C) Pipe surface | Heat loss coefficient (kJ/m/hr) |
|---|---|---|---|---|---|
| Boiler plant to chillers | 76 | 100 | 29 | 149 | 2,383 |
| Finishing department to chillers | 50 | 100 | 29 | 149 | 2,383 |
| Spinning department to chillers | 25 | 100 | 24 | 149 | 2,511 |
| Boiler plant to finishing department | 252 | 150 | 29 | 149 | 2,383 |

Appendix 12

Insulation of Condensate Pipework

**Assumptions**

Reduction in heat loss from bare pipe by insulating = 90 percent.

**Data**

Boiler plant hours of operation = 4,600 hours/year

Boiler plant efficiency = 82.2 percent

Uninsulated pipework details: see table attached.

**Calculations**

**Energy Savings**

$$= \frac{\text{(Heat loss coefficient) (length) (hours/year) (0.90)}}{\text{(boiler efficiency) } (10^6)}$$

Chiller condensate return to feedwater tank

$$= \frac{(459)\ (155)\ (4{,}600)\ (0.90)}{(0.822)\ (10^6)}$$

= 358 GJ/year.

Return from finishing department

$$= \frac{(208)\ (60)\ (4{,}600)\ (0.90)}{(0.822)\ (10^6)}$$

= 63 GJ/year.

Return to feedwater tank

$$= \frac{(318)\ (41)\ (4{,}600)\ (0.90)}{(0.822)\ (10^6)}$$

= 66 GJ/year.

Insulation of Condensate Pipework

Boiler house

$$= \frac{(118)\ (12.2)\ (4{,}600)\ (0.90)}{(0.822)\ (10^6)}$$

= 7 GJ/year.

Feedwater tank

$$\text{surface} = \frac{(1{,}755)\ (2.1)\ (4{,}600)\ (0.90)}{(0.822)\ (10^6)}$$

= 19 GJ/year.

$$\text{sides} = \frac{(1{,}015)\ (2)\ (0.45)\ (4{,}600)\ (0.90)}{(0.822)\ (10^6)}$$

= 5 GJ/year.

Total for four units = 96 GJ/year.

Feedwater pipe

$$= \frac{(199)\ (5)\ (4{,}600)\ (0.90)}{(0.822)\ (10^6)}$$

= 5 GJ/year.

Total for four units = 20 GJ/year.

Feedwater filter

$$\text{surface} = \frac{(877)\ (1.5)\ (4{,}600)\ (0.90)}{(0.822)\ (10^6)}$$

= 7 GJ/year.

Total for four units = 28 GJ/year.

Insulation of Condensate Pipework

Total savings

= 638 GJ/year.

**Cost Savings**

= (GJ/year) (Sucres/GJ)

= (638) (82.38)

= S/52,558 per year.

**Cost of Implementation**

The cost of implementation is estimated as follows:

| Pipe diameter | Length required | Unit cost | Total cost |
|---|---|---|---|
| 25 mm | 33 m | S/840/m | S/27,720 |
| 63.5 mm | 265 m | S/1,319/m | S/337,664 |
| feedwater filter | 41 $m^2$ | S/1,300/$m^2$ | S/5,200 |
| feedwater tanks (4) | 24 $m^2$ | S/1,300/$m^2$ | S/31,200 |
| | | | S/401,784 |

**Simple Payback Period**

$$= \frac{\text{Cost of implementation}}{\text{annual savings}}$$

$$= \frac{401,784}{52,558}$$

= 7.6 years.

Appendix 12 (continued)

Insulation of Condensate Pipework

It should be noted that these savings are based on condensate return at the temperatures measured. Increase of condensate temperature to 80°C by implementation of other measures will result in the following savings:

Energy savings = 839 GJ/year
Cost savings = S/69,117 per year.

This will result in a simple payback period of 5.8 years.

**Energy savings = 638 GJ/year**
**Cost savings = S/52,558 per year**
**Cost of implementation = S/401,784**
**Simple payback period = 7.6 years.**

Uninsulated Condensate Pipework Details

| Location | Length (m) | Diameter (mm) | Temperature (°C) Ambient | Temperature (°C) Pipe surface | Heat loss coefficient (kJ/m/hr) |
|---|---|---|---|---|---|
| Chiller condensate return to feedwater tank | 155 | 63.5 | 34 | 80 | 459 |
| Return from finishing department | 60 | 63.5 | 34 | 57 | 208 |
| Return to feedwater tank | 41 | 63.5 | 34 | 68 | 318 |
| Boiler house | 12.2 | 25 | 34 | 61 | 118 |
| Feedwater tank (4) | 2.1 | 760 | 34 | 61 | 1,785/1,015* |
| Feedwater pipe (4) | 5 | 25 | 34 | 76 | 199 |
| Feedwater filter (4) | 1.5 | 200 | 34 | 68 | 877 |

*Coefficient for vertical sides in KJ/hr/$m^2$.

Appendix 13

Repair of Steam Leaks

## Data

Boiler plant hours of operation = 4,600 hours/year

Boiler plant efficiency = 82.2 percent

Heat required to raise steam from make-up water = 2,769.1 - 150.4 = 2,618.7 kJ/kg.

| Steam leaks | Location | Pressure | Size of orifice |
|---|---|---|---|
| 1 | Finishing department steam trap | 7 bar | 5 mm |
| 2 | Valve them machine #2 | 7 bar | 7 mm |

## Calculations

### Energy Savings

Leakage rate (kg/hr) = $0.4\ d^2\ (p + 1)$

Leak #1 = $(0.4)\ (5)^2\ (7 + 1) = 80$ kg/hr

Leak #2 = $(0.4)\ (7)^2\ (7 + 1) = 157$ kg/hr.

### Savings

$$= \frac{\text{(Leakage rate) (heat input) (hours/year) (load factor)}}{\text{(boiler efficiency) } (10^6)}$$

$$= \frac{(80)\ (2{,}618.7)\ (4{,}600)\ (0.8)}{(0.822)\ (10^6)} + \frac{(157)\ (2{,}618.7)\ (4{,}600)\ (0.6)}{(0.822)\ (10^6)}$$

$$= 938 + 1{,}381 = 2{,}319 \text{ GJ/year.}$$

Appendix 13 (continued)

Repair of Steam Leaks

**Cost Savings**

= (GJ/year) (Sucres/GJ)

= (2,319) (82.38)

= S/191,039 per year.

**Cost of Implementation**

The cost of implementation is minimal as these are minor repairs.

**Energy savings = 2,319 GJ/year**
**Cost savings = S/191,039/year**
**Cost of implementation = minimal**
**Simple payback period = immediate.**

Appendix 14

Improved Condensate Return

Clean condensate was observed being sent to drain in the finisning department. The drain was located adjacent to an existing condensate return line.

**Data**

Boiler plant hours of operation = 4,600 hours/year

Boiler plant efficiency = 82.2 percent

Heat required to raise make-up water temperature to feedwater temperature
= 317.5 - 150.4 = 167.1 kJ/kg

Measured rate of flow = 33 kg/hour.

**Calculation**

**Energy Savings**

$$= \frac{\text{(Flow rate) (hours/year) (heat content) (load factor)}}{\text{(boiler efficiency) } (10^6)}$$

$$= \frac{(33)\ (4{,}600)\ (167.1)\ (0.8)}{(0.822)\ (10^6)}$$

= 25 GJ/year.

**Cost Savings**

= (GJ/year) (Sucres/GJ)

= (25) (82.38)

= S/2,060 per year.

Appendix 14

Improved Condensate Return

**Cost of Implementation**

The cost of implementation is estimated to be minimal since this only requires that a length of pipework be connected to an existing condensate return line.

**Energy savings = 25 GJ/year**
**Cost savings = S/2,060/year**
**Cost of implementation = minimal**
**Simple payback period = immediate.**

Appendix 15

Increased Overall Plant Power Factor

The textile plant currently maintains a power factor of 0.91 by means of installed capacitors. The electric utility plans to change their tariffs to impose a penalty on users with a power factor below 0.95. Addition of extra capacitor capacity will alleviate the new power factor penalty.

## Data

Calculation based on 1983-1984 monthly kilowatt-hour consumption and costs:

| | | |
|---|---|---|
| Current kilowatt-hour charge | = | S/3.30 per kWh |
| Current kilowatt demand charge | = | S/60 per kW per month |
| Annual kilowatt-hour consumption | = | 2,292,400 kWh |
| Monthly peak electric demand | = | 840 kW |

## Calculations

**Cost Savings (based on marginal costs)**

Annual cost at current tariff:

= (kWh) (Sucres/kWh) + (kW) (12) (Sucres/kW)

= (2,292,400) (3.30) + (840) (60) (12)

= S/8,169,720.

Annual cost at proposed tariff:

= (current cost) (0.95/0.91)

= S/8,528,829.

Difference in annual cost = S/359,109.

Appendix 15 (continued)

Increased Overall Plant Power Factor

**Size of Capital Required**

With a connected load of 1,000 kW, the current reactive power is:

Reactive power (as found) = (kW (tan (arc cos r))); r = 0.91

= 1,000 (0.456)

= 456 kVAr.

New reactive power = kW (tan (arc cos r)); r = 0.95

= 1,000 (0.329)

= 329 kVAr.

Capacitor capacity required = 127 kVAr.

**Cost of Implementation**

The installed cost of capacitors is estimated at S/3,500 per kVAr. The total cost would then be S/444,500.

**Simple Payback Period**

$$= \frac{\text{Cost of implementation}}{\text{annual savings}}$$

$$= \frac{444,500}{359,109}$$

= 1.2 years.

**Energy savings = nil**
**Cost savings = S/359,109/year**
**Cost of implementation - S/444,500**
**Simple payback period = 1.2 years.**

Appendix 16

Repair of Compressed Air Leaks

**Assumptions**

Compressor utilization factor = 50 percent
Motor load factor = 80 percent.

**Data**

Flow through orifice ($m^3$/min) = (0.0094) $d^2$ (p + 1) d = m, p = bar.

Compressor operating hours = 5,625 hours/year.

**Compressed Air Leaks**

| Location | Size of leak (mm) | Pressure (bar) | Flow ($m^3$/min) |
|---|---|---|---|
| Spinning | 1 | 6.2 | 0.068 |
| Weaving (5 leaks) | 1 | 6.2 | 0.340 |
| Dyeing | 1 | 6.2 | 0.068 |
| Atte #7 | 0.2 | 1.0 | 0.001 |
| Atte #5 | 0.2 | 1.0 | 0.001 |
| Compressor #4 | 4 | 7.6 | 1.293 |
| | | | 1.771 |

| | | | |
|---|---|---|---|
| Compressor capacity | #1 | 42 $ft^3$/min (power input) | 10 hp |
| | #2 | 42 $ft^3$/min | 10 hp |
| | #3 | 42 $ft^3$/min (assumed) | 15 hp |
| | | 126 $ft^3$/min | 35 hp |

Appendix 16 (continued)

Repair of Compressed Air Leaks

## Calculations

**Energy Savings**

$$\text{Compressor power requirement} = \frac{(hp)\ (kW/hp)\ (0.8)}{(cfm)}$$

$$= \frac{(35)\ (0.746)\ (0.8)}{(26)}$$

$$= 0.166\ kW/cfm.$$

Leakage rate = 1.771 $m^3$/min x 35.31 = 62.53 $ft^3$/min.

Losses through leaks

= (leakage rate) (compressor power) (hours/year) (load factor)

= (62.53) (0.166) (5,625) (0.5)

= 29,193 kWh/year x .0036 = 105 GJ/year.

**Cost Savings**

= (GJ/year) (Sucres/GJ)

= (105) (916.67)

= S/96,250 per year.

**Cost of Implementation**

The cost of implementation of repairing compressed air leaks is minimal.

**Energy savings = 1105 GJ/year**
**Cost savings = S/96,250/year**
**Cost of implementation = minimal**
**Simple payback period = immediate.**

Appendix 17

Replacement of Steam Absorption Chillers by Electrical Systems

**Standards**

Conversion of gals to kg = 3.773
Conversion of hp to kW = 0.746
1 ton refrigeration = 12,000 Btu/hour.

**Assumptions**

Enthalpy change from 0.8 bar steam to condensate = 2,279 KJ/kg
C.O.P. (compressor only) of a modern centrifugal unit = 4.4
Electrical motor efficiencies = 85 percent
Chilled water pumping system remains unchanged.

The following data is typical:

| | Absorption M/C | Electrical M/C |
|---|---|---|
| Condenser waterfeed losses (ft $H_2O$): | | |
| Condenser | 30 | 30 |
| Tower | 10 | 10 |
| Line losses | 10 | 10 |
| Centrifugal pump efficiency (%) | 65 | 65 |
| Average load factor: | | |
| Refrigeration | 0.67 | 0.67 |
| Water circulation | 0.67 | 0.67 |
| System internal pumping power (hp) | 3.5+(0.017/ton) | 0 |

**Data**

| | | |
|---|---|---|
| Chiller reference | = | Chiller #1 and #2 |
| Capacity of chiller unit | = | 454 tons (total) |
| Hours of cooling system use | = | 3,750 hours/year |
| Boiler efficiency | = | 82.2 percent |
| Condenser water flow | = | 1,680 gpm |
| Absorption chiller average steam input | = | 24 lbs/ton = 10.9 kg/ton |
| Cooling tower fan power | = | 40 hp (total) |
| Condenser pump power | = | 30 hp (total) |
| Chiller water pump power | = | 100 hp (total) |

Appendix 17 (continued)

Replacement of Steam Absorption Chillers by Electrical Systems

**Sample Calculations**

Total energy savings = Savings at chiller unit*

Savings at chiller unit = Energy use on absorption unit - energy use on electrical chiller

Energy use on absorption chiller = Energy to (internal pumps + steam used)

Internal pump cons.

$$= \frac{(\text{hp})\ (\text{cooling hours})\ (0.67)\ (0.746)\ (0.0036)}{(\text{motor efficiency})}$$

$$= \frac{(3.5 + 0.017/\text{ton})\ (3{,}750)\ (0.67)\ (0.746)\ (0.0036)}{(0.85)}$$

$$= 27.78\ \text{GJ/yr} + 0.135\ \text{GJ/yr/ton}$$

Steam used = (kg/ton) (cooling season) (average load factor)

= (10.9) (3,750) (0.67)

= 27,386 kg/ton/yr

Energy in steam = (steam KJ/kg) (kg/ton/yr)

$$= (2{,}279)\ (27{,}386) \times 10^{-6}$$

= 62.4 GJ/yr/ton

Energy to raise steam

$$= \frac{\text{Energy in steam}}{\text{Weighted boiler combustion efficiency}}$$

$$= \frac{62.4\ \text{GJ/yr/ton}}{0.822}$$

= 75.9 GJ/yr/ton

*Neglecting savings on boiler ancillaries, etc.

Appendix 17 (continued)

Replacement of Steam Absorption Chillers by Electrical Systems

Energy use on electrical chiller $= \frac{(12{,}000)\ (\text{cooling hours})\ (\text{average load factor})}{(\text{C.O.P.}) \times 10^6}$

$= \frac{(12{,}000)\ (3{,}750)\ (0.67)\ (1.055)}{4.4 \times 10^6}$

= 7.23 GJ/yr/ton

**Energy Savings**

Boiler fuel savings = (unit capacity) (energy to raise steam)

= (454) (75.9 GJ/yr/ton)

= 34,459 GJ/year

Increased electrical use = Chiller electric use - intenral pumping use

= (7.23) (454) - (27.78 + (0.135) (454))

= 3,193 GJ/yr

Overall energy savings = 34,459 - 3,193

= 31,266 GJ/yr.

**Energy Cost Savings**

= (Fuel oil GJ/yr) (Sucres/GJ) - (electric GJ/yr) (Sucres/GJ)

= (34,459) (82.38) - (3,193) (916.67)

= 2,838,732 - 2,926,927

= -S/88,195/year (additional cost)

Appendix 17 (continued)

Replacement of Steam Absorption Chillers by Electrical Systems

**Increased Electric Demand**

$$= \frac{(\text{capacity})\ (12{,}000\ \text{Btu/ton})}{(3{,}413\ \text{Btu/kW})\ (\text{C.O.P.})}$$

$$= \frac{(454)\ (12{,}000)}{(3{,}413)\ (4.4)}$$

$$= 363\ \text{kW}$$

Monthly electric power demand can increase by a total of 363 kW due to use of electric chiller.

**Demand Cost**

= (Sucres/kW) (kW/month) (12 months/year)

= (60) (363) (12)

= S/261,360

**Total Cost Savings**

= -88,195 - 261,360

= -S/349,550 (increased cost)

**Cost of Implementation**

The cost of implementation of two 225-ton electric centrifugal chillers is estimated at S/31,803,800, with installation estimated at S/2,756,000; the total installed cost is estimated at S/34,559,800.

Because of the dependence of this item on the relative costs of energy, it is recommended that a feasibility study be conducted.

**Energy savings: 31,266 GJ/year**
**Increased demand: 363 kW**
**Increased costs: S/349,550**
**Cost of implementation: S/34,559,800.**

Appendix 18

Cooling Tower Filtration

**Assumptions**

| | | |
|---|---|---|
| Average load factor | = | 0.67 |
| Average fouling factor with filtration | = | 0.001 |

**Standards**

| | | |
|---|---|---|
| Enthalpy of steam from 0.8 bar to condensate | = | 2,279 KJ/kg |

**Data**

| | | |
|---|---|---|
| Cooling system reference | = | both chillers and cooling towers |
| Capacity of chiller units | = | 454 tons (total) |
| Hours of cooling system use | = | 3,750 hours |
| Weighted boiler combustion efficiency | = | 82.2 percent |
| Absorption unit steam input | = | 10.9 kg/ton |

**Sample Calculations**

Incorporation of a filtration system downstream from the cooling towers will significantly reduce the concentration of suspended solids inherent in the system. Energy savings have been calculated assuming that without a filtration system, an average increase in fouling factor from 0.001 to 0.002 occurs over a normal cooling season. Extra power required of an unfiltered system over a filtered system is 2.4 percent for an absorption unit.

**Energy Savings**

$$= \frac{(0.024)\ (\text{capacity})\ (\text{kg/ton})\ (\text{KJ/kg})\ (\text{hours/year})\ (\text{load factor})}{(\text{boiler efficiency})\ (10^6)}$$

$$= \frac{(0.024)\ (454)\ (10.9)\ (2{,}279)\ (3{,}750)\ (0.67)}{(0.822)\ (10^6)}$$

$$= 827 \text{ GJ/year.}$$

Appendix 18 (continued)

Cooling Tower Filtration

**Cost Savings**

= (GJ/yr) (Sucres/GJ)

= (827) (82.38)

= S/68,128/year

**Cost of Implementation**

The implementation cost of two tower filtration systems is estimated to be S/2,000,000.

**Simple Payback Period**

$$= \frac{\text{Cost of implementation}}{\text{annual savings}}$$

$$= \frac{2{,}000{,}000}{68{,}128}$$

= 29.4 years.

**Energy savings = 827 GJ/year**
**Cost savings = S/68,128/year**
**Cost of implementation = S/2,000,000**
**Simple payback period = 29.4 years.**

Appendix 19

Eliminate Return Air from Service Corridor

Return air to the seven air handling units is provided from unconditioned as well as conditioned plant areas. Elimination of return air from those areas will reduce air volume requirements for cooling and humidification.

**Assumptions**

10 percent of return air is supplied from unconditioned space.
Motor efficiency = 85 percent.
Fan load factor = 75 percent.

**Data**

| Air handling unit | Measured air flow cfm | Fan motor hp |
|---|---|---|
| 1 | 47,000* | 40 |
| 2 | 24,811 | 25 |
| 3 | 25,392 | 25 |
| 4 | 26,997 | 25 |
| 5 | 23,621 | 25 |
| 6 | 24,660 | 30 |
| 7 | 44,712 | 40 |
| | 217,193 | 210 |

*Rated, unit not operating at time of test.

Hours of operation = 4,250 hours/year.

**Calculations**

**Energy Savings**

Savings will be achived by reducing fan speed.
Fan law: speed is directly proportional to volume of air moved.
New speed: 0.90 x old speed.
Fan law: power is proportional to cube of speed.

Appendix 19 (continued)

Eliminate Return Air from Service Corridor

$$\text{New power} = (\text{old power}) \frac{(\text{new speed})^3}{(\text{old speed})^3}$$

$$= (210 \text{ hp}) \ (0.90)^3 = 153 \text{ hp.}$$

Horsepower savings = 210 - 153 = 57 hp.

Energy savings

$$= \frac{(\text{hp}) \ (\text{hours/year}) \ (0.002648 \text{ GJ/hp-hr}) \ (\text{load factor})}{(\text{motor efficiency})}$$

$$= \frac{(57) \ (4{,}250) \ (0.002648) \ (0.75)}{(0.85)}$$

= 566 GJ/year

**Cost Savings**

= (GJ/year) (Sucres/GJ)

= (566) (916.67)

= S/518,835/year

**Cost of Implementation**

This measure can be implemented by sealing the return air grates in the corridor and by installing plastic strips in the openings between the plant and the corridor. The plastic strips will allow free access between the areas, but will reduce air infiltration from the corridor into the plant. The implementation cost is estimated to be S/200,000.

Appendix 19 (continued)

Eliminate Return Air from Service Corridor

**Simple Payback Period**

$$= \frac{\text{Cost of implementation}}{\text{annual savings}}$$

$$= \frac{200,000}{518,835}$$

$$= 0.4 \text{ years.}$$

**Energy savings = 566 GJ/year**
**Cost savings = S/518,835/year**
**Cost of implementation = S/200,000**
**Simple payback period = 0.4 years.**

Appendix 20

Eliminate Return Air From Main Corridor

Return air fo the office fan coil air conditioning unit is provided by natural flow through the main corridor, which is not space conditioned and is rarely occupied. By providing return air directly from the conditioned space, the use of incremental room air conditioning units can be eliminated.

## Assumptions

Room air conditioner hours of operation = 2,500 hours/year
Compressor load factor = 70 percent
Room air conditioner capacity = 6 tons (estimated)
Room unit C.O.P. = 2.0.

## Calculations

**Energy Savings**

$$= \frac{(\text{Capacity})\ (12{,}660\ \text{KJ/ton})\ (\text{load factor})\ (\text{hours of use})}{(\text{C.O.P.})\ (10^6)}$$

$$= \frac{(6)\ (12{,}660)\ (0.70)\ (2{,}500)}{(2)\ (10^6)}$$

$$= 66\ \text{GJ/year}$$

**Cost Savings**

= (GJ/year) (Sucres/GJ)

= (66) (916.67)

= S/60,500/year

**Cost of Implementation**

Return air can be returned to the fan coil unit by blocking or replacing existing louvered doors and installing open grills in the walls between the various rooms that are cooled. The cost is estimated to be less than S/10,000. Balancing and adjusting of existing supply ductwork may also be required at an additional cost of S/10,000.

Appendix 20

Eliminate Return Air From Main Corridor

**Simple Payback Period**

$$= \frac{\text{Cost of implementation}}{\text{annual savings}}$$

$$= \frac{20,000}{60,500}$$

$$= 0.3 \text{ years}$$

**Energy savings = 66 GJ/year**
**Cost savings = S/60,500/year**
**Cost of implementation = S/20,000**
**Simple payback period = 0.3 years.**

Appendix 21

Remove Ballasts from Unused Fluorescent Fixtures

In many areas in the plant, fluorescent light fixtures are unused, but ballasts are still live. These ballasts should be disconnected.

**Data**

| Area | Number of ballasts | Hours of use per year |
|---|---|---|
| Boiler house | 2 | 4,600 |
| Spinning | 43 | 4,000 |
| Thread stores | 2 | 3,000 |
| Dye stores | 2 | 3,000 |
| Parts stores | 2 | 6,000 |
| Winding | 25 | 6,000 |
| Loom shed | 16 | 6,000 |

Ballast power consumption = 15 watts.

**Calculations**

**Energy Savings**

$$= \frac{(\text{number of ballasts})\ (\text{watts/ballast})\ (\text{hours/year})\ (3.6 \times 10^{-3})}{1{,}000}$$

$$= \frac{((2)\ (4{,}600) + (43)\ (4{,}000) + (4)\ (3{,}000) + (43)\ (6{,}000))\ (15)\ (3.6 \times 10^{-3})}{1{,}000}$$

$$= 24 \text{ GJ/year}$$

**Cost Savings**

= (GJ/year) (Sucres/GJ)

= (24) (916.67)

= S/22,000/year.

Appendix 21 (continued)

Remove Ballasts from Unused Fluorescent Fixtures

**Cost of Implementation**

The cost of implementation of this measure is minimal.

**Energy savings = 24 GJ/year**
**Cost savings = $22,000/year**
**Cost of implementation = minimal**
**Simple payback period = immediate.**

Appendix 22

Thermal Fluid Boiler Details

Location: Finishing Department

| | 1 | 2 |
|---|---|---|
| **Boiler:** | | |
| Manufacturer | Konus-Kressel | Konus-Kressel |
| Maximum temperature | 800°F | 800°F |
| Age (years) | 12 | 12 |
| Medium raised | Thermal fluid Marlotherm S | Thermal fluid Marlotherm S |
| **Burner:** | | |
| Number of burners | 1 | 1 |
| Fuel fired | Diesel | Diesel |
| Manufacturer | Weishaupt | Weishaupt |
| Age (years) | 12 | 12 |
| Draft | Induced | Induced |

Appendix 23

Thermal Fluid Boiler Combustion Tests

Boiler No. 1

| | |
|---|---|
| Firing rate | Medium |
| $CO_2$ in flue gas | 14 percent |
| $O_2$ in flue gas | 4 percent |
| Exhaust gas temperature | 254°C |
| Combustion air temperature | 45°C |
| Combustion efficiency | 85.4 percent |
| Radiation loss (assuming 2.5 percent at MCR) | 5 percent |
| Boiler efficiency (net) | 80.4 percent |

Appendix 24

Insulation of Thermal Fluid Overflow Tank

**Assumption**

Insulation will reduce heat loss by 90 percent.

**Data**

Ambient air temperature = 28°C
Tank dimensions = 0.7 meter (diameter) x 2.1 meter (length)
Surface temperature = 60°C
Hours of operation = 16 hours/day x 5 days/week x 50 weeks/year = 4,000 hours/year
Thermal fluid boiler efficiency = 80.4 percent.

**Calculations**

**Energy Savings**

Heat loss from cylinder surfaces = 1,085 $KJ/m^2$-hr

Cylinder area = 4.62 $m^2$

Heat loss from cylinder ends = 1,204 $KJ/m^2$-hr

Ends area = 0.77 $m^2$

Heat loss = (1,085) (4.62) + (1,204) (0.77) = 5,940 KJ/hr.

Energy savings

$$= \frac{\text{(heat loss) (0.9) (hours/year)}}{\text{(boiler efficiency) } (10^6)}$$

$$= \frac{(5{,}940)\ (0.9)\ (4{,}000)}{(0.804)\ (10^6)}$$

= 26 GJ/year

Appendix 24 (continued)

Insulation of Thermal Fluid Overflow Tank

**Cost Savings**

= (GJ/yr) (Sucres/GJ)

= (26) (140.22)

= S/3,646/year

**Cost of Implementation**

The cost of insulation is estimated to be S/1,300 per square meter for a total area of 5.5 $m^2$. Hence, the cost of implementation is estimated to be S/7,150.

**Simple Payback Period**

$$= \frac{\text{Cost of implementation}}{\text{annual savings}}$$

$$= \frac{7,150}{3,646}$$

= 2.0 years

**Energy savings = 26 GJ/year**
**Cost savings = S/3,646/year**
**Cost of implementation = S/7,150**
**Simple payback period = 2 years.**

Appendix 25

Stenter Tests

**Nameplate Data**

Manufacturer: Famatex
Type: thermal fluid/air heat exchanger
Processes performed: thermal fixing and drying
Maximum production rate: 80 meters/minute
Maximum temperature: 400°C

**Typical Production Characteristics**

Thermal fixing:
Thermal fluid temperature: 190°C
Production rate: 12 meters/minute

Drying:
Thermal fluid temperature: 150°C
Production rate: 20-25 meters/minute

Hours of operation: 16 hours/day, 5 days/week

**Product Processed During Test**

Fabric: Blusa Flame 2052 (70 percent polyester, 30 percent rayon)
Lined density: 200 grams/meter
Fabrid width: 1.5 meters
Process performed: drying
Production rate: 18.8 meter/min at beginning of test; 17 meters/min at end of test
Fabric moisture content: 75 percent entering
(estimated by production supervisor): 4 percent leaving
At average flow of 17.9 m/min x 0.2 kg/m: 3.58 kg fabric/minute
Water extracted: (0.75 - 0.04) (3.58) = 2.54 kg/min

Appendix 25 (continued)

Stenter Tests

## Test Measurements and Data

### Thermal Fluid Flow

Entering temperature: 202.5°C
Leaving temperature: 185°C
Density: 0.9 kg/liter
Pump nameplate data:
  Nominal flow: 80 $m^3$/hr
  15 kW power 49A
Pump measured data: 14.7 kW power; 45A; 210V; 0.92 PF

### Entering Air Data

Temperature: 39°C dry bulb
Relative humidity: 44 percent
Enthalpy: 40 Btu/lb dry air (107 KJ/kg dry air)
Humidity ratio: 0.0194 kg water/kg dry air
Specific volume: 14.6 $ft^3$/lb dry air (0.91 $m^3$/kg dry air)

Area of entrance: 0.1716 $m^2$
Entering velocity: 980 feet/minute (#1); 916 feet/minute (#2)
Entering air flow: 3,503 $ft^3$/min = 99.2 $m^3$/min

### Leaving Air Data (stack area = 0.0661 $m^2$)

| Stack | Temperature (°C) | Velocity (fpm) | Flow ($m^3$/min) |
|---|---|---|---|
| 1 | 56 | 2,789 | 52.37 |
| 2 | 127 | 1,989 | 37.35 |
| 3 | 150 | 1,678 | 33.82 |
| 4 | 150 | 1,833 | 34.42 |
| 5 | 140 | 1,075 | 20.19 |
| 6 | 71 | 4,087 | 76.76 |

Average temperature = 103°C (217°F)
Adjusted flow rate = (adjusted to average temperature)

Appendix 25 (continued)

Stenter Tests

$$\frac{(52.37)\ (103 + 273)}{(56 + 273)} + \frac{(37.35)\ (103 + 273)}{(127 + 273)} + \frac{(33.82)\ (103 + 273)}{(150 + 273)}$$

$$+ \frac{(34.42)\ (103 + 273)}{(150 + 273)} + \frac{(20.19)\ (103 + 273)}{(140 + 273)} + \frac{(76.76)\ (103 + 273)}{(71 + 273)}$$

$$= 240.17\ m^3/min \qquad (8{,}480.27\ ft^3/min)$$

**Moisture Balance**

Moisture in entering air + moisture removed from cloth = moisture in exiting air

Moisture in entering air = $M_1$ (kg/kg dry air)
Moisture removed from cloth = 2.54 kg/min = 5.58 lb/min
Moisture in exiting air = $M_3$ (kg/kg dry air)

This yields the relationship:

$$\frac{8{,}480.27}{S_3} = \frac{5.58}{M_3 - 0.0194}$$

where $S_3$ is the specific volume of the leaving air

by rearranging

$$M_3 = 0.00066\ S_3 + 0.0194$$

at 217°F in psychrometric chart, we use an iterative process to determine the values of M and S which satisfy this relationship.

| Test $S_3$ | Result $M_3$ | Actual $M_3$ |
|---|---|---|
| 18.572 | 0.03166 | 0.05607 |
| 17.936 | 0.03124 | 0.03282 |
| 17.881 | 0.03120 | 0.03084 |
| 17.908 | 0.03122 | 0.03183 |
| 17.895 | 0.03121 | 0.03133 |
| 17.891 | 0.03121 | 0.03123 |

Calculation performed iteratively using Hewlett-Packard HP41 psychrometrics program.

Appendix 25 (continued)

Stenter Tests

Moisture content = 0.03121 kg/kg dry air
Specific volume = 17.891 $ft^3$/lb dry air (1.116 $m^3$/kg dry air)

**Heat Loss in Air Exhaust**

Enthalpy of incoming air = 46 Btu/lb dry air (107 KJ/kg)

Enthalpy of outlet air (at inlet air conditions) = 75 Btu/lb dry air (174 KL/kg dry air)

Quantity of air

$$= \frac{\text{Flow rate } (m^3/\text{min})}{\text{Specific volume } (m^3/\text{kg})}$$

$$= \frac{240.17}{1.116}$$

$$= 215.2 \text{ kg/min}$$

Heat loss

$$= (215.2)\ (75 - 46): \quad 6{,}241 \text{ KJ/min}$$

At average, 50 percent load over operating period, heat loss

$$= \frac{(6{,}241)\ (60)\ (16)\ (5)\ (50)\ (0.50)}{10^6}$$

$$= 749 \text{ GJ/year}$$

Appendix 25 (continued)

Stenter Tests

**Heat Required to Evaporate Moisture**

Moisture evaporate rate = 2.54 kg/min

Specific volume of dry air at dryer exhaust temperature

= 17.03 $ft^3$/lb dry air = 1.062 $m^3$/kg dry air

Specific volume of steam at exhaust conditions

= 24.45 $ft^3$/lb steam = 1.525 $m^3$/kg steam

Moisture content of exhaust air = 0.03123 kg/kg dry air

Volume of moisture = (1.525 $m^3$/kg steam) (0.03123) = 0.04763 $m^3$/kg

The partial pressure of the water vapor

= (1,013.25) (0.04763)/(1.062) = 45.44 millibar

From the steam tables, the total heat of vapor at the partial pressure and exhaust temperature is 2,690 KJ/kg. The sensible heat of water at fresh air inlet temperature is 163 KJ/kg.

Hence, the heat added to the moisture in the dryer is 2,690 - 163 = 2,527 KJ/kg and the heat added to evaporate moisture is (2.54) (2,527) = 6,419 KJ/min.

At 50 percent load factor, heat required to evaporate moisture

$$= \frac{(6{,}419)\ (60)\ (16)\ (5)\ (50)\ (0.50)}{10^6}$$

= 770 GJ/year

Appendix 25 (continued)

Stenter Tests

**Heat Input Via Thermal Fluid**

Average specific heat of thermal fluid = 0.511 kcal/kg - °C

$Q = m\ Cp\ (T_2 - T_1)$

$= (80\ m^3/hr)\ (0.9\ kg/l)\ (1{,}000\ l/m^3)\ (0.511)\ (202.5 - 185)$

$= 643{,}860$ kcal/hr x 4.186 KJ/kcal

$= 2{,}695{,}198$ KJ/hr

At 50 percent local factor, annual energy input:

$$\frac{(2{,}695{,}198)\ (16)\ (5)\ (50)\ (0.50)}{10^6}$$

$= 5{,}390$ GJ/year

**Heat Balance**

Thermal fluid input = 5,390 GJ/year

Sensible heat in air exhaust = 749 GJ/year

Heat required to evaporate moisture = 770 GJ/year

Other losses (by difference) = 3,871 GJ/year

Drying efficiency = 14 percent.

Appendix 26

Heat Recovery for Stenter Air Preheating

Waste heat from the stenter can be recovered from the exhaust air streams and used to preheat incoming stenter air.

**Assumptions**

Efficiency of heat exchanger = 50 percent.

**Data**

Heat lost in air = 749 GJ/year (see Appendix 25).

**Calculations**

**Energy Savings**

= (Heat lost in air) (recovery efficiency)

= (749) (0.50)

= 375 GJ/year

**Cost Savings**

= (GJ/year) (Sucres/GJ)

= (375) (140.22)

= S/52,583/year

**Cost of Implementation**

This measure requires the installation of two air-to-air heat exchangers in the exhaust air ducts and blowers to pull ambient air through the cold side of the exchanger. In addition, ductwork is required to deliver the preheated air to the stenter inlet. The cost for all of this work is estimated at S/3,000,000.

Appendix 26 (continued)

Heat Recovery for Stenter Air Preheating

**Simple Payback Period**

$$= \frac{\text{Cost of implementation}}{\text{annual savings}}$$

$$= \frac{3{,}000{,}000}{52{,}583}$$

$$= 57.1 \text{ years}$$

**Energy savings = 375 GJ/year**
**Cost savings = $/52,583/year**
**Cost of implementation = $/3,000,000**
**Simple payback period = 57.1 years.**

Appendix 27

Suppliers of Energy Audit Instrumentation

| Type | Supplier | F.O.B. price[1] (U.S. dollars) |
|---|---|---|
| **Flue gas analyzers** | | |
| Chemical $CO_2$, $O_2$ concentration combustion test kit, including smoke gun | Export Manager - Bacharach Instruments<br>301 Alpha Drive<br>Pittsburgh, PA 15238<br>Telephone: (412) 782-3500<br>Telex: 866407 | 300 |
| Electrochemical digital Fyrizer Model 10 | Export Manager - Bacharach Instruments<br>301 Alpha Drive<br>Pittsburgh, PA 15238<br>Telephone: (412) 782-3500<br>Telex: 866407 | 2,500 |
| Electrochemical fuel efficiency monitor | Neotronics N.A. Inc.<br>P.O. Box 370<br>411 Bradford Street, NW<br>Gainsville, GA 30503<br>Telephone: (404) 535-0600 | 1,470 |
| **Temperature measurement** | | |
| Digital temperature indicator Model 9300 | Tesoterm, Inc.<br>P.O. Box 111509<br>Nashville, TN 37211-1509<br>Telephone: (615) 834-5082<br>Telex: 55-5112 | 200 |
| Probes for above | Tesoterm, Inc.<br>P.O. Box 111509<br>Nashville, TN 37211-1509<br>Telephone: (615) 834-5082<br>Telex: 55-5112 | 60-100 |

[1]As of August 1984.

Appendix 27 (continued)

Suppliers of Energy Audit Instrumentation

| Type | Supplier | F.O.B. price[1] (U.S. dollars) |
|---|---|---|
| **Temperature measurement (continued)** | | |
| Digital temperature indicator -- Digital Series 450 | Omega Engineering Inc.<br>One Omega Drive<br>Box 4047<br>Stamford, CT 06907<br>Telephone: (203) 359-7700<br>Telex: 996404 | 275 |
| Probes for above | Omega Engineering Inc.<br>One Omega Drive<br>Box 4047<br>Stamford, CT 06907<br>Telephone: (203) 359-7700<br>Telex: 996404 | 75-150 |
| Infrared pyrometer -- Model 10 HT-3CPH (1,100°C-1,750°C) | Mikron Instrument Company Inc.<br>P.O. Box 211<br>Ridgewood, NJ 07451<br>Telephone: (201) 891-7330 | 1,700 |
| Infrared pyrometer -- Model 10 DHS - 19XC (600°C-1,700°C) | W. Wahl, Export Manager<br>Wahl International Ltd.<br>5750 Hannum Avenue<br>Culver City, CA 90230<br>Telephone: (213) 641-6931<br>Telex: 66-4406 | 2,250 |
| Infrared pyrometer -- Model 10 OS-2000A (-30°C-1,400°C) | Omega Engineering Inc.<br>One Omega Drive<br>P.O. Box 4047<br>Stamford, CT 06907<br>Telephone: (203) 359-7700<br>Telex: 996404 | 1,900 |
| Infrared pyrometer -- Model 500 (0°C-700°C) | Tesoterm, Inc.<br>P.O. Box 111509<br>Nashville, TN 37211-1509<br>Telephone: (615) 834-5082<br>Telex: 55-5112 | 1,125 |

As of August 1984.

Appendix 27 (continued)

Suppliers of Energy Audit Instrumentation

| Type | Supplier | F.O.B. price[1] (U.S. dollars) |
|---|---|---|
| **Humidity measurement** | | |
| Electronic psychrometer Model 6400 | Tesoterm, Inc.<br>P.O. Box 111509<br>Nashville, TN 37211-1509<br>Telephone: (615) 834-5082<br>Telex: 55-5112 | 675 |
| Mechanical psychrometer | Vista Scientific Corporation<br>85 Industrial Drive<br>Northampton Industrial Park<br>Ivyland, PA 18974<br>Telephone: (215) 322-2255 | 125 |
| **Air/gas flow measurement** | | |
| Alnor velometers, Series 6000P | Alnor Instruments Company<br>7301 North Caldwell Avenue<br>Niles, IL 60648<br>Telephone: (312) 647-7866<br>Telex: 72-4458 | 800 |
| Hot wire anemometer | Alnor Instruments Company<br>7301 North Caldwell Avenue<br>Niles, IL 60648<br>Telephone: (312) 647-7866<br>Telex: 72-4458 | 1,000 |
| Pitot tube and manometer, Series 400 | Dwyer Instruments Inc.<br>P.O. Box 373<br>Michigan City, IN 46360<br>Telephone: (219) 872-9141 | 300 |
| **Draft measurement** | | |
| "U" tube manometers | Dwyer Instruments Inc.<br>P.O. Box 373<br>Michigan City, IN 46360<br>Telephone: (219) 872-9141 | 25-100 |

[1]As of August 1984.

Appendix 27 (continued)

Suppliers of Energy Audit Instrumentation

| Type | Supplier | F.O.B. price[1] (U.S. dollars) |
|---|---|---|
| **Draft measurement (continued)** | | |
| TDS meter -- conductivity meter | John J. Berg, Export Manager<br>Myron L. Company<br>6231C Yarrow Drive<br>Carlsbad, CA 92008-4893<br>Telephone: (619) 438-2021<br>Telex: 695009 | 150 |
| **Electrical measurement** | | |
| Clamp-on ammeter | Epic, Inc.<br>150 Nassau Street<br>New York, NY 10038<br>Telephone: (212) 349-2470 | 285 |
| Clamp-on power factor meter | Epic, Inc.<br>150 Nassau Street<br>New York, NY 10038<br>Telephone: (212) 349-2470 | 450 |
| Clamp-on wattmeter | Epic, Inc.<br>150 Nassau Street<br>New York, NY 10038<br>Telephone: (212) 349-2470 | 450 |
| Clamp-on ammeter, Model 1000 | T.I.F. Instruments, Inc.<br>3661 NW 74th Street<br>Miami, FL 33147<br>Telephone: (305) 696-7100<br>Telex: 512302 | 175 |
| Clamp-on wattmeter, Model 2000 | T.I.F. Instruments, Inc.<br>3661 NW 74th Street<br>Miami, FL 33147<br>Telephone: (305) 696-7100<br>Telex: 512302 | 400 |

[1]As of August 1984.

Appendix 27 (continued)

Suppliers of Energy Audit Instrumentation

| Type | Supplier | F.O.B. price[1] (U.S. dollars) |
|---|---|---|
| **Electrical measurement (continued)** | | |
| Clamp-on power factor meter, Model 1000 | T.I.F. Instruments, Inc.<br>3661 NW 74th Street<br>Miami, FL 33147<br>Telephone: (305) 696-7100<br>Telex: 512302 | 400 |
| **Light meter** | Simpson Electric Company<br>(subsidiary of Katy Industries, Inc.)<br>853 Dundee Avenue<br>Elgin, IL 60120<br>Telephone: (312) 697-2260<br>Telex: 72-2416 | 350 |

[1]As of August 1984.