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Reliance Energy Services

ENERGY AUDIT REPORT

for

COMPANIA DE CERVEZAS NACIONALES C.A.

GUAYAQUIL, ECUADOR

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EXECUTIVE SUMMARY

This report details savings from reducing energy consumption at Las Penas Brewery of Compania de Cervezas Nacionales, C.A., Guayaquil, Ecuador. Savings estimates are based upon 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 four days. The purpose of this session was to instruct course participants in the use of portable instrumentation, and in data collection and test procedures. During five days of site work at Las Penas Brewery, the participants were responsible for testing a wide range of equipment in the plant, including boilers 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 analysis of collected data, formulation of energy conservation strategies, and calculation of savings possible by implementation of the recommended measures. This session lasted a further 7 days.

In order 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. Equipment was tested to determine the level of energy waste and amount of energy that could be usefully recovered.

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

- boiler plant, steam distribution and condensate return systems
- chilled water distribution, and space conditioning systems
- lighting systems
- compressor systems
- electrical distribution and motors
- brewing and fermentation operations
- bottling and packaging operations

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

Analysis of data collected led to identification of potential for energy conservation. This was followed by formulation of strategies to achieve energy savings. Each strategy was then further analyzed to estimate implementation costs 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 energy savings presented can be achieved by implementation of projects and strategies identified during the course of the audit and data analysis.

The major findings and recommendations of the study are:

- Potential savings identified in this report represent 3.36 million Sucres based on marginal costs in effect in August 1984. Energy use can be reduced by 16.9% when compared to the energy usage of the last twelve months.

- Capital costs required to implement the recommended changes are estimated to be 4.38 million Sucres, giving a simple payback of 1.3 years for the program. A summary of the savings is shown in Exhibit 1.

- Electricity is used to provide motive power, cooling, compressed air, and environmental services. It accounts for 13.9% of the energy usage at Las Penas.

- Bunker is burned to produce steam in the boiler plant. Steam is used for process purposes. Bunker provides about 86% of the energy needs of the plant.

- As a cost item electricity forms 61% of the bill, bunker approximately 39%.

- An Energy Management Program should be established at Las Penas to ensure energy conservation opportunities identified are implemented. The program should include:

  - appointing a part-time energy coordinator for the plant. This person should be reesponsible for all energy-related activities in the plant. He should as a minimum:

    1) Develop and maintain a data base of energy-related information, including major energy consuming equipment, consumption and cost data, and production and environmental data.

EXHIBIT 1

SUMMARY OF MEASURES

ITEM	ENERGY SAVED GJ	COST SAVED SUCRES	% SAVINGS GJ	% SAVINGS SUCRES	IMPLEMENTATION COSTS SUCRES	SIMPLE PAYBACK YEARS
Replace Steam Pump	1,576	84,354	5.2	2.5	152,000	1.8
Pipework Insulation	2,496	205,620	8.2	6.2	671,421	3.3
Insulate Washers, Pasteurizers, Cond. Tanks	6,398	527,067	21.1	15.7	1,046,123	2.0
Repair Steam Traps	132	10,874	0.4	0.3	25,000	2.3
Return Condensate	1,104	90,948	3.6	2.7	300,000	3.3
Use Firetube Boiler	17,158	1,413,476	56.5	42.0	-	-
Replace Fluorescents	53	34,980	0.2	1.0	50,050	1.4
Fit time Switches	158	104,280	0.5	3.1	150,000	1.4
Power Factor Corr.	-	783,926	-	23.3	784,000	1.0
Oxygen Trim	1,267	104,375	4.3	3.2	1,200,000	11.5
Replace Water Tube Boiler	(24,277)	(1,999,939)	-	-	(15,000,000)	(7.5)
Totals, Excluding Boiler Replacement	30,342	3,360,900	100.0	100.0	4,378,594	1.3

2) Monitor energy use at the plant.

3) Oversee the implementation of measures recommended in this report.

- Purchase instrumentation to support conservation activities. Instrumentation should include a boiler test kit, thermocouples, TDS meter, smoke tester, steam meters, electric consumption and demand meters, and water meters to mintor use of water by the boilers.

- Develop a new energy monitoring system to evaluate energy usage on a departmental basis, that will permit energy costs to be assigned by use rather than as overhead.

- Determine an energy consumption index to accurately reflect energy usage at Las Penas. Separate indices should be developed for electricity and bunker. To establish a meaningful index, regular monitoring of certain parameters is required. Parameters that should be monitored should include:

  - energy use by fuel type, by department
  - production data for each department
  - operating schedules for each department
  - environmental data
  - water consumption by the boilers and the remainder of the plant

After the monitoring program has been established for a period of six to twelve months, it should be possible to develop plant norms for energy use within departments and possibly by individual process. Various parameters can be used such as production or operating hours to determine the best indicator of energy usage. With a good data base, the most appropriate indicators can easily be identified by the plant and then monitors in the future.

- Establish an energy awareness program for all employees including posters highlighting conservation methods, distributing information on the cost of energy wastage.

- Train boiler operators in safe and efficient operation of the boilers. Training should include aspects of combustion, water treatment and safety.

o Improvements in energy utilization at Las Penas can reduce energy use by some 17%, under existing operating schedules and production output if recommended measures identified in this report are implemented. The measures identified include reducing loading on the boilers through implementation of certain measures that would permit the firetube boiler to operate as the base load boiler, thereby saving even more energy due to the higher efficiency of the boiler as compared to the watertube. The firetube boiler efficiency was measured at 87.76%; the efficiency of one of the watertubes 69.09%.

The calculated efficiencies are based on a method known as the loss method. In the loss method, overall efficiency is calculated by estimating all losses from the boiler due to 1) combustion, 2) radiation and 3) blowdown. The losses are then subtracted from the fuel input (100%) to give the overall efficiency. The losses for the two boilers are:

	Fire Tube	Water Tube
Loss due to Combusion	13.53	22.15
Radiation Loss	3.03	8.40
Blowdown Loss	0.68	0.36
Total Losses	17.24	30.91

Although not strictly a steam generation efficiency (as steam flow, pressure and dryness fraction, water flow and fuel input are not metered) the above calculation gives a very good indicator of boiler efficiency and generation capabilities. The method is recognized by such bodies as the American Society for Mechanical Engineers, and the British Standards Institute.

- Alternatively the existing watertube boilers could be replaced by a packaged boiler to give energy savings of some 13.5%. However, this option is not as attractive financially. The total savings from boiler replacement and implementation of all measures would be a total of 21% of energy usage at Las Penas.

- Option 1, the recommended measures of operating the firetube boiler as baseload requires the following measures be implemented:

  - replace steam reciprocating pump

  - pipework insulation of steam, hot water and condensate lines

  - insulation of washers, pasteurizers and condensate return tanks

  - repair faulty steam traps

  - return condensate from pasteurizers to boilerhouse

  The fire tube boiler should be used as the base load boiler as after implementation of the measures the average steam demand at Las Penas can be met by the fire tube.

  The fire tube boiler should also be used because:

  - it is equipped with automatic safety controls

- it has a higher operating efficiency due to:

  a) higher combustion efficiency
  b) less radiation losses
  c) better state of repair with noticeably less gas leaks
  d) not as old as water tubes
  e) does not use steam for optimization

In addition, the following measures can be implemented to reduce steam loading:

- fit an oxygen trim system to automatically control combustion.

Total Savings from implementation represent approximately 17% of the energy usage. Implementation cost are estimated at 3.39 million Sucres and savings 2.44 million Sucres, giving a simple payback of 1.4 years.

o Option 2, replacing the boiler plant and implementation of the measures outlined in Option 1 with the exception of oxygen trim to reduce boiler loading would require an investment cost of 17.2 million Sucres for a savings of 2.92 million, giving a simple payback of 5.9 years.

o Electrical consumption can be reduced by implementation of the following measures:

- use high efficiency tubes instead of standard fluorescents

- fit time switches to control lights in the fermentaion and office areas which are not occupied continuously

A total savings of about 139,000 Sucres per year is possible for an expenditure of 200,000 Sucres, giving a simple payback of 1.4 years.

- Overall plant power factor was measured at 0.91. By raising this to 0.95 electrical power factor penalties will be avoided. The utility company intends to raise the level at which penalties are imposed from 0.90 to 0.95. Savings in avoided costs are estimated to be 784,000 Sucres per year. Capacitors can be installed at a cost of 784,000 Sucres giving a simple payback of one year.

- The efficiency of the ammonia compressors was measured and found to be satisfactory. Although improvements could be made through installation of new equipment, the payback periods would be extended.

As a first step in implementing the measures identified, an action plan has been developed. The plan is shown in Exhibit 2.

EXHIBIT 2

IMPLEMENTATION ACTION PLAN

Item	Time Frame	Action Required
Phase 1		
Appoint Energy Coordinator	Immediate	Select one in-house engineer to act as part-time coordinator
Procure Instrumentation	Immediate	Purchase and install (as necessary new instrumentation. Establish testing schedule.
Energy Monitoring Program	On delivery of new instrumentation	Commence Testing Program and Energy Monitoring Program: develop standards for departmental operations
Employee Awareness Program	Immediate	a) Obtain support of department heads and supervisor personnel b) Train boiler operators in aspects of combustion, water treatment and safety c) Inform plant operation personnel of importance of energy

EXHIBIT 2, cont'd

IMPLEMENTATION ACTION PLAN, continued

Item	Time Frame	Action Required
Phase 1		
Replace Steam Pump	Immediate	a) Order new pump b) Fit and replace steam pump
Insulate Washers, Pasteurizers and Condensate Return Tanks	Immediate	a) Contact local insulation suppliers b) Select and purchase materials c) Install using in-house or contractor labor
Repair Steam Traps	Immediate	a) Identify faulty traps b) Repair as part of routine maintenance
Pipework Insulation	Immediate	a) Contact local insulation suppliers b) Select and purchase materials c) Install using in-house or contract labor
Return Condensate to Boilerhouse	Immediate	a) Isolate Pasteurizer discharge b) Pipe to condensate return system

EXHIBIT 2, cont'd

IMPLEMENTATION ACTION PLAN, continued

Item	Time Frame	Action Required
Phase II		
Use Firetube Boiler for Base Load	After Implementation of Above Measures	a) Use firetube boiler to meet base load steam needs
Fit Oxygen Trim to Firetube	After Implementation of Above Measure	a) Contact local supplier b) Purchase and install system
Fit Time Switches to Control Lights in Fermentation/ Office areas	Immediate	a) Determine location of switches b) Purchase and install
Power Factor Correction	Prior to increase by utility	a) Order new capacitors to increase power factor to 0.95 b) Install
Use High Efficiency Bulbs	On Attrition Basis	a) Order high efficiency fluorescents instead of regular bulbs b) Fit as required

1. BACKGROUND

1.1 Introduction

This report has been prepared as part fulfillment of a 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 Las Penas Brewery of Compania de Cervezas Nacionales, C.A., in Guayaquil, Ecuador, during September, 1984. Data collected during field work has been used to estimate energy savings that can be achieved by implmentation of the measures recommended.

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

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, and subsequently were involved in the plant portion of the training.

To collect necessary information to complete this report, 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 a Detailed Energy Audit (DEA).

To evaluate energy performance, the plant was broken down into discrete process and service areas as follows:

- boiler plant, steam distribution and condensate return systems
- chilled water distribution, and space conditioning systems
- lighting systems
- compressor systems
- electrical distribution and motors
- brewing and fermentation operations
- bottling and packaging operations

Each team carried out instrumented tests in the above areas. This report has been prepared from analysis of data collected in those tests.

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 interviewing 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

The authors would like to thank the management of Compania de Cervezas Nacionales, C.A. for allowing the use of its plant for training purposes.

1.2 Plant Description

Las Penas Brewery is located on a 26,000 square meter site adjacent to the Guayas River in downtown Quayaquil. Originally constructed in 1913, the plant is a mixture of old and new buildings, covering a floor area of some 9,800 square meters.

Installed production capacity is 1.1 million hectoliters per year but the brewery operates at a production level of 600,000 hectoliters per annum. Reduced production is a result of two sister plants being built in the 1970's, one in Quito, the other on the outskirts of Guayaquil.

Currently five hundred people are employed at the plant. Some one hundred are involved in managerial and administrative functions, the remainder are production personnel.

Three types of beer are produced: Pilsener, Club and Malta. All products are produced using the same basic process, variations in raw materials and conditions accounting for different qualities of the beers. A brief process description follows:

Beer is produced using three production steps 1) brewing, 2) fermentation and 3) bottling.

In brewing, raw materials, barley malt (produced at the nearby sister plant), rice and corn are fed from silos to grinding mills, to reduce their particle size. Water is mixed with the materials to control pH. After passing through the mills, the malt and other raw materials are mixed and cooked under pressure to convert insoluble starch to liquified starch and soluble malt starch into dextrin and malt sugars.

The cooled mixture is then passed through filters to separate insoluble spent grains from the mixture. The mixture (known as wort) is passed to a brewing kettle, and hops added.

In the brewing kettle the wort is boiled for approximately one and a half hours, which permits concentration, sterilization, destruction of all enzymes, coagulations of certain proteins and extraction of tannin and aroma from the hops.

From the brewing kettle wort and spent hops pass through a whirlpool which separates the two. Wort is then passed through a plate heat exchanger before entering the fermentation part of the cycle.

In fermentation, the cooled wort is aerated and mixed with yeasts prior to storage in fermentation tanks. Fermentation takes one to two weeks, depending upon the type of beer, during which times the temperature is controlled between 10 and 12°C. Carbon dioxide is given off from the fermenting liquor.

The beer is then transferred to the final fermentation tanks for completion of the fermentation process. Tank temperatures are about 0°C.

The beer when ready for bottling is passed through a filter and carbon dioxide added. Bottling is completed in one of two bottling lines (line 4 or 3). Line 4 is used for bottling Club or Malta and line 3 for Pilsener.

Beer is shipped from the brewery in bottles packed in crates. The initial operation in the bottling plants involves removal of empty bottles from crates and subsequent crate and bottle washing. Both lines are automated.

Washing is completed using hot water and a 3% solution of sodium hydroxide. After the bottles are washed, rinsed and inspected, they are filled with beer and capped. They then pass through the pasteurizer, labelled and packed in crates for shipping.

1.3 Operating Schedules

Operations in the brewery are broken down into a number of process departments as follows:

Operation	Hours/Day	Days/Week
Brewing	22	5
Fermentation	24	7
Bottling	15	5
Boiler Plant & Services	24	7

The plant functions on a three shift basis. Operations are staggered in the bottling departments because of the inherent delays in providing clean washed bottles for filling.

1.4 Production Data

Las Penas produces three types of beer - Club, Pilsener and Malta. Currently the brewery production is 50% Pilsener, 40% Club and 10% Malta. The following table details monthly production for years 1983 and 1984.

Month	1983		1984	
	Production 10^3 Hectoliters	% Capacity Utilization	Production 10^3 Hectoliters	% Capacity Utilization
January	29	33	61	69
February	28	32	52	59
March	27	31	52	59
April	53	60	50	57
May	27	31	22	25
June	60	68	0	0
July	80	91	53	60
August	47	53	53	60
September	69	78	-	-
October	60	68	-	-
November	50	57	-	-
December	80	91	-	-
TOTAL	610	58	343	43

Annual production for the years 1980 through 1984 was:

	1980	1981	1982	1983	1984
Total Production Hectoliters x 10^3	909	758	572	610	343

The impact of new breweries opening in 1979-80 can be seen from the fall in production from 1980.

1.5 Energy Consumption and Costs

The tables below show energy consumption by type and costs for the year September 1983 to August 1984. Also shown are relative amounts of consumption and cost plus marginal costs of energy, as at August 1984. The marginal cost is the cost paid for the last unit of energy consumed and reflects cost savings that would be made by reducing the consumption by that amount.

Consumption and Costs

Type	Units	Consumption	Annual Cost	% Total Cost
Electric (Peak)	kW	1,764	--	--
Electricity	kWh	6,942,600	18,425,087	61.4
Bunker	Gal	982,621	11,586,638	38.6
Total			30,011,725	100.0

Thermal Equivalents

Type	Annual Energy Equivalent GJs*	Marginal Energy Costs $/GJ	% of Total Energy
Electric kW	--	61.93/kW	--
Electricity kWh	24,993	660.00	13.9
Bunker	155,058	82.38	86.1
Totals	180,051		100.0

Conversion to GJs*

Electricity = 0.0036 x kWh Bunker = 0.1578 x Gal

Electricity is purchased from the Empressa Electrica del Ecuador under the I 2 rate schedule. Charges are made for maximum demand, consumption and a power penalty is imposed if the power factor falls below 0.90. The charge for demand (August 1984) is currently 56.3 sucres per kilowatt of demand. Consumption is charged at 2.16 sucres per kilowatt hour. In addition, a charge of 10% is levied against the total bill to pay for rural electrification projects that the utility are undertaking. A further 30 sucres is added to the bill to pay for firepumps. The marginal cost per kW and kWh are at present 61.93 sucres and 2.38 respectively.

Bunker is purchased from CEPE, the state petroleum corporation at a cost (August 1984) of 13 sucres per gallon. This price includes all handling and delivery charges.

1.6 Major Energy Systems

Energy is consumed in large amounts by several major energy systems. A listing of the major consumers is given in Appendix 3. Electricity is used predominately for motive power, compression of ammonia for cooling, carbon dioxide and air, and lighting. Bunker is burned to produce steam for process requirements.

The boiler plant comprises two watertube boilers and one firetube boiler. The watertube boilers are Babcock and Wilcox boilers, rated at 10.9 tonnes per hour at a working pressure of 11 bar. The firetube boiler was manufactured by York Shipley, and is rated at 7.7 tonnes per hour at a working pressure of 10 bar. Each watertube boiler is fitted with an economizer used for feedwater preheating by recovering heat from the stack gases.

Steam is supplied to production areas at about 9 bar, and used predominantly in the bottling and brewing departments. The main consumers in the bottling departments are the washers and pasteurizers, and in the brewhouse the brew kettle. The brew kettle operates at about 110°C. The washers and pasteurizers use steam directly at about 5 bar.

Cooling is provided from six ammonia compressors, although one is only used in an emergency, and a series of glycol/ammonia and ammonia/water heat exchangers. The five compressors used have a combined rating of 675 HP.

The glycol and chilled water produced are used to cool fermentation tanks to various temperatures or to provide air conditioning to cool various tank rooms. The cooling load is not known.

Compressed air is provided from three air compressors rated at 255 HP, at a pressure of 7 bar. The amount of compressed air produced is not known. Air is used in all departments for pneumatic cylinders, instrumentation and controls.

Carbon dioxide is compressed using four compressors with a combined rating of 50 HP. Carbon dioxide is used as an additive to the beer, after the final fermentation stages.

Internal lighting is predominantly by fluorescent lamps with some incandescents. Mercury vapor lamps are used for external lighting. The internal lighting load is estimated to be less than 100 kW. Lighting is only used as required in most of the plant, the exception being the fermentation tank rooms where lights are continually left on.

The other major electrical consumers are the bottling lines (approximately 240 HP each).

2. FINDINGS

The following sections summarize the findings of the energy audit. Two distinct areas are focused upon: energy management within the brewery and energy utilization within specific systems and departments.

2.1 Energy Management Program

There is no formal Energy Management Program at the brewery, and it is believed no program at any of the associated breweries.

Technical management does monitor energy consumption and check invoices for electricity and bunker consumption but no other use is made of collected data. Few resources are available to manage energy as most of the technical staff are fully occupied by day to day operations.

Little instrumentation for monitoring energy is available at the plant. Only incoming electricity supply (one kWh and one kWh/kW meter) is metered on the electrical side, and only oil flow to each boiler and the return to the storage tanks is metered on the fuel side. Total plant water consumption is measured but individual meters for steam flow, boiler feedwater flow, or condensate return are not provided.

There is some process instrumentation comprising ammeters, voltmeters, thermometers, temperature recorders, pressure gauges and temperature indicators for various processes. However, in tests, many instruments were found to be out of calibration (particularly the pasteurizer temperature controls) and this should be attended to.

Measures have been taken to reduce energy costs at the plant. Capacitor banks have been installed to raise power factor levels to about 0.92 in response to the utility raising the level below which power factor penalties are levied.

2.2 Energy Utilization

2.2.1 Boiler Plant

The boiler plant consists of two watertube boilers, manufactured by Babcock and Wilcox and one three-pass firetube boiler, manufactured by York Shipley. The two watertube boilers are identical, both rated at 10.9 tonnes per hour at a pressure of 11 bar. The firetube is rated at 7.7 tonnes per hour at a pressure of 10 bar. All boilers fire bunker oil with a viscosity of 3500 seconds Redwood Number 1, purchased from CEPE.

In normal operation, one of the two watertube boilers operates at mid fire, the other is not fired, and the York Shipley is operated to meet any high demands.

Duty of the two watertube boilers is alternated on a regular basis. In a normal week the watertube boiler operates for 152 hours (shut down 16 hours on Sunday), the firetube 50 hours per week. The average steam demand is estimated at 8.1 tonnes per hour with peak loads of about 12 tonnes per hour.

The boiler plant is in generally fair condition with scope for improvement. The firetube boiler is in good condition but the watertube boilers are in a relatively poor state.

One watertube boiler had recently ruptured a watertube and could not be operated during the audit. While operating, the other boiler had very high surface temperatures and many leaks through the brickwork. Inspection of the internals of the boiler off line revealed that the brickwork was in poor condition with evidence of corrosion caused by acid deposition. The gas passages through the economizer were partially blocked with soot deposits.

Boiler efficiency was measured for the two boilers operating; the watertube, boiler Number two, was found to have an efficiency of 69.1%,

the firetube, boiler Number three 82.8%. The overall boiler plant efficiency was calculated based upon ther relative operating schedules as 72.5%. Boiler efficiency was measured based upon the loss method in which all losses from the plant are accounted for and then subtracted from 100 to determine the efficiency.

A number of factors contribute to the poor efficiency of the watertube boiler:

Boiler burners (three per watertube) are of the pressure jet type, with steam atomization. Fuel/air ratio control is adjusted manually. When changing firing rate, the operators tended to adjust the fuel flow to the burners rather than both fuel and air.

Combustion efficiency was not particularly good (measured at 77.9%) due to high excess air levels. However, the operators do not have much in the way of instrumentation to assist them in maintaining efficient operation. Combustion conditions are controlled by visual inspection of flue gas conditions. The operators observe the stack of the boilers and adjust the fuel and/or air flow, depending upon the clarity of the discharge from the stack. Not all three burners are adjusted which will cause uneven firing inside the combustion chamber.

Fuel oil temperature was measured at the burner at 108°C which is low for successful atomization. It should be about 125 - 130°C.

Another area of concern is the lack of low and high water level controls on the watertube boilers. <u>This situation is extremely dangerous and should be remedied immediately</u>.

One tube failure has already occured on Number one boiler and although safety controls will not completely eliminate the risk, they should reduce the potential problem somewhat. Automatic controls should not be taken by management and operators as a panacea for all potential problems. Rather the operators should be given training in boiler

operation and maintenance that should include aspects of combustion, steam generation, water treatment and safety. This would permit them to understand their jobs better and enable them to carry out their duties more effectively. Similarly, they should be supplied with instrumentation to monitor conditions better.

Because of the tube failure on Number one boiler, it was not possible to test the boiler but based upon inspection of its internals and its similarity to Number two, it is unlikely that the efficiency will be any different.

Radiation losses were high from boiler two and many gas leaks were found indicating that the brickwork is in a very poor state of repair. It is understood that the management is considering a major rebuild of the watertube boilers. However, the rebuild may not improve the efficiency that much and as an alternative replacement of the boilers should be considered seriously. A feasibility study determining the optimum solution should be conducted.

The firetube boiler was found to be operating reasonably efficiently. Combustion efficiency was measured at 86.5% which is good. However, the smoke number was 4.5 on the Bacharach scale of 1 to 9. This number is a little high indicating that some adjustment of the fuel air ratio is required to give cleaner combustion. Too high a smoke number indicates soot that will deposit itself on the heat transfer surfaces thereby reducing efficiency.

All controls, including safety controls, were found to be functioning. Currently the boiler does not operate continuously despite its higher efficiency than that of the watertube boilers. Given its efficiency, it may be beneficial to operate the firetube boiler as the base load boiler and use the watertubes for peaking purposes only.

Make up water is supplied from the city and softened by base exchange. Condensate is returned from a number of areas around the plant. Based

upon tests conducted, the condensate return was about 50%. Feedwater is supplied from condensate and makeup water tanks, which heats the water to about 95°C. This temperature is adequate for removal of dissolved gases such as oxygen. The water used by the watertube boilers passes through the associated economizer which further raises its temperature. Tests for total dissolved solids (TDS) indicated that blowdown was satisfactory. Currently blowdown is completed every 80 minutes.

Within the boiler house area there are some small steam leaks and missing insulation. In addition, the condensate tanks are not insulated.

2.2.2 Steam Distribution and Condensate Return System

The steam distribution and condensate return systems are in reasonable states of repair. The steam distribution system has some minor leaks and areas where insulation is missing or damaged. Condensate, although returned from some areas, is not collected from all possible locations and some improvements can be made, notably from the bottling departments The majority of steam traps are functioning although some were found to be passing live steam.

One area of significant waste is a steam reciprocating pump, used to pump water, outside the bottling department (line 3).

2.2.3 Brewing and Fermentation Departments

Energy used in the brewing department is primarily steam for process heating. Electricity is the predominant fuel used in the fermentation in the form of chilled glycol, water or ammonia.

Little scope for savings exist in either departments. Most of the equipment used is fairly modern. In brewing, processes are temperature and time cycle controlled. All instrumentation, steam pipework and traps are in a good state of repair.

In fermentation some scope exists for control of lighting in tank rooms. Lights are left on during periods when the areas are not occcupied.

2.2.4 Bottling Departments

Energy sources used in the bottling departments (lines 3 and 4) are steam for process heating and electricity for motive power, compressed air and lighting. Steam is the major consumption, being directly injected into water baths in the washers and pasteurizers.

In the washers, steam is used to heat water for cleaning bottles prior to filling with fresh beer. Steam is injected directly into the washers at about 5 bar. The washer in line 3 processes up to 50,000 bottles per hour, the washer in line 4, approximately 36,000 bottles per hour. Temperature is controlled and varies throughout the washing cycle (depending upon where the bottle is in the washer) from 49°C to 80°C.

In the pasteurizers, steam is also directly injected at about 5 bar. Once again temperature is controlled to give various conditions in the pasteurizer. The most critical temperature is in the middle of the pasteurizers where beer temperature must be held at 60-63°C for approximately 10 minutes to ensure complete pasteurization takes place.

During testing it was found that some of the temperature controllers were not operating correctly. In most cases desired temperatures were not being met and it recommended that controls be checked and recalibrated as necessary.

Scope for conservation exists in several areas. Insulation was missing or damaged on many steam lines and there were also several steam leaks. A number of steam traps were malfunctioning.

Condensate from the pasteurizers is not returned to the boiler but run to drain. Radiation losses from the machines are also high.

2.2.5 Electrical Systems

In general, electrical systems in the plant were found to be in good condition. Some scope for improvement was identified, however. Overall plant power factor was estimated at 0.91. In the near future the utility company is planning to raise the level at which power factor penalties are levied to 0.95. The company should consider installing further power factor correction equipment to raise the power factor to 0.95.

2.2.6 Compressed Air Systems

Compressed air for the plant is provided by three air compressors. The compressors are adequate for the required duty and the compressed air distribution system is in a good state of repair. A thorough inspection of the system found no leaks and no opportunity for conservation exists.

2.2.7 Ammonia Compressors

The ammonia compressors (six installed, five used for duty) are used to provide cooling in the fermentation department. Cooling is provided in a number of ways by glycol, water and ammonia via air handling units and coils in the fermentation tanks. Although the equipment is relatively old, it is operating at a good efficiency.

2.2.8 Lighting and Environmental Systems

Internal lighting is primarily by fluorescent fixtures, supplemented in some areas by incandescents. External lighting is provided by mercury vapor luminaires which are controlled by photocells.

A lighting survey of the departments indicated there is no scope for reducing lighting levels in any areas. In some areas, however, lights are used unnecessarily or left on when the area is unoccupied. This is most noticeable in the fermentation department.

In addition to fitting timer controls to turn off the lights in unoccupied areas, energy can be saved by using high efficiency tubes instead of standard fluorescents. Incandescent bulbs can also be replaced with screw in fluorescents to reduce energy consumption.

There are few environmental systems apart from the ones used in the fermentation department for cooling the fermentation tank rooms. These units were found to be functioning satisfactorily.

3. RECOMMENDATIONS

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 brewery 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 one of the engineers assume this responsibility on a part-time basis. 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. In order 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, TDS meter, and a smoke tester. Boilers should be tested at least daily, to verify that optimum efficiency is being achieved.

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

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

- Water meters, to monitor the use of water by the boilers.

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

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.

Parameters that should be monitored should include:

- energy use by fuel type, by department

- production data for each department

- operating schedules for each department

- environmental data

- water consumption by the boilers and the remainder of the plant

After the monitoring program has been established for a period of six to twelve months, it should be possible to develop plant norms for energy use within departments and possibly by individual process. Various parameters can be used such as production or operating hours to determine the best indicator of energy usage. With a good data base, the most appropriate indicators can easily be identified by the plant and then monitored in the future.

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 machine 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 based upon marginal costs in effect at August 1984.

3.2.1 Measures With Simple Paybacks Under One Year

Energy cost reduction measures recommended here have simple paybacks of one year or under.

3.2.1.1 Use Firetube Boiler For Base Load Instead of Watertube

Energy can be saved by operating the firetube boiler to meet the base load instead of the watertube. In order to operate satisfactorily, it is necessary to implement several measures to reduce the existing load on the boiler plant. Through implementation of all of the following measures, the energy savings generated from them and the savings from operating the firetube boiler full time instead of the watertube would recover the total implementation costs under one year.

The measures to be implemented are:

Measure	Energy Savings GJ	Cost Savings Sucres	Cost of Implementation Sucres
Pipework Insulation Appendix 10	2,496	205,620	671,421
Replace Steam Pump Appendix 9	1,576	85,354	152,000
Insulate Washers, Pasteurizers, Condensate Tanks Appendix 11	6,398	527,067	1,046,123
Repair Steam Traps Appendix 12	132	10,874	25,000
Return Condensate to Boiler Appendix 13	1,104	90,948	300,000
Use of Firetube Appendix 14	17,158	1,413,476	
TOTAL	28,864	2,333,339	2,194,544

ENERGY SAVINGS	= 28,864 GJ/year
COST SAVINGS	= 2,333,339 Sucres/Year
COST OF IMPLEMENTATION	= 2,194,544 Sucres
SIMPLE PAYBACK	= 0.9 Years

3.2.1.2 Power Factor Correction

The utility company intends raising the level at which power factor penalties are imposed from 0.90 to 0.95. Currently the plant factor is 0.91. By raising the power factor to 0.95 by installing capacitors, energy cost penalties will be avoided as outlined in Appendix 20.

ENERGY SAVINGS	= Nil
COST SAVINGS	= 783,926 Sucres/Year
COST OF IMPLEMENTATION	= 784,000 Sucres
SIMPLE PAYBACK	= 1.0 Years

3.2.2 Measures with Simple Paybacks Over One Year

Energy cost reduction measures recommended here have simple paybacks in excess of one year.

3.2.2.1 Replace Fluorescent Tubes With High Efficiency Tubes

Existing fluorescent tubes can be replaced on an attrition basis with high efficiency tubes, saving energy without appreciable reduction in lighting levels. Appendix 17 outlines the energy savings possible.

ENERGY SAVINGS	= 55 GJ/year
COST SAVINGS	= 34,980 Sucres/Year
COST OF IMPLEMENTATION	= 50,050 Sucres
SIMPLE PAYBACK	= 1.4 Years

3.2.2.2 Fit Time Switches To Turn Off Lights In Fermentation and Offices

Certain parts of the fermentation and office buildings are currently lit continuously even though the areas are not occupied on a continuous basis. Existing on-off switches could be replaced with time switches so that lights do not remain on all the time, but only when the area is in use. Appendix 18 outlines the savings possible.

3.2.2.3 Replace Steam Reciprocating Pump

The steam driven reciprocating pump can be replaced with an electric pump to give energy savings. Implementing this measure would permit the firetube boiler to run full time to meet the plant's base load steam needs, giving further savings, as discussed in Section 3.2.1.1.

Savings from implementation of this measure on a stand alone basis are detailed in Appendix 9.

ENERGY SAVINGS	= 1576 GJ/Year
COST SAVINGS	= 85,354 Sucres/Year
COST OF IMPLEMENTATION	= 152,000 Sucres
SIMPLE PAYBACK	= 1.8 Years

3.2.2.4 Insulate Washers, Pasteurizers and Condensate Return Tanks

Insulating the surfaces of the washers, pasteurizers and condensate return tanks would reduce radiation losses and boiler loading. Implementing this measure would permit the firetube boiler to run full time to meet the plant's base load steam needs, giving further savings as detailed in Section 3.2.1.1.

Implementation of this measure on a stand alone basis would give energy savings as outlined in Appendix 11.

ENERGY SAVINGS	= 6398 GJ/Year
COST SAVINGS	= 527,067 Sucres/Year
COST OF IMPLEMENTATION	= 1,046,123 Sucres
SIMPLE PAYBACK	= 2.0 Years

3.2.2.5 Repair of Steam Traps

There are five failed steam traps that are passing steam on the Line 4 washer. Repairing the traps would reduce steam needs and would permit the firetube boiler to run full time to meet the plant's base load steam needs, giving further savings, as discussed in Section 3.2.1.1.

Implementation of this measure on a stand alone basis would give savings as detailed in Appendix 12.

ENERGY SAVINGS	= 132 GJ/Year
COST SAVINGS	= 10,874 Sucres/Year
COST OF IMPLEMENTATION	= 25,000 Sucres
SIMPLE PAYBACK	= 2.3 Years

3.2.2.6 Pipe Work Insulation

Insulation of bare steam, condensate and hot waterpipe work throughout the plant will reduce radiation losses and boiler loading. Implementing this measure would permit the firetube boiler to run full time to meet

the plant's base load steam needs, giving further savings as discussed in Section 3.2.1.1.

Savings from implemetation of this measure on a stand alone basis are detailed in Appendix 10.

ENERGY SAVINGS	= 2496 GJ/Year
COST SAVINGS	= 205,620 Sucres/Year
COST OF IMPLEMENTATION	= 671,421 Sucres
SIMPLE PAYBACK	= 3.3 Years

3.2.2.7 Return Condensate to Boilerhouse

Condensate is currently run to drain from the pasteurizers that could be returned to the boilers, giving energy savings. Implementing this measure would permit the firetube boilers to run full time to meet the plant's base load steam needs, giving further savings, as discussed in Section 3.2.1.1.

Savings by implementing this measure on a stand alone basis are detailed in Appendix 13.

ENERGY SAVINGS	= 1104 GJ/Year
COST SAVINGS	= 90,948 Sucres/Year
COST OF IMPLEMENTATION	= 300,000 Sucres
SIMPLE PAYBACK	= 3.3 Years

3.3 Projects For Future Consideration

3.3.1 Replace Water Tube Boilers

The existing watertube boilers have very low efficiencies. Significant energy savings could be made by replacement of the plant. This measure should be considered as an alternative to using the firetube boiler as the base load. Work involved to determine the best option for a new

plant is beyond the scope of this study and given the existing fuel prices, this measure is not as attractive financially. Energy savings are indicated for replacement of the plant with a packaged boiler to meet all steam requirements for the plant are shown in Appendix 16.

ENERGY SAVINGS	= 24,277 GJ/year
COST SAVINGS	= 1,999,939 Sucres/Year
COST OF IMPLEMENTATION	= 15,000,000 Sucres
SIMPLE PAYBACK	= 7.5 Years

3.3.2 Fit an Oxygen Trim System To Firetube Boiler

If the firetube boiler operates as the base load boiler, then it would be worthwhile fitting an automatic oxygen trim system to control combustion conditions. Given existing fuel prices, this measure is not very attractive financially. However, it is presented for future consideration should fuel prices rise. Energy savings are detailed in Appendix 15.

ENERGY SAVINGS	= 1267 GJ/Year
COST SAVINGS	= 104,375 Sucres/Year
COST OF IMPLEMENTATION	= 1,200,000 Sucres
SIMPLE PAYBACK	= 11.5 Years

APPENDIX 1

SUMMARY OF MEASURES

ITEM	ENERGY SAVED GJ	COST SAVED SUCRES	% SAVINGS GJ	% SAVINGS SUCRES	IMPLEMENTATION COSTS SUCRES	SIMPLE PAYBACK YEARS
Replace Steam Pump	1,576	84,354	5.2	2.5	152,000	1.8
Pipework Insulation	2,496	205,620	8.2	6.2	671,421	3.3
Insulate Washers, Pasteurizers, Cond. Tanks	6,398	527,067	21.1	15.7	1,046,123	2.0
Repair Steam Traps	132	10,874	0.4	0.3	25,000	2.3
Return Condensate	1,104	90,948	3.6	2.7	300,000	3.3
Use Firetube Boiler	17,158	1,413,476	56.5	42.0	-	-
Replace Fluorescents	53	34,980	0.2	1.0	50,050	1.4
Fit time Switches	158	104,280	0.5	3.1	150,000	1.4
Power Factor Corr.	-	783,926	-	23.3	784,000	1.0
Oxygen Trim	1,267	104,375	4.3	3.2	1,200,000	11.5
Replace Water Tube Boiler*	(24,277)	(1,999,939)	-	-	(15,000,000)	(7.5)
Totals, Excluding Boiler Replacement	30,342	3,360,900	100.0	100.0	4,378,594	1.3

* Figures not included in totals, presented for reference only.

APPENDIX 2

SUMMARY OF SAVINGS BY FUEL TYPE

Fuel	Annual Savings	GJ* Savings	Cost Savings
Electricity	37,222 kWh	134	872,366**
Bunker	191,432 Gal	30,208	2,488,534
Totals		30,342	3,360,900

Conversion to GJ*

Electricity - 0.0036 x kWh
Bunker - 0.1578 x gallons

** Includes savings due to improved power factor.

APPENDIX 3

EQUIPMENT INVENTORY

Item	HP
Brew House	
Malt Mills x 2	each 30
Brewing Kettle Pump	30
Filter	-
Adjunct Vat	
Rice Mills	10
Corn Mills	15
Extractor Filter	40
Dust Extractor	
Residue Pump	
Whirlpool	
Silo Air Conveyor	40
Wort Pump x 2	each 44
Fermentation	
Basement	
Tank Cleaning Pump	15
Washing Pump	5
Fifth Floor	
Fan	5
NaOH Pump	3
Glycol Pump x 4	each 5
Water Pump	5
Cold Water Pump	10
Elevator	10.5
Air Extractor	0.33
Fan	2
Compressor House and Terrace	
NH_3	380
Fan x 3	each 15
Water Pumps x 4	1.5
Water Pumps x 3	1
NH_3 Compressor x 4	each 100
NH_3Compressor	125
Air compressors x 2	each 100

APPENDIX 3, cont'd

EQUIPMENT INVENTORY

Item	HP
Offices	
Elevator	10
Fan	3
Water Pump, North	1.5
Water Pump, South	1.5
Water Pump, River	0.5
Water Pump, Hill	0.5
Water Pump	10
First Floor	
Small Air Compressor	0.5
Water Pumps x 4	each 5
Beer Pump	20
Carbonated Water Pump	5
Carbon Dioxide Compressors x 2	each 10
Fans 2	each 8
Fans 2	each 7.5
Fans 2	each 0.25
Third Floor	
Beer Pump	15
Fourth Floor	
Fan	5
Cold Water Pump	1
Air Conditioning	2
Basement Beer Pump x 2	each 5
Bottling	
Line 4	
Washer	40
Pasteurizer	75
Hydraulic system x 2	each 40
Crate Washer	51

APPENDIX 3, cont'd

EQUIPMENT INVENTORY

Item	HP
Line 3	
Washer	36
Pasteurizer	76
Silo	
Air Conveyor	40
Boiler Plant	
Watertube Boilers x 2	10.9 tonnes per hour
Firetube Boiler	7.7 tonnes per hour
Fuel Pump	10
Feedwater Pump x 1	38
Feedwater Pumps x 2	each 123.5
Water Tank	90
Gas Extractor x 2	each 15
Water Pump	20

APPENDIX 4

BOILER DETAILS

Location: Boilerhouse

Boiler	1	2	3
Manufacturer:	Babcock & Wilcox	Babcock & Wilcox	York Shipley
Type:	Watertube	Watertube	Firetube
Rating tonnes/hr:	10.9	10.9	7.7
Medium Raised:	Steam	Steam	Steam
Normal Operating Pressure (bar):	11	11	10

Burners

Number:	3	3	1
Fuel Fired:	Bunker	Bunker	Bunker
Manufacturer:	Babcock & Wilcox	Babcock & Wilcox	York Shipley
Type:	Pressure Jet	Pressure Jet	Pressure Jet
Atomization:	Steam	Steam	Air
Draft:	Induced	Induced	Forced
Burner Controls:	Manual	Manual	Automatic
Draft Control:	Manual	Manual	Automatic

APPENDIX 5

BOILER COMBUSTION TESTS

Boiler No. 2 of 3 Date of Test: 9/12/84

Fuel Fired: Bunker Time: 9:30 am - 1

Test Results

Item	Units	Measurement
Firing Rate		
CO_2 in Flue Gases after Economizer	%	5
O_2 in Flue Gases after Economizer	%	15
Ambient Temperature	°F	81
Flue Gas Temperature after Economizer	°F	370
Smoke Number		2
Draft	ins.w.g.	-5.0
Feedwater into Economizer	°F	194
Feedwater out of Economizer	°F	203
Steam Pressure	bar	9
Flue Gas Losses	%	22.15
Combuston Efficiency	%	77.85

Measurement	Instrument Used
% CO_2 in Flue Gases	Fyrite
% O_2 in Flue Gases	Fyrite
Flue Gas Temp. after Economizer	Thermocouple & Indicator
Ambient Air Temperature	Mercury in Glass Thermometer
Smoke Number	Truespot Smoke Pump
Feedwater Temperature	Thermocouple & Indicator

APPENDIX 5, cont'd

BOILER COMBUSTION TESTS

Boiler No. 3 of 3 Date of Test: 9/11/84

Fuel Fired: Bunker Time: 11:00 am

Test Results

Item	Units	Measurement
Firing Rate		Medium
CO_2 in Flue Gases	%	12.2
O_2 in Flue Gases	%	7.3
Ambient Temperature	°F	90
Flue Gas Temperature	°F	381
Smoke Number		4.5
Draft	ins.w.g.	-0.3
Feedwater Temp.	°F	119
Steam Pressure	bar	7.6
Flue Gas Losses	%	13.53
Combuston Efficiency	%	86.47

Measurement	Instrument Used
% CO_2 in Flue Gases	Fyrite
% O_2 in Flue Gases	Fyrite
Flue Gas Temperatures	Thermocouple & Indicator
Ambient Air Temperature	Mercury in Glass Thermometer
Smoke Number	Truespot Smoke Pump
Feedwater Temperature	Thermocouple & Indicator
Steam Pressure	Pressure Gauge

APPENDIX 6

WATER TESTS AND ESTIMATE OF BLOWDOWN

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

Location of Measurement	Boiler 2	Boiler 3
Boiler Drum Water	5900	3200
Feedwater	100	110
Condensate Return	0	40
Make Up Water	200	190

Percentage Make-Up Water

ppm Feedwater = X (ppm of make Up) + (1-X) ppm Condensate

Boiler 2

$$100 = X(200) + (1-X)(0)$$

$$100 = 200X$$

$$X = 0.5 \text{ or } 50\%$$

Boiler 3

$$110 = X(190) + (1-X)(40)$$

$$110 = 190X + 40 - 40X$$

$$110 = 150X + 40$$

$$70 = 150X$$

$$X = \frac{70}{150}$$

$$X = 0.47 \text{ or } 47\%$$

APPENDIX 6, cont'd

	Boiler 2	Boiler 3
% Make Up	50	47
% Condensate Return	50	53

$$\% \text{ Blowdown} = \frac{(\% \text{ Make Up X TDS Make Up})}{100\ (\text{TDS Boiler Drum} - \text{TDS Make Up})}$$

Boiler 2 $= \frac{(50 \times 200)}{(100)(5900-200)}$

$= 0.0175$ kg/kg steam

Boiler 3 $= \frac{(190 \times 47)}{(3200-190)\ (100)}$

$= 0.03$ kg/kg steam

$$\text{Percentage Blowdown Loss} = \frac{\text{Heat Content in Blowdown}}{\text{Heat Input to Boiler}}$$

$$\text{Estimated Steam Generated} = \frac{\text{Fuel Input to Boiler x Boiler Eff}}{\text{Heat Required to Raise kg Steam}}$$

Data	Boiler 2	Boiler 3
Feedwater Temp. °C	88	88
Boiler Pressure bar	9	9
Temperature of Make Up Water °C	33	33
Heat Content of Make Up Water kJ/kg	138	138
Boiler Combustion Efficiency	77.85	86.47
Annual Fuel Input GJ/yr	125,756	29,302
Heat Content of Steam at 98% dryness kJ/kg	2722	2722

APPENDIX 6, cont'd

	Boiler 2	Boiler 3
Heat Content of Water at 9 bar, 2% kJ/kg	15	15
Heat Content of Feedwater kJ/kg	369	369
Heat Added in Boiler kJ/kg = (2722 + 15) - (369) =	2368	2368

Boiler 2

$$\text{Steam Generation} = \frac{(125{,}756)(0.7785)(10^6)}{(2368)}$$
$$= 41{,}343{,}347 \text{ kg/year}$$

Boiler 3

$$\text{Steam Generation} = \frac{(29{,}302)(0.8647)(10^6)}{(2368)}$$
$$= 10{,}699{,}932 \text{ kg/year}$$

Boiler 2

$$\text{Blowdown} = (0.0175)(41{,}343{,}347)$$
$$= 723{,}509 \text{ kg/year}$$

Boiler 3

$$\text{Blowdown} = (0.03)(10{,}699{,}932)$$
$$= 320{,}998 \text{ kg/year}$$

$$\text{Net Heat Content of Blowdown} = 763 - 138$$
$$= 625 \text{ kJ/kg}$$

$$\text{Percent Blowdown Loss} = \frac{(\text{Net Heat Content})(\text{kg/year})(100)}{(\text{Fuel Input})(10^6)}$$

Boiler 2

$$= \frac{(625)(723{,}509)(100)}{(125{,}756)(10^6)}$$

$$= 0.36\%$$

Boiler 3

$$= \frac{(625)(320{,}998)(100)}{(29{,}302)(10^6)}$$

$$= 0.68\%$$

APPENDIX 7

RADIATION LOSSES FROM BOILERS

Assumptions

Radiation loss from Boiler 2 = 5% at MCR

Radiation loss from Boiler 3 = 2% at MCR

Data

		Boiler 2	Boiler 3
Steam Produced Per Year kg/hr (See Appendix 6)	=	41,343,347	10,699,932
Hours of Operation 1983-84	=	42 weeks x 152	42 x 50
	=	6384	= 2100
MCR kg/hr	=	10,884	= 7710

Load Factor $= \frac{(\text{kg/year})}{(\text{Hours/year})(\text{MCR})}$

Boiler 2 $= \frac{41,343,347}{(6384)(10,884)}$

$= 0.595$

Boiler 3 $= \frac{(10,699,932)}{(2100)(7710)}$

$= 0.661$

Radiation Loss $= \frac{(\text{Radiation Loss at MCR})}{(\text{Load Factor})}$

Boiler 2 $= \frac{5}{0.595}$

$= 8.40\%$

Boiler 3 $= \frac{2}{0.661}$

$= 3.03\%$

APPENDIX 8

BOILER EFFICIENCY

Data	Boiler 2	Boiler 3
% Flue Gas Loss See Appendix 5	22.15	13.53
% Blowdown Loss See Appendix 6	0.36	0.68
% Radiation Loss See Appendix 7	8.40	3.03
TOTAL LOSSES	30.91	17.24

Boiler Efficiency = 100% - Total Losses

Boiler 2 = 100 - 30.91

= 69.09%

Boiler 3 = 100 - 17.24

= 82.76%

Total Plant Hours of Operation = 8484

		Boiler 2	Boiler 3
% Hours of Operation	=	6384	2100
Overall Boiler Efficiency	=	$\frac{6384}{8484} \times (69.09)$	$\frac{2100}{8484} \times (82.76)$
	=	51.99 + 20.49	
	=	72.48%	

APPENDIX 9

REPLACEMENT OF STEAM RECIPROCATING PUMP

The steam reciprocating pump used for pumping water exhausts to atmosphere. Energy can be saved by replacing the pump with an electric driven pump.

Data

Steam Pressure Into Pump	=	8.4 bar
Steam Pressure Out of Pump	=	2.00 bar
Enthalpy of Steam In	=	2771 kJ/kg
Enthalpy of Steam Out	=	2707 kJ/kg
Specific Volume In	=	0.2400 M^3/kg
Specific Volume Out	=	0.8856 M^3/kg
Stroke Frequency	=	35 cycles per minutes
Size of Pump Stroke	=	203.2 x 254 mm
Water Pressure Out of Pump	=	6.3 bar
1 bar	=	10^5 Newtons/M^2
1 kJ	=	10^3 Nm
Pump Operating Hours	=	6000
Electric Pump Efficiency	=	85%

Calculation

Water Flow = Strokes/hour x Volume of Chamber

Volume of Chamber $= \frac{D^2 \times L}{4}$

$$= \frac{3.142 \times (203.2)^2 \times 254}{4 \times 10^3 \times 10^3 \times 10^3}$$

$$= 0.0082 \ M^3$$

Steam/Water Flow = 35 x 60 x 0.0082

= 17.3 M^3/hr

Energy Given to Water = 17.3 x 6.3 x 10^5

= 10.9 x 10^6 Nm hour

= 10.9 x 10^3 kJ/hour

Energy Used By Pump = Energy in Steam In - Energy In Steam Out

Energy In Steam In = $\frac{\text{Volume x Enthalpy}}{\text{Specific Vol.}}$

Energy In Steam In = $\frac{17.3 \times 2771}{0.24}$

= 199.7 x 10^3 kJ/hr

Energy In Steam Out = $\frac{17.3 \times 2707}{0.8856}$

= 52.9 x 10^3 kJ/hr

Energy Used By Pump = 199.7 x 10^3 - 52.9 x 10^3

= 146.8 x 10^3 kJ/hr

Efficiency of Pump = $\frac{\text{Energy Given to Water}}{\text{Energy Consumed}}$

= $\frac{10.9 \times 10^3 \times 10^2}{146.8 \times 10^3}$

= 7.4%

Energy Consumed at Boiler = $\frac{\text{Energy Entering Pump x Hours}}{\text{Boiler Eff.}}$

= $\frac{199.7 \times 10^3 \times 6000}{0.7248 \times 10^6}$

= 1653 GJ/year

Energy Cost = (1653)(82.38)

= 136,174 Sucres/year

Size of Electric Pump $= \frac{\text{Energy Given to Water}}{\text{Efficiency} \times 3.6 \times 10^3} \text{ kW}$

$= \frac{10.9 \times 10^3}{0.85 \times 3.6 \times 10^3} \text{ kW}$

= 3.56 kW

= 4.7 HP

Energy Usage of Electric Pump = kW x Hours

= 3.56 x 6000

= 21,360 kWh/year

= 77 GJ/year

Cost = (77)(660)

= 50,820 Sucres/year

Energy Savings

= (1653) - (77)

= 1576 GJ/year

Cost Savings

= (136,174) - (50,820)

= 85,354 Sucres/year

Cost of Implementation

The cost of a replacement electric pump is estimated to be 152,000 Sucres.

Simple Payback

$$= \frac{152,000}{85,354}$$

$$= 1.8 \text{ years}$$

ENERGY SAVINGS	= 1576 GJ/Year
COST SAVINGS	= 85,354 Sucres/Year
COST OF IMPLEMENTATION	= 152,000 Sucres
SIMPLE PAYBACK	= 1.8 Years

APPENDIX 10

PIPEWORK INSULATION

Assumptions

Heat loss reduction by insulation = 90 percent
Pipework fittings equivalent length = 15 percent

Data

Operating hours = 7056 hrs/year, general
= 4620 hrs/year, Brewhouse
= 3150 hrs/year, Line 3
= 3150 hrs/year, Line 4
Boiler efficiency = 72.48 percent
Missing insulation is detailed in data sheets following the calculation

Calculation

Energy Savings (general) $= \frac{(\text{Wasted heat loss}) \times (\text{operating hours} \times (0.9)}{(\text{boiler efficiency}) \times 10^6}$

$= \frac{(169,449)(7056)(0.9)}{(0.7248)\ (10^6)}$

= 1485 GJ/year

Similar savings are possible in the Brewhouse, Lines 3 and 4 to give total savings of 2496 GJ/Year

Cost Savings = (GJ/yr) (S/GJ)

= (2496)(82.38)

= 205,620 Sucres

Cost of Implementation

The cost of implementation is estimated as follows:

Pipe Diameter	Length Required M	Unit Cost S/M	Total Cost Sucres
20 mm	10	820	8,200
25 mm	25	840	21,000
40 mm	132	1020	134,640
65 mm	97.5	1319	128,603
75 mm	6	1492	8,952
90 mm	76	1750	133,000
100 mm	4	1923	7,692
150 mm	11.2	2637	29,534
155 mm	74	2700	199,800
			671,421

Simple Payback

$$= \frac{\text{Cost of Implementation}}{\text{Cost Savings}}$$

$$= \frac{671{,}421}{205{,}620}$$

$$= 3.3 \text{ years}$$

ENERGY SAVINGS	= 2496 GJ/Year
COST SAVINGS	= 205,620 Sucres/Year
COST OF IMPLEMENTATION	= 671,421 Sucres
SIMPLE PAYBACK	= 3.3 Years

APPENDIX 10, cont'd

DATA SHEET

Location	Pipe OD mm	Length M	Heat Loss kJ/Hr/M	Total Loss kJ/hr	Pipe Temp. °C	Operating Hours
General						
Roof of Fermentation Building	65	13	712	9,256	96	7,056
Branch off above line	65	54	712	38,448	96	7,056
Line on Brewhouse Roof to Compressor House	40	7	599	4,193	110	7,056
Hot Water Pipe From Roof of Fermentation to Brewhouse	155	74	1,168	86,432	71	7,056
Condensate Pipe From Fermentation to Bottling Line 4	40	80	389	31,120	75	7,056
Total				169,449		
Brewhouse						
Condensate Return from Brew Kettle	90	76	1,185	90,060	100	4,620
Condensate Return from Preheating Tank	75	3	1,004	3,011	82	4,620
Total				96,082		

APPENDIX 10, cont'd

DATA SHEET, continued

Location	Pipe OD mm	Length M	Heat Loss kJ/Hr/M	Total Loss kJ/hr	Pipe Temp. °C	Operating Hours
Line 3						
Steam Line from Boiler to Washers	115	8.5	1,743	14,816	118	3,150
Hot Water Pipe to Washers	65	8.5	712	6,052	81	3,150
Hot Water Pipe from Storage to Upper Tank	25	25	285	7,125	50	3,150
Hot Water Pipe from Washer to Storage	65	22	285	6,270	50	3,150
Steam Line To Pasteurizer	100	4	1,805	7,220	115	3,150
Total				41,483		
Line 4						
Steam Line to Pasteurizer	115	16	2,016	32,256	120	3,150
Steam Line to Washer	150	11.2	2,508	28,090	120	3,150
Hot Water From Storage to Washer	20	10	285	2,850	50	3,150
Hot Water From Storage On Hill to Storage Tank on Second Floor	40	45	285	12,825	0	3,150
Total				76,021		

APPENDIX 11

INSULATION OF WASHER, PASTEURIZER AND CONDENSATE RETURN TANKS

Data

Hours of Operation = Washers 3,045 hours/year
pasteurizers 3,1250 hours/year
Condensate Return Tanks 7,056 hours/year

Boiler Efficiency = 72.48%

Item	Location	h Watts	Area M^2	dT°C	Heat Loss w/Hr
Washer, Line 4	Sides	15.00	114.2	36	61,668
	Roof	17.16	77.75	53	70,712
Line 3	Sides	12,00	95.25	24	27,432
	Roof	17.16	63.86	53	58,079
Sub-Total			351.06		217,891
Pasteurizer Line 4	Sides	11.4	100.44	18	20,610
	Roof	16.77	100.24	30	50,431
Line 3	Sides	12.9	96,72	25	31,192
	Roof	16.77	105.11	30	52,881
Sub-Total			402.51		155.114
Condensate Tank 1 and 2	Sides 1	13.8	17.97	59	14,631
	Sides 2	13.8	17.97	54	13,391
	Top 1	17.9	3.80	62	4,217
	Top 2	17.9	3.80	53	3,605
Condensate Tank 1 and 2	Bottom 1	9	3.8	55	1,881
	Bottom 2	9	3.8	54	1,847
Sub-total			51.14		39,572

Energy Savings

$$= \frac{(\text{Wasted Heat})(\text{Hours of Operation})(0.9)(3.6)}{(\text{Boiler Eff.})\ (10^6)}$$

Washers $= \frac{(217891)(3045)(0.9)(3.6)}{(0.7248)(10^6)}$

= 1966 GJ/Year

Pasteurizers $= \frac{(155,114)(3150)(0.9)(3.6)}{(0.7248)\ (10^6)}$

= 2184 GJ/year

Condensate Return Tanks $= \frac{(39,572)(7056)(0.9)(3.6)}{(0.7248)(10^6)}$

= 1248 GJ/Year

Total Energy Savings = 2966 + 2184 + 1248
= 6398 GJ/Year

Cost Savings

= (6398)(82.38)
= 527,067 Sucres/Year

Cost of Implementation

The cost of insulation is estimated as follows:

Item	Area M^2	Unit Cost Sucres/M^2	Total Cost Sucres
Washers	351.06	1,300	456,378
Pasteurizers	402.51	1,300	523,263
Condensate Tanks	51.14	1,300	66,482
Total			1,046,123

Simple Payback

$$= \frac{\text{Total Cost}}{\text{Cost Savings}}$$

$$= \frac{1{,}046{,}123}{527{,}067}$$

$$= 2.0 \text{ years}$$

ENERGY SAVINGS	= 6398 GJ/Year
COST SAVINGS	= 527,067 Sucres/Year
COST OF IMPLEMENTATION	= 1,046,123 Sucres
SIMPLE PAYBACK	= 2.0 Years

APPENDIX 12

REPAIR OF STEAM TRAPS

Assumptions

Average leakage per failed trap = 2.5 kg/hr

Data

Steam system operating hours = 3150 hrs/yr
Number of failed traps = 5 traps on Line 4 washer
Boiler efficiency = 72.48 percent

Net heat content of steam at:
5.44 bar = 2434 kJ/kg

Calculation

Energy Savings

$$= \frac{(\text{No. of traps})(\text{leakage/trap})(\text{hrs/yr})(\text{heat content})(\text{load factor})}{(\text{boiler efficiency})(10^6)}$$

$$= \frac{(5)(2.5)(3150)(2434)}{(0.7248)(10^6)}$$

= 132 GJ/year

Cost Savings = (GJ/yr)(S/GJ)

= (132)(82.38)

= 10,874 Sucres/year

Cost of Implementation

The cost of repairing steam traps is estimated to be 5,000 Sucres per trap, giving a total implementation of of 25,000 Sucres.

APPENDIX 12

Simple Payback

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

$$= \frac{(25,000)}{(10874)}$$

= 2.3 Years

ENERGY SAVINGS	= 132 GJ/Year
COST SAVINGS	= 10,874 Sucres/Year
COST OF IMPLEMENTATION	= 25,000 Sucres
SIMPLE PAYBACK	= 2.3 Years

APPENDIX 13

RETURN CONDENSATE TO BOILERHOUSE

Condensate is currently run to drain from the pasteurizers and could be returned to the boilerhouse.

Data

Line	Section	Temperature °C	Flow Liters/hr	Heat Content GJ/hr
Pasteurizer				
3	2	50	672	0.065
3	5	65	95	0.015
3	7	52	40	0.004
3	7	52	135	0.014
3	8	50	93	0.009
3	10	39	12	0.001
Pasteurizer				
4	1	30	464	0.006
4	2	39	220	0.011
4	4	67	541	0.090
4	10	50	281	0.027
4	12	37	284	0.012
TOTAL				0.254

Temperature of Make Up Water = 27°C

Hours of Operation = 3150

Boiler Efficiency = 72.48%

Energy Savings

$$= \frac{(\text{Recoverable Heat})(\text{Hours})}{(\text{Boiler Eff.})}$$

$$= \frac{(0.254)(3150)}{(0.7248)}$$

$$= 1104 \text{ GJ/year}$$

Cost Savings

= (GJ/year)(Sucres/GJ)

= (1104)(82.38)

= 90,948 Sucres/year

Cost of Implementation

To make necessary connections and add a filtration system would cost 150,000 Sucres per system, for a total cost of 300,000 Sucres.

Simple Payback

$$= \frac{\text{Total Cost}}{\text{Savings}}$$

$$= \frac{3{,}000.00}{90{,}948}$$

= 3.3 years

ENERGY SAVINGS	= 1104 GJ/Year
COST SAVINGS	= 90,948 Sucres/Year
COST OF IMPLEMENTATION	= 300,000 Sucres
SIMPLE PAYBACK	= 3.3 Years

APPENDIX 14

USE FIRETUBE BOILER FOR BASELOAD INSTEAD OF WATERTUBE

By implementing the measures indicated steam loading can be reduced by 890 kg an hour on the boiler to give an average loading of 7.3 tonnes per hour. This load can be met using the firetube boiler. By using the firetube instead of the watertube, energy will be saved.

Assumptions

Radiation losses at MCR = 2% Firetube; 5% Water Tube
MCR kg per hour = 7710 Firetube;
10,884 Watertube
Annual Steam Demand = 46,360,680 kg/year

20% Steam will be generated by Watertube

Data

Boiler Efficiency Firetube = 82.76%

Boiler Efficiency Watertube = 69.09%

Existing Fuel Usage on Watertube = 125,756 GJ/year

Existing Fuel Usage on Firetube = 29,302 GJ/year

New Steam Generation Watertube = 9,272,122 kg/year

New Steam Generation Firetube = 37,088,558 kg/year

Net Heat Content Added in Boiler = 2368 kJ/kg

Calculation

Energy Used by Firetube $= \frac{37,088,558 \times 2368}{0.8276 \times 10^6}$

= 106,121,GJ/year

Energy Used by Watertube $= \frac{9,272,122 \times 2368}{0.6909 \times 10^6}$

= 31,779 GJ/year

Energy Savings

= Old usage - New Usage

= (125,756 + 29,302) - (106,121 + 31,779)

= 17,158 GJ/year

Cost Savings

= (17,158)(82.38)

= 1,413,476 Sucres/year

Cost of Implementation

To implement this measure it is necessary to implement the following:

	Cost Savings Sucres	Cost Sucres
Pipework Insulation	205,620	671,421
Replace Steam Pump	85,354	152,000
Insulate Washers, Pasteurizers, Condensate Tanks	527,067	1,046,123
Repair Steam Traps	10,874	25,000
Return Condensate	90,948	300,000
TOTAL	919,863	2,194,544

Total Savings will then be 2,333,339 Sucres per year. There is no cost involved in using the Firetube for base load.

Simple Payback

$$= \frac{\text{Cost of Implementation}}{\text{Cost Savings}}$$

$$= \frac{2,194,544}{2,333,339}$$

= 0.9 years

ENERGY SAVINGS	= 17,158 GJ/year
COST SAVINGS	= 1,413,476 Sucres/year

APPENDIX 15

FIT OXYGEN TRIM TO FIRETUBE BOILER

An automatic combustion control system should be fitted to the Firetube boiler if it is used as the base load boiler.

Assumptions

Improvement in Efficiency = 1%

Data

Fuel Usage (after implementation) = 106,121 GJ/year (See Appendix 14)

Existing Boiler Efficiency = 82.76%

Calculation

Energy Savings

$$= \frac{(\text{New Eff.} - \text{Old Eff})\ (\text{Fuel Usage})}{(\text{New Eff})}$$

$$= \frac{(83.76 - 82.76)\ (106{,}121)}{(83.76)}$$

= 1267 GJ/year

Cost Savings

= (1267)(82.38)

= 104,375 Sucres/year

Cost of Implementation

The cost of an oxygen trim automatic combustion control is estimated at 1,200,000 Sucres.

Simple Payback

$$= \frac{1{,}200{,}000}{104{,}375}$$

= 11.5 years

ENERGY SAVINGS	= 1267 GJ/Year
COST SAVINGS	= 104,375 Sucres/Year
COST OF IMPLEMENTATION	= 1,200,000 Sucres
SIMPLE PAYBACK	= 11.5 Years

APPENDIX 16

REPLACE WATERTUBE BOILER

The existing Watertube Boilers could be replaced by a single package boiler sized at 12 tonnes per hour to produce all steam needs for the plant.

Data

Existing Fuel Usage Watertube	= 125,576 GJ/year
Existing Fuel Usage Firetube	= 29,302 GJ/year
Boiler Efficiency Watertube	= 69.09%
Boiler Efficiency Firetube	= 82.76%
Boiler Efficiency Packaged	= 85%

Calculation

Energy Savings

$$= \frac{\text{(New Eff. - Old Eff) (Fuel Usage)}}{}$$

Savings over Firetube $= \frac{(85 - 82.76)(29,302)\ \text{(New Eff)}}{(85)}$

$= 772$ GJ/year

Savings over Watertube $= \frac{(84 - 69.09)\ (125,576)}{(85)}$

$= 23,505$ GJ/year

Total Savings $= 772 + 23,595$

$= 24,277$ GJ/year

Cost Savings

= (GJ/year)(S/GJ)

= (24,277)(82.38)

= 1,999,939 Sucres/year

Cost of Implementation

The cost of a packaged boiler installed is estimated to be 15,000,000 Sucres.

Simple Payback

$$= \frac{15 \times 10^6}{1,999,939}$$

$$= 7.5 \text{ years}$$

ENERGY SAVINGS	= 24,277 GJ/year
COST SAVINGS	= 1,999,939 Sucres/Year
COST OF IMPLEMENTATION	= 15,000,000 Sucres
SIMPLE PAYBACK	= 7.5 Years

APPENDIX 17

REPLACE FLUORESCENT TUBES WITH HIGH EFFICIENCY TUBES

There are 1001 40 watt fluorescent tubes that can be replaced with 35 watt tubes to give energy savings. See Appendix 19 for locations.

Assumptions

Hours of Operation = 2920 average

Calculation

Energy Savings

$$= \frac{\text{(Number of tubes)(Wats Saved)(Hours) kWh}}{(10^3)}$$

$$= \frac{(1001)(5)(2920)}{(10^3)}$$

= 14,615 kWh X 0.0036

= 53 GJ/year

Cost Savings

= (GJ/year)(S/GJ)

= (53) (660)

= 34,980 Sucres/year

Cost of Implementation

The cost differential between regular fluorescents and high efficiency tubes is estimated to be 50 Sucres. The brewery should replace existing bulbs on an attrition basis with high efficiency tubes. The estimated implementation cost is 50,050 Sucres.

Simple Payback

$$= \frac{\text{Cost of Implementation}}{\text{Cost Savings}}$$

$$= \frac{50{,}050}{34{,}980}$$

= 1.4 years

ENERGY SAVINGS	= 53 GJ/year
COST SAVINGS	= 34,980 Sucres/Year
COST OF IMPLEMENTATION	= 50,050 Sucres
SIMPLE PAYBACK	= 1.4 Years

APPENDIX 18

INSTALL TIME SWITCHES TO TURN OFF LIGHTS IN FERMENTATION AND OFFICE DEPARTMENTS

There are many lights in the fermentation and office departments that are left on even when the rooms are unoccupied. A timer switch can be fitted so that lights are only used when the rooms are occupied.

Assumptions

Current lighting operating hours = 8760 Fermentation; 2088 Offices
Operating hours after fitting switches = 2920 Fermentation; 1044 Offices
1 kWh x 0.0036 = 1 GJ

Data

Location	Type	Number	Wattage	Total Wattage
South Zone				
Second Floor Tank Room	Incandescent	5	100	500
Pre Gasification Room	Fluorescent	6	95	570
Third Floor				
Tank Room	Fluorescent	6	95	570
	Incandescent	2	100	200
Fourth Floor				
Fermentation	Fluorescent	13	165	2145
Room L1 & L2	Fluorescent	1	165	165
Washing	Fluorescent	4	95	380
Fifth Floor				
Fermentation	Fluorescent	11	95	1045
Subtotal				5575
Administration				
Second Floor Store	Fluorescent	3	95	285
Fourth Floor Offices	Fluorescent	60	175	10,500
Subtotal				10,785

Calculation

Energy Savings

$$= \frac{(0.0036)(\text{total Wattage})(\text{Difference in Hours Operated})}{(10^3)}$$

Fermentation

$$= \frac{(0.0036)(5575)(8760 - 2920)}{(10^3)}$$

$$= 117 \text{ GJ/year}$$

Offices

$$= \frac{(0.0036)(10,785)(2088-1044)}{(10^3)}$$

$$= 41 \text{ GJ/year}$$

Total Savings = 117 + 41

= 158 GJ/year

Cost Savings

= (GJ/year)(Sucres/GJ)

= (158)(660)

= 104,280 Sucres/year

Cost of Implementation

The cost of fitting switches is estimated to be 10,000 Sucres per switch. 15 switches are required, giving a cost of 150,000 Sucres.

Simple Payback

$$= \frac{\text{Cost of Implementation}}{\text{Cost Savings}}$$

$$= \frac{150,000}{104,280}$$

= 1.4 years

ENERGY SAVINGS	= 158 GJ/year
COST SAVINGS	= 104,280 Sucres/Year
COST OF IMPLEMENTATION	= 150,000 Sucres
SIMPLE PAYBACK	= 1.4 Years

APPENDIX 19

LIGHTING SURVEY

Location	Number of Lamps	Type	Watts/ Bulbs	Bulbs per Lamp	Number of Ballasts	Total Watts	Foot Candles	Hours Operated
Line 4								
Labelling	20	F	40	4	2	3500	13.5	3654
Pasteurizer	20	F	40	4	2	3500	103	3654
Washer	15	F	40	4	2	2625	30	3654
Crate Washer	9	F	40	4	2	1575	30	1044
Boilers	2	F	75	2	1	350	7.5	3393
	6	F	40	2	1	570	20	3393
	5	F	40	2	1	475	70	3393
Compressor House	15	F	40	2	1	1524	9.5	8760
Transformer Bank #2	3	F	40	1	1	165	13.5	8760
Filtration/ Gasification Controls	5	F	75	2	1	875	25	8760
	5	F	40	4	2	875	60	8760
	8	I	100	1	-	800	3.5	8760
First Floor Fermentation	4	F	40	2	1	380	6	8760
	6	I	100	1	-	600	5	8760
Second Floor Fermentation	5	I	100	2	1	380	6	8760
	6	F	40	2	1	570	5.5	8760
	2	I	100	2	-	200	5.5	8760
Third Floor Fermentation	6	F	40	2	1	570	7	8760
	2	I	100	1	-	200	8	8760
Mezzanine	1	I	100	1	-	100	1	8760
Fourth Floor Fermentation	13	F	75	2	1	2145	18	8760
	4	F	40	2	1	380	15	8760

APPENDIX 19, cont'd

LIGHTING SURVEY

Location	Number of Lamps	Type	Watts/ Bulbs	Bulbs per Lamp	Number of Ballasts	Total Watts	Foot Candles	Hours Operated
Attic Room								
1 & 2	1	F	75	2	1	165	18	8760
Corridor	3	I	100	1	-	300	8.5	8760
Mezzanine	2	I	100	1	-	200	-	-
Fifth Floor								
Fermentation	11	F	40	2	1	1045	20	8760
Corridor	4	I	100	1	-	400	5	8760
Mezzanine	5	I	100	1	-	500	7.5	4380
	1	I	100	1	-	100	-	
Mechanics								
Store	3	F	40	2	1	285	11	2088
Machine Area	16	F	40	2	1	1520	40	2088
Electric Shop	4	F	40	2	1	380	19	2088
Shop	3	F	75	2	1	495	25	2088
Store								
Zone 1	10	F	40	2	1	950	22.5	2088
Zone 2	32	I	150	1	-	4800	8	2088
Store	24	F	40	2	1	2280	21	2088
Store								
Sec. Fl 1	13	F	4	2	1	1235	120	2088
Sec. Fl 2	6	I	100	1	-	600	200	1044
Offices	60	F	40	3	2	9000	140	2088
Fourth Floor								
Stores	4	F	40	4	2	700	42	2088
Technical Dept.	16	F	40	4	2	2800	50	2088
Line 3	67	F	40	2	1	6365	50	2088
Production	27	F	75	2	1	4455	60	2088
Third Floor								
Laboratory	18	F	40	2	1	1710	25	2088
Offices	6	F	40	2	1	570	25	2088

APPENDIX 20

POWER FACTOR CORRECTION

The brewery currently maintains a power factor of 0.91 by means of installed capacitors. The electric utility plan to increase the penalty for plants operating at power factors below 0.95. Addition of extra capacitor capacity will alleviate the penalty.

Data

Based on current utility data:

Current kWh charge = 2.38 Sucres/kWh
Annual kWh usage = 6,942,600 kWh
Current demand charge = 61.93 Sucres/kW
Monthly Peak Demand = 1764 kW

Calculation

Cost Savings

Annual Cost at current tariff based on marginal costs:

= (kWh)(Sucres/kWh)+(kW)(12)(Sucres/kW)
= (6,942,600)(2.38) + (1764)(12)(61.93)
= 16,523,388 + 1,310,934
= 17,834,322 Sucres/year

Annual Cost at proposed tariff:

$$= (\text{Current Cost})\ \frac{(0.95)}{(0.91)}$$

$$= (17{,}834{,}322)\ \frac{(0.95)}{(0.91)}$$

= 18,618,248 Sucres/year

Savings = 18,618,248 - 17,834,322

= 783,926 Sucres/year

Size of Capacitors Required

Existing Reactive Load kVAr = kW (Tan r)
= 1764 (0.456)
= 804 kVAr

New Reactive Load kVAr = kW (Tan r)
= 1764 (0.329)
= 580 kVAr

Capacitor capacity required = 804 - 580
= 224 kVAr

Cost of Implementation

The installed cost of capacitors is estimated at 3500 Sucres per kVAr. Total cost is calculated at 784,000 Sucres

Simple Payback

$$= \frac{\text{Cost of Implementation}}{\text{Cost Savings}}$$

$$= \frac{784{,}000}{783{,}926}$$

$$= 1.0 \text{ year}$$

ENERGY SAVINGS	= Nil
COST SAVINGS	= 783,926 Sucres/Year
COST OF IMPLEMENTATION	= 784,000 Sucres
SIMPLE PAYBACK	= 1.0 Years

APPENDIX 21

EFFICIENCY OF AMMONIA COMPRESSORS

Date of Tests: 9/14/84

Data

Compressors	Time	Compressor 2	Compressor 3	250 hp Sulzer
Current (Amp)	15:15	157	142	24
	15:25	157	142	23.9
	15:35	156	140	23.9
	15:45	156	141	23.9
Average		156.5	141.25	23.9
Pressure Suction Discharge	15:15	23	23	27.5
		186	186	177
	15.25	22.8	22.8	27.5
		186	186	177
	15:35	22.5	22.5	28
		185	185	176
	15:45	22.8	22.8	26
		185	185	175
Voltage		236	236	4160
Power Factor (assumed)		1	1	1

Cooling Towers		1	2	3	4	5	6	7	8
Air Temperature In	db °F	Off	83	82	83	Off	84	87	85.5
	wb °F		74	74.5	75	Off	75	77	75
Air Temperature Out (1)	db °F	Off	83.5	85.5	85	Off	83.25	87	88.25
	wb °F		81.5	84.5	82		81.25	86.5	87.75
Air Temperature Out (2)	db °F	Off	84.5	85	85	Off	-	-	-
	wb °F		82.5	83.5	83		-	-	-
Air Temperature Out (3)	db °F	Off	84	85	85	Off	-	-	-
	wb °F		82	82.5	82		-	-	-
Air Temperature Our (4)	db °F	Off	85	84	85	Off	-	-	-
	wb °F		84	82.5	81		-	-	-

APPENDIX 21, cont'd

EFFICIENCY OF AMMONIA COMPRESSORS, cont'd

Cooling Towers	1	2	3	4	5	6	7	8
Air Volume In cfm	Off	16,716	15369	21,021	Off	-	-	-
Air Volume Out (1) cfm	Off	4,214	3,485	6,165	Off	31,920	6,901	10,639
Air Volume Out (2) cfm	Off	4,557	2,004	5,600	Off	-	-	-
Air Volume Out (3) cfm	Off	4,728	3,032	4,248	Off	-	-	-
Air Volume Out (4) cfm	Off	2,740	3,400	4,572	Off	-	-	-
Temperature of Ammonia In °F	Off	129	Off	131	Off	131	129	131
Temperature of Ammonia Out °F	Off	97	Off	93	Off	90	95	95
Specific Heat of Ammonia Btu/lb °F		1.22						
Mositure Contents 16 moisture/lb dry air								
Air In	Off	0.016	0.017	0.017	Off	0.017	0.018	0.017
Air Out 1	Off	0.023	0.026	0.023	Off	0.023	0.028	0.029
Air Out 2	Off	0.024	0.025	0.024	Off	-	-	-
Air Out 3	Off	0.023	0.024	0.023	Off	-	-	-
Air Out 4	Off	0.025	0.024	0.022	Off	-	-	-
Enthalpy of Air In Btu/lb	Off	37.8	38.2	38.5	Off	38.5	40.4	38.5
Enthalpy of Air Out (1) Btu/lb	Off	45.3	48.75	45.8	Off	45.0	51.2	52.8
Air Out (2) Btu/lb	Off	46.4	47.6	47.0	Off	-	-	-
Air Out (3) Btu/lb	Off	45.8	46.4	45.8	Off	-	-	-
Air Out (4) Btu/lb	Off	48.2	46.4	44.7	Off	-	-	-

APPENDIX 21, cont'd

EFFICIENCY OF AMMONIA COMPRESSORS, cont'd

Cooling Towers	1	2	3	4	5	6	7	8
Specific Volumes								
Air In cf/lb	Off	14.02	14.00	14.03	Off	14.05	14.16	14.09
Air Out (1)	Off	14.18	14.29	14.22	Off	14.17	14.37	14.43
Air Out (2)	Off	14.22	14.26	14.25	Off	-	-	-
Air Out (3)	Off	14.20	14.23	14.22	Off	-	-	-
Air Out (4)	Off	14.27	14.21	14.20	Off	-	-	-
Mass of Air In/lb	Off	1192	1097.8	1498.3	Off	-	-	-
Mass of Air Out/lb (1)	Off	297.2	243.9	433.5	Off	2252.6	480.2	737.3
Mass of Air Out/lb (2)	Off	320.5	140.5	393.0	Off	-	-	-
Mass of Air Out/lb (3)	Off	333.0	213.07	298.7	Off	-	-	-
Mass of Air Out/lb (4)	Off	192.01	239.3	322.0	Off	-	-	-
Mass of Water In	Off	19.07	18.66	25.47	Off	-	-	-
Mass of Water Out (1)	Off	6.84	6.34	9.97	Off	51.81	13.45	21.38
Mass of Water Out (2)	Off	7.69	3.51	9.43	Off	-	-	-
Mass of Water Out (3)	Off	7.66	5.11	6.87	Off	-	-	-
Mass of Water Out (4)	Off	4.80	5.74	7.08	Off	-	-	-

Heat Removed From Ammonia = Heat In Air Leaving Tower - Heat In Air Entering Tower

Heat Entering the Cooling Towers = CT1 + CT2 + CT3 + CT4 + CT5 + CT6 + CT7 + C8

= (mass of air x enthalpy) for towers 1 through 8

EFFICIENCY OF AMMONIA COMPRESSORS, cont'd

$= (0)_1 + (1192 \times 37.8)_2 + (1097.8 \times 38.2)_3 + (1498.3 \times 38.5)_4 + (0)_5 + (2252.6 \times 38.5)_6 + (480.2 \times 40.4)_7 + (737.3 \times 38.5)_8$

$= (0)_1 + (45,058)_2 + (41,936)_3 + (57,685)_4 + (0)_5 \ (86,725)_6 + (19,400)_7 + (28,386)_8$

= 279, 190 Btu/min

Heat Leaving the Cooling Tower

= CT1 + CT2 + CT3 + CT4 + CT5 + CT6 + CT7 + C8

$= (0)_1 + (297.2 \times 45.3)_{21} + (320.5 \times 46.4)_{22} + (333 \times 45.8)_{23} + (192.01 \times 48.2)_{24} + (243.9 \times 48.75)_{31} + (140.5 \times 47.6)_{32} + (213.07 \times 46.4)_{33} + (239.3 \times 46.4)_{34} + (433.5 \times 38.5)_{41} + (393 \times 45.8)_{42} + (298.7 \times 45.8)_{43} + (322 \times 44.7)_{44} + (0)_5 + (2252.6 \times 45)_{61} + (480.2 \times 51.2)_{71} + (737.3 \times 52.8)_{81}$

= (0) + (13,463) + (14,871) + (15,251) + (9,255) + (11,890) + (6,688) + (9,886) + (11,104) + (16,690) + (17,999) + (13,680) + (14,393) + (0) + (101,367) + (24,586) + (38,929)

= 320,052 Btu/min

Heat Removed = (320,052) - (279,190)

= 40,862 Btu/min x (60)

= 2,451,720 Btu/hour

= 204 Tons/Cooling

Electrical Input

$= (VAPF)\ comp^2 + (VAPF) comp^3 + (VAPF)\ Sulzer$

$= \frac{(236 \times 156.5 \times 1.0)}{(10^3)} + \frac{(236 \times 141.25 \times 1.0)}{(10^3)} + \frac{(4160 \times 23.9 \times 1.0)}{(10^3)}$

= 36.9 + 33.33 + 99.4

= 169.6 kW

For 1 hour = 169.6 kWh

APPENDIX 21, cont'd

EFFICIENCY OF AMMONIA COMPRESSORS, cont'd

$$\text{Efficiency} = \frac{\text{Tons of Cooling}}{\text{Electrical Input}}$$

$$= \frac{204 \times 12{,}000}{169.6 \times 3413}$$

COP = 4.2

COP of new Machines = 4.4

$$\text{Energy Savings} = \frac{(\text{New Eff.} - \text{Old Eff})}{(\text{New Eff})} \times \text{Energy Usage} \times \text{Hours}$$

Hours = 8760

Energy Usage = 169.6 kWh

$$\text{Energy Savings} = \frac{(4.4 - 4.2)}{(4.4)} \times 169.6 \times 8760$$

= 67,532 x 0.0036

= 243 GJ/year

COST SAVINGS

= (GJ/year) (Sucres/GJ)

= (243) (660)

= 160,380 Sucres/Year

COST OF IMPLEMENTATION

A new refrigeration system would cost an estimated 20 million sucres.

Simple Payback

$$= \frac{20 \times 10^6}{160{,}380}$$

= 124.6 years

ENERGY SAVINGS	= 243 GJ/year
COST SAVINGS	= 160,380 Sucres/year
COST OF IMPLEMENTATION	= 20,000,000 Sucres
SIMPLE PAYBACK	= 124.6 years