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ENERGY AUDIT REPORT
FOR
THULHIRIYA TEXTILE MILLS
THULHIRIYA, WARAKAPOLA
SRI LANKA
FINAL REPORT

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Industrial Energy Conservation Program (IECP)

A Component of the National Energy Demand Management and Conservation Program (NEDMCP)

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FOREWORD

This Audit Report is part of the Industrial Energy Conservation Program (IECP) component of a comprehensive National Energy Demand Management and Conservation Program (NEDMCP) undertaken by the energy Efficiency Demand Management and Conservation (EDMAC) task force of the Ministry of Power and Energy of Sri Lanka.

The four phase IECP was launched by EDMAC in late 1982. Phase I, sensitization, was completed in 1983, and Phase II, which is receiving assistance from the United States Agency for International Development (USAID), has entailed extensive training of plant staff and government officials in energy management for the last twelve months, including on-site training in energy audit techniques.

The major objective of Phase III of the IECP is the implementation of specific projects with the potential for significant energy cost savings. In Phase IV, scheduled for 1985, the IECP will be entirely self substaining, with private and government institutions providing energy audit consultancy services, while EDMAC plays a catalytic and policy oriented role.

This report details findings of an energy audit at Thulhiriya Textile Mill, undertaken in March, 1984, conducted as part of Phase II of the IECP.

The plant was selected jointly by EDMAC and USAID consultants in December, 1983 based upon their suitability for auditing and with relevance to the Sri Lankan industrial sector.

The energy consuming systems examined during the audit are common to many industrial plants and it is envisioned that similar audit evaluations can be conducted in the majority of the industrial facilities in Sri Lanka, resulting in major conservation savings.

ACKNOWLEDGEMENTS

This energy audit was performed under a joint program sponsored by the Energy Efficiency Demand Management and Conservation (EDMAC) task force, Ministry of Power and Energy, Sri Lanka, the Bureau for Science and Technology U.S. Agency for International Development (USAID), Washington, D.C., U.S.A., and the USAID Mission to Sri Lanka, Colombo, Sri Lanka.

Technical assistance was provided by consultants from Hagler, Bailly & Company, Washington, D.C., U.S.A., and Reliance Energy Services, New York, U.S.A.

EXECUTIVE SUMMARY

This report details energy cost savings at Thulhiriya Textile Mills identified during an energy audit training program. The audit training program was jointly sponsored by EDMAC and USAID and completed in March, 1984.

The potential savings identified in this report represent Rs 2.24 million per year based upon first quarter 1984 marginal costs. This is equivalent to an overall energy use reduction of 9.1% when compared to 1983.

The savings can be categorized in two distinct areas. One area is housekeeping measures or alternatively measures that have simple paybacks under one year.

The second area is capital intensive measures or those measures with simple paybacks in excess of one year.

Savings due to housekeeping represent some RS 1.38 million or 6.5% of 1983 usage. These items are usually easy to implement and it is understood from discussions held with plant management in May, 1984 that they have taken steps to implement or have already implemented these items.

Capital intensive measures can save a further Rs 0.86 million but require a capital investment of Rs5.44 million. The payback periods for all of these items is in excess of four years, some have very much greater paybacks. These measures should be considered with respect to any other capital measures that the company may be planning to improve productivity or modernization before any definite decision is made to implement.

The training program began with a classroom session, lasting two 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 the ten days of site work, the engineers were responsible for testing the wide range of equipment within the plant, including the boiler and ancillary equipment, dryers, process equipment, motors and ventilation systems.

EXHIBIT I

SUMMARY OF MEASURES

ITEM	Energy Saved GJ*	Cost Saved Rs.	% Savings GJ	% Savings Rs.	Implementation Cost/Rs.	Simple Payback (Yrs)
Housekeeping Measures						
Steam Pipe Insulation	151	17,446	0.9	0.8	15,000	0.9
Steam Leaks	1,402	161,496	8.4	7.2	40,000	0.3
Steam Traps	933	107,472	5.6	4.8	42,000	0.4
Condensate Recovery	7,032	810,016	41.9	36.0	100,000	0.1
J-Box Temp Control	1,824	210,107	10.9	9.4	150,000	0.7
Printer Improvements	615	70,842	3.7	3.2	20,000	0.3
Total House-keeping	11,957	1,377,379	71.4	61.4	367,000	0.3
Capital Intensive Measures						
Stenter Heat Recovery	2,456	282,907	14.6	12.6	1,250,000	4.4
Replace MG Sets	257	105,616	1.5	4.7	1,050,000	9.9
Load Management	217 KVA	234,360	-	10.5	1,125,000	4.8
Printer Heat Recovery	1,785	205,614	10.6	9.2	1,875,000	9.1
Flash Steam Recovery	314	36,170	1.9	1.6	150,000	4.1
Total Capital Intensive Measures	4,812	864,667	28.6	38.6	5,440,000	6.3
Total All Measures	16,769	2,242,046	100.0	100.0	5,817,000	2.6

*GJ = 10^9 x Joules

The balance of the training program 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.

The energy savings can be achieved by implementation of the projects identified during the course of the audit and data analysis sessions. These projects range from the repair of such obvious sources of waste as steam leaks, to heat cascading and recovery projects involving some capital expense.

In order to identify the areas where improvement in energy utilization are possible, the plant was analyzed in the following manner:

A visual inspection of the plant was conducted to familiarize the auditors 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 the major departments in the plant
- details on currently practiced energy management programs
- 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 process equipment. This equipment was then 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 team of audit engineers was responsible for conducting tests on equipment in each of the areas. The areas were:

- blowing and carding departments
- ring spinning department
- sizing and weaving department
- finishing department
- boiler plant and steam distribution and condensate return systems
- electrical distribution and motors
- lighting and environmental system
- compressed air systems

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

Analysis of the data collected enabled the identification of the potential for energy conservation available. 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 the implementation and cost savings enable the development of an energy conservation action plan.

The major findings and recommendations of this study are as follows:

- Thulhiriya Textile Mills is engaged in the production of finished textile products, yarn, sized beams and greige goods. The plant operates on a three-shift per day basis (although some departments and processes operate on a two-shift per day basis), six days per week, exclusive of holidays. The plant is in operation for a total of about 300 days per year.

- A number of steam and condensate leaks were identified. These should be repaired immediately. In addition, some pipework insulation was found to be missing or damaged; this should be replaced.

- The steam distribution and condensate return systems were found to be in generally good condition. About half of the steam traps tested were found to be inoperative and passing live steam. These traps should be repaired or replaced, and a regular steam trap maintenance program instituted.

- Numerous steam leaks were found in the sizing room. These should be repaired immediately. In addition, there is an opportunity for energy savings by installation of a pocket ventilation system, using sizer exhaust air heat recovery, to improve the drying efficiency of the sizing machines.

- The J-box scour range was found to be overheated. The installation of thermostatically controlled steam valves is recommended.

- Recovery of heat in exhaust air from the stenters and printers is recommended. The exhaust air can be used to preheat incoming air and reduce steam requirements for drying. In addition, the volume of exhaust air from the printers was found to be excessive, and should be reduced. Flash steam can be recovered from stenter condensate and used to provide at least part of the requirement of the steam ager.

- Electricity consumption has been reduced by about 35% by shutting down the chilled water plant.

- Plant power factor is maintained at 99% by an automatic capacitor bank located at the incoming service; no further

- Electricity is used to provide motive power for motors and accounts for approximately 42% of the total energy consumed on site. Fuel oil is used to raise steam in the boiler plant for process heating and drying, and accounts for approximately 58% of the energy consumed on site. Small amounts of diesel fuel and petrol are also used.

- Electricity accounts for approximately 70% of the annual energy cost expenditure; fuel oil accounts for the balance.

- The plant has established an energy management program, which is headed by the Deputy Chief Engineer. The program has identified a number of areas where energy use could be reduced, and these projects have been implemented. A more formal program is required, however, especially in the area of energy use monitoring, and the establishment of energy use targets by process area.

- The boiler plant was found to be operating very efficiently, especially considering the lack of automatic controls and instrumentation. Boiler efficiency was calculated to be 84.1%. Improvements can be made in the maintenace of boiler water total dissolved solids (TDS) levels, by purchase and use of a conductivity meter. Little improvement to the boiler plant can be made economically by changes in burners, etc. Opportunity exists to reduce overall steam production costs by fuel substitution. This item is the subject of a feasibility study which was conducted in parallel to the audit as part of IECP Phase II.

- According to measurements taken during the audit, only about 16% of the steam from the boiler is returned as condensate. Management believes this is not typical, condensate return normally being around 40-50%. A number of areas have been identified where condensate is being lost. It is recommended that this loss be eliminated by return of condensate to the boiler.

improvement to the power factor is required. Peak electric demand can be controlled somewhat by shedding non-essential loads when the peak is approached. This would be accomplished by use of an automatic load controller, interfaced with the utility electric meter.

- Lighting levels were found to be significantly lower than recommended standards. Delamping in many areas have accomplished this. As the lighting levels appear to be adequate for production purposes, no further improvements are recommended.

- A number of motor generator sets are used to drive large motors. Since these are relatively inefficient replacement by thyristor rectifiers can further reduce electricity consumption and demand.

As a first step in implementing the measures identified, a three phase action plan has been developed. This plan has been developed based on the relative savings and costs associated with each energy conservation measure, and is shown in Exhibit 2.

Phase I of the program includes those items which are relatively low in cost, and have payback periods of less than one year. Because of the rapid return on investment, these items should be implemented immediately. Projects included in Phase II and Phase III have higher capital investments associated with them, and the payback periods range from four to ten years. Because of the longer payback periods, these projects should be considered for implementation within the framework of future capital programs that the management may be considering for productivity amd modernization.

EXHIBIT 2

IMPLEMENTATION ACTION PLAN

Phase I

- Repair all steam leaks
- Insulate pipework
- Institute a steam trap maintenance program
- Return condensate to the boiler
- Reduce exhaust from printers
- Fit temperature control to J-box

Phase II

- Fit flash steam recovery system to stenters
- Fit automatic load management system
- Heat recovery from stenters

Phase III

- Heat recovery from printers
- Replace motor generator sets

1. BACKGROUND

1.1 Introduction and Objectives

Reliance Energy Services has produced this report as part fulfillment of our contract with U.S. AID to provide energy audit training to Sri Lankan engineers. The report summarizes energy conservation opportunities identified during a ten day energy audit training program, completed at the Thulhiriya Textile Mills in March, 1984. Data collected during the field work has been used to generate meaningful energy savings that can be achieved through implementation of the measures recommended.

The energy audit completed at Thulhiriya Textile Mills was conducted in the following manner:

First, the Sri Lankan engineers received instructions in energy audit techniques in classroom sessions. Half were then assigned to perform an actual plant audit at Thulhiriya.

To collect the necessary information to compile this report, the sixteen engineers were split into three teams. Each team was under the guidance of a USAID consultant.

The teams then followed a systematic approach through which they collected data. The approach used includes, as an initial step, conducting a visual inspection and collection of readily available energy related data. This is known as a Preliminary Energy Audit (PEA).

The PEA permits identification of major energy consuming systems that can be evaluated using portable instrumentation during a full Energy Audit.

Each major energy consuming system is then tested as part of the Energy Audit to determine its relative energy efficiency and to identify energy cost reduction opportunities.

Having collected the data, it is analyzed to estimate cost benefits arising

from implementation of the recommended measures.

An important part of the Energy Audit process is the interviewing of plant personnel to establish procedures, schedules and operation details. During the Energy Audit personnel from the following departments were interviewed:

Corporate management
Plant engineering
Operations and maintenance
Production
Quality control
Services

In January and February 1984, members of the EDMAC unit had collected background information that enabled an early determination of areas on which to focus the Energy Audit. The key areas were:

- Boiler Plant
- Steam Distribution and Condensate Return
- Blowing and Carding
- Spinning
- Sizing and Weaving
- Finishing
- Electrical Systems, including compressed air, lighting and ventilation

Each of the three teams carried out instrumented tests on the above areas, and it is from that data that the report has been generated.

Reliance Energy Services would like to thank the management of the Thulhiriya Textile Mill for allowing its facility to be used for training purposes. Particular thanks are due Mr. K. M. Randeria, General Manager, and Mr. J. C. Sethi, Mill Manager for all their kind assistance, members of the EDMAC team, and all the participants of the training program.

1.2 Plant Description

Thulhiriya Textile Mills is located in a rural area about 60 kilometers from Colombo. The plant consists of a number of buildings, which house the processing department, administrative and sales offices, boilers, electrical distribution systems, the chilled water plant and other plant services.

The mill produces finished cloth, greige goods, sized beams and yarn from raw fibers. Both natural (cotton) and synthetic fibers are used. A brief process description appears below. A plant layout diagram appears in Exhibit 3.

Baled cotton and synthetic fibers are delivered to the incoming storage areas. There, the bales are sorted and classified. The bales are opened in the blow room; there are two blow machines. In this area, the baled fibers are opened into a blow machine, which "opens" the fibers and removes foreign materials. The foreign material amounts to 14 to 15% of the raw cotton and about 5% of the man-made fiber.

The cleaning and opening process produces a sheet of fibers called a lap. The lap is fed to a carding engine which draws the fibers into a continuous sliver. The sliver can then be either combed or carded. These operations are all mechanical in nature and serve to fix the density of the fiber material and parallelize the fibers.

The combed or carded sliver is then drawn down to a smaller and tighter size yarn by sequential processing on a number of different types of machines, such as the draw frame and fly frame.

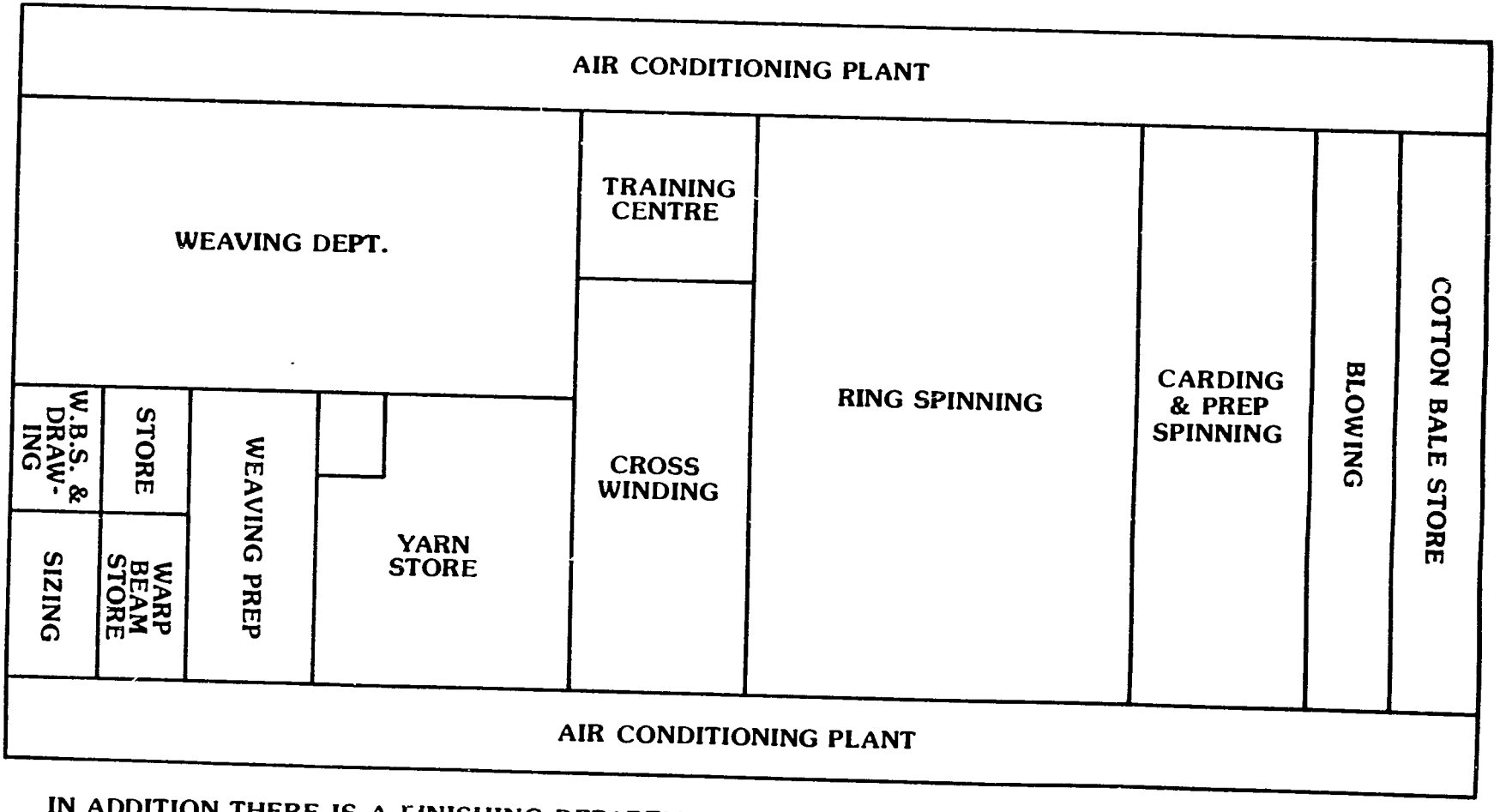
The actual thread is produced by ring spinning. The ring spinning machines spin the drawn yarns into into the tight threads which are eventually used in the weaving operation. There are 226 ring spinning machines in the mill.

The thread undergoes a series of operations between the spinning and weaving steps. The warp is produced by winding the spun yarn onto large spindles.

THULHIRIYA TEXTILE MILLS

EXHIBIT 3

LAYOUT OF MAIN PRODUCTION AREAS



IN ADDITION THERE IS A FINISHING DEPARTMENT

There, these spindles are wound onto large beams. The beams are sized in the sizing area. This operation involves the application of a sizing material to the yarn to impart additional strength to the threads. This is accomplished by application of the sizing chemical in a heated bath, followed by the drying of the material over a steam heated cylinder. The weft is produced by a number of simple winding operations.

The sized warp and the weft are combined in the weaving department to form the raw (greige) cloth. The loom shed contains 560 automatic looms, producing a combination of 50 inch, 62 inch and 68 inch wide cloths.

The woven materials are then further processed in the finishing department. The cloth is inspected and then passed to the shearing/cropping operation. In this step, mechanical blades cut protruberances from the surface of the cloth. The cloth is then passed to the singeing operation, where direct contact with a flame burns off any stray threads and imparts a smooth surface to both sides of the cloth. The cloth is then desized. The desizing is accomplished by passing the cloth through a heated chemical bath, and then allowing the cloth to reside in a storage pit for several hours while the chemicals take effect.

The cloth, which is now treated as a rope rather than a continuous sheet, is scoured in a series of J-box scourers. These boxes subject the cloth to high temperatures, by direct injection of steam. The cloth has a residence time of about 90 minutes in the J-box; temperature should be maintained at about 100°C. When conducting the audit a number of temperature measurements were taken inside the J Box and the average temperature being maintained was 120°C.

The scoured cloth may then be bleached. The cloth rope is then opened up and dried on a steam heated cylinder dryer. At this point, the cloth may be mercerized and dyed, or printed.

Dyeing is performed in one of the eight jigger dyers available. The dyeing process uses a series of hot and cold temperature steps to ensure that the cloth is uniformly permeated with dye, and that the dye has set. The dyed cloth is then washed to remove any residual dye.

The printing operation is performed on one of three screen printing machines. The printed cloth is then dried in a drier which is integrated into the printer. The cloth is further finished by stentering (to set size) and by ageing, curing, sanforizing or calendering. The sequence of operations depends on the nature of the final product required.

The finished rolls of cloth are then stored prior to shipment.

1.3 Operating Schedules

The operation of the textile mill is broken down into a number of process departments. While the operation of the factory as a whole is 24 hours per day, 6 days per week (0600 Monday through 0600 Sunday), exclusive of holidays, the operating schedules of each department are given in the table below:

	OPERATING SCHEDULE	
	Shifts/Day	Days/Week
Blowing and Carding	2	6
Pre-Spinning	2	6
Ring Spinning	2	6
Winding and Warping	3	6
Sizing	3	6
Weaving	3	6
Finishing	3	6

Normal Shift times are 0600-1400 hours; 1400-2200 hours; and 2200-0600 hours. As can be seen, shifts are of eight hours duration. Meal times are staggered to prevent loss of production time.

The boiler plant is started up somewhat earlier than 0600 Monday morning in order to provide steam at the start of the production week.

1.4 Production Data

Thulhiriya Textile Mills is engaged in the production of finished textile products, yarn, sized beams and greige goods. The table below reflects the relative production of various operating departments in the plant for the years 1982 and 1983. Note that this table reflects both production sold to customers, and operating department production utilized by other departments in the plant.

	1982	1983
Spinning - kg	2,673,844	3,133,281
Winding - kg	2,800,427	3,544,304
Warping and Sizing - meters	11,082,788	11,972,799
Weaving - meters	5,289,659	6,604,335
Finishing - meters	12,610,985	10,805,845

1.5 Energy Consumption and Costs

The following tables show the energy consumption and costs by type for the year 1983, with costs as billed for first quarter 1984.

Consumption and Costs

	Units	Consumption	Annual Cost Rs.	Total Cost %
Electricity -	kWh	21,261,514	23,175,051	56.6
Peak	KVA	5,750	5,454,000	13.3
Fuel Oil -	Gallons	569,505	12,307,003	30.1
			40,936,053	100.0

Thermal Equivalents

	Annual Energy Equivalent GJ	Marginal Energy Cost Rs/GJ	Total Energy %
Electricity	76,541	411.11	41.7
Fuel Oil	106,839	115.19	58.3
	183,380		100.0

Conversion to GJ

Electricity - 0.0036 x kWh

Fuel Oil - 0.1876 x gallons

1.6 Fuels and Energy Rate Analysis

Electricity

Electricity is purchased from the Ceylon Electricity Board (CEB) under the IP-3 Rate Schedule (Industrial Power). The first quarter 1984 charge for electricity is Rs 1.48 per kilowatt-hour (inclusive of all adjustments). In addition, a demand charge of Rs 90.00 per kilovolt-ampere (KVA) is levied. There is no separate charge for kilowatt demand; hence the levied demand charge accounts for power factor.

Fuel Oil

Fuel Oil is purchased from the Ceylon Petroleum Company (CPC). Fuel oil with a viscosity of 1000 seconds is used; this has a heating value of 10,278 kcal/kg. The fuel has a specific gravity of 0.86, and a heating value of 44,850 kcal/gallon. The cost is Rs. 21.61 per gallon.

1.7 Major Energy Systems

Fuel oil is burned in the boiler plant to produce steam at 9 bar. The steam is used almost exclusively in the finishing department for a number of drying, heating, and process steps. A lesser amount of steam is used in the sizing department, for heating and drying.

The major steam consuming systems are as follows:

- J-box scour ranges
- cylinder dryer
- washer
- jigger dyers
- mercerizer
- printers
- stenters
- cure box

- steam ager
- sanforizer
- heated chemical storage tanks and baths
- sizing machines

Electricity is used primarily to provide motive power to process motors, fans and other drives. All process equipment within the plant uses electricity as a source of motive power.

Small amounts of other fossil fuels are used. Diesel fuel is used to power an emergency generator. Petrol is used to fire the singer in the finishing department. The use of these fuels is minor compared to fuel oil and electricity.

2. FINDINGS

2.1 Energy Management Program

2.1.1 Manpower and Funding Resources

The energy management program at Thulhiriya is coordinated by Mr. Herath, the Deputy Chief Engineer. Mr Herath can call upon the assistance of about thirty persons, including engineers and advisory staff, in his efforts.

The lines of authority and responsibility in the identification and implementation of energy saving opportunities are rather vague. No one person has responsibility for any ongoing project; the responsibility appears to be shared by all persons involved. The duties are agreed to by all participants; the project itself must be approved by senior management.

The management of Thulhiriya is very keen on achieving energy savings in the plant. A number of projects have been implemented, or were underway at the time of the plant audit. These projects include:

- permanent shutdown of chilled water plant, as air conditioning was found to be unnecessary
- cascading of hot process chemicals and liquors to eliminate heating requirements
- use of ventilation systems only as required

To the extent possible, the management has committed resources to energy management, and implementation of savings opportunities. Despite the apparent lack of structure of the program, it appears to be succeeding.

2.1.2 Energy Monitoring

Thulhiriya has an energy monitoring program in place. Fuel oil and electricity use are monitored on a regular basis, and plotted against production figures for the identification of any variances from expected

values. The monitoring is maintained by the Mill Manager, and by the Finishing Department manager.

The monitoring program is hampered somewhat by the lack of installed instrumentation and meters. For instance, fuel oil consumption is measured by insertion of a dipstick into the fuel tanks. Electricity is metered at the incoming service and at the transformers. Metering by specific department or process machinery is not done. Steam distribution to the various points of consumption is not metered or monitored.

Thulhiriya management are very aware of energy consumption norms, and make an attempt to compare their facility to those norms. It is difficult to make valid comparisons without the required meters and specific monitoring devices.

2.1.3 Energy Awareness

The management of Thulhiriya is very interested in achieving energy cost reduction in the mill. This interest is evidenced by the high priority given by management at all levels in energy conservation. This high level of interest takes the place of a formal energy awareness program in the plant.

2.2 Energy Utilization

2.2.1 Boiler Plant

The boiler plant consists of three water tube boilers and economizers of East German manufacture. The boilers also include combustion air preheating. The boilers are each rated to produce 6.8 tonnes of steam per hour at a pressure of 13 bar. In normal operation, one boiler operates at high fire and a pressure of 9 bar to meet demand. The other boilers are under maintenance. Duty is rotated every three months. In a normal work week, the boiler is fired at 0430 Monday morning and continues operation until all processing is completed at about 0600 Sunday morning.

The boilers are fitted with rotary cup burners and fire 1000 second Redwood Number 1 fuel oil. The burners are in a good state of repair, with little sign of leakage. Inspection of the burners not in use showed that the rotary cups are beginning to wear; at present, measured combustion conditions indicate that this is not adversely impacting burner performance. Combustion does not appear to come to completion within the combustion chamber, but continues through the economizer. This means that some of the heat available for preheating feedwater is lost in the flue gases. However, the temperature at the economizer exit was around 200°C, which is relatively low when the length of the flues and height of the chimney are considered. It is very likely that the exhaust gas temperature has fallen below acid dewpoint and sulphuric acid may be condensing on the inside of the chimney. It is recommended that this be investigated further. If sulphuric acid is being formed, then the chimney mortar and cement will suffer from acid corrosion, with associated deterioration of the chimney structure.

Because of the high combustion efficiency, it is not recommended that an automatic oxygen trim system be fitted to the burners. It is unlikely that improvements would justify the expense.

The boiler plant is in very good condition, operating at high efficiency. The overall boiler efficiency is estimated to be 84.1%, based on measurements

made during the audit. The measurements taken include flue gas analysis, water quality and total dissolved solids (TDS) levels, and surface temperatures of the boiler shell. Adjustments to fuel air ratios are made manually, and despite this, combustion conditions were found to be good throughout the operating range. The boiler operators should be commended for their skill in maintaining efficiency at such high levels.

One area that should be improved is boiler blowdown. On several occasions, the TDS level in the boiler water was checked and found to vary significantly. On first testing, the TDS was found to be 4400 ppm. This level is too high and could lead to scale formation on the heat transfer surfaces. Upon checking the TDS level two days later, it was found to be 250 ppm. The boiler operator had blown down the boiler for an extended period, reducing the TDS level significantly. To control the TDS level to a level of 3000 ppm, it is recommended that a suitable water analysis kit, capable of measuring TDS, be purchased and the boiler operators be trained in its use.

The boilers are well insulated and radiation losses are at a relatively low level. Within the boiler house there are some minor areas of missing insulation and leaks, but in general, the standard of maintenance is good.

reedwater to the boiler is supplied from a deaerator which is operated at 105°C. This temperature is considered satisfactory for removal of dissolved oxygen. Makeup water is supplied from a demineralization plant. Condensate return was estimated to be about 16%, based on measurements made during the audit which is quite low, and there is scope for improvement. Management estimates that condensate return normally is of the order of 40-50%. The boiler house has provision for supplying feedwater using either steam or electric pumps. The relative economics at this time indicate that it is correct to use the electric pumps to feed the boilers.

Instrumentation within the boiler house could be improved to enable the operators to continue their fine efforts. Much of the original instrumentation does not work or has not been recently calibrated. It is recommended that the company upgrade the exisiting instrumentation by either repair or direct replacement. In addition, they should invest in instruments to:

- o measure oil flow to individual burners
- o analyze flue gas composition by electrochemical means
- o test boiler water chemistry

2.2.2 Steam Distribution and Condensate Return Systems

Steam is distributed from the boiler house at boiler pressure (9 bar) to a steam distribution room in the finishing department. There are two headers in the steam distribution room, one high pressure and one low pressure. The high pressure header operates at about 8 bar and is used to supply steam to the sizing department and printers, stenters and calenders and curing machines in the finishing department. The low pressure header feeds the wet processing machinery in the finishing department and the steam agers and sanforizing machines.

The steam distribution system is in good condition with the exception of one component - steam traps. Approximately 30% of the traps were tested during the audit and more than 50% found to be malfunctioning. It is recommended that a regular trap testing and maintenance program be established.

Missing pipework insulation and leaks around the system are minor but savings can be made by attending to this matter.

Approximately 16% of the steam used for process is returned to the boiler as condensate. There are several areas identified where condensate is not returned to the boiler. The costs involved in making the necessary connections and the potential savings make this an attractive conservation measure. The possibility exists to reuse some condensate for flash steam generation. The stenter condensate could be used to generate flash steam for the steam ager to give energy savings.

2.2.3 Blowing and Carding

In these sections of the plant, the baled fibers are processed to form a sliver. The operations are mechanical in nature, and use electricity for motor drives. No specific recommendations have been made concerning this area.

2.2.4 Spinning

The spinning process is mechanical in nature, and electricity is used to drive the spinning machines. Test measurements were made of amperes drawn by the spinning machine, as a function of machine speed. As would be expected, unit energy use increases with machine speed. Of the 226 machines in the mill, about one-third were not in use at the time of the plant visit.

2.2.5 Sizing and Weaving

The sizing area consists of a number of winding and warping machines, sizing machines and looms. No specific recommendations were developed for winding and warping.

The sizing department consists of two sizing machines. In these machines the warp threads pass through a heated chemical bath and then are dried on steam heated cylinders. Each machine incorporates an exhaust air blower to ensure drying of the threads.

There are numerous steam leaks around the sizing department. In addition, there is poor return of condensate to the boiler house. An examination was made of the possiblity of flash steam recovery from the cylinders for use in chemical heating, but this was found to be uneconomical.

The sizing bath is not temperature controlled, and was found to be 4°C - 5°C above the normal process requirement. The use of a temperature control valve for the steam supply was found to be uneconomical. Better manual control could be achieved by using a portable or fixed thermocouple to monitor temperatures and modulate steam supply.

An additional examination was made into the use of waste heat in the exhaust air in conjunction with a pocket ventilation system. Spurious results were obtained in the testing of the sizing machines and it is not possible to calculate the savings potential at this time. However, such a scheme should be considered.

In the loom shed, no specific recommendations can be made. It should be noted, however, that loom motors were running while the machines were in "neutral" awaiting operator attention. A means of modifying the machines to shut off the motors in the event of a thread break should be investigated.

2.2.6 Finishing Department

The finishing department employs a number of discrete thermal and mechanical operations to convert greige cloth from the loom shed to finished cloth, which may then be dyed or printed.

The J-box scour ranges are heated by direct injection of steam. The seals on one of the boxes are inadequate, with steam being vented from the top of the box. In addition, existing temperature controls are inoperative, and overheating of the J-box was observed. Steam valves which are thermostatically controlled should be fitted to this area.

Chemical storage tanks in the area are not covered or insulated. Corrective action should be taken, as the tanks are heated.

The stenters and printers use once-through air in the drying process. With the exhaust at over 100°C, heat recovery from the exhaust by either recirculation or heat exchange should be undertaken. In addition, exhaust air flow rates for the printer are high, and should be reduced.

The cylinder dryer was tested and found to be reasonably efficient. The practice of using two widths of cloth to cover the cylinder should be continued. Installation of a pocket ventilation system to further increase drying efficiency should be considered by the plant.

An examination was made into temperature control of the jiggers, mercerizer and washer, but this was not found to be economically viable. In addition, separation of hot and cold discharge from the jiggers for heat recovery was not found to be economically viable.

An investigation into flash steam recovery from stenter condensate was made. The flash steam would be used in the steam ager. This is technically feasible, although the economic attractiveness might be considered marginal.

The use of solar collectors to heat hot water for process use in the finishing department was examined. While a portion of the department's hot water requirements could be met by this means, the high cost of solar panels makes this option uneconomic. Payback periods of over 10 years were found.

2.2.7 Electrical Systems

The electrical systems in the plant were found to be operating satisfactorily with little scope for improvement.

Electricity is used for motive power, lighting, ventilation and compressed air. The predominant use of electricity is for motive power driving production motors. Electricity is supplied to nine major transformer stations. Each transformer station has the capability to correct for power factor. Power factor at the plant is maintained at about 99%. No further improvement in power factor is required.

The overall load factor is 71%, which is good for a three shift operation, especially when compared to the excess production capacity that exists. There is a connected electrical load of about 14,000 kW whereas actual peak demand is now around 4,200 kW.

The reason for the good load factor is good management of the plant on an integrated basis by the various production managers. They are aware of the impact of energy waste upon production costs, and manage energy effectively. Only machinery necessary to meet production needs is operated. Many times during the audit large sections of some departments did not operate. The environmental services were used in the same manner, with lighting and ventilation being supplied only as needed.

Some scope for improvement was found in load management, but this will require the installation of an automatic load controller. Interfaced with the incoming utility supply, at times of approaching peak demand, the devices will automatically turn off preselected loads until the peak falls below a predetermined level.

There did appear to be some possibility of rescheduling the operations of the spinning and blowing and carding departments so they would not operate at the same time, thereby giving a demand saving of some 750 kVa. However, at the time of the audit it was suggested that too many operational difficulties may exist to be able to implement and the measure is being considered further by the textile plant management.

2.2.8 Compressed Air Systems

Compressed air is supplied to the plant from a series of 29 compressors with a combined electrical rating of 140 kW. Not all of the units are operated. The compressors operate at various pressures depending upon the duty required. A pressure of 6 bar is used in the finishing department where the air is used for pneumatic cylinders on production machinery. A pressure of 1 bar is used throughout the plant for instrumentation and controls. The plant is investigating the possibility of switching from the individual units to one central system. However, they could not supply any information on total compressed air needs. This must be determined prior to making any committment to one central plant.

The units that were operating were found to function satisfactory with no leakage problems.

2.2.9 Lighting and Environmental Systems

Lighting throughout the plant is provided by 3-tube fluorescent fixtures. Many of the original fixtures have been delamped so either one or no bulbs are operating. Lighting levels were measured in various departments and found to be significantly lower than recommended standards for similar work areas. The lighting appeared to be adequate and no further suggestions are

offered. Because of the relatively low lighting load, it would be uneconomic to retrofit the existing lighting systems with higher efficiency systems.

Ventilation is provided from a series of forced air systems. These systems are designed to provide the following conditions in the production departments:

	Relative Humidity
Winding	50 - 60%
Warping	60 - 70%
Weaving - Cotton	80 - 84%
- Synthetics	70 - 75%

Originally the plant was totally air conditioned. In July 1983 modifications were made to the return air and exhaust system. This enabled the plant to shut down the chilled water plant. Humidity is now being maintained by spray washing and exhaust alone. Energy savings from this measure are estimated to be some 35% of the previous electricity consumption.

The ventilation systems were tested for flow rate. The average air change rate was measured to be 8.25 per hour. No recommendations to decrease this are made, as this is believed to be the minimum needed for comfortable environmental conditions.

3. RECOMMENDATIONS

In the sections below, the items identified as having potential for energy savings are described. It should be noted that energy cost savings shown in this section are based on first quarter 1984 prices to the plant, and that no attempt has been made to account for price fluctuations.

In addition, the simple payback periods used in this report are defined as the ratio of implementation cost to first year energy savings.

3.1 Energy Management Program

As noted in Section 2.1 above, the energy management program at Thulhiriya is successful. In fact a number of projects identified during the audit have been either implemented or are underway by the plant personnel according to discussions held at the end of May, 1984. A few recommendations as to the improvement of this program are in order, however.

First, the program needs to be more formal and organized than it is currently. This will require the establishment of formal duties and responsibilities for the energy coordinator. He alone should be responsible for the implementation of energy conservation strategies, and should monitor the performance of equipment and systems that have been improved or modified.

The plant should establish energy consumption norms for the various products processed. These norms should be developed by use of instrumentation in place at the plant. While it is recognized that published information is available, particularly through BTRA, Thulhiriya management should not rely exclusively on these published norms. They should serve as a guideline, but the actual performance of the plant must be determined first.

A monitoring system which relates energy consumption to various plant operating variables, such as product mix, production, operating hours, etc., should be developed. This will better allow the plant to track energy performance over a period of time, by eliminating differences in operating

practice from the comparisons. A method used with success in the textile industry is that of developing a multiple linear regression model of energy consumption with respect to the operating variables listed above. A computer and the appropriate software are required in this approach.

Additional metering equipment is required to establish a data base for use in energy modelling of the plant, and in tracking trends in energy consumption by department. This metering should include:

- o electric consumption and demand meters, with provision for recording data over a period of time
- o steam meters, both at the boiler and at the points of consumption, or, as an alternate, water meters for measurement of condensate from the point of consumption
- o fuel oil meters, installed on each of the three boilers

As noted above, the program has been effective in reducing energy consumption. These suggestions are provided in order to give the program a focus and direction.

3.2 Measures With Simple Paybacks Under One Year

In this section, energy conservation projects which have simple payback periods of less than one year are identifed and described. Because these projects involve little capital expense and have quick payback, they should be implemented immediately.

3.2.1 Steam and Condensate Pipe Work Insulation

During the site audit, a number of areas were identified where steam and condensate pipework and fittings were missing insulation. Insulation applied in the proper thickness can reduce surface heat losses by 90%, and hence reduce boiler loading. This project has a very rapid payback period and should be implemented immediately.

Appendix 15

Energy Savings	= 151 GJ/Year
Cost Savings	= Rs17,446/Year
Cost of Implementation	= Rs15,000
Simple Payback	= 0.9 Years

3.2.2 Repair of Steam Leaks

During the site audit, a number of steam leaks were observed. These leaks should be repaired immediately as they represent a completely unnecessary source of waste. Steam leaks can be identifed and tagged when the plant is in operation; repairs can be made during plant shutdown periods and Sundays. In addition, a steam leak repair program should be instituted at Thulhiriya. The purpose of the program would be to inspect the steam system at regular intervals and make necessary repairs. This project has a very quick payback and should be implemented immediately.

Appendix 16

Energy Savings	= 11,402 GJ
Cost Savings	= Rs161,496 /Year
Cost of Implementation	= Rs40,000
Simple Payback	= 0.3 Years

3.2.3 Repair of Steam Traps

A survey of the steam traps at Thulhiriya was made during the energy audit. About 30 percent of the total traps were tested to determine the state of maintenance and operation. Of these steam traps, about half were found to be improperly operating, and passing steam to the condensate return system. These steam traps should be repaired or replaced as appropriate. Repair kits for most steam traps are available. In addition, a steam trap maintenance program should be established. This program would include regular inspection of steam traps and repair of defective traps. The payback period for this project is very short, and this project should be implemented immediately.

Appendix 17

Energy Savings	= 933 GJ/Year
Cost Savings	= Rs107,472/Year
Cost of Implementation	= Rs42,000
Simple Payback	= 0.4 Years

3.2.4 Return Condensate to Boilerhouse

Analysis of boiler water, condensate, feedwater and makeup water total dissolved solids (TDS) levels during the energy audit indicated that only about 16% of the condensate is being returne to the boiler. This level is very low, especially considering that steam is used for direct injection process heating in only a few areas. Management estimates that normally condensate return levels are about 40-50%. During the audit, a number of areas were observed where condensate is being run to drain instead of being piped into the condensate return system. While some modifications may be required to install needed pipework, this project has a very quick payback and should be implemented immediately. Any necessary modifications can be made on Sundays, when the plant is shut down.

Appendix 18

Energy Savings	= 7,032 GJ/Year
Cost Savings	= Rs810,081/Year
Cost of Implementation	= Rs100,000
Simple Payback	= 0.1 Years

3.2.5 J-Box Temperature Control

Inspection of the J-boxes during the plant audit indicated that the boxes were overheated by several degrees. This problem is due to the lack of temperature controls on the boxes. The problem can be overcome by installation of thermostatically controlled steam valves, to maintain J-box temperature at the required 100°C. This project has a quck payback period and should be implemented immediately.

Appendix 19

Energy Savings	= 1,824 GJ/Year
Cost Savings	= Rs210,107/Year
Cost of Implementation	= Rs150,000
Simple Payback	= 0.7 Year

3.2.6 Printer Improvements

The analysis of the printers indicated that amounts of air in excess of that required for drying were being exhausted by the printers. The amount of air should be reduced by installing lower speed motors. This will reduce the amount of steam needed for drying, as it was determined that 91% of the heat input to the printer drying section was being exhausted. This project has a quick payback and should be implemented immediately.

Appendix 21

Energy Savings	= 615 GJ/Year
Cost Savings	= Rs70,842/Yr
Cost of Implementation	= Rs20,000
Simple Payback	= 0.3 Year

3.3 Measures With Simple Paybacks Over One Year

In this section, energy conservation projects which have simple payback periods of more than one year are identified. Because more capital is required to implement these projects than those described in Section 3.2 above, these projects should be given a lower priority for implementation. Those projects with a simple payback period of between one and five years should be implemented within one year. Those projects with payback periods which exceed five years may require further study, and should be given a lower priority for implementation.

3.3.1 Stenter Heat Recovery

Analysis of the stenters indicated that a large portion of the heat input is exhausted as a medium temperature air steam. The heat in this air can be recovered by use of a number of different types of heat exchangers. The recovered heat can be applied in a number of ways, including direct recirculation into the stenter or preheating of stenter incoming air. Because of the number of options available, both in terms of heat exchanger configuration and use of the recovered heat. Further study of this measure may be required. The savings shown here are an estimate based upon a conservative estimate of heat exchanger efficiency.

Heat exchange efficiency is a function of the type and design of the best exchanger used and the temperature differentials involved between the two fluids used in the heat exchange process.

The heat exchanger can be installed in the exhaust ducting. The heated medium would then be ducted (in the case of air) or piped (in the case of water) to the point where it would be used.

Appendix 20

Energy Savings	= 2456 GJ/Year
Cost Savings	= Rs282,907/Yr
Cost of Implementation	= Rs1,250,000
Simple Payback	= 4.4 Years

3.3.2 Load Management

Peak electric demand is charged by the electric utility at a rate of Rs90 per kVA per month. Since Thulhiriya corrects power factor to a level of 99%, kVA and kW demand are essentially identical. The electric utility provides only a peak meter, which provides no information on load patterns, or when the peak demand is established. An automatic load controller can be installed at Thulhiriya to help reduce peak demand. The controller would shed low priority electric loads when a pre-established peak electric demand level was being approached. The loads would be brought on-line again when the peak was avoided. The priorities for the order of load shedding and restoration would be established by Thulhiriya personnel. Alternately various production departments may be rescheduled thereby enabling peak demand to be reduced. Management is considering this option seriously as approximately 750 KVA may be saved. The savings shown below represent those possible through installing the automatic demand controller.

Appendix 23

Energy Savings	= 217 kVa/month
Cost Savings	= Rs234,360/Yr
Cost of Implementation	= Rs1,125,000
Simple Payback	= 4.8 Years

3.3.3 Flash Steam Recovery

Condensate at relatively high pressure from the stenters is sent back into the condensate return system. At the same time, low pressure steam is used in the steam agers for direct injection. The stenter condensate can be used to generate low pressure steam by flashing in an appropriately sized vessel, eliminating or reducing the need for a separate steam supply to the ager. To implement this measure would require breaking into the condensate lines from the stenters and piping to a flash vessel. The flash steam generrated would then be piped to the steam ager. This measure is similar to what the plant has done in the wet processing side of the finishing department to preheat washing water.

Appendix 25

Energy Savings	= 314 GJ
Cost Savings	= Rs36,270Yr
Cost of Implementation	= Rs150,000
Simple Payback	= 4.1 Years

3.3.4 Printer Heat Recovery

Analysis of the printers indicated that a large portion of the heated input is exhausted as a medium temperature air stream. The heat in this air can be recovered by use of one of a number of heat exchangers. The recovered heat can be used for several purposes, inducing direct recirculation or preheating of incoming air. Because of the number of options available, both in terms of heat exchanger configuration and use of recovered heat. further study of this measure may be required. The savings shown here are an estimate. This measure is commonly completed by other textile facilities.

Appendix 24

Energy Savings	= 2,785 GJ
Cost Savings	= Rs205,614/Yr
Cost of Implementation	= Rs1,875,000
Simple Payback	= 9.1 Years

3.3.5 Replace Motor Generator Sets

Fourteen motor generator sets are used to provide DC power for large motor drives. These motor generators are not very efficient and can be replaced with higher efficiency thyristor rectifiers. The payback period for this project is rather extended, and hence additional study of this item may be required.

Appendix 22

Energy Savings	= 257 GJ
Cost Savings	= RS105,616/Yr
Cost of Implementation	= Rs1,050,000
Simple Payback	= 9.9 Years

APPENDIX I

SUMMARY OF MEASURES

ITEM	ENERGY DATA				COST DATA				OPERATING DATA	
	Energy Saved GJ*	Cost Saved Rs.	% Savings GJ	% Savings Rs.	Design Cost - Rs.	Supply Cost Rs.	Insulation Cost - Rs.	Total Cost Rs.	Annual Maintenance Cost Rs	Useful Life
Steam Pipe Insulation	151	17,446	0.9	0.8	2,500	9,375	3,125	15,000	5,000	15
Steam Leaks	1,402	161,496	8.4	7.2	-	20,000	20,000	40,000	2,000	15
Steam Traps	933	107,472	5.6	4.8	-	38,000	4,000	42,000	5,000	10
Condensate Recovery	7,032	810,016	41.9	36.0	10,000	70,000	20,000	100,000	5,000	15
J-Box Temp Control	1,824	210,107	10.0	9.4	2,000	111,000	37,000	150,000	2,000	15
Stenter Heat Recovery	2,456	782,907	14.6	12.6	125,000	937,500	187,500	1,250,000	10,000	25
Printer Improvements	615	70,842	3.7	3.2	5,000	12,500	2,500	20,000	1,000	15
Replace MG Sets	257	105,616	1.5	4.7	105,000	800,000	145,000	1,050,000	5,000	15
Load Management	217 KVA*	234,360	-	1[illegible].5	112,500	800,000	212,500	1,125,000	5,000	15
Printer Heat Recovery	1,785	205,614	10.6	9.2	187,500	1,406,250	281,250	1,875,000	20,000	25
Flash Steam Recovery	314	36,170	1.9	1.6	15,000	108,000	27,000	150,000	5,000	15
TOTAL	16,769	2,242,046	100.0	100.0	564,500	4,312,625	939,875	5,817,000	65,000	

*Per month

*GJ = 10^9 x Joules

APPENDIX 2

SUMMARY OF SAVINGS BY FUEL TYPE

FUEL	ANNUAL SAVINGS	GJ SAVINGS*	COST SAVINGS
Electricity (demand)	217 kVA	-	234,360
Electricity (usage)	71,389 kWh	257	105,616
1000 Seconds Fuel Oil	88,017 Gallons	16,512	1,902,070
TOTALS		16,769	2,242,046

*Conversion to GJ

Electricity - 0.0036 x kWh
1000 Secs. Fuel Oil - 0.1876 x gallons

APPENDIX 3

INVENTORY OF MAJOR ELECTRICAL EQUIPMENT

Blowing and Carding			
Bale Opener (4)	Each	10.4	kW
Draw Head Cleaner (4)	Each	3	kW
Double Horizontal Cleaner (4)	Each	15.2	kW
Fine Opener (4)	Each	10.22	kW
Scutcher (4)	Each	31.6	kW
Filter Plant		4.5	kW
Blowroom Dust Collector		9	kW
Bale Store Area Blower		8	kW
Carding Machines (102)	Each	3.2	kW
Suction Motor (17)	Each	13.5	kW
Grinding Motors (2)	Each	3.6	kW
Flat Clipping		1.5	kW
Pre-Spinning			
Draw Frames (2)	Each	3.3	kW
Pre-draw Frames (12)	Each	3.3	kW
Draw Frames (46)	Each	3.3	kW
Sliver Laps (6)	Each	3	kW
Comber (24)	Each	3	kW
Fly Frames (27)	Each	4	kW
Spinning			
Ring Spinning (226) (High Speed)	Each	17	kW
Blower Motors (226)	Each	1.5	kW

APPENDIX 3 (Cont'd)

Winding and Warping			
Core Winding (34)	Each	7.4	kW (Total)
Twisting (6)	Each	17	kW
Doubling (2)	Each	7.4	kW (Total)
Hank Reeling (17)	6 at	2.2	kW
	1 at	1	kW
	8 at	3	kW
Warping (2)	Each	9.75	kW
Pirn Winding (10)	Each	4.8	kW
Pirn Cleaning		1.3	kW
Loom Shed			
50" Looms (464)	Each	1.1	kW
Larger Looms (100)	Each	1.1	kW
Sizing			
Main Motor	Each	7	kW
Ancillaries (2)	Each	3.5	kW
Finishing			
Inspecting (8)	Each	1.5	kW
Shearing & Cropping (3)	Each	18.9	kW
Singeing		28.5	kW
Scouring and Bleaching		163	kW (Total)
Opening/Calendering (2)	Each	22	kW
Cylinder Dryer		15	kW
Mercerizer		69	kW
Washing		27.5	kW
Jiggers		17.6	kW (Total)
Padder		18	kW (Total)

APPENDIX 3 (Cont'd)

Printing (3)	Each	48.4	kW
Stenters (2)	Each	141.8	kW
Folding (4)	Each	3.4	kW
Sanforizing		37.9	kW
Calendering		25	kW
Winch		2.3	kW
Bale Blower		7.5	kW
Ventilation			
Blowing - Blowers (2)			
- Pumps (2)			
Carding - Blowers (4)	Each	55	kW
- Pumps (4)	Each	30	kW
Spinning - Blowers (8)	Each	75	kW
- Pumps (8)	Each	55	kW
Winding - Blowers (1)		75	kW
- Pumps (1)		55	kW
Training - Blower (1)		40	kW
- Pump (1)		25	kW
Weaving - Blower (2)	Each	75	kW
- Blower (1)		82	kW
- Pump (1)		55	kW
- Pump (1)		30	kW
Sizing - Exhaust Fans (3)		N/A	
Finishing - Exhaust Fans (2)	Each	30	kW
- Exhaust Fans (2)		40	kW
Bleaching - Exhaust Fans (17)	Each	0.5	kW
Roof Top Exhaust (8)	Each	3	kW
Lighting			
Total		100	kW

APPENDIX 4

BOILER DETAILS

Location: Boiler House

Boiler	1	2	3
Manufacturer:	East German	East German	East German
Age (years):	14	14	14
Type:	Water Tube	Water Tube	Water Tube
Rating (kg/hr):	6,800	6,800	6,800
Medium Raised:	Steam	Steam	Steam
Normal Operating Pressure(bar):	9	9	9

Burner(s)			
Number:	1	1	1
Fuel(s) Fired:	1000 Secs.F.0	1000 Secs.F.0	1000 Secs.F.0
Manufacturer:	East German	East German	East German
Age (years):	14	14	14
Type:	Rotary Cup	Rotary Cup	Rotary Cup
Draft:	Forced	Forced	Forced
Atomization:	Air	Air	Air
Burner Controls:	Manual	Manual	Manual
Draft Control (Dampers):	Modulating	Modulating	Modulating

APPENDIX 5

BOILER COMBUSTION TESTS

Boiler No: 1 of 3

Date of Test: 3/22/84

Fuel Fired: 1000 Secs. Fuel Oil

Test Results:	Before Econ.	After Economizer
Firing Rate	Medium	Medium
CO_2 in Flue Gases (%)	12.67	13.5
O_2 in Flue Gases (%)	4.25	3.4
Flue Gas Temperature (°C)	320	203
Ambient Air Temperature (°C)	37	37
Smoke Number	5	3
Losses due to Flue Gases (%)	19.6	15.4
Combustion Efficiency (%)	80.4	84.6

Measurements/Readings From:

Measurement	Instrument
% CO_2 in Flue Gases	Fyrite
% CO_2 in Flue Gases	Fyrite
Flue Gas Temperature	Electronic Thermometer
Ambient Air Temperature	Mercury in Glass Thermometer
Smoke Number	Truespot Smoke Pump
Losses Due to Flue Gases	Bacharach Combustion Slide Rule

APPENDIX 6

PRINTER TESTS

Date of Test	3/26/84
Exhaust Air Volume	= 49.29 m^3/minute
Temperature	= 109°C
Inlet Air Temperature	= 35/28°C db/wb
Cloth Code	= 422/4C-4
Density	= 9.85 m/kg
Throughput	= 10m/min.

Cloth Conditions In

Temperature	= 33°C
Moisture Content	= 79.04%

Cloth Conditions Out

Temperature	= 39°C
Moisture Content	= 2.23%

Standard outlet moisture content should be less than 2%, but less than 3% acceptable.

Dryer Shell

Surface Area	= 22.24m^2
Surface Temperature	= 45°C
Steam Pressure	= 1 bar
Steam Consumption	= 156 kg/hr

APPENDIX 6 (Cont'd)

To balance need to determine moisture content of exhaust.

Humidity ratio kg/kg of dry air varies linearly with specific volume.

Specific Volume = S Humidity Ratio = M

From Psychrometric chart at 109°C

S	M
1.22	0.08
1.11	0.02

$$\frac{S - 1.11}{M - 0.02} \quad \frac{1.22 - 1.11}{0.08 - 0.02} \qquad - (A)$$

$$M = 0.55S - 0.63$$

Exhaust Air Flow Rate = $2957.4 m^3/hr$

Moisture Removed From Cloth $= \frac{(10)}{(9.85)} (60)(0.7904 - 0.0223)$

= 46.79 kg/hr

Moisture in Air is = 0.009 kg/kg

Moisture in $= \frac{(2957.4)}{S} \times (0.009)$

APPENDIX 6 (Cont'd)

Moisture Out $= \left[\frac{(2957.4)}{(S)} \times (0.009)\right] + 46.79 - (B)$

Moisture Out Also $= \left[\frac{2957.4}{S}\right] (M)$

$= \left[\frac{2957.4}{S}\right] (0.55S - 0.63) \quad - (C)$

Equate (B) and (C)

$\frac{(2957.4)}{S} (0.009) + 46.79 = \left[\frac{2957.4}{S}\right] (0.55S - 0.63)$

S $= 1.196\ m^3/kg$ of dry air
M $= 0.028\ m^3/kg$

Heat Content kJ/kg

S	M
1.196	291

at Inlet Conditions = 93.7 kJ/kg

Dry air at exhaust temperature (109°C) = 174.5 kJ/kg

Heat lost through Air = (174.5 - 93.7) (Mass of dry air)

Mass of Air $= \frac{(2,957.4)}{(1.196)}$

Heat Loss = 199,674 kJ/hr

From Steam Tables Specific Volume of moisture at exhaust conditions if all steam = 1.739 m^3/kg

Moisture Volume = (1.739)(Moisture)

= (1.739)(0.028)
= 0.048 $^3/kg$

APPENDIX 6 (Cont'd)

Specific Volume of dry air at Exhaust if all dry = 1.077 m^3/kg
Partial Pressure of Moisture = 0.1 bar
Steam Enthalpy = 2,705 kJ/kg
Sensible Heat in Moisture at inlet conditions = 147 kJ/kg
Moisture Evaporated = 46.79 kg/hr
Heat Required to Evaporate Moisture = (2,705 - 147) (46.79)
= 119,689 kJ/hr

Heat Balance

Heat In = 156 (2,675 - 417)
= 352,248 kJ/hr

Heat Out:

Exhaust to Vaporize Moisture	= 119,689 kJ/hr	34%
Exhaust Air Heat Content	= 199,674 kJ/hr	57%
Wall and Fabric Losses (by difference)	= 32,885 kJ/hr	9%

APPENDIX 7

STENTER TESTS

Measurements:

Exhaust Air	Velocity	= 16,916 m/hr
	Duct Area	= 0.1 m^2
	Flow Volume	= 1,692 m^3/hr
	Temperature	= 128°C
Inlet Air	Temperature	= 38.3/26.4°C db/wb
Cloth In	Density	= 9.85 m/kg
	Width	= 90 cm
	Moisture	= 80.02% dry basis
	Feed Rate	= 40m/min
	Temperature	= 33°C
Cloth Out	Moisture	= 1.30% dry basis
	Temperature	= 54°C
Steam/Condensate	Pressure	= 5 bar
	Steam Flow	340 kg/hr
Dryer Shell	Area	= 30 m^2 sides
		= 43 m^2 top
		= 6.5 m^2 front/back
	Surface Temp.	= 45°C

APPENDIX 7 (Cont'd)

Heat Balance Around Stenter

To balance need to determine moisture content of exhaust.
Humidity ratio kg/kg dry air varies linearly with specific volume
Specific volume = S Humidity Ratio = M

From psychrometric chart at 128°C

	S	M (Humidity Ratio)
	1.15	0.0072
	1.25	0.0810

Therefore $\frac{S - 1.15}{M = .7385} = \frac{1.25 - 1.15}{0.8414}$ (1)

By Trial & Error

Closure S	= 1.35 m^3/kg dry air
Exhaust Air	= 1692 m^3/hr
Therefore Dry Air	= 1257.3 kg/air
Moisture in air	= 25.067 kg/hr

APPENDIX 7 (Cont'd)

Moisture out = 191.8 + 25.067
= 216.87

From (1), M = 0.1548

Moisture Out = 1253.3 x 0.1548 = 194.0

Therefore S = 1.35 is not correct

S	Dry Air	Moisture In	Moisture Out	M	Moisture Out
1.35	1253.3	25.067	216.87	0.1548	194
1.40	1208.6	24.171	215.97	0.1917	231.7
1.36	1249.1	24.88	216.68	0.1672	202.8
1.38	1226.1	24.52	216.82	0.1764	216.89

Therefore S = 1.38 is accurate.

S	H kJ/kg Dry Air
1.15	150
1.20	240
1.25	330
1.38	564

128°C H Exhaust Air = 564 kJ/kg
38°C H. Inlet Air = 100.7 kJ/kg

Enthalpy of Dry Air at Inlet at 128°C
Moisture Content = 185 kJ/kg
Heat Loss through Air = (185-100.78) x mass dry air
= 103,323 kJ/hr.
Specific Volume of Steam at
Exhaust Conditions if all steam = 1.7652 m^3/kg x 0.17697
= Moisture Volume =0.8123 m^3/kg

APPENDIX 7 (Cont'd)

Specific Volume of Dry Air at Exhaust Conditions if all dry = 1.14 m^3/kg

Therefore partial pressure = 0.274 bar of moisture from steam tables

Therefore steam out enthalpy = 2739 kJ/kg

Sensible Heat of Moisture at fresh air inlet = 162.78 kJ/kg

Moisture evaporated = 191.8 kg/hr

Heat required to evaporate moisture = 496,695 kJ/hr (2739-162.78) 191.8

Heat In = 340 (H Steam - H condensate)
= 717,155 kJ/hr

	kJ/kg	%
Heat In	717,155	100
Heat Used		
To vaporize moisture	494,119	69
Exhaust Air	103,323	14.4
Wall Losses and fabric	119,713	16.6

APPENDIX 8

ELECTRICAL MEASUREMENTS

TEXTILE PLANT

LOCATION	Nameplate Data kW/HP	V	A	PF	Measured Data kW	V	A	P.F
Spinning Department	40 kW	400	74	0.87	6.6	92	42.4	
Blower/Blower Fan	74.6kW	400	141	0.85	17.5	393	114	0.75
Condensate	5.6kW	230/400	19/11	0.88		390	7.8	0.82
Stock Compr.	5.6kW	230/400	19/11	0.88	2.5kW	392	9.5	0.85
Fine Opener	1.12	230/400	4.75/2.75	0.77				
	2.9	400	6.6	0.83				
	1.12	230/400	5.25/3.05	0.71				
	1.12	230/400	5.25/3.05	0.71				
	0.82	230/400	8.8/2.2	0.83				
	3.06	230/400	10.4/6	0.88				
Double Hopper Feeder Beater Scutcher and Lap M/G	2.99	400	6.6	0.83				
	4.03	270/400	14.3/8.7	0.81				
	0.187	230/400	1.3/.75	0.71				
	0.82	230/400	5.25/3.03	0.71				
	1.222	230/400	5.25/3.05	0.71				
	1.12	230/400	5.25/3.05	0.71				
	0.82	230/400	3.8/2.2	0.83				
	3.06	230/400	10.4/6	0.88				
	1.50	230/400	6/6/3.8	0.80				
Bale Opener	1.1kW	230/400	5.23/3	0.83				
	1.1	230/400	5.25/3.05	0.71				
	0.41	230/400	2.12/1.22	0.71				
Conveyor Belts	0.82	230/400	2/12/1.22	0.71				
Draw Head Cleaner	2.98	400	6.6	0.83				
Double Horizontal Opener	2.98	400	6.6	0.83	1.53		4.5	.8
	2.238	230/400	9/5.2	0.83				
	4.03	400	8.8	0.83	1.71		4.7	.8
	1.11	230/400	5.25/3.05		.62		1.3	.8
	1.11	230/400	5.25/3.05		.74		1.9	.7
	0.82	230/400	3.26/2.9					
	3.05	230/400	10.4/6		1.06		2.1	.9

APPENDIX 8 (Cont'd)

TEXTILE PLANT

LOCATION	Nameplate Data kW/HP	V	A	PF	Measured Data kW	V	A	P.F
Carding Dept. Ventilation Room	3.0kW	290/440	10.4/6	0.88	1.8	391	4.4	0.62
Spinning-Dept. Ventilation Room Compressor	3.0kW	290/440	10.4/6	0.88	1.15	387	4.16	0.4
Spinning Dept. Ventilation-Compressor	3.0kW	290/440	10.4/6	0.88	2.08	392	3.8	0.81
Printing Department-Compressor No. 1	5.5kW	280/440	18.5/10.8	0.87	5.5	399	9.0	0.9
Printing Department-Compressor No. 2	5.5kW	280/440	18.5/10.8	0.87	5.1	399	8.7	0.86
Winding Department-Blower Fan Motor	46.3kW	400	85/5	0.85	44.8	386	8.7	0.80

APPENDIX 8 (Cont'd)

MOTOR GENERATOR SETS

LOCATION	AC MOTOR NAMEPLATE	MEASURED	DC GENERATOR NAME PLATE	MEASURED
			Generator	
1. Printing - 3 M/G	17.5 HP 400 V 23.5 A 0.9 P.F 2910 RPM	3.1 kW 396 V 5 A	460 V 17.4 A 8.0 kW 0.85 2910 RPM (195/220V) Excit.	220 V 545 A
			EXCITER 230 V 6.95 A 1.6 kW 2910 RPM	210 V 3 A
	M/G was Operating at 10 Meters/Min.			
			D.C. Generator	
2. Washing Machine	22 kW 400 V 40 A 2900 RPM P.F. 0.91	16.7 A 399 V 0.61 P.F.0.61 6.829 kW	450 V 32.5 A 15 K 2900 RPM (165/220V)Excit.	D.C.Generator 135 A 180 V
			Exciter	
			220/230 V 10.85 A 2.5 kW 2900 RPM	2.3 A
3. Stenter II	75 kW 400 V 99 Amp 0.89 P.F. 2910 rpm	450 V P.F.= 0.8 3 = 35.4 amp	Gen. 41kW 460V-89 Amp 2910 rpm Exciter 160(220) 450 amp.	

APPENDIX 8 (Cont'd)

MOTOR-GENERATOR SETS

LOCATION	AC MOTOR NAMEPLATE	MEASURED	DC GENERATOR NAME PLATE	MEASURED
			Chain Motor 440V/57 Volts 40.8/40.8 amp. 16/1.1kW 1450/2210 rpm.	100 Volts 14 amp.
			Padder Motor 440/81 volts 51.7/51.7 amp 20.6/1.4 kW 1450/2210 rpm.	100 volts 9.5 amp
4. Bleaching Stage I	400 volts 135 amp. 1450 amp.	13.8 kW 36.4 amp. pf = 0.3 75 kW	Gen. 460 volts 115 amp 53 kW. 1450 rpm. Exit. 180(220V)	150 volts
			Washing M/I	9 amps.
			V 440 160 101 62 3 36 36 31 36 P 14 4.67 2.38 1.4 N 1500 5400 300 150 2040	150 volts
			Impregnation M/C I	5 amps
			V 440 160 101 62 3 19.2 19.2 16.5 19.2 P 7.5 2.5 1.45 0.75 N 1500 500 300 150 2040	150 volts
			Washing M/C II	10 amps
			Washing M/C III	10.5 amps
			Impregnation	10 amps

APPENDIX 8 (Cont'd)

CONSUMPTION Vs SPEED TESTS

Ring Spinning M/G = No:443 - 60 - P/V

Spindle rpm	Power Consumption (kW)	Yarn Production kg/shift	Electric Power Consumption kW/rg
10,400	6.9	21.6	0.319
11,100	7.7	23.0	0.335
12,430	8.44	25.71	0.328
13,169	10.33	27.20	0.379

Operating Speed of the M/G - 12,430 rpm

Winding M/G - No. 34 - Cotton 40

Shaft Speed rpm.		Power Consumption kW	Production hr/shift	Specific Pow. pow/kg/shift
Left	Right			
750	750	5.2	423	0.0123
950	950	5.7	536	0.0106
1100	1080	6.38	607	0.0105

Loom Shed - M/G - 350

Picks/Min.	Power Consumption kW	Cloth Production Inch/W	Sheer Power kW/hg - per hour
167	0.80	137.3	5.827×10^{-3}
175	0.84	143.8	5.841×10^{-3}
180	0.90	167.9	6.085×10^{-3}

DOUBLING MACHINE

SPEED r.p.m.	POWER - In kW.
660/650	3.7
725/660	3.8
530/570	3.6

WARPING M/G I

SPEED	M.G. Input Power (kW)
0 (No Load)	3.05
43.22	3.12
59.05	3.16
86.45	3.66
98.08	3.62

APPENDIX 8 (Cont'd)

	SIZING - Motor 1 (Winding Side)	SIZING - Motor 2 (Finishing Side)	
SPEED/max/min	Power/kW	SPEED/max/min	Power/kW
70	3.7	50	3.2
60	2.9	40	3.3

Speed is limited to 50 max/min. to avoid yarn breaking.

APPENDIX 9

CYLINDER DRYER TESTS

Cloth Identity	= 200-3
Cloth Throughput	= 20 m/minute
Cloth Density	= 9.8 m/kg
Moisture In	= 78.2%
Moisture Out	= 5.4%
Steam In Pressure	= 2 bar
Measured Condensate Rate	= 135 kg/hour

Moisture Removal

$$= (\text{mass})(\text{Moisture In} - \text{Moisture Out})$$

$$= \frac{(20)(60)}{(9.8)}(0.782 - 0.054)$$

$$= 89.14 \text{ kg/hr}$$

Heat to Remove 1 kg of water at 1 bar = 2675 - 159
= 2516 kJ/kg

To Remove 89.14 kg/hour

Energy Needed = (89.14)x(2516)
= 224,276 kJ/hour

Actual Steam Consumption = 135 kg/hr at 2 bar

APPENDIX 9 (Cont'd)

CYLINDER-DRYER TESTS

Heat Content = 2707 - 505
= 2202 kJ/kg

Energy Used = (2202)(135)
= 297270 kJ/hr

Efficiency = $\frac{(224276)}{(297270)} \times (100)$
= 75%

Specific Steam Consumption = $\frac{\text{kg of Steam}}{\text{kg of Moisture Evap.}}$
= $\frac{135}{89.14}$

= 1.51 kg/kg

APPENDIX 10

SIZING MACHINE TESTS

Exhaust Air Volume	= 61.6 m^3 per min
Exhaust Air Temperature	= 53.4°C/33°C db/wb
Cloth	= 1,000 ends
Cloth Throughput	= 5.5 m/minute
Cloth Density	= 68 m/kg
Cloth Moisture Before Sizing	= 8.55%
Cloth Moisture After Sizing	= 168.05%
Cloth Moisture After Drying	= 1.13%
Steam In	= 2.4 bar
Steam Flow	= 240 kg/hr

Moisture Removal

$$= (\text{Mass})\ (\text{Moisture In} - \text{Moisture Out})$$

$$= \frac{(5.5)}{68}\ (168.05 - 10.13)\ (60)$$

$$= 766.4 \text{ kg/hr}$$

Heat to Remove 1 kg of water at 1 bar = 2,516 kJ/kg

Energy to Remove 766.4 kg/hr

$$= (766.4)(2{,}516)$$

$$= 1{,}928{,}259 \text{ kJ/hr}$$

APPENDIX 10 (Cont'd)

Actual Steam Consumption	= 240 kg/hr
Heat Content	= 2715 - 535 = 2,182 kJ/kg
Actual Energy Used	= (2,182)(240) = 523,680 kJ/hour
Efficiency	$= \frac{1,928,259}{523,680} \times 100$
	= 368%

This efficiency is impossible

The test results are erroneous and so no comment can be made on the efficiency.

APPENDIX 11

WATER TESTS AND ESTIMATE OF BLOWDOWN

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

TDS Levels Measured	ppm
Before demineralization Plant	50
After demineralization Plant	50
Feedwater to Boiler	46
Condensate Return	25
Boiler Drum Water	2866

Percentage Make-Up Water

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

$$46 = X(50) + (1 - X)(25)$$

$$46 = 25x + 25$$

$$X = \frac{21}{25}$$

= 84%

Make Up = 84%

Condensate Return = 16%

Blowdown $= \frac{(84 \times 50)}{(2866 - 50)}$

= 0.015 kg/kg steam

APPENDIX 11 (Cont'd)

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

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

Data

Feedwater Temp	= 53°C
Boiler Pressure	= 9 bar
Temperature of City Water	= 28°C
Heat Content of City Water	= 113 kJ/kg
Boiler Efficiency	= 84.6% from Appendix 5
Annual Fuel Input	= 106,839 GJ/Year
Heat Content of Steam at 98% Dryness	= 2,723 kJ/kg
Heat Content of Water at 9 bar, 2%	= 15 kJ/kg
Heat Content of Feedwater	= 226 kJ/kg
Heat Content of Water at 9 bar	= 763 kJ/kg
Heat Added in Boiler	= (2,723 + 15) - 226
	= 2964 kJ/kg

Steam Generation $= \frac{106{,}839 \times 0.846 \times 106}{2{,}964}$

= 30,494,532 kg/year

Blowdown = 457,418 kg/year

Net Heat Content of Blowdown = 763-113

= 650 kJ/kg

Percent Blowdown Loss $= \frac{(650)(457{,}418)(100)}{(106{,}839)(10^6)}$

= 0.3%

APPENDIX 12

BOILER SURFACE TEMPERATURE MEASUREMENTS

LOCATION	TEMPERATURE °C
1. Sidewalls - Left and Right	47
	48
	48
	50
	49
	46
	47
	47
2. Top	50
	50.3
	55
	51
	43
	43
Average	48.2°C

APPENDIX 13

ESTIMATE OF BOILER RADIATION LOSSES

Radiation losses from the boiler can be estimated using the following data:

Data:

Boiler Surface Temperature	= 48.2°C
Surface Area of Sidewalls	= 16.72 m^2 x 2
Surface Area of Front and Back	= 9.93 m^2 x 2
Surface Area of Top	= 7.43 m^2 x 2
Heat Transfer Coefficients Sides, Front and Back	= 12.79 $W/m^2/°C$
Top	= 14.8 $W/m^2/°C$
Ambient Air Temperature	= 37°C
Conversion of Watts to Joules	= 3.6
Operating Hours	= 7,200/year
Heat Losses	= h x area x dt
Side Walls	= 12.79 x 16.72 x 2 x (48.2 - 37)
	= 4,790 Watts
Front and Back	= 12.79 x 9.93 x 2 x (48.2 - 37)
	= 2,845 Watts
Top	= 14.8 x 7.43 x 2 x (48.2 - 37)
	= 2,463 Watts
Total Losses/Year	= $\frac{10,098 \times 7,200}{1000} \times 0.0036)$
	= 262 GJ
Boiler Input	= 106,839
Percentage Radiation Loss	= $\frac{262}{106,839} \times 100$
	= 0.2%

APPENDIX 14

BOILER EFFICIENCY CALCULATIONS

Efficiency = 100% - Total Losses (%)

Losses

Flue Gas Loss	= 15.4%	See Appendix 5
Blo down Loss	= 0.3%	See Appendix 11
Radiation Loss	= 0.2%	See Appendix 13
Total Losses	= 15.9%	
Efficiency	= 100 - 15.9	84.1%

APPENDIX 15

STEAM PIPEWORK INSULATION

Assumptions

Heat Loss Reduction by Insulation	= 90%
Pipework Fittings Equivalent Length	= 0.4 meters

Data

Boiler Operating Hours	= 7,200
Boiler Efficiency	= 84.1%

Calculation

See Data Sheets for Location of Missing Insulation

Energy Savings

$$= \frac{(\text{Wasted Heat Loss})(\text{Operating Hours})(0.9)(3.6)}{(\text{Boiler Efficiency})(10^6)}$$

$$= \frac{(5460)(7200)(0.9)(3.6)}{(0.841)(10^6)}$$

= 151 GJ/year

Cost Savings

= (GJ) (Rs/GJ)
= (151) (115.19)
= Rs17446/Year

APPENDIX 15 (Cont'd)

Cost of Implementation

This is estimated to be Rs15,000 installed.

Simple Payback

$$= \frac{(15,000)}{(17,446)} = 0.9 \text{ Years}$$

ENERGY SAVINGS	= 151 GJ
COST SAVINGS	= RS17,446/Yr
COST OF IMPLEMENTATION	= Rs15,000
SIMPLE PAYBACK	= 0.9 Years

APPENDIX 15 (Cont'd)

DATA SHEET

Location	Pipe OD MM	Length In	Heat Loss W/M	Total Loss W	Temperature
Cylinder Dryer	50	2.5	360	900	125
	40	3.7	200	740	100
Inspection Room	100	2	820	1640	150
Washer	20	1	200	200	125
Steam Dist. Room	80	3	600	1980	150
TOTAL		12.2		5460	

APPENDIX 16

REPAIR OF STEAM LEAKS

Assumptions

All losses will be saved when leaks are fixed.

Leakage rate in kg/hr = $8.4\ (d^2)(p + 1)$

Where d = mm, p = bar

Data

For leaks see attached data sheets

Net Heat Content at bar Pressure:

5.5	= 2632.3 kJ/kg
3.0	= 2610.4 kJ/kg
2.2	= 2600.6 kJ/kg
2.0	= 2597.5 kJ/kg
1.05	= 2591.0 kJ/kg
0.033	= 2560.0 kJ/kg

Boiler Efficiency = 84.1%

Operating Hours = 7200

Load Factor = 0.8

Calculation

$$\text{Energy Savings} = \frac{(\text{Loss kg/hr})(\text{Hours})(\text{Heat Content})(\text{Load Factor})}{(\text{Boiler Efficiency})(10^6)}$$

5.5 Bar $= \dfrac{(10.4)(7200)(2632.3)(0.8)}{(0.841)(10^6)}$

= 188 GJ/year

3.0 Bar $= \dfrac{(14.4)(7200)(2610.4)(0.8)}{(0.841)(10^6)}$

= 257 GJ/year

APPENDIX 16 (Cont'd)

REPAIR OF STEAM LEAKS

Calculations

2.2 Bar $= \frac{(1.28)(7200)(2600.6)(0.8)}{(0.841)(10^6)}$

$= 23$ GJ/year

2.0 Bar $= \frac{(5.1)(7200)(2597.5)(0.8)}{(0.841)(10^6)}$

$= 91$ GJ/year

1.6 Bar $= \frac{(1.06)(7200)(2591)(0.8)}{(0.841)(10^6)}$

$= 19$ GJ/year

0.033 Bar $= \frac{(47)(7200)(2560)(0.8)}{(0.841)(10^6)}$

$= 824$ GJ/year

Total Energy Savings = (188) + (257) +(23) + (91) + (19) + (824)

= 1,402 GJ/year

Cost Savings

= (GJ) (Rs./GJ)
= (1402) (115.19)
= Rs161,496/Year

Cost of Implementation

The cost to fix the leaks is estimated to be Rs40,000. The leaks can be attended to by in-house labor as part of the normal routine maintenance.

APPENDIX 16 (Cont'd)

REPAIR OF STEAM LEAKS

Simple Payback

$$= \frac{40,000}{161496}$$

= 0.3 years

ENERGY SAVINGS	=	1402 GJ
COST SAVINGS	=	Rs161,496/Yr
COST OF IMPLEMENTATION	=	Rs40,000
SIMPLE PAYBACK	=	0.3 Years

APPENDIX 16 (Cont'd)

DATA SHEET

LOCATION	PRESSURE BAR	ORIFICE mm	LOSS KG/HR
Near Calender On Main Line	3	3	14.4
Steam Dist. Room from Valves	5.5	4 x 1	10.4
Cylinder Dryer	1.64	1	1.06
Cylinder 6	2	0.5	0.3
Cylinder 8	2	2	4.8
Cylinder 14	2.2	1	1.28
Flash Drum	0.033	Measured	47 kg/hr

APPENDIX 17

REPAIR OF STEAM TRAPS

Assumptions

Average Leakage Rate per Failed Trap = 2.5 kg/hr

Data

Steam System Operating Hours		= 7,200
Load Factor		= 0.8
Boiler Efficiency		= 84.1%
Net Heat Content of Steam at:	5.5 bar	= 2632.3 kJ/kg
	3.0 bar	= 2610.4 kJ/kg
	2.0 bar	= 2597.5 kJ/kg
	1.65 bar	= 2591.0 kJ/kg
	1.2 bar	= 2583.0 kJ/kg

Calculation

$$\text{Energy Savings} = \frac{(\text{No. of Failed Traps})(\text{Leakage})(\text{Hours})(\text{Heat Content})(\text{Load Factor})}{(\text{Boiler Efficiency})\ (10^6)}$$

5.5 bar

$$= \frac{(2)(2.5)(7200)(2632.3)(0.8)}{(0.842)(10^6)}$$

$$= 90 \text{ GJ/year}$$

3.0 bar

$$= \frac{(2)(2.5)(7200)(2610)(0.8)}{(0.841)(10^6)}$$

$$= 89 \text{ GJ/year}$$

APPENDIX 17 (Cont'd)

2.0 bar $= \frac{(7)(2.5)(7200)(2597.5)(0.8)}{(0.841)(10^6)}$

= 311 GJ/year

1.65 bar $= \frac{(2)(2.5)(2591)(7200)(0.8)}{(0.841)(10^6)}$

= 89 GJ/year

1.2 bar $= \frac{(8)(2.5)(7200)(0.8)(2583)}{(0.841)(10^6)}$

= 354 GJ/year

Total Savings = (90) + (89) + (322) + (89) + (354)

= 933 GJ/year

Cost Savings

= (GJ) (Rs/GJ)

= (933) (115.19)

= Rs107,472/Year

Cost of Implementation

The cost of replacement steam traps is estimated to be Rs2,000 per trap installed giving a total implementation cost of Rs42,000.

APPENDIX 17 (Cont'd)

Simple Payback

$$= \frac{42,000}{107,472}$$

= 0.4 Years

ENERGY SAVINGS	= 933 GJ
COST SAVINGS	= Rs107,472/Year
COST OF IMPLEMENTATION	= Rs42,000
SIMPLE PAYBACK	= 0.4 Years

Data

Location No.	Pressure Bar	Load Factor	Hours
Sizing -	1.2	0.8	7200
Printers - 2	5.5	0.8	7200
Cylinder Dryer - 7	2	0.8	7200
Main Line - 2 Bleaching Dept.	3	0.8	7200
Cylinder Dryer - 2	1.65	0.8	7200

APPENDIX 18

RETURN CONDENSATE TO BOILER HOUSE

Condensate is being lost from the sizing baths, the condense return pump, and the washing machine in the finishing department.

Data

Operating Hours	= 7,200
Load Factor	= 0.8
Make Up Water Temperature	= 28°C
Heat Content	= 113 kJ/kg
Boiler Efficiency	= 84.1%
Condensate Temperature	= 90°C (measured) washing dept. = 96°C (measured) sizing dept. = 70°C (measured) steam dist. room pump
Net Heat Content at 90°C	= 267 kJ/kg
96°C	= 288 kJ/kg
70°C	= 278 kJ/kg
Leakage Rates Washing	= 1,940 kg/hr (measured)
Sizing	= 4 x 334 kg/hr (measured)
Pump	= 446 kg/hr (measured)

APPENDIX 18 (Cont'd)

Calculation

Energy Savings by Returning Condensate to Boiler

$$= \frac{(\text{kg/hr})(\text{Net Heat Content})(\text{Hours})(\text{Load Factor})}{(\text{Boiler Efficiency})(10^6)}$$

90°C

$$= \frac{(1940)(267)(7200)90.8)}{(0.841)(10^6)}$$

= 3548 GJ/year

96°C

$$= \frac{(1336)(288)(7200)(0.8)}{(0.841)(10^6)}$$

= 2635 GJ/year

70°C

$$= \frac{(446)(278)(7200)(0.8)}{(0.841)(10^6)}$$

= 849 GJ/year

Total Energy Savings = (3,548) + (2,635) + (849)

= 7,032 GJ/year

Cost Savings

= (GJ) (Rs/GJ)

= (7,032)(115.19)

= Rs810,016/year

APPENDIX 18 (Cont'd)

Cost of Implementation

Condensate can be recovered by fitting some piping in the washing department and sizing baths to connect to existing condensate lines. The gland leak on the pump can also be repaired. The estimated cost for the repairs and new piping is Rs100,000.

Simple Payback

$$= \frac{(100,000)}{(810,016)}$$

= 0.1 Years

ENERGY SAVINGS	= 7032 GJ
COST SAVINGS	= Rs810,106/Year
COST OF IMPLEMENTATION	= Rs100,000
SIMPLE PAYBACK	= 0.1 Years

APPENDIX 19

TEMPERATURE CONTROL OF J-BOXES

Assumptions

Steam required in J-Box Operation = 1.3 kg per kg of cloth (factory data).

75% of production goes through J-Boxes.

Data

Production through finishing	= 3.133×10^6 kg/year
Measured Temperature in J-Box	= 124°C
Required Temperature in J-Box	= 100°C
Net Heat Content	= 2,707 - 113 = 2,594 kJ/kg

Calculation

Production through J-Box $= 3.133 \times 10^6 \times 0.75$ kg/year
$= 2{,}349{,}750$ kg/year

Steam Consumption $= 1.3 \times 2{,}349{,}750$
$= 3{,}054{,}675$ kg/year

Heat Content at 1 bar $= \dfrac{(3{,}054{,}675)(2594)}{(0.841)\ (10^6)}$

APPENDIX 19 (Cont'd)

= 9,422 GJ/year

Excess Heat Supplied $= \frac{(124 - 100) \times (100)}{(124)}$

= 19%

By fitting a steam temperature control valve the excess heat can be saved.

Energy Savings

= (% overheat)(energy use)
= (0.19)(9,422)
= 1,824 GJ/year

Cost Savings

= (GJ) (Rs/GJ)
= (1,824)(115.19)
= Rs210,107/year

Cost of Implementation

The estimated cost of a steam control valve for the J-Box is Rs150,000 installed.

Simple Payback

$= \frac{150,000}{210,107}$ = 0.7 Years

ENERGY SAVINGS	=	1,824 GJ
COST SAVINGS	=	Rs210,107/Year
COST OF IMPLEMENTATION	=	Rs150,000
SIMPLE PAYBACK	=	0.7 Years

APPENDIX 20

FIT HEAT EXCHANGER TO STENTER

See Appendix 7 for details of balance.
A heat exchanger can be fitted to the exhaust of the stenter to give energy savings by preheating air or water.

Data

Operating Hours	= 7200
Load Factor	= 0.8
Boiler Efficiency	= 84.1%
Heat Exchanger Efficiency	= 30%
Heat Available	= 597,442 kJ/hr

Calculation

Heat Recoverable = (0.3)(597,442)
= 179,232 kJ/hr

Energy Savings $= \frac{(\text{Hours/yr})(\text{Load Factor})(\text{kJ/kg})}{(\text{Boiler Efficiency})(10^6)}$

$= \frac{(7{,}200)(0.8)(179{,}232)}{(0.841)(10^6)}$

= 1,228 GJ/year

Assuming a similar peformance for the second stenter.

APPENDIX 20 (Cont'd)

Total energy savings = (1228)(2)

= 2456 GJ/year

Cost Savings

= (GJ)(Rs/GJ)

= (2456)(115.19)

= Rs282,907/year

Cost of Implementation

The cost of two air to air heat exchangers will depend upon the type of system installed. Further engineering design should be considered before finalizing costs. There are four types that could be fitted:

i) a rotary heat wheel, ii) a heat pipe system, iii) a direct contact water heater, iv) an air to air economizer. Estimated costs for a suitable size is Rs625,000 per unit giving a total of Rs1,250,000.

Simple Payback

$$= \frac{(1,250,000)}{(\ 282,907\ )} = 4.4 \text{ Years}$$

ENERGY SAVINGS	=	2,456 GJ
COST SAVINGS	=	Rs282,907/Year
COST OF IMPLEMENTATION	=	Rs1,250,000
SIMPLE PAYBACK	=	4.4 Years

APPENDIX 21

PRINTER EFFICIENCY IMPROVEMENTS

The amount of air being exhausted from the printer is excessive resulting in a high heat loss in the exhaust. 91% of the heat input is currently being exhausted. By reducing the exhaust volume through reducing motor speed energy can be saved.

Assumptions

A 15% reduction in air volume can be achieved without affecting dryer performance.

Data

Current Exhaust Volume (Appendix 6)	= 49.29 m^3/minute
Heat Content of Exhaust (Appendix 6)	= 199,674 kJ/hour
Hours	= 7,200
Load Factor	= 0.8

Calculation

$$\text{Energy Savings} = \frac{(199{,}674)(0.15)(7{,}200)(0.8)}{(0.841)(10^6)}$$

$$= 205 \text{ GJ/year}$$

It is assumed that the other printers operate in a similar manner.

APPENDIX 21 (Cont'd)

Total Energy Savings = 615 GJ/year

Cost Savings = (GJ) (Rs/GJ)
= (615)(115.19)
= Rs70842/year

Cost of Implementation

Speed change can be accomplished by fitting lower speed motors at an estimated cost of Rs20,000.

Simple Payback

$$= \frac{20,000}{70,842} = 0.3 \text{ Years}$$

ENERGY SAVINGS	= 615 GJ
COST SAVINGS	= Rs70,842/Year
COST OF IMPLEMENTATION	= Rs20,000
SIMPLE PAYBACK	= 0.3 Years

APPENDIX 22

REPLACE MOTOR GENERATOR SETS BY THYRISTORS

Motor generator sets have inherent low efficiencies and they can be replaced by thyristors to give energy savings.

Assumptions

Measured efficiency of MG sets	= 0.37
Efficiency of Thyristor	= 0.85

Data

Operating Hours:

Bleaching J-Box	= 2820
J-Box	= 2820
J-Box	= 2820
Cylinder Dryer	= 5760
Washing Machine	= 3540
Mercerizing	= 2375
Printing	= 5760
Stentor	= 5760
Sanforizing	= 1200
Warping	= 7200

Load Factor = 0.8

Ratings:

Bleaching J-Box	= 53 kW
J-Box	= 26 kW
J-Box	= 44 kW
Cylinder Dryer	= 11 kW
Washing Machine	= 16 kW

APPENDIX 22 (Cont'd)

Mercerizing	= 44 kW
Printing	3 x 8 kW
Stentor	2 x 41 kW
Sanforizing	17 kW
Warping	2 x 5.8 kW

Calculation

Usefull Work Produced by Cylinder Dryer mg = 0.37 x 11 x 5760
= 23,444 kWh

Using Thyristor at 85% Efficiency = 23,443 x 0.85 = 19927

Savings = 23,443 - 19927
= 3,515 kWh x 0.0036
= 13 GJ/year

Cost Savings = (GJ)(Rs/GJ)
= (13)(411.11

= Rs5202/Year

Similar savings can be made on the mg sets as listed to give energy savings as follows:

	GJ/Year	Rs/Year
Bleaching Department	69	28,491
Cylinder Dryer	13	5,202
Washing Machine	11	4,652
Mercering	21	8,584
Printing	28	11,355
Stenter	94	38,796
Sanforizing	4	1,676
Warping	17	6.860
TOTALS	257	105,616

Simple Payback

$$= \frac{1,050,000}{105,616} = 9.9 \text{ Years}$$

ENERGY SAVINGS	= 257 GJ
COST SAVINGS	= Rs105,616/Year
COST OF IMPLEMENTATION	= Rs1,050,000
SIMPLE PAYBACK	= 9.9 Years

APPENDIX 23

LOAD MANAGEMENT

Demand at the textile plant can be controlled using an automatic load controller. Non-essential loads, such as exhaust fans, can be shut down for short periods without adverse impact on the production and environmental conditions in the plant. The control of these loads is done automatically through the load controller which is interfaced with the utility metering to determine the onset of a peak demand.

Data

Non-Essential Loads Identified:

Ventilation

Carding	85 kW x 1
Spinning	115 kW x 1
Winding	45 kW

Exhaust

Blowing, Carding, Spinning, Winding, Loom Shed = 8 x 3 kW

Total kW Sheddable	= 269 kW
Assume 80% loading	= 269 x 0.8
	= 215 kW
Power Factor	= 0.99

APPENDIX 23 (Cont'd)

LOAD MANAGEMENT (Cont'd)

Calculation

Energy Savings

$$= \frac{kW}{PF}$$

$$= kVA$$

$$= \frac{215}{0.99}$$

$$= 217 \text{ kVA/month}$$

Cost Savings

$$= (kVA)(Rs/kVA)(12)$$

$$= (217)(90)(12)$$

$$= Rs234,360/Year$$

Cost of Implementation

The installed cost of an automatic load controller is estimated to be Rs1,125,000.

Simple Payback

$$= \frac{1,125,000}{234,360} = 4.8 \text{ Years}$$

ENERGY SAVINGS	=	217 kVA
COST SAVINGS	=	Rs234,360/Year
COST OF IMPLEMENTATION	=	Rs1,125,000
SIMPLE PAYBACK	=	4.8 Years

APPENDIX 24

FIT HEAT EXCHANGER TO PRINTER

See Appendix 6 for details of balance.

A heat exchanger can be fitted to the exhaust of the printer to give energy savings by preheating air or water.

Data

Operating Hours	= 7,200
Load Factor	= 0.8
Boiler Efficiency	= 84.1%
Heat Exchanger Efficiency	= 30%
Heat Available	= 289,412 kJ/hr after reducing volume

Calculation

Heat Recoverable = (0.3)(289,142)
= 86,824 kJ/jr

Energy Savings $= \frac{(\text{Hours/Yr})(\text{Load Factor})(\text{kJ/hr})}{(\text{Boiler Efficiency})(10^6)}$

$= \frac{(7,200)(0.5)(86,824)}{(0.841)(10^6)}$

= 595 GJ/year

Assuming a similar performance for the other printers.

Total Energy Savings = (595)(3)
= 1,785 GJ/Year

APPENDIX 24 (Cont'd)

Cost Savings

= (GJ)(Rs/GJ)

= (1,785)(115.19)

= Rs205,614/Year

Cost of Implementation

The cost of three heat exchangers will depend upon the type of system installed. Further engineering design should be considered before finalizing costs. There are four types that could be fitted: i) a rotary heat wheel, ii) a heat pipe system, iii) a direct contact water heater, iv) an air to air economizer. Estimated costs for a suitable size is Rs625,000 per unit giving a total of Rs1,875,000.

Simple Payback

$$= \frac{(1,875,000)}{205,614}$$

= 9.1 Years

ENERGY SAVINGS	= 1785 GJ
COST SAVINGS	= Rs205,614/Year
COST OF IMPLEMENTATION	= Rs1,875,000
SIMPLE PAYBACK	= 9.1 Years

APPENDIX 25

FLASH STEAM RECOVERY FOR STEAM AGER

Date

Steam Pressure Required at Ager	= 2 bar
Steam Pressure at Stenter	= 5 bar
Steam Used by Stenter	= 340 kg/hr
Heat Content of Steam at 5 bar and 98% dryness	= 2,694 kJ/kg
Heat Content of Moisture Associated with Steam	= 13 kJ/kg
Total Heat Content at 5 bar	= 2,707 kJ/kg
Heat Content of Steam at 2 bar	= 2,707 kJ/kg
Heat Content of Condensate at 5 bar	= 640 kJ/kg
Stenter Operating Hours	= 7,200
Load Factor	= 0.8
Boiler Efficiency	= 8.41%
Heat of Vaporization at 2 bar	= 2,202 kJ/kg

APPENDIX 25 (Cont'd)

Calculation

By passing condensate into a flash vessel operating at a lower pressure than that of the incoming condensate, flash steam can be formed due to the excess heat in the condensate. The calculation assumes that if the steam ager does not require steam the flash steam will be used for preheating washing water.

Excess Heat in condensate = 640 - 505 kJ/kj
= 135 kJ/kg

= 0.061 kg/kg of condensate

Steam Consumption of Stenter = 350 kg/hr

Flash Steam Available = 0.061 x 340 x 7200 x 0.8
= 120,065 kg/year

This represents a saving at the boiler:

$$= \frac{120,065 \times 2,202}{.841 \times 10^6}$$

= 315 GJ/year

Cost Savings

= (GJ)(Rs/GJ)
= (314)(115.19)
= Rs36,170/year

Cost of Implementation

The cost of a suitable flash vessel, interconnecting pipework and fittings is estimated to be Rs150,000 installed.

Simple Payback $= \frac{150,000}{36,170} = 4.1$ Years

ENERGY SAVINGS	= 314 GJ
COST SAVINGS	= Rs36,170/Year
COST OF IMPLEMENTATION	= Rs150,000
SIMPLE PAYBACK	= 4.1 Years

APPENDIX 26

USE OF STEAM DRIVEN PUMP VERSUS ELECTRICAL PUMP

There are two steam pumps in the boiler house that can be used for boiler feed water supply.

Data

Rating of Electric Pumps	= 23 HP
Load Factor	= 0.8
Efficiency	= 0.85
Steam - Consumption of Steam Pumps	= 50 kg/hr per water horsepower
Operating Hours	= 7200
kW/HP	= 0.746
GJ	= 0.0036 x kWh

Calculation

Electrical Consumption

$$= 0.0036 \times \frac{HP \times 0.746 \times Hours \times Load\ Factor}{Efficiency}$$

$$= 0\ 0036 \times \frac{23 \times 0.746 \times 7{,}200 \times 0.8}{0.85}$$

= 419 GJ/Year

Cost

= (419) (411.11)

= Rs172,080/Year

APPENDIX 26 (Cont'd)

Steam Consumption	= kg/hr/water horsepower
Water Horsepower	= (liters/hr)(bar)
	= 26,518
Flow Rate	= 6.8 ton per hour = 6,816 liters per hour
Pressure	= 20 bar
Water HP	$= \frac{(6,816) \times (20)}{(26,518)}$
	= 5.14 HP
Steam Consumption	= 50 x 5.14 = 257 kg/hr
Heat Content at 9 bar	= 2,774 kJ/kg
Heat Content of Feedwater	= 295 kJ/kg
Heat Added in Boiler	= 2,479 kJ/kg
Energy Use for Pumping	$= \frac{(257)(2,479)(7,200)}{(0.841)(10^6)}$
	= 5,455 GJ/Year
Cost of Steam to Pump	= (5,455) (115.19) = Rs628,397/Year
Cost Savings by use of Electric Pump	= Rs456,317

APPENDIX 27

LIGHT METER READINGS

LOCATION	TYPE OF FIXTURE	NO. OF FIXTURES	LIGHT READINGS FOOT CANDLES
Sizing	Fluorescent	18	Dryer (1) 2, 3.2, 3.5 .5, 4 Dryer (2) 4, 1.5, 5.5 4, 6,1
Loom Shed	Fluorescent (Sections)	302	4.5
Spinning	Fluorescent	6 10 7 7 6 10 4 20	8.5 10 6.5 5 5 7 2.5 20
Pre Spinning	Fluorescent	96	3.1
Inspection	Fluorescent	24	2.0
Shearing & Cropping	Fluorescent	9	1.5
Singeing		3	0.8
Bleaching		54	Nat. Light. 30 Art Lights 2.5
Printing and Finishing		56	Nat Light 150 Art Light (Part Nat) 10