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Reliance Energy Services

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ENERGY AUDIT REPORT
FOR
SRI LANKA TYRE CORPORATION
KELANIYA, SRI LANKA
FINAL REPORT

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In Collaboration with

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and

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New York, New York

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An Activity Undertaken for the
Industrial Energy Conservation Program (IECP)

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

SRI LANKA
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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 if 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-sustaining, with private and government institutions providing energy audit consulting services, while EDMAC plays a catalytic and policy oriented role.

This report details findings of an energy audit at the Sri Lanka Tyre Corporation, undertaken in March 1984.

The plant was selected jointly by EDMAC and USAID consultants in December 1983 based upon their suitability for auditing and 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

The 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. ., and the USAID Mission to Sri Lanka, Colombo, Sri Lanka.

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

EXECUTIVE SUMMARY

This report details savings from reducing energy consumption at the Sri Lanka Tyre Corporation. Savings estimates are based upon the findings of an energy audit training program conducted under joint sponsorship by EDMAC and USAID in March, 1984.

Potential savings identified in this report, excluding replacement of the boiler plant*, represent 6.82 million Rupees based upon current marginal costs. The energy use reduction is equivalent to 15.9% of the 1983 energy usage. Capital costs required to implement the recommended changes are estimated to be 2.64 million Rupees, giving a simple payback of 0.4 years for the program. A summary of the savings is shown in Exhibit 1.

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 eight days of site work, the engineers were responsible for testing the wide range of equipment within the plant, including the boiler and ancillary equipment, calender dryers, process equipment, motors and ventilation systems.

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

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

*Boiler plant replacement would save a further 10.6 million Rupees or 33.6% of the energy use at the Tyre Company. The boiler replacement scheme is the subject of an associated feasibility study and hence no costs relating to this measure are presented in this report.

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:

- o energy use by fuel type and source delivered
- o energy costs
- o inventory of major energy consuming equipment in the plant
- o operating schedules for the major departments in the plant
- o details on current energy management programs
- o 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:

- o boiler plant, steam distribution and condensate return systems
- o electrical distribution and motors
- o lighting and environmental systems
- o compressed air system
- o chilled water plant
- o compounding department
- o Tyre Building
- o calendering department
- o vulcanization department

EXHIBIT 1

ITEM	ENERGY DATA				COST DATA	
	ENERGY SAVED GJ*	COST SAVED Rs	% OF SAVINGS JG*	% OF SAVINGS Rs	TOTAL COST	SIMPLE PAYBACK YEARS
1. Reduce Blowdown	6107	703,465	4.5	4.0	5,000	-
2. Steam Pipe Insulation	7890	908,849	5.8	5.2	850,000	0.9
3. Steam Leaks	11196	1,289,667	8.2	7.4	200,000	0.2
4. Steam Traps	1261	145,255	0.9	0.8	60,000	0.4
5. Return Condensate	11526	1,327,680	8.5	7.6	25,000	-
6. Power Factor Con.	508KVA	548,640	-	3.1	325,200	0.6
7. Compressed Air Leaks	1661	682,854	1.2	3.9	100,000	0.1
8. Reservoir Vol. Red.	94	38,644	0.1	0.2	15,000	0.4
9. Insul. of Boiler	2954	340,271	2.2	2.0	266,913	0.8
10. Replace Boilers	(92365)	(10,639,524)	67.9	60.9	NA	-
11. Reschedule Depts.	400KVA	432,000	-	2.5	NA	-
12. M G Set Replace	625	260,871	0.5	1.5	375,000	1.4
13. Chillers	348	143,216	0.3	0.8	420,000	2.9
Totals Excluding Boiler	43,672	6,821,412				
Totals Including Boiler	136,037	17,460,936	100.0	100.0	2,642,113**	

*GJ = 10^9 Joules

**Does Not Include Cost For Boiler Replacement

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

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

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

- o Electricity is used to provide motive power, compressed air, chilled water and environmental services. It accounts for about 17% of the energy use at SLTC.

- o Fuel Oil is used for steam generation in boiler plant. The steam is used for process heating and drying. Fuel oil consumption represents about 83% of the energy use at the plant.

- o As a cost item, electricity forms 46% of the energy bill, fuel oil 54%.

- o Improvements are needed in the existing energy management program to ensure conservation opportunities are implemented. The improvements include:

  - Hiring a full time employee to assist Mr. P. P. Subasinghe. The duties of the assistant should be confined to energy management, and in the short term focus upon implementing measures with short payback periods. In the longer term he should be responsible for conducting energy analysis on an on going basis.

  - Purchase of instrumentation to support conservation activities including a combustion analysis kit, water test kit, and an electrical equipment test kit.

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

- Determining an energy consumption index that accurately reflects energy usage within SLTC. The existing index of energy consumption per standard type is inadequate and does not track energy efficiency within the plant accurately. Separate indices should be developed for electricity and fuel oil.

- Establishing an energy awareness program for all employees, including posters highlighting conservation methods, distributing information on the cost of energy wastage, possible extension of the incentive schemes given to boiler operators to include other production departments based upon their ability to save energy.

o Improvements in energy utilization at STLC can be made to reduce energy use close to 49%, under existing operating schedules and production output if measures identified in this report are implemented. The measures identified include replacing the existing boiler plant. This item is subject of a separate feasibility study and costs etc. are not discussed here. Potential savings of about 34% of energy use at SLTC can be saved. Efficiency tests showed the boiler efficiency to be 54.1%. The existing plant is in a poor state of repair and near the end of its useful life. Because of this, major capital expenditure which would be necessary to improve the efficiency of the plant is not recommended.

o In the short term, significant energy savings can be made with the plant by reducing the amount of water blown down from the boiler drums. Blow down is done to reduce the level of total dissolved solids (TDS) in boiler water to prevent scaling of the heat transfer surfaces. Currently TDS levels of 175 ppm are maintained as against international standards of 3500 ppm. Little investment is required to implement this measure. Instrumentation for monitoring TDS on a daily basis can be purchased for approximately Rs5000 and blowdown rates adjusted accordingly by the boiler operators.

- A major improvement is required in the operation and maintenance of the steam distribution and condensate return system. Areas for improvement include:
  - insulation
  - repair of leaks
  - repair of steam traps
  - returning condensate to the boiler

  Estimated savings from the rehabilitation of the steam system are 11.6% of the energy use in 1983. All measures are relatively easy to implement, requiring investment of approximately Rs1.1 million, including costs for supply of material and labor to install new materials.

- Overall plant power factor was measured at 0.8. By raising this to 0.95, electrical demand savings would be in excess of Rs500,000 per annum. This measure requires the installation of power factor correction equipment, either static capacitors or using synchronous motors. Estimated capital costs are Rs325,000.

- The compressed air system is in a similar state of repair to the steam distribution system. There are numerous leaks around the system and compressed air is used indiscriminately for comfort cooling by the employees. Savings of Rs680,000 are possible through repairing leaks.

- Electrical consumption can be reduced by implementation of the following measures:
  - reducing the chilled water reservoir volume
  - replacing ac-dc motor generator sets with thyristor drives
  - installing a cooling tower to recirculate condensor water

A total savings of about Rs442,000 is possible for an estimated expenditure of Rs810,000. Implementation will require the purchase of the necessary replacement thyristors and design, purchase and installation of a suitable cooling tower.

As a first step in implementing the measures identified, a three-phase action plan has been developed. The plan, shown in Exhibit 2, is based upon the relative cost benefits and ease of implementation associated with each measure.

EXHIBIT 2

IMPLEMENTATION ACTION PLAN

Phase	Item	Time Frame	Action Required
1	Assistant Energy Conservation Engineer	Immediate	Recruit either in-house or outside.
1	Energy Monitoring Program	On installation of new metering	Establish guidelines for energy monitoring, production monitoring by department
1	Employee Awareness Program	Immediate	a. Post conservation stickers about plant - available from EDMAC. b. Hold informal meeting with factory personnel to outline conservation program c. Collate data on individual department energy performance. d. Advise of cost of energy conservation actions.
1	Boiler Blowdown	Immediate	a. Reduce blowdown to 1 time per 4 hours - 30 seconds duration. b. Purchase TDS monitoring equipment. c. Check TDS 1 time per shift and adjust blowdown until 3000 ppm.
1	Condensate Return	Immediate	Install pipework to reconnect condensate receiving tanks to condensate return system

EXHIBIT 2 (Cont'd)

IMPLEMENTATION ACTION PLAN

Phase	Item	Time Frame	Action Required
1	Steam Leaks	Immediate	Locate leaks and plan program to repair as part of maintenance on week-end shutdown
1	Compressed Air Leaks	Immediate	Locate leaks and plan program to repair as part of maintenance on week-end shutdown
1	Insulate Pipework	Immediate	a. Identify missing insulation b. Contact local suppliers c. Order materials d. Install using in-house labor or subcontract
1	Steam Traps	Immediate	a. Identify faulty traps b. Contact local suppliers c. Order materials d. Install using in-house labor or subcontract.
1	Boiler Replacement	Immediate	a. Feasibility study (underway) b. Take action based on findings of feasibility study

EXHIBIT 2 (Cont'd)

IMPLEMENTATION ACTION PLAN

Phase	Item	Time Frame	Action Required
2	Power Factor Correction	Immediate	a. Contact local suppliers and CEB b. Specify static capacitors or synchronous motors c. Order materials d. Install using in-house labor or subcontract
2	Chilled Water Reservoir	Immediate	a. Reduce volume by either altering controls or by filling with bricks
2.	Cooling Tower	Immediate	a. Contact local engineering design for cost-estimate for tower and initial design b. Specification and bid for final design, construction and installation c. Select contractor d. Install
2	M.G. Sets	Immediate	a. Contact local suppliers or CEB b. Specification and budget pricing c. Select replacements d. Purchase and install using in-ho se labor

EXHIBIT 2 (Cont'd)

IMPLEMENTATION ACTION PLAN

Phase	Item	Time Frame	Action Required
3	Areas Requiring Further Study	(see below)	
3	Reschedule Departments	Immediate	a. Set up management team to investigate b. Interview production personnel to determine labor needs, production schedules, etc. c. Prepare report on findings d. Implement if cost effective
3	Insulate Existing Boilers	Await Feasibility Study and results	a. Insulate if no decision to replace within 18 months.
3	Raise Chilled Water Temperature	Immediate	a. Monitor existing chilled water temperature pattern at users b. Compare to requirements c. Adjust as possible

EXHIBIT 2 (Cont'd)

IMPLEMENTATION ACTION PLAN

Phase	Item	Time Frame	Action Required
3	Chilled Water Recirculation from Tread Aggregator	Immediate	a. Monitor chilled water flow and temperatures through tread aggregator and compare to requirements b. Install recirculation system c. Adjust till optimized
3	Calender Drying	Immediate	a. Check cord specification and condition daily b. Check moisture contents in and out of calender daily for extended period c. Determine whether drying required d. Reduce number of heated cylinders
3	Pipework Layout in Vulcanization Department	Immediate	a. Establish operating needs for vulcanization process for superheated hot water, steam. b. Monitor system performance including scrap, etc. c. Re-evaluate system efficiency

1. BACKGROUND

1.1 Introduction

Reliance Energy Services have produced this report as part fulfillment of their contract with USAID to provide energy audit training to 32 Sri Lankan engineers. The report summarizes energy conservation opportunities identified during an energy audit training program, completed at the Sri Lanka Tyre Corporation (SLTC) plant at Kelaniya in March, 1984. Data collected during the field work has been used to estimate energy savings that can be achieved through implementation of the measures recommended.

The energy audit training was conducted in the following manner:

First, the Sri Lankan engineers received instructions in energy audit techniques in classroom sessions. Half of the 32 were then assigned to perform an actual plant audit at SLTC.

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

The teams then followed a systematic approach through which they collected data. The approach used entails, as an initial step, conducting a visual inspection and collation 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.

The plant had been previously visited in December 1983 by members of the training program to conduct a rudimentary PEA. Subsequently, 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 identified were:

- Boiler Plant
- Steam Distribution and Condensate Return
- Compounding and Extrusion, including chilled water
- Calendering
- Tyre Building
- Vulcanization
- Electrical Systems, including compressed air, lighting and ventilation

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

Each major energy consuming system is tested as part of an 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 by various members of the three teams:

- Corporate management
- Plant engineering
- Operations and maintenance
- Production
- Quality control
- Services

Discussions were also held with representatives from B.F. Goodrich, who are providing technical assistance to SLTC to determine what recommendations they had made regarding energy conservation.

Reliance Energy Services would like to thank the management of the Sri Lanka Tyre Corporation for allowing its facility to be used for training purposes, Palita P. Subasinghe, Senior Power Engineer, for all his kind assistance, members of the EDMAC team and all participants of the training program.

1.2 Plant Description

The Sri Lanka Tyre Company is located on a sizeable tract of land in Kelaniya, about 10 kilometers from Colombo. The company is engaged primarily in the manufacture of tyres and tubes for automobiles, motorcycles and scooters, trucks, and agricultural vehicles. A plant layout identifying major functional departments is shown in Exhibit 3. A brief process description follows.

Raw materials in the form of natural and synthetic rubbers are received, graded, and stored. Rubber is selected for manufacture into tyres based on the requirements of the particular tyre and the properties of the rubber. In a sequence of mixing and milling, the rubber is plastisized and mixed with chemicals and additives, chiefly carbon black and sulphur. The mills consist of rotating cylinders, operating at different speeds which masticate the rubber mix purely by mechanical work. These mills are cooled using chilled water to prevent unwanted chemical reactions and scorching from frictional heating. The rubber is then cooled and dried in a festooner dryer.

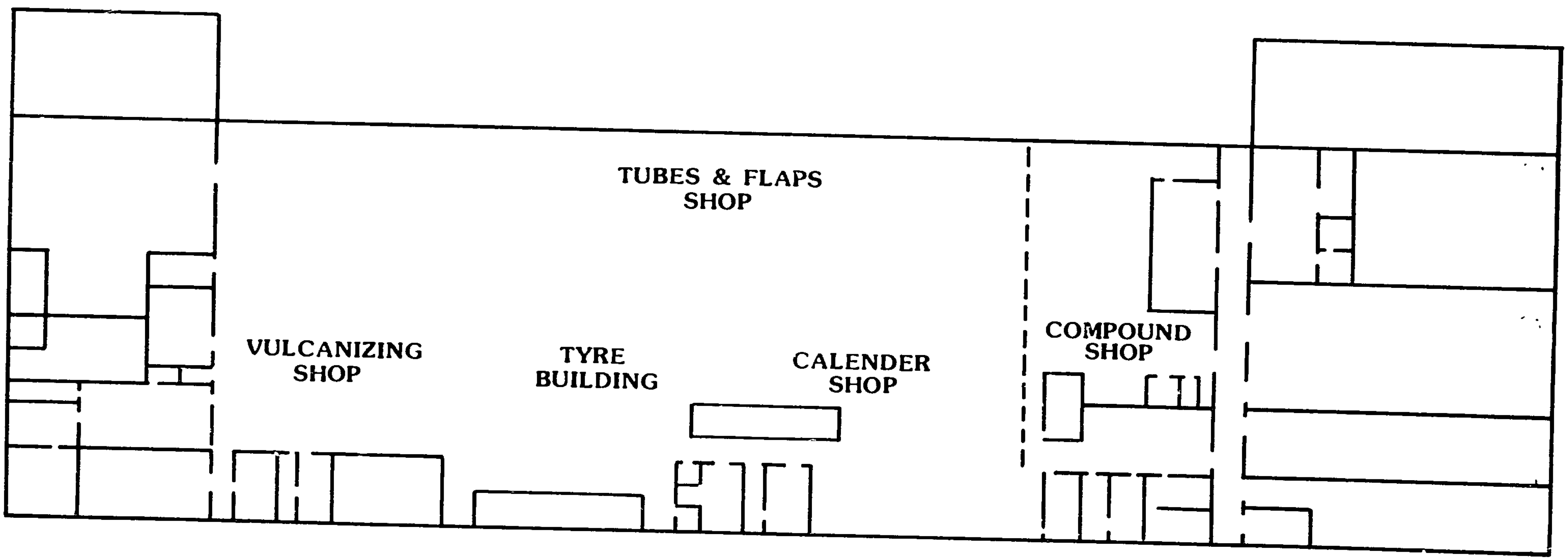
In the extrusion step that follows, the rubber is again milled and then formed into the tread and sidewall shapes. A portion of the rubber is sent to a calendering operation where it is bonded mechanically to nylon fabric to form the cord. Another portion of the rubber is bonded mechanically to copper coated steel wire to form the bead.

In the tyre building step, the cord, sidewalls, tread, and bead are assembled into a "carcass", which bears little resemblence to the finished tyre. This step is very labor-intensive,and involves a great deal of training for operators to become skilled in this process.

SRI LANKA TYRE CORPORATION

PRODUCTION PLANT LAYOUT

EXHIBIT 3



Using pneumatic presses, the carcass is formed into a shape resembling the final tyre. From there, the carcass is placed in a vulcanizer. Vulcanization is the last manufacturing step. Two types of machines are used in this process. The first type, uses a curing bag, a thick walled rubber tube, similar to an inner tube, which is inserted inside the tyre. The vulcanizer contains a mould with the tyre tread and sidewall patterns. Under high temperature, the tyre is formed by melting the rubber into its final form; in addition, a chemical reaction between rubber and sulphur occurs, imparting the desired strength, flexibility and durability characteristics to the tyre. Steam and superheated hot water are used to provide heat to this process. The alternate type of machine used in this step is the Bag-o-matic, which does not require the preliminary forming step or the use of the curing bag. The Bag-o-matic machine is slightly less energy-intensive than the curing bag vulcanization process.

The next stage in the process is quality control, where tyres are inspected and tested. The finished tyre is then stored in a warehouse area prior to shipment.

The manufacture of tubes follows a similar sequence of operation, except that additional extrusion steps take place, and a separate type of vulcanization machine is use.

The physical plant consists of a number of buildings, including the factory, and a number of workshops, administrative office buildings, and employee service buildings. This audit is limited to the first three of these.

The factory was built with support from the USSR; hence most of the equipment within the plant is of Soviet or Eastern Bloc manufacture. The original design employee complement was 550; at present, about 2,000 are employed. Since the original construction in the later 1960's, additional manufacturing capacity has been provided. Currently, the Sri Lanka Tyre Company is participating in a technical assistance program with B.F. Goodrich, at an annual cost of Rs.12 million.

1.3 Operating Schedules

The operation of the tyre factory is broken into a number of process departments. While the operation of the factory as a whole is 24 hours per day, six days per week, (0600 Monday morning through 0600 Sunday morning), exclusive of holidays, individual operating schedules are given in the table below:

	Operating Schedule	
Department	Shifts/Day	Days/Week
Compounding	3	6
Extrusion	2	6
Calendering	1	6
Tyre Building	3	6
Vulcanizing	3	6
Tube Making	2	6

Normal Shift times are: 0600-1400, 1400-2200, 2200-0600 and, as can be seen, are of eight hours duration. Meal times are not staggered; in addition, production is halted for a period before and after shift changes.

To provide steam and chilled water at the start of production on Monday morning, services commence operation several hours before the 0600 Monday start-up time.

1.4 Production Data

Sri Lanka Tyre Company is engaged in the production of tyres, tubes and flaps. The table below reflects the relative production of each type of product for the three years 1981 through 1983. For internal accounting purposes, the plant measures production on the basis of "standard tyres". A standard tyre is equivalent to 33kg of product; these data are shown below as well.

	1981	1982	1983
Tyres:			
Scooter and Motorcycle	544	2,587	3,668
Car and Jeep	89,400	93,402	99,948
Truck	88,206	95,521	97,478
Agricultural	26,724	25,716	25,591
Total Tyres	204,874	217,226	226,685
Bearcat	1,419	2,727	1,117
Tubes:			
Car	61,682	68,872	70,622
Truck	79,912	89,186	86,675
Agriculture	3,181	2,803	2,208
Total Tubes	144,775	160,861	159,505
Flaps	19,519	18,768	22,546
Carpet	1,754	Nil	Nil
Standard Tyres	155,951	165,387	170,444

1.5 Energy Consumption and Costs

The tables below show the energy consumption by type for the year 1983. The costs shown are the use multiplied by the marginal energy costs as billed during the first quarter 1984. This data applies to the tyre factory only, and does not include energy utilization at the water treatment plant.

Consumption and Costs

	Units	Consumption	Annual Cost Rs.(1)	Total Cost %
Electricity	kWh	12,493,800	18,490,824	38.0
Peak	kVA	3,500	3,780,000	7.8
Fuel Oil	gal	1,222,259	26,400,079	54.2
			48,670,903	100.0

Thermal Equivalents

	Annual Energy Equivalent GJ	Marginal Energy Cost Rs/GJ	Total Energy %
Electricity	44,978	411.11	16.5
Fuel Oil	229,296	115.19	83.5
	274,274		100.0

Conversion to GJ

Electricity - 0.0036 x kWh
Fuel Oil - 0.1876 x gallons

(1) Based on costs in first quarter 1984.

Electricity is purchased from the Ceylon Electricity Board (CEB) under the IP-3 Rate Schedule (Industrial Power). The current 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 is purchased from the Ceylon Petroleum Corporation (CPC). Currently, fuel oil with a viscosity of 1000 seconds is used; this has a heating value of 10,178 kcal/kg. The fuel has a specific gravity of 0.96. The cost is Rs. 21.61 per gallon.

1.6 Major Energy Systems

Energy is consumed by several major energy systems. A listing of the major users is given in Appendix 3. Electricity is used predominantly for motive power, chilled water generation, compressed air and lighting. Fuel oil is burned to produce steam that is used almost exclusively for process requirements.

The boiler plant comprises three water tube boilers, each rated at 6.5 tonnes per hour at a working pressure of 16 bar. Each boiler has an associated economizer. The economizer is used for feedwater preheating by heat recovery from the stack gases.

The steam generated is supplied to the production areas at two pressures, 16 and 8 bar, where approximately 95% is used for process needs. The other 5% is used for cooking and water heating.

The single largest consumer of steam is the vulcanization department, which accounts for about 85% of the plant steam needs. Steam is used at 16 bar to generate superheated hot water at 175°C in three shell and tube heat exchangers. It is also used directly inside the vulcanizers at 16 and 8 bar.

The vulcanization process consumes about 80% of the overall steam generated. Flash steam is generated at 3 bar from condensate and used in the calendering department. The remaining steam is used for making flaps and mats in plattens, in the laboratory, and in the compounding department for heating chemicals.

Chilled water is produced at 16°C in an ammonia refrigeration plant rated at 500 tons. Approximately 200-300 tons of refrigeration are normally used. The chilled water is used for cooling mills in the compounding, extrusion and calendering departments.

Compressed air is produced in three reciprocating compressors capable of supplying up to 90 M^3 per minute of compressed air at 7 bar. The compressed air is used in all departments for penumatic cylinders, instrumentation and controls.

Lighting is provided predominantly by mercury vapor lamps. The estimated lighting load is 375 kW. Lighting is only used part of the day in certain areas where natural lighting is insufficient.

The main electric consumers are AC-DC motors in the various departments. The largest motors are used in the compounding and extrusion departments, for mixing rubber and chemicals and for forming the several components that make up a tyre.

2. FINDINGS

The following sections summarize the findings of the energy audit. Two distinct areas are focused upon, the first the management of energy within SLTC and secondly energy utilization within specific systems and departments.

2.1 Energy Management Program

2.1.1 Structure

An energy management program was established in 1981. The program is under the direction of Mr. P. P. Subasinghe, Senior Power Engineer. As Senior Power Engineer, the amount of time that can be devoted to the program is extremely limited. At the time of the audit, for example, the Tyre plant had only two electrical engineers including Mr. Subasinghe himself.

The effect of the lack of manpower with time to spend on energy-related matters means that the program has not been able to establish sufficient direction. Management has stated that it is willing to provide funding for energy conservation projects and they will be given a high priroity. This view is supported by its encouragement of various agencies to review the energy status of the plant. Despite the reviews and management's positive view of energy conservation the plant is unable to document any energy savings.

There are two possible reasons why SLTC cannot demonstrate energy savings at the plant. The first is that projects that have been implemented may not have had sufficient impact to offset any fall off in energy efficiency that may have occured elsewhere in the plant. Secondly, the plant energy monitoring system and consumption index may not be adequate to indicate any savings that are being acheived.

2.1.1 Achievements

Based upon discussions with plant personnel during the Energy Audit measures that have been implemented include:

- increasing chilled water temperature from 15°C to provide 18°C at the process
- using a more effective chemical peptizer to aid plastication of the rubber, thereby reducing energy in the mixing process
- elimination of part of the cooling cycle in the vulcanization process
- constant monitoring of product quality and specification
- improving natural lighting by using clear fibreglass sheets for roofing, and cutting back on artificial lighting
- staggering machine start up
- eliminating pipe leaks
- insulating pipe lines
- using an incentive scheme to reward boiler operators for efficient operation

2.1.3 Monitoring

Plant energy use is monitored on a monthly basis, and efficiency gauged using an index of energy consumption per standard tyre. No attempt is made to break out energy use for any stage of production and costs are assigned as overhead rather than by function.

Steps have been taken to improve the monitoring program by purchase of four oil meters to be fitted in the boilerhouse to measure oil flow to individual boilers. Although other metering instrumentation is fitted much of it is old and obsolete or spares are difficult to obtain.

2.2 Energy Utilization

2.2.1 Boiler Plant

The boiler plant consists of three watertube boilers of Russian manufacture. The boilers are each rated to produce 6.5 tonnes of steam per hour at a pressure of 16 bar. In normal operation, one boiler operates at high fire, one at low to medium fire, and the third is under maintenance. Duty is rotated every six months. The average steam demand is of the order of 7.5 tonnes per hour, with instantaneous peaks up to 10 tonnes occuring for periods of less than two minutes. In a normal work week, the boilers are fired at 0430 Monday morning and continue operation until all processing is completed on Sunday morning.

The boilers fire fuel oil with a viscosity of 1000 seconds. Fuel oil is obtained from Ceylon Petroleum Corporation (CPC).

The Boiler plant is in generally poor condition owing to a number of factors. The main cause is the apparent lack of regular and formal preventive maintenance procedures. This is compounded by the difficulty in obtaining spare parts for the boiler and ancillary systems.

The overall boiler plant efficiency is estimated to be 54.1% for both boilers firing at the time of the test. This was determined by measurement of fuel and feedwater flow rates for both boilers. An attempt was made to measure combustion efficiency using chemical analysis, but these results are not reliable. The high degree of smoking by the boilers necessitated the approach taken. Measurements taken with a Bacharach True-Spot Smoke Tester showed the smoke number of be in excess of 9 on a scale of 1 to 9, on all firing rates for both boilers. This was observed even when the combustion air dampers were adjusted to provide maximum combustion air.

A number of factors contribute to the poor efficiency of the boiler plant. The fuel oil is heated to 110°C prior to firing, but even though this temperature is recommended by CPC, it is evidently too low.

The boiler burners are of the pressure jet type, with steam atomization. Each boiler employs two burners. The burner housings are in poor condition, being bent and distorted. This causes uneven distribution of oil with respect to primary and secondary combustion air supply. The burners overfire and the flame impinges on the back wall of the combustion chamber, causing soot deposit.

The burners are manually controlled. Observation of plant practice indicated that only the oil flow is adjusted when the firing rate changes; the combustion air supply is not adjusted. In addition, only one of the two burners is adjusted, causing uneven firing.

The boiler brickwork is also in poor condition, showing signs of deterioration by acid corrosion. This is due to the high sulphur content of the fuel oil fired and the soot depositing on the brickwork.

The incomplete combustion and uneven firing causes soot buildup and pressurization within the combustion chamber. As a result, the relief vent is permanently open. In addition, sootblowing must occur every four hours to remove soot deposit buildup. The boilers are not well-insulated. The boiler shell itself is bent and distorted. In addition, there are numerous steam leaks and leaking valves in the boiler plant. Many pipes have missing or damaged insulation.

Makeup water is supplied from the pumping plant located at the river. The water is softened by base exchange. At the time of the plant visit, no condensate was being returned to the boiler and 100% makeup water was being used. Feedwater is supplied from a deaerator, which heats the water to 88°C. This temperature is not high enough to ensure removal of dissolved oxygen. Feedwater is pumped to the boiler using an electric pump. A steam driven feedwater pump is used during power outages; because this pump is undersized it cannot be used except during these times.

Tests of total dissolved solids (TDS) levels in the boiler feedwater indicate that the boilers are being blowndown too frequently. The company should purchase a conductivity meter to measure boiler TDS and blowdown only when necessary.

The boilers are each fitted with economizers for preheating boiler feedwater. The economizers draw outside air, reducing their ability to achieve maximum heat transfer.

As a general comment, the state of boiler plant instrumentation and safety equipment is poor. Boiler water level alarms, both high level and low level, are inoperative, which is extremely dangerous. It is recommended that these conditions be remedied immediately.

A major upgrading of the boiler plant is required. While replacement of the boiler burners may increase combustion efficiency, the design of the boilers may require complete rebuilding of the front of the boilers to accomodate the new burners. This replacement may not increase combustion efficiency sufficiently to warrant the expense. It is recommended that a complete boiler plant replacement be undertaken.

2.2.2 Steam Distribution and Condensate Return System

The steam distribution and condensate return systems are generally in poor condition. The steam distribution system has numerous leaks and areas where insulation is missing or damaged. In addition, there are few steam traps, and in particular none on the main 8 bar and 16 bar distribution lines. Of the steam traps existing, none are maintained regularly. In the main steam lines are uninsulated near the point of consumption. In a number of areas insulation thickness is inadequate and valves, flanges and other fittings are uninsulated. At the time of the site visit, no condensate was being returned to the boilers. Condensate is collected in recesses in several areas in the plant and then sent to drain.

The major use of steam is in the vulcanizing department. Steam is used directly at 8 bar and 16 bar, and is also used to generate superheated hot water. A separate power unit within the main plant produces superheated hot water in a bank of heat exchangers. The heat exchangers are poorly insulated. Instrumentation in the area is poor and generally not functioning. In addition, a number of problems exist in producing superheated hot water at the temperatures and in the quantities required by the vulcanizers. Variations in superheated hot water supply have adverse effects on product quality.

It should be noted that the steam traps serving the vulcanizers are malfunctioning. The steam traps incorporate an air relief valve, which, in many cases, passses live steam to the atmosphere.

Part of the condensate from the steam used to produce superheated hot water is used to produce flash steam for use in the calender dryer. It was noted that the steam pipework from the flash vessel to the calender dryer was flooded. In addition, many of the steam traps serving the dryer were inoperative or leaking steam.

Steam control valves are generally oversized, which contributes to the erosion of valve seats. This is particularly serious in the vulcanizing area.

2.2.3 Compounding Department

Energy use in the compounding department is primarily electricity for motive power and chilled water. The compounding department is responsible for the production of rubber by addition of carbon black, sulfur and other chemicals to the raw rubber. In the process, the raw rubber is masticated in compounding mills, to impart the desired properties and ensure mixing of rubber and additives.

There are two compounding mills in this department, one of 430 hp and one of 215 hp. A single festooner mill uses a 215 hp motor. All of these motors are of the synchronous type.

There is little scope for savings in this area. One possible opportunity is to ensure that operators in this department do not run the mills unnecessarily when no rubber is being processed. Another is to ensure that the chilled water supply to idling units is shut down.

2.2.4 Extrusion Department

Energy use in the extrusion department is primarily electricity for motive power and chilled water. The extrusion process supplies additional mastication of the rubber prior to incorporation into the tyre carcass. A number of warming mills operate on a common shaft from a single motor generator. Low power factor was observed on some smaller motors in this area.

2.2.5 Calendering Department

Energy used in the calendering department is electricity and steam. Both are used in the calendering process. This department is responsible for the production of rubberized tyre cord. The cord is made by impregnating nylon fabric with rubber under conditions of heat and pressure.

The nylon fabric is dried and heated by passage through a drying chamber prior to the actual calendering operation. A number of problems were observed in this drying operation. First, the nylon fabric was tested and found to be within the dryness specification before drying.

The dryer is an enclosed chamber which contains several stands of steam heated cylinders. There are a number of major steam leaks within the dryer, from steam traps and from rotary joints. The net effect is that the dryer vents live steam to the atmosphere, and very little drying actually occurs. The dryer outlet also vents air heavily laden with water vapor, causing the fabric to be rewetted. Finally, due to the distance between the dryer outlet and the calender mill, the nylon fabric has cooled to ambient temperature again while travelling this distance. It is recommended that SLTC perform tests to determine if the drying operation is needed and if the cord quality drops if the step is eliminated. Based on observations made during the site visit, SLTC would probably be able to eliminate this drying step.

It was further observed, with respect to the dryer, that the incoming steam line is flooded. In addition, steam traps have failed and live steam is passed through to the condensate line.

2.2.6 Tyre Building Department

The tyre building department incorporates a labor-intensive step to assemble the tyre from its component parts. No specific recommendations can be made for this area.

2.2.7 Vulcanizing Department

In the Vulcanizing department, the assembled tyre carcass is subject to high temperature and pressure to cause the chemical reaction (vulcanization) and physical changes required to produce the finished tyre through the use of steam, at 16 and 8 bar, superheated hot water and chilled water. Two types of vulcanizing machines are used in this department. The first type, shear strip vulcanizers, are older machines requiring the use of a curing bag. The second type, the "Bag-O-Matic" vulcanizers are much newer and incorporate a thin-walled bladder which serves the purpose of the curing bag. The Bag-O-Matic machines are more energy efficient than the shear strip machines and require a shorter cycle time.

A number of problem areas were observed in this department. The major problem is in the distribution of superheated hot water to the vulcanizer. Because of uneven and almost random time demands by the vulcanizers for superheated hot water during the process regime, there is difficulty in maintaining the temperature and quantities of hot water required. The problem is compounded by the lack of controls and functioning instrumentation in the Power Unit. Vulcanization capacity has been added without increasing the superheated hot water production capacity of the Power Unit.

While this is more of a process problem than an energy problem, the difficulty is reflected in energy use, since it contributes to products which do not meet quality standards and are rejected, causing waste. It is recommended, therefore, that SLTC investigate, through B.F. Goodrich and other resources, avenues for improvments in this area, including controls and process scheduling.

Another problem identified is that of surface heat losses from the vulcanizing machines. Air from the ventilation system serving the vulcanizing area impinges directly on the vulcanizers, causing an excessive heat loss. This is compounded by the lack of surface insulation on the vulcanizers. It is recommended that the distribution pattern of the ventilation air be changed to reduce this problem.

Feeder lines to the vulcanizers are uninsulated, causing a large drop in temperature along the feeder line. These lines should be insulated immediately. Many of the steam traps serving the vulcanizers are operating improperly. Some pass steam to the atmosphere, due to the relief vent being unsecured; others pass steam into the condensate system, due to malfunction. Both of these problems should be corrected immediately.

Steam and superheated hot water supply lines to inactive vulcanizers should be secured, as a number of these machines were found to be leaking. The leaks should be repaired, as well.

During the site visit, a number of two-tyre vulcanizers were found to be processing only a single tyre. This practice should be discouraged, as it is extremely wasteful because steam and superheated hot water is supplied to both chambers.

2.2.8 Tube Manufacturing

The tube manufacturing section of the plant was not operating (except for the tube vulcanization) at the time of the site visit. It is expected that this department experiences many of the same problems as the others, particularly in the extrusion areas.

2.2.9 Electrical Systems

In general, electrical systems in the plant were found to be in good condition. A number of areas for improvement were identified, however.

Overall plant power factor was estimated to be in the 80-85 percent range. A number of motors were observed to be running at low load, and low power factor. It is possible to increase overall power factor by installation of a capacitor bank at the incoming factor; or to improve the power factor of the culprit motors by installation of local capacitors. In addition, the existing synchronous motors can be used for power factor correction by adjustment of motor excitation. It is also recommended that the installed power factor meters, which are inoperative, be replaced.

Examination of current plant operations and scheduling revealed that there may be a savings in peak demand available through the rescheduling of some departments. The departments are extrusion and calendering. This would ensure that certain motors in the rescheduled departments are not used simultaneously.

A number of points need to be considered before rescheduling, to determine if a net savings would be accrued to the plant. These factors include employee shift premiums, and the ability of the plant to respond to potential changes in production priorities.

During the site visit, it was observed that motors in some areas operate unnecessarily. This includes exhaust fans operating when the department or process area served are inactive. This practice should be discouraged.

2.2.10 Compressed Air Systems

Compressed air for the plant is provided by three 180 kW air compressors. While the compressors themselves are adequate, the use of the compressed air within the plant is not efficient.

The compressed air distribution system is poor, with numerous leaks. In addition, compressed air is used by employees for personal comfort cooling. Finally, local compressed air control valves are not secured when the compressed air is not needed; the valves generally serve a length of rubber tubing. It is recommended that compressed air leaks be repaired and that a spring loaded valve be fitted to the ends of the rubber tubing. The use of compressed air for comfort cooling should be discouraged.

2.2.11 Chilled Water Plant

The chilled water plant consists of five 100 ton ammonia compressors which are manually started ε d sequenced. Automatic controls for supply temperatures and sequencing should be considered. Chilled water is used to cool process equipment, particularly mills. Chilled water is produced at 14°C for use in the plant. Chilled water is required to be about 16°C at the mills, in order to prevent scorching. The chiller plant operates continously during plant operation hours, but is started at midnight Monday morning to provide sufficient chilled water for plant needs.

The supply temperature of the chilled water has been increased gradually, at Mr. Subasinge's suggestion, to reduce energy consumption. The limiting factor, however, is the tendency of the milled rubber in the compounding department to exhibit undesirable properties when the mill rolls are not kept cool enough. Mr. Subasinghe should continue in his efforts to increase chilled water temperature until the maximum temperature that does not cause problems is reached. The temperature controls should then be maintained at this level.

Heat is rejected from the condenser of the chiller plant by a once-through cooling system employing river water. Since the river water must be pumped some distance, savings can be achieved by installation of a cooling tower.

The chilled water is returned from the plant into a 250 cubic meter reservoir. During the hours before plant startup on Monday morning the chiller plant operates for the sole purpose of cooling down this reservoir; during these hours, a bypass valve allows the chilled water to be circulated between the evaporator and the reservoir without being pumped through the plant.

The reservoir may be oversized for plant needs based on pumping capacity. It is suggested that the reservoir volume be gradually reduced, and the start-up time shortened, to achieve energy savings.

It was noted that the chiller plant operates during normal working hours with the bypass valve open. Chilled water cirulates between the chiller and the reservoir. The reservoir water temperature was found to be less than the return chilled water temperature. Chiller plant operators must close this bypass when the process operations are in use.

Losses of ammonia from the system were observed, as were uninsulated areas of pipework and ancillary equipment. These conditions should be remedied.

There may be an opportunity to recycle chilled water in the tread aggregator. Currently, a once-through spray system is used to cool the tread. It may be possible to recirculate the chilled water, by the way of a sump, to reduce requirements in this area, and achieve energy savings. In addition, there may be an opportunity for chilled water cascading. This involves using the chilled water discharge from one process as supply to another which can use chilled water at a higher temperature than the first process.

2.2.12 Lighting and Environmental Systems

Lighting is primarily by mercury vapor luminaires, which is supplemented by daylight. Translucent panels are being added to the roof to admit more natural light. This ongoing program was initiated by Mr. Subasinghe.

Savings may be achieved by conversion of luminaires to high pressure sodium. Because of the color of the lighting, however, caution should be taken in initiating HPS luminaires in the bead making area, since the copper coated wire used there cannot be seen in the light produced from high pressure sodium lamps.

Few lights are used unnecessarily, or left on when the area was unoccupied. The tyre storage area is an exception to this, however, and lights were observed to be in use when the area was unoccupied.

As mentioned above, some ventilation system motors operate unnecessarily. This practice should be eliminated. In addition, some ventilation air flows were noted to be quite high. Energy savings can be made by adjusting the pullies to reduce air flow.

3. RECOMMENDATIONS

The following sections present recommendations for improving energy efficiency at SLTC. Recommendations have been made in two areas, energy management and energy utilization. The measures in the energy management area detail improvements in the existing company energy management program designed to foster an ongoing committment to energy conservation at SLTC. The measures in the energy utilization area represent real cost reduction opportunities at SLTC. Opportunities are identified in three distinct groups - those measures that have simple paybacks of less than one year, those with simple paybacks over one year and those opportunities that offer significant potential but require further investigation and study before any firm committment to implement can be made.

3.1 Energy Management

3.1.1 Structure

The structure of the existing energy management program is reasonably sound but there is scope for improvement. A greater committment of resources should be made by SLTC, both in terms of manpower and funds. The following paragraphs discuss specific recommendations felt necessary to bring about implementation of measures identified and to be able to demonstrate the savings associated with the measures:

Because of Mr. Subasinghe's other duties, he is unable to give the program all the attention it warrants. Hence, it is recommended that SLTC provide a full-time assistant to Mr. Subasinghe, whose duties would be related solely to energy conservation and management.

The assistant should have an engineering background but have knowledge of economics. His duties would be to coordinate all energy management activities under the supervision of Mr. Subasinghe, and to take a very active role in the implementation phase of the program. He should be responsible for developing an energy data base and for data collection within the facility. He should initially focus his time upon three things:

- Implementation of identified projects with quick paybacks and projects requiring further study.
- Establishing a new monitoring and reporting system.
- Developing an employee awareness program.

After these projects are under way, he should concentrate upon:

- Implementation of identified projects with extended paybacks.
- Developing an energy index that better describes energy use with respect to production, product mix and operational parameters that impact energy efficiency.
- Conducting the energy audit process on a continuous basis thereby maintaining energy efficiency.
- Establishing energy targets and norms for individual energy consuming equipment and processes within SLTC.

Funding should be provided by SLTC to allow the purchase of instrumentation for testing purposes to ensure that energy consuming equipment is operating at peak efficiency. While it is recognized that SLTC has allocated funds for the purchase of flow metering equipment for the boiler plant, additional equipment is required.

This instrumentation should include:

- Combustion analysis equipment including flue gas analyser, temperature indicating equipment and draft gauge.
- Water test kit including equipment for measurement of TDS, dissolved oxygen pH levels, sulphite and chlorides as a minimum.
- Electrical measuring equipment to measure volts, amps, power factor, and kilowatts.

3.1.2 Monitoring

A new energy monitoring system should be developed that seek to evaluate energy use on a departmental basis. Also, variables such as operating hours, production and product mix, should be tracked on the same time frame. Using installed metering should permit the monitoring to take place on a weekly basis.

When the new monitoring program is in place, then data should be used to develop a new energy index for the plant. Rather than combining energy as at present, separate indices should be established for electricity and oil. One method that can be used to develop indices is the multilinear regression technique. This uses historical data to develop a model for the plant based upon energy use. However, sufficient historical data must be available to ensure the model's validity.

3.1.3 Awareness

To succeed in energy conservation efforts, it is necessary for all employees to take part in the energy management program. To do this an energy awareness program for company employees is needed. This program should take the form of both formal and informal activities which will increase employee participation and cooperation in achieving an overall reduction in plant energy use.

These activites should include:

- Posters highlighting easy conservation methods such as turning unwanted lights off, value of compressed air leaks.
- Informing operations employees of the value of energy wastage.
- Possible incentive schemes for departments demonstrating energy conservation.

3.2 Energy Utilization

Energy savings shown have been developed at the basis of existing production levels and operating schedules. Cost savings have been calculated on the basis of market marginal costs in effect for the first quarter of 1984. No attempt has been made to predict future fluctuations in energy costs.

3.2.1 Measures With Simple Paybacks Under One Year

The following recommendations for energy cost reduction measures in this section have simple paybacks under one year.

3.2.1.1 Reduce Blowdown

Measurements of the boiler drum water indicated very low levels of TDS. On average, the level was found to be 175 ppm. The American Association of Boiler Manufacturers' recommended level of TDS for boilers similar in design and pressure to those at SLTC is 3000 ppm. Raising the TDS through reduction of blowdown will give energy savings as outlined in Appendix 15. To implement this measure successfully SLTC should purchase a TDS meter to monitor water conditions on a daily basis.

Energy Savings	= 6,107 GJ/Year
Cost Savings	= Rs 703,465/Year
Cost of Implementation	= Rs 5,000
Simple Payback	= 0.01 Years

3.2.1.2 Steam and Condensate Pipe Work Insulation

Insulation of bare steam and condensate pipework, flanges and valves throughout the plant will reduce radiation losses and boiler loading. Appendix 16 gives details of areas where insulation is missing. Implementation can be carried out using in-house labor.

Energy Savings	= 7890 GJ/Year
Cost Savings	= Rs 908,849/Year
Cost of Implementation	= Rs 850,000
Simple Payback	= 0.9 Years

3.2.1.3 Repair of Steam Leaks

Energy can be saved by a steam leak repair program throughout the distribution system. Appendix 17 shows the location of leaks. Implementation of the measure can be done using in-house labor.

Energy Savings	= 11196 GJ/Year
Cost Savings	= Rs 1,289,667/Year
Cost of Implementation	= Rs 200,000
Simple Payback	= 0.2 Years

3.2.1.4 Repair of Steam Traps

There are a number of steam traps that have failed and are passing steam. A program for steam trap maintenance including testing and repair will give reduced steam requirements. Appendix 18 gives the location of the faulty traps. Implementation can be done using in-house labor.

Energy Savings	= 1261 GJ/Year
Cost Savings	= Rs 145255/Year
Cost of Implementation	= Rs 60,000
Simple Payback	= 0.4 Years

3.2.1.5 Return Condensate to Boilerhouse

Condensate that is currently run to drain can be returned to the boiler and reduce energy consumption for steam generation. The implementation of this measure is easy to do and only entails some repiping. Appendix 19 gives details of the estimated savings.

Energy Savings	= 11526 GJ/Year
Cost Savings	= Rs 1,327,680/Year
Cost of Implementation	= Rs 25,000
Simple Payback	= 0.1 Years

3.2.1.6 Power Factor Correction

Overall plant power factor is 0.8 and can be raised to 0.95 by installing static capacitors, or by using the synchronous motors. Appendix 21 gives details of the potential savings.

Energy Savings	= 508 KVA
Cost Savings	= Rs 548,640/Year
Cost of Implementation	= Rs 325,200
Simple Payback	= 0.6 Years

3.2.1.7 Repair of Compressed Air Leaks

A compressed air system maintenance program will realize significant savings through repair of leaks from pipework fittings. Many of the leaks were found to consist of hoses that were used for comfort cooling by the employees. They should be made aware of the costs of compressed air wastage. Appendix 22 details the location of the leaks.

Energy Savings	= 1661 GJ
Cost Savings	= Rs 682854/Year
Cost of Implementation	= Rs 1000,000
Simple Payback	= 0.1 Years

3.2.1.8 Reduction in Reservoir Volume

The plant uses a reservoir of chilled water (250 cubic meter volume) to ensure on-time starting on Mondays. The capacity of the chilled water reservoir can be reduced without adverse effect on production start up on Monday mornings. Appendix 24 outlines savings.

Energy Savings	= 94 GJ
Cost Savings	= Rs 38644/Year
Cost of Implementation	= Rs 15,000
Simple Payback	= 0.4 Years

3.2.2 Measures with Simple Paybacks Over One Year

3.2.2.1 Use of Cooling Tower to Recirculate Condenser Water

The existing ammonia chilling plant has a once through condenser water system which consumes a lot of water. Condenser water can be recirculated to the Chiller Plant via a cooling tower rather than running the water to drain. Appendix 23 gives details. To implement this will require some engineering design for the exact type of cooling tower.

Energy Savings	= 348 GJ
Cost Savings	= Rs 143,216/Yr
Cost of Implementation	= Rs 420,000
Simple Payback	= 2.9 Years

3.3 Projects Requiring Further Study

3.3.1 Replacement of Existing Boiler Plant

The existing boilers have very low efficiencies due to poor combustion conditions, and state of repair. Significant energy savings could be made by replacement o' the plant. The work involved to determine the best option for the new plant is beyond the scope of this study. A feasibility study is being prepared examining the options available. It is estimated that energy savings will be significant enough to give a good rate of return on investment. The numbers shown in Appendix 26 indicate potential savings based on replacement with a plant using the same fuel.

Energy Savings	= 92,365 GJ/Year
Cost Savings	= Rs 10,639, 524/ Yr

3.3.2 Thermal Insulation of Boiler Plant

Energy can be saved by insulating the existing boilers to reduce their radiation losses. However this measure should be considered with respect to replacement of the existing plant before any decision is made to implement.

Energy Savings	= 2954 GJ
Cost Savings	= Rs 340271/Year
Cost of Implementation	= Rs 266913
Simple Payback	= 0.8 Yrs

3.3.3 Demand Savings Through Rescheduling Department Operating Schedules

Demand savings can be realized by rescheduling the operations in the extrusion and callendering department to three shift operations. Appendix 25 details proposed changes. Because this would involve changes in labor requirements it is recommended that this be studied further before the measure be implemented. The energy cost savings are presented to indicate potential if the measure can be implemented.

Energy Savings = 400 KVA
Cost Savings = Rs 432,000/Year

ITEM	ENERGY DATA				COST DATA					
	ENERGY SAVED GJ	COST SAVED Rs	% OF SAVINGS GJ	% OF SAVINGS Rs	DESIGN COSTS	SUPPLY COST	INSTALLATION COST	TOTAL COST	MAINTENANCE COST	USEFUL LIFE YRS
1. Reduce Blowdown	6107	703,465	4.5	4.0	-	5,000	-	5,000	-	25
2. Steam Pipe Insulation	7890	908,849	5.8	5.2	50,000	600,000	200,000	850,000	50,000	15
3. Steam Leaks	11196	1,289,667	8.2	7.4	-	100,000	100,000	200,000	50,000	15
4. Steam Traps	1261	145,255	0.9	0.8	-	54,00	6,000	60,000	20,000	10
5. Return Condensate	11526	1,327,680	8.5	7.6	-	15,000	10,000	25,000	20,000	15
6. Power Fact Con.	508KVA	548,640	-	3.1	32,500	219,525	73,175	325,200	10,000	20
7. Compressed Air Leak	1661	682,854	1.2	3.9	-	75,000	25,000	100,000	20,000	
8. Reservoir Vol. Red.	94	38,644	0.1	0.2	-	7,500	7,500	15,000	1,000	20
9. Insul. of Boiler	2954	340,271	2.2	2.0	16913	187,500	62,500	266,913	20,000	15
10. Replace Boilers	(92365)	(10,639,524)	67.9	60.9	NA	NA	NA	NA	NA	25
11. Reschedule Depts.	400KVA	432,000	-	2.5	NA	..NA	NA	NA	NA	NA
12. M G Set Replace	625	260,871	0.5	1.5	37,500	253,125	84,375	375,000	20,000	15
13. Chillers	348	143,216	0.3	0.8	42,000	30,000	78,000	420,000	20,000	20
Totals Excluding Boiler	43,672	6,821,412								
Totals Including Boiler	136,037	17,460,936	100.0	100.0	178,913	1,816,650	646,550	2,642,113*	231,000	

*Does Not Include Cost For Boiler Replacement

GJ = 10^9 x Joules

APPENDIX 2

SUMMARY OF SAVINGS BY FUEL TYPE

FUEL	ANNUAL SAVINGS		GJ SAVINGS*	COST SAVINGS Rs
Electricity	908	kVA	-	980,640
Electricity	663,889	kWh	2,390	982,369
1000 secs Fuel Oil	710,549	Gal.	133,299	15,354,711
Totals			135,689	17,317,720

CONVERSION TO GJ*

Electricity	-	0.0036 x kWh
1000 secs Fuel Oil	-	0.1876 x gallons

APPENDIX 3

INVENTORY OF MAJOR EQUIPMENT

COMPOUNDING DEPARTMENT

Item	HP	(kW)
Banbury Mixers (2)	each 770 HP	(574 kW)
Plasticising Mill (1)	215 HP	(160 kW)
Compounding Mill (2)	each 430 HP	(321 kW)
Festooner Mill (1)	215 HP	(160 kW)
Festooner Dryer	65 HP	(48 kW)
Strainer		(100 kW)

EXTRUSION DEPARTMENT

Mills (3)	each 470 HP	(351 kW)
Mills (2)	each 430 HP	(321 kW)
Motor Generator		(160 kW)

CALENDERING DEPARTMENT

Calender Drive (DC)	250 kW
Dryer (Main)	19 kW
Dryer (Intermediate)	11 kW
Squeegee Calender (DC M.G.)	100 kW

TUBE MAKING	kW
Motor Generator	160 kW
Strainer	100 kW
Mills (2)	125 kW
Mill	165 kW

TYRE BUILDING

Motor Generator	75 kW
Motor Generator	32 kW

BOILER PLANT

3 Boilers, each 6.5 tonnes/hour steam at 16 bar

CHILLED WATER PLANT

5 Compressors	each 100 kW
Chilled Water Pump	35 kW
Condenser Water Pump	46 kW

COMPRESSED AIR PLANT

3 Compressors	each 180 kW

APPENDIX 4

BOILER DETAILS

LOCATION: Boiler House

Boiler	1	2	3
Manufacturer:	Not known	Not known	Not known
Age (years):	20	20	20
Type:	Water Tube	Water Tube	Water Tube
Rating (T/hr):	6.5	6.5	6.5
Medium raised:	Steam	Steam	Steam
Normal operating pressure (bar):	16	16	16

Burners			
Number:	2	2	2
Fuel fired:	Fuel oil	Fuel oil	Fuel oil
Manufacturer:	Not known	Not known	Not known
Age (years):	20	20	20
Type:	Pressure Jet	Pressure Jet	Pressure Jet
Draft:	Induced	Induced	Induced
Atomization:	Steam	Steam	Steam
Burner controls:	Manual	Manual	Manual
Draft control (dampers):	Manual	Manual	Manual

APPENDIX 5

BOILER COMBUSTION TESTS

Boiler No: 1 of 3

Date of Test: 3/12/84

Test Results

Fuel Fired: 1000 secs Fuel Oil

Item	Unit	Measurement
Firing Rate		Medium
CO_2 in Flue Gases	%	9.9
O_2 in Flue Gas	%	9.8
Flue Gas Temperature Before Econ	°C	291
Flue Gas Temperature After Econ	°C	181
Ambient Air Temperature	°C	39
Smoke Number		7.5
Feedwater into Econ	°C	75
Feedwater out of Econ	°C	87.5

Measurement	Instrument
% CO_2 in Flue Gases	Fyrite
% O_2 in Flue Gases	Fyrite
Flue Gas Temperature Before/After Eron	Electronic Thermometer
Ambient Air Temperature	Mercury in Glass Thermometer
Smoke Number	Truespot Smoke Pump
Feed Water Temp Before/After Econ	Electronic Thermometer

APPENDIX 5 (Cont'd)

BOILER COMBUSTION TESTS

Boiler No: 3 of 3

Date of Test: 3/9/84

Test Results

Fuel Fired: 1000 seconds fuel

Item	Unit	Measurement
Firing Rate		High
CO_2 in Flue Gases	%	10.5
O_2 in Flue Gases	%	4.8
Flue Gas Temperature Before Econ	°C	300
Flue Gas Temp After Econ	°C	185
Ambient Air Temperature	°C	38
Smoke Number		9

Measurements/Readings From:

Measurement	Instrument
% CO_2 in Flue Gases	Fyrite
% O_2 in Flue Gases	Fyrite
Ambient Air Temp	Mercury in Glass Thermometer
Smoke Number	Truespot Smoke Pump
Flue Gas Temperature Before/After Econ	Electronic Themometer
Feedwater Temperature Before/After Econ	Electronic Themometer

APPENDIX 6

BOILER EFFICIENCY TESTS

Date: March 17, 1984

Boilers 1 and 3 firing

Fuel Type: 1000 seconds Fuel Oil

Boiler Number	Burner Location	Pressure Bar	Equivalent Oil Flow liter per minute
1	Left	0.6	3.9
1	Right	0.3	2.75
3	Left	0.3	2.75
3	Right	0.5	3.55

Nozzle Sizes = 3 mm diameter

Steam Pressure

Boiler 1	=	14	bar
Boiler 3	=	14.7	bar
Average	=	14.35	bar

Feedwater Flowrate = 8440 kg per hour

Instrumentation - Pressure gauge
Ultrasonic flow meter

APPENDIX 7

CALENDERING TESTS

Chamber Temperatures

Location	Readings 1	2	3	
Side walls °C =	39	36.2	39.2	
	40	38.7	43.5	
	47.8	38.1	39.2	
Top °C =	46	49.2	47.8	49.2

Steam Temperature in = 90°C
Condensate Out = 81°C
Fabric Temperature In = 34°C
Fabric Temperature Out = 88°C
Exhaust Temperature = 100°C
Humidity Inside Dryer = 100°C

Moisture Content of Fabric In = 0.92%
Moisture Content of Fabric Out = 0.46%
Fabri Specification Moisture Content = 2.5% before
Fabric Specification Moisture Content = 1.0% after

APPENDIX 8

CHILLER TESTS

Condenser Number 1

	Measurement	Instrument Reading
Inlet Water	29.7°C	-
Outlet Water	33.7°C	34
NH_3	80.6°C	-
NH_3	32.9°C	-

Chilled Water Heat Exchanger - 1

Inlet	22.3	20.5
Outlet	18.4	16.0

Chilled Water Heat Exchanger - 2

Inlet	22.4	-
Outlet	18.2	15

Return Water to Reservoir = 17.6°C

Condener Water Outlet = 32.4°C

Condenser Water Flow Rate = 672 gpm

APPENDIX 9

ELECTRICAL MEASUREMENTS

Location	Nameplate Data HP/kW	V	A	Measured Data V	A	PF
Plasticate Mill	215	400	275	386	187	0.85
Festooner	215	400	275	-	-	-
Strainer						
10 Worm Drive	100kW	400	189	380	-	0.75
MG Set Drive Motor	75kW	400	130	-	-	-
2 x 60" Mill Main Drive	125kW	400	225	386	186	0.87
MG Set Motor	160kW	400	279		85	-
MG Set CC6 Motor	160kW	400	279	388	107	0.58
Chiller Comp. 1	100kW	400	186	386	128	0.87
Chiller Comp. 2	100kW	400	186	385	127	0.83
Chiller Comp. 3	100kW	400	186	382	131	0.82
Chiller Comp. 4 & 5	100kW	400	186	-	-	-
Chiller Condensor						
Pump 1	40kW	400	71	388	81	0.87
Pump 2 & 3	40kW	400	71	-	-	-
Chiller Evaporator						
Pump 1	40kW	400	71	388	63	0.95
Pump 2	40kW	400	71	393	52	0.90
Pump 3	40kW	400	71	-	-	-
S.H.W. Feed-Water						
Pump 1	27kW	400	46	-	40	-
Pump 2	27kW	400	46	-	-	-
Calender Warming						
Mill 1 x 84"	165kW	400		-	-	-

APPENDIX 10

BOILER WATER TESTS AND ESTIMATE OF BLOWDOWN

Assumptions

A constant T.D.S. is maintained in the boiler.

Data

Boiler Feedwater TDS	=	25	=	B
Make Up Water TDS	=	25		
Boiler Drumwater TDS	=	175	=	A
Percentage Make Up	=	100%	=	M

Calculation*

$$\text{Percent Blowdown} = \frac{(B \times M)}{(A - B)}$$

$$= \frac{25 \times 100}{175 - 25}$$

$$= 16.7\%$$

*Calculation technique similar to Exhibit 5.20, Energy Audit Manual

APPENDIX 11

BOILER SURFACE TEMPERATURE MEASUREMENTS

Boiler Number 1

Location	Measurement 1	Measurement 2	Measurement 3
Side Walls °C =	102	104	95
	107	110	92
	93	106	97
Rear °C =	103	102	110
	94	96	98
Front °C =	97	99	100

Boiler Number 3

Location	Measurement 1	Measurement 2	Measurement 3
Side Walls °C =	115	107	95
	92	99	102
	97	101	102
Rear °C =	104	100	93
	96	95	95
Front °C =	102	101	102

APPENDIX 12

ESTIMATE OF BOILER RADIATION LOSS

Radiation losses from the boiler can be estimated using the data from Appendix 14.

Boiler Surface Temperature	=	100°C
Surface Area of Sidewalls	=	16.5 m^2 x 2
Surface Area of Front and Back	=	13.1 m^2 x 2
Surface Area of Top	=	7.9 m^2 x 2
Heat Transfer Coefficients Front, Back and Sidewalls	=	12.79
Heat Transfer Coefficients, Top	=	14.8
Ambient Air Temperature °C	=	40
Conversion of kWh to Joules	=	0.0036
Operating Hours	=	6912
Heat Losses	=	h x a x dt
Total Loss Per Year	=	$\frac{(65,946)}{(1000)}$ x 6912 x 0.0036
for 1 boiler	=	1641 GJ
Boiler Input	=	229,296 GJ
% Radiation Loss for Plant	=	$\frac{1641}{229,296}$ x 100 x 2
	=	1.4%

APPENDIX 13

BOILER EFFICIENCY CALCULATION

The following efficiency calculation is based upon measured values of oil flow through nozzles and water flow into the boilers. Metering of individual boilers was not possible and so the efficiency developed is based on total flow rates.

Data

Boiler Number One Operating Pressure	=	14 bar
Boiler Number Two Operating pressure	=	14.7 bar
Metered Water Flow Rate	=	8440 kg/hour
Feed water Temperature	=	88°C
Boiler Number One Oil Pressure left burner	=	0.6
Boiler Number One Oil Pressure right burner	=	0.3
Boiler Number Three Oil Pressure left burner	=	0.3
Boiler Number Three Oil Pressure right burner	=	0.5
Nozzle Sizes	=	3 mm
Flow Rate at 0.6 bar thro 3mm Nozzle	=	3.90 liters per min.
Flow Rate at 0.3 bar thro 3mm Nozzle	=	2.75 liters per min.
Flow Rate at 0.3 bar thro 3mm Nozzle	=	2.75 liters per min.
Flow rate at 0.5 bar thro 3mm Nozzle	=	3.55 liters per min.
Total Flow		12.95 liters per min.

Calorific Value of 1000secs Oil	=	43075.2 kJ/kg
Specific Gravity	=	0.96
Enthalpy of Steam at 14.35 bar	=	2790.7 kJ/kg
Enthalpy of Water at 88°C	=	369 kJ/kg
Blowdown Rate (see Appendix 10)	=	0.167 kg/kg
Dryness fraction assumed	=	0.98

APPENDIX 13 (Cont'd)

Calculation

Boiler Efficiency = $\frac{\text{(Heat Content of Steam + Water leaving) - Heat Content of Water Entering}}{\text{(Heat Content of Fuel In)}}$

Heat Content of Steam Out = (Dryness Fraction x Enthalpy of Steam at Boiler Pressure) (Mass of Steam)

Heat Content of Water Leaving Boiler = (1-dryness Fraction)x(Enthalpy of Water at Boiler Pressure)x(Mass of Steam)+(Enthalpy of Water at Boiler Pressure)x(Mass of water in blowdown)

Heat Content of Water Into Boiler = (Mass of Steam + Mass of Blowdown) (Enthalpy at Feedwater Temp)

Heat Content of Fuel In = (Calorific value) x (mass of fuel used)

Heat Content of Steam = (0.98) (2,790.7) (7,030.52) kJ/hr
= 19,227,671 kJ/hr

Heat Content of Water Out = (0.02)(835)(7030.52)+(835)(0.167) (8,440)
= (117,410) + (1,176,916)
= 1,294,326 kJ/hr

Heat Content of Water Into Boiler = (8,440) (369)
3,114,360 kJ/hr

Heat Content of Fuel In = (43,075.2) (12.95) (60) (0.96)
= 32,130,653 kJ

APPENDIX 13, Cont'd

Boiler Efficiency $= \frac{((19,227,671 + 1,294,326) - (3,114,360))\ 100}{(32,130,653)}$

$= 54.1\%$

APPENDIX 14

INSTALLING THERMAL INSULATION ON BOILER AND ANCILLARY PLANT

Assumptions

Reduction in heat losses by insulation: 90 percent

Data

Boiler operating hours: 6912/yr
Boiler ancillaries operating hours: 6912/yr
Boiler efficiency: 54.1 %

Plant/ equipment	Shape/ Position	h	Area (m2)	dT (°C)	Heat Loss (Watts)	Insulation Proposed	Estimated cost
Boiler:							
1, 2,	Side wall	12.79	16.5	60	12662	40 mm cal	
and 3	Side wall	12.79	16.5	60	12662	Silicate	3275 Rs/m^2
	Lower top	14.8	7.9	60	7015	and 15 mm	
	Lower top	14.8	7.9	60	7015	cement	
	Top	16.63	6.5	60	6486	finish	
	Front	12.79	13.1	60	10053		
	Back	12.79	13.1	60	10053		
			TOTAL		65946	TOTAL	266,913

APPENDIX 14 (Cont'd)

Energy Savings

Boiler	=	Heat loss/hr x 0.9 x plant operating time / 10^6
	=	(65946 x 3.6) (0.9) (6912) / 10^6
	=	1477 GJ x 2 boilers
	=	2954 GJ

Total energy savings = (1477) + (1477)
= 2954 GJ

Cost savings

= (2954) (115.19)
= Rs. 340,271/yr

Cost of Implementation

The total cost of insulating is estimated to be Rs. 266,913.

Simple Payback = $\frac{266,913}{340,271}$
= 0.8 years

Energy savings	= 2954 GJ/Year
Cost savings	= Rs. 340,271/Yr
Cost of Implementation	= Rs 266,913
Simple Payback	= 0.8 Years

APPENDIX 15

REDUCING BLOWDOWN

Blowdown is often used excessively to control the level of total dissolved solids (TDS) in a boiler. Dissolved solids can be deposited as scale on the heat transfer surfaces in a boiler. A compromise between energy waste owing to blowdown and owing to scaling is reached by maintaining blowdown levels up to 3.000 parts per million for most industrial boilers.

Calculation*

Assumptions

Maximum acceptable TDS level	=	3,500 ppm
Estimated mean TDS level	=	3,500 ppm

Data

Boiler efficiency	=	54.1	percent	(See Appendix 13)
Percent makeup water	=	100	percent	
Makeup TDS	=	25	ppm)	
Blowdown TDS	=	175	ppm)	from treatment company reports
Energy input to boilers	=	229296	GJ/year	
Feedwater temperature	=	88	°C	
Boiler pressure	=	16	bar	
Heat content in city water	=	126	kJ/kg	
Heat content of 98% Steam 16 bar	=	2738	kJ/kg	
Heat content of Feedwater	=	369	kJ/kg	

*Calculation technique similar to Exhibit 5.11, Energy Audit Manual

APPENDIX 15 (Cont'd)

Present blowdown rate $= \frac{\text{(Percent Makeup x Makeup TDS)}}{\text{(100 x Blowdown TDS)}}$

$= \frac{(100 \times 25)}{100 \times 175}$

= 0.167 kg/kg of steam produced

Heat required to raise kg of steam = hg @ boiler pressure -hw of feedwater

= 2738 - 369

= 2369 kJ/kg

Steam produced/year $= \frac{\text{(Energy input to boilers x average boiler efficiency}}{\text{Heat Required to Raise kg of Steam}}$

$= \frac{(229296 \times 0.541)}{(2369)\ (10^6)}$

= 52.4 kg x 10^6 kg/year

Reducing Blowdown

Blowdown per year = blowdown rate x steam produced/year

= $(0.167)(52.4 \times 10^6)$

= 8.74 kg x 10^6 /year

Heat content in blowdown = Sensible heat in blowdown-sensible heat of city water

= 859 - 126

= 733 kJ/kg

Percent blowdown loss $= \frac{\text{(Blowdown/Yr x Net Heat Content of Blowdown x 100)}}{\text{Energy Input to Boilers}}$

$= \frac{(8.74 \times 106 \times 733 \times 100)}{229{,}296 \times 10^6}$

= 2.8 percent

Blowdown rate @ 3,000 $= \frac{\text{(Percent of Makeup x Makeup TDS)}}{\text{100 x (3,000 - makeup TDS)}}$

$= \frac{(100 \times 25)}{(100)\ (3{,}000 - 25)}$

= 0.008 kg/kg of steam produced

APPENDIX 15 (Cont'd)

Energy Savings

= (Existing - new blowdown rate) x (steam produced/year)x(heat content in blowdown)

= $(0.167 - 0.008) + (52.4 \times 10^6)(733)$

= 6107 GJ/year

Cost Savings

= (GJ/year) (Rs./GJ)

= (6107) (115.19)

= Rs.703465/yr

Implementation Costs

To provide an instrument to monitor the TDS level of the boilers on a regular basis should cost approximately Rx 5000.

Energy savings	= 6107 GJ/year
Cost savings	= Rs703,465/year
Cost of Implementation	= Rs 5,000
Simple Payback	= 0.01 years

APPENDIX 16

PIPEWORK INSULATION

Assumptions

Heat Loss Reduction by Insulation =90%

Pipework Fittings Equivalent Length =0.4M

Data

Boiler Plant Operating Hours =6912hrs/yr

Boiler Efficiency =54.1%

Missing insulation is detailed in data sheets following the calculation.

Calculation

Energy Savings

$$= \frac{(\text{Wasted Heat Loss}) \times (\text{Operating hrs}) \times (0.9)}{\text{Boiler Eff.} \times 10^6}$$

$$= \frac{(190601 \times 3.6)(6912)(0.9)}{0.541 \times 10^6}$$

= 7890 GJ/year

Cost Savings

= (GJ/yr)(Rs/GJ)

= (7890)(115.19)

= 908,849 Rs/year

Cost of Implementation

This is estimated to be 850,000Rs installed for the insulation required.

Simple Payback

$$= \frac{850,000}{908,849}$$

= 0.9 years

ENERGY SAVINGS	= 7890 GJ/yr
COST SAVINGS	= Rs908,849/year
COST OF IMPLEMENTATION	= Rs850,000
SIMPLE PAYBACK	= 0.9 years

APPENDIX 16 (Cont'd)

DATA SHEET

Location	Pipe Dia OD mm	Length of Bare Pipe M	Heat Loss W/M	Total Loss W	PipeTemp °C	Hours of Operation
Boiler House						
Boiler 1						
Membrane Valve	80	0.3	880	264	175	6912
Safety Valve	80	0.3	880	264	175	6912
Boiler 3						
Membrane Valve	80	0.3	880	264	175	6912
Safety Valve	80	0.3	880	264	175	6912
Main Header	150	0.4	1450	580	175	6912
Flange on 8 Bay Header	100	0.4	1000	400	175	6912
PRV - 16 bar	100	0.4	1000	400	175	6912
Relief Valve (16 bar)	50	0.4	625	250	175	6912
Gate Valve 8 bay	150	0.4	1450	580	175	6912
2 Valves-16 bar	50	0.8	625	500	175	6912
By Pass Valve 16 bar	80	0.4	880	352	175	6912
Pipe to Deareator 2.75 bar	80	7.0	880	6160	175	6912
Soot Blower 16 bar	80	4.0	880	3520	175	6912

APPENDIX 16 (Cont'd)

DATA SHEET

Location	Pipe Dia OD mm	Length of Bare Pipe M	Heat Loss W/M	Total Loss W	PipeTemp °C	Hours of Operation
Heat Exchanger Room						
Trench	150	2.00	1100	2200	175	6912
Valves	80	0.75	660	495	150	6912
Calender Line	80	0.3	660	.198	150	6912
Header-8 bar	80	3.00	660	1980	150	6912
Hot water tank line	50	10.00	475	4750	150	6912
3 Bar Line at header	80	3.00	660	1980	150	6912
Distilled Water line	25	20.00	275	5500	150	6912
By Pass line	80	0.5	660	330	150	6912
Deaereator line	80	12.00	660	7920	150	6912
CALENDER						
Main Supply	80	7.00	660	4620	150	6912
Dryer dist.	40	30.00	375	11250	150	6912
Tyre Vulcanization						
Headers	50	10.00	475	4750	150	6912
Distribution Lines (total)	20	300.00	225	67500	150	6912
Tube Vulcanization						
Distribution Lines (total)	20	10.00	225	2250	150	6912
Header	50	5.00	475	2375	150	6912

APPENDIX 16, Cont'd

DATA SHEET

Location	Pipe Dia OD mm	Length of Bare Pipe M	Heat Loss W/M	Total Loss W	PipeTemp °C	Hours of Operation
Tread Extruder						
3 Bar Line	25	2.00	275	550	150	6912
3.5 Bar Line to the Canteen	50	120.00	475	57000	150	6912
Flap Extruder	25	3.00	275	825	150	6912
Tube Extruder	80	0.5	660	330	125	6912

APPENDIX 17

REPAIR OF STEAM LEAKS

Assumptions

All losses will be saved when leaks are fixed.

Leakage Rate in kg/hr = 0.4 (d2) (p+1)

where d = mm, p = bar

Data

For leaks see attached data sheets

Net Heat Content at 16 bar	=2670 kJ/kg
8 bar	=2648 kJ/kg
2.5 bar	=2591
2.0 bar	=2581
0.5 bar	=2519
Boiler Efficiency	=54.1
Steam System Operating hrs.	=6912 except 2.5 bar and 0.5 bar=2308 hours
Load Factor	=0.8

Calculation

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

16 bar $= \frac{(309.4)\ (6912)\ (2670)\ (0.8)}{(0.541)\ (10^6)}$

= 8444 GJ

8 bar $= \frac{(96.3)(6912)(2648)(0.8)}{(0.541)\ (10^6)}$

=2606 GJ

2.5 bar $= \frac{(12.6)(2304)(2591)(0.8)}{(0.541)\ (10^6)}$

=109 GJ

2.0 bar $= \frac{(1.2)(6912)(2581)(0.8)}{(0.541)\ (10^6)}$

$= 32$ GJ

0.5 bar $= \frac{(0.6)(2304)(2519)(0.8)}{(0.541)\ (10^6)}$

$= 5$ GJ

Cost Savings

=(GJ)(Rs/GJ)

=(11196)(115.19)

=1,289,667 Rs/year

Cost of Implementation

The cost of repairs to the steam distribution system are estimated to be 200,000 Rs. The majority of the leaks can be fixed using in house labor.

Simple Payback

$= \frac{200,000}{1,289,667}$

= 0.2 years

Energy Savings	= 11196 GJ
Cost Savings	= Rs1,289,667/year
Cost of Implementation	= Rs200,000
Simple Payback	= 0.2 years

APPENDIX 17 (Cont'd)

DATA SHEET

Location	Pressure bar	Size of Leak mm	Loss kg/hr
Safety Relief Boiler #3	16	1	6.8
Flow Measuring Orifice	16	0.5	1.7
8bar PRV	8	0.5	0.9
Main Valve	16	1	6.8
Air Vent	16	0.5	1.7
Steam Pump	16	1	not working
Economizers (3)	16	1	20.4
Valves (5)	16	1	34.0
Steam Header	16	1	6.8
Oil Preheater	16	1	6.8
3.5 bar PRV	8	1	3.6
Main Feed to PV	16	1	6.8
Regulator Valve	16	1	6.8
Water for Batteries	8	1	3.6
Instrumentation	8	1	3.6
S.D Duct	16	1	6.8
Tunnel (Header)			
Flash Vessel	2	1	1.2
Vulcaniser 1	16	1	6.8
2	16	1	6.8
	16	1	6.8
3	8	1	3.6
	16	1	6.8
4	8	0.5	0.9
5	16	1	6.8
6	8	1	3.6
	16	1	6.8
7	8 bar	1	3.6
	16 bar	1	6.8
8	16 bar	1	6.8
9	16 bar	1	6.8
10	16 bar	1	6.8
11	8	1	3.6
12	16	1	6.8
13	16	1	6.8
14	8	2	14.4
	16	2	27.2

APPENDIX 17 (Cont'd)

Location	Pressure bar	Size of Leak mm	Loss kg/hr
15	8	1	3.6
16	8	1	3.6
	16	1	6.8
17	8	1	3.6
18	8	2	14.4
	16	1	6.8
19	8	1	3.6
20	-	-	-
21	8	1	3.6
	16	1	6.8
22	16	1	6.8
23	16	1	6.8
24	16	1	6.8
25	8	0.5	0.9
26	8	1	3.6
	16	1	6.8
27	8	1	3.6
	16	1	6.8
28	8	1	3.6
	16	1	6.8
Bag'O'matics 1			
BOM 1	16	1	6.8
BOM 2	16	1	6.8
	8	1	3.6
BOM 3	16	1	6.8
	16	1	6.8
BOM 4	16	1	6.8
Pre Cal Drier	2.5	1 (6 points)	8.4
Steam traps	2.5	1	1.4
Calender valve	2.5	1	1.4
Condenser	0.5	0.5 (3 points)	0.6
Cal rollers	2.5	1 (6 points)	1.4
rubber mat valve	8	1	3.6
pipe	8	1	3.6

Total Leakage at 16 bar = 309.4 kg/hour
8 bar = 96.3 kg/hour
2.5 bar = 12.6 kg/hour
2.0 bar = 1.2 kg/hour
0.5 bar = 0.6 kg/hour

APPENDIX 18

REPAIR OF STEAM TRAPS

Assumptions

Average Leakage Per Failed Trap = 2.5 kg/hr

Data

Steam system operating hours	= 6912/year except 1.8 bar steam
1.8 bar Steam operating hours	= 2304 hrs/yr
Number of Failed Traps	= see Data Sheet following calculation
Boiler Efficiency	= 54.1 %
Net Heat Content of Steam at:	
16 bar	= 2670 kJ/kg
8 bar	= 2648 kJ/kg
2.7 bar	= 2610 kJ/kg
1.8 bar	= 2597 kJ/kg
Load Factors:	
16, 2.7 bar	= 1
8 bar, 1.8 bar	= 0.8

Calculation

Energy Savings

$$= \frac{(\text{Number of Failed Traps})(\text{Leakage})(\text{Hours})(\text{Heat Content})(\text{Load Factor})}{(\text{Boiler Efficiency})\ (10^6)}$$

16 bar

$$= \frac{(2)(2.5)(6912)(2670)(1)}{(0.541)\ (10^6)}$$

$$= 171 \text{ GJ}$$

APPENDIX 18 (Cont'd)

8 bar

$$= \frac{(9)(2.5)(6912)(2648)(0.8)}{(0.541)(10^6)}$$

= 609 GJ

2.7 bar

$$= \frac{(1)(2.5)(6912)(2610)(1)}{(0.541)(10^6)}$$

= 83 GJ

1.8 bar

$$= \frac{(18)(2.5)(2304)(2597)(0.8)}{(0.541)(10^6)}$$

= 398 GJ

Total Savings

= (171) + (609) + (83) + (398)

= 1261 GJ

Cost Savings

= (GJ) (Rs/GJ)

= (1261) (115.19)

= 145,255 Rs/year

Cost of Implementation

The cost of replacement steam traps is estimated to be 2000 Rs per trap installed giving a total implementation cost of Rs 60,000.

Simple Payback

$$= \frac{60,000}{145,255}$$

=0.4 years

Energy Savings	= 1261 GJ
Cost Savings	= 145,255 Rs/Year
Cost of Implementation	= 60,000 Rs
Simple Payback	= 0.4 years

APPENDIX 18 (Cont'd)

DATA SHEET

Location	Steam Pressure Bar	Load Factor	Operating Hours
Boiler Room			
1	16	1	6912
Main Header - 1	16	1	6912
Vulcanizers			
9	8	0.8	6912
Calender			
18	1.8	0.8	2304
Power Room Flash Vessel - 1	2.7	1	6912

APPENDIX 19

RETURN CONDENSATE TO BOILER HOUSE

Condensate from the Vulcanization processes, calendering and superheated hot water system is currently collected in condensate receivers and then run to drain. A condensate return pipework system is installed and in a good state of repair. Condensate should be returned to the boiler.

Assumptions

Condensate Temperature = 80°C
MakeUp Water Temperature = 30°C
Feedwater Temperature = 88°C
75% of Condensate can be returned.

Data

From other appendices as indicated

Steam Production

$$= \frac{(229{,}296)(0.541)(10^6)}{((.98)(2791)+(835 \times 0.02)-369)}$$

= 52,058,490 kg/year
= 126,086 GJ/year

Losses due to leaks =2,274,324 kg/year
Appendix 17 = 11196 x 0.541 = 6057 GJ

Loss due to Failed Traps = 0 kg/yr
Appendix 18 = 1261 x 0.541 = 682 GJ
Loss due to Insulation = 0 kg/year
Appendix 16 = 7890 x 0.541 = 4268 GJ

Loss due to Condensate
- balance of mass = 49,784,166 kg/year
assume 70°C = $(293-126)(10^{-6})(49{,}784{,}166)$
= 8314 GJ

75% of Condensate can be returned to the boiler

APPENDIX 19 (Cont'd)

Energy Savings

$$= 0.75 \frac{(8314)}{(0.541)}$$

= 11,526 GJ

Cost Savings

= (GJ) (Rs/GJ)
= (11526)(115.19)
= 1,327,680 Rs/year

Cost of Implementation

Very little is required to reconnect the condensate return system to the condensate recovery tanks in the power room. The estimated cost is 25,000 Rs for new fittings, piping and insulation.

Simple Payback

$$= \frac{25,000}{1,327,680}$$

= 0.1 year

Energy Savings	= 11,526 GJ
Cost Savings	= 1,327,680 Rs/Yr
Cost of Implementation	= 25,000 Rs
Simple Payback	= 0.1 years

APPENDIX 20

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

Efficiency of M G Sets	= 0.6 - site date indicated efficiency of 0.39 for sample measured
Efficiency of Thyristor	= 0.85

Data

Operating Hours	= 2304 for Extrusion and Calendering
	6912 for main plant
Load Factors	= 0.8
Ratings - extrusion mg	= 160kW
Squeegee calender mg	= 100kW
Tube of dept mg	= 160kW
Tyre Building	= 75 kW
	32 kW

Calculation

Useful work produced by extrusion mg	= 0.6 x 160 x 2304 x 0.8
	= 176,947 kWh
Using Thyristor @ 0.85 efficiency	= 176,947 x 0.85 = 150,405
Savings	= 176,947 - 150,405
	= 26542 kWh x 0.0036
	= 96 GJ
Cost Savings	= (GJ)(Rs/GJ)
	= 39,282 Rs/year

APPENDIX 20 (Cont'd)

Similar Savings can be made on the mg sets in the calendering, tube and tyre building departments to give energy savings as follows:

	GJ	Rs
Extrusion	96	39,282
Calendering	60	24,667
Tube	287	117,989
Tyre Building	192	78,933
Totals	635	260,871

Cost of Implementation

The costs for thyristor drives is estimated to be 75,000 Rs installed, giving a total cost of 375,000 to implement this measure.

Simple Payback

$$= \frac{375,000}{260,871}$$

$$= 1.4 \text{ years}$$

Energy Savings	= 634 GJ
Cost Savings	= Rs260,871/Yr
Cost of Implementation	= Rs375,000
Simple Payback	= 1.4 years

APPENDIX 21

POWER FACTOR CORRECTION

The power factor for the plant was measured at 0.8. This can be raised by installing capacitors to bring savings based upon reduced demand charges.

Data

Measured Power Factor	= 0.8
Proposed Power Factor	= 0.95
Average Demand	= 3217 kVa
Current Demand Charge	= 90 Rs per kVa

Calculation

Power Factor $= \frac{kW}{kVA}$

kW = kVA x Power Factor

Existing kW = 3217 x 0.8

kW = 2574

If P. F. raised to 0.95, can estimate new kVA based upon existing kW

New kVA $= \frac{kW}{\text{Power Factor}}$

$= \frac{2574}{0.95}$

= 2709 kVA

kVA Savings = 3217 - 2709

= 508 kVA

Cost Savings

= (kVA saved) (Rs/kVA) (months/year)

= (508) (90) (12)

= 548640 Rs/year

APPENDIX 21 (Cont'd)

Cost of Implementation

Capacitors can be purchased at an installed cost of 300 Rs per kVAr. A total of 1084 kVAr are required to raise the power factor to 0.95 giving an implementation cost of 325,200

Simple Payback

$$= \frac{325,200}{548,640}$$

$= 0.6$ years

Energy Savings	= 508 GJ
Cost Savings	= Rs548,640/Yr
Cost of Implementation	= Rs325,200
Simple Payback	= 0.6 years

APPENDIX 22

Assumptions

Flow Rate in M^3/min	= (0.0094)(d^2)(p+1)
where d	= mm
p	= bar

Data

Compressor Operating Hours	= 6912 hours
Load Factor	= 0.80
Compressor Rating	= 20 m^3/min @ 7.5 bar x 3
Compressor kW	= 180 x 3 (rated) 142 kW (measured)
$1m^3$/m	= 4.73 kW
Leakage	= 17.642 m^3/min (see data sheets) for locations

Energy Savings

= (Loss in m^3/m)(Hours Operation)(kw/m^3/min)(Load Factor)

= (17.642)(6912)(4.73)(0.8)

= 461426.65 kWh/year x 0.0036

= 1661 GJ/year

Cost Savings

= (GJ/yr)(Rs/GJ)

(1661)(411.11)

= 682854 Rs/year

Cost of Implementation

The cost to fix all compressed air leaks is estimated to be 100,000 Rs, for some fittings.

APPENDIX 22 (Cont'd)

Simple Payback

$$= \frac{100,000}{682,854}$$

= 0.1 year

Energy Savings	= 1661GJ
Cost Savings	= Rs682,854/Yr
Cost of Implementation	= Rs100,000
Simple Payback	= 0.1 years

APPENDIX 22 (Cont'd)

COMPRESSED AIR LEAKS - TYRE PLANT

DATA SHEETS

Location	Size of Leak (mm)	Pressure Bar	Loss M^3/Min kW
1) Maintenance Work Shop	0.2	7	0.003
2) Boiler room	0.3	7	0.007
3) Workshop A	0.2	7	0.003
4) Tyre Repair Shop	0.2	7	0.003
5) Curing Bag Shop	0.2	7	0.003
6) Curing Bag			
Joining M/C	0.7	7	0.037
7) Tube Shop	0.2	7	0.003
8) Quality Control	0.2	7	0.003
9) Curing Bag	2.0	7	0.3
Removing M/C			
1100-28			
750-16			
10) Type Vulcanizing			
4-6-2	2.0	7	0.3
4-5-4	0.7	7	0.37
4-4-3	2.0	7	0.3
11) Bag'O'matic			
7	0.2	7	0.003
6	0.2	7	0.003
3	2.0	7	0.3
5	2.0	7	0.3

APPENDIX 22 (Cont'd)

COMPRESSED AIR LEAKS - TYRE PLANT

DATA SHEETS

Location	Size of Leak (mm)	Pressure Bar	Loss M^3/Min kW
12) Tube Forming			
1	1.0	7 bar	0.075
6	1.0	7 bar	0.075
8	1.0	7 bar	0.075
10	1.0	7 bar	0.075
13) Tube Forming			
Press 4-H	2.0	7 bar	0.3
14) Power Unit	8.0	7 bar	4.81
15) Type Building M/C	2.0	7 bar	0.003
9-1	0.2	7 bar	0.003
A	0.2	7 bar	0.003
C	0.2	7 bar	0.003
3-11-1	0.2	7 bar	0.003
3-11-3	0.7	7 bar	0.037
3-12-4	0.2	7 bar	0.003
3-11-3	2.0	7 bar	0.3
3-12-3	0.2	7 bar	0.003
3-12-2	0.2	7 bar	0.003
16) Bead Making M/C	2.0	7 bar	0.3
17) Tube Joining M/C	0.2 + 0.2	7 bar	0.003
18) tube Extruder	8.0	7 bar	4.81
19) Squeegee M/C	8.0	7 bar	4.81
20) Calender Drier	0.2	7 bar	0.003
21) Banburning Mixer	2.0	7 bar	0.3
22) Plasticating Mixer	0.7	7 bar	0.037
23) Valve Rubberizing			
M/C	0.2	7 bar	0.003

APPENDIX 23

USE OF COOLING TOWER VERUS RUNNING WATER TO DRAIN

Assumptions

Cooling Tower Pump Efficiency	= 80%
Cooling Tower Height	= 30 Feet
Pumping Head Loss	= 10%
Make Up Water	= 20%

Data

Conderser Water to Drain	= 672 gpm
Water Treatment Plant Pump	= 90 hp; 1500 gpm
Average Water from WTP	= 38×10^6 monthly; 1016 gal. per minute
River Water Pumps	= 2 x 25 hp
Tank Water Pumps	= 55 kW (1172 gpm)

Calculation

Energy Required to Pump Water from

River to Tank $= \dfrac{(\text{Volume of Condensor Water}) \times (\text{Load Factor}) \times \text{Pump Rating})}{(\text{Capacity of River Water Pump})}$

Load Factor $= \dfrac{1016}{1500} = 0.68$

$$= \frac{(672) \times (0.68) \times (140 \times 0.746)}{(1500)}$$

$= 32$ kW

APPENDIX 23 (Cont'd)

Energy Required to Pump Return Water From Tower To Condenser Inlet

Pressure assuming 30 ft tower + 10% loss = 33 ft of water

1 ft of water = 0.4339 psig

33 ft = 0.4339 x 33

= 14 psig

Liquid Horsepower Required $= \frac{(\text{gal/min})\ (\text{pressure})}{(1430)}$

$= \frac{(672)\ (14)}{(1430)}$

= 6.57 hp

Pump Horsepower $= \frac{6.57 \times 0.746}{0.8}$

= 6.1 kW

Energy to supply 20% Make Up $= \frac{(\text{Water Volume}) \times (\text{Pump Rating})}{(\text{Capacity of Tank Pump})}$

$= \frac{(672 \times 0.2) \times (104) = 11.9\ \text{kW}}{(1173)}$

Energy to Run Tower = (6.1) + (11.9)

= 18 kW

Energy Savings = (Pumping from River) - (Tower Consumption)

= 32 - 18 = 14 kW

Energy Savings

= (kW) (Hours/Operation)

= (14) (6912)

= 96,768 kWh x 0.0036

= 348 GJ

APPENDIX 23 (Cont'd)

Cost Savings = (GJ/Year (Rs/GJ)
= (348) (411.11)
= 143,216 Rs/Year

Cost of Implementation

The cost of a natural draught cooling tower designed and built in Sri Lanka is estimated to be Rs420,000.

Simple Payback $= \frac{420{,}000}{143{,}216}$

= 2.9 Years

Energy Savings	= 348 GJ/Year
Cost Savings	= Rs143,216/Yr
Cost of Implementation	= Rs420,000
Simple Payback	= 2.9 Years

APPENDIX 24

REDUCTION IN RESERVOIR VOLUME

The Tyre plant has a chilled water reservoir of 250 m^3. The reservoir is cooled down prior to start up on a Monday morning. The reserve can be reduced to one hour of pumping capacity to give energy savings.

Assumptions

Water Temperature at start of cool down = 26°C

Data

Chilled water temperature required	= 20°C
Reservoir capacity	= 250,000 litres
Chiller Capacity	= 100 tons or 1,266,090 GJ
Density of Water	= 980 kg/m^3
Chiller Pump Capacity	= 1591 Litres/min
Chiller Rating	= 100 kW

Calculation

Energy to be removed

$$= (250 \times 980)(4.2)(26-20)$$
$$= 6,174,000 \text{ kJ}$$

Current time required to cool

$$= \frac{6,174,000}{1,266,090}$$
$$= 4.876 \text{ hours}$$

Chiller Pump Capacity

$$= \frac{1591 \times 60 \times 980}{1000} \text{ kg/hr}$$
$$= 93,551 \text{ kg/hr}$$

APPENDIX 24 (Cont'd)

Cooldown time required for 1 hour = $4.876 \times \frac{93551}{(250 \times 980)}$

= 1.86

Savings = 4.876 - 1.861

= 3.0 hours

Energy Savings = (Chiller Compressor) + (Condenser Pump) + (Chilled Water Pump)

= (100 kW) + (46 kW) + (35)

= 181 kW/hour

= 181 x 3

= 543 x 48 x 0.0036

= 94 GJ/year

Cost Savings = (GJ) (Rs/GJ)

= (94) (411.11)

= 38,644 Rs/Yr

Cost of Implementation

There are two possible methods of implementing this measure. One method is to alter float level controls, the other is to add bricks to the reservoir, therby reducing its volume. Both methods do not require major expenditure. Implementation costs are estimated to be 15,000 Rs.

APPENDIX 24 (Cont'd)

Simple Payback $= \frac{15,000}{38,644}$

= 0.4 years

Energy Savings	= 94 GJ/Year
Cost Savings	= Rs38,644/Yr
Cost of Implementation	= Rs15,000
Simple Payback	= 0.4 Years

APPENDIX 25

DEMAND SAVINGS THROUGH LOAD RESCHEDULING

At present the various production departments operate on the following schedules:

	Hrs/Yr	Current Operating Days	Actual kW	Proposed Operating Days
Compounding	6912	Mon-Sat 3-shifts	1919	Mon-Sat 3-Shifts
Extrusion	4608	Mon-Sat 2 shifts	832	Mon-Thurs 3-Shifts
Calendering	2304	Mon-Sat 1 shift	380	Fri-Sat 3-Shifts
Tyre Building	6912	Mon-Sat 3 shifts	107	Mon-Sat 3-Shifts
Tube Dept.	6912	Mon-Sat 3 shifts	545	Mon-Sat 3-Shifts
Vulcanizing	6912	Mon-Sat 3 shifts	855	Mon-Sat 3-Shifts

This means the peak demand occurs when all departments are operating simultaneously. By rescheduling the extrusion and calendering departments for 3 shift operations, it would be possible to meet production requirements in 4 days in the extrusion department and 2 days in the calendering department. By doing that, a peak demand reduction of 380 kW is possible.

APPENDIX 25 (Cont'd)

Assuming the power factor is improved to 0.95 then the kVa reduction is 400.

Cost Saviings

= (kVa) (Rs/kVA) (12)
= (400) (90) (12)
= 432,000 Rs/Year

Cost of Implementation

The costs to implement this measure are difficult to determine. Further study is required into the potential for operating the two respective departments on a three shift basis. This may involve increased labor costs, but these may be offset due to other savings that may accrue due to elimination of heat up times and provision for maintenance hours during the week.

Energy Savings	= 400 kVA
Cost Savings	= Rs432,000/Yr

APPENDIX 26

REPLACEMENT OF BOILER PLANT

Assumptions

It is assumed a plant firing the same fuel will be used, all measures relating to the steam system will be implemented including repair of leaks, traps and insulation and condensate will be returned to the boiler. The anticipated efficiency of the new plant is 78%.

Data

Boiler Efficiency	= 54.1%
Savings through implementation	= 31,873 GJ
Current Boiler fuel use	= 229,296 GJ

Calculation

Heat Condensate Steam Generated By Existing Plant = 0.541 x (229296 - 31873)
= 106,806 GJ

Energy required using new plant $= \frac{106806}{0.78}$
= 136,931

Energy Savings = 229,296 - 136,931
= 92,365 GJ

APPENDIX 26 (Cont'd)

Cost Savings = (GJ) (Rs/GJ)
= (92,365) (115.19)
= 10,639,524 Rs/Year

Cost of Implementation

This measure requires a feasibility study to fully examine all possibilities for implementation. The calculation presented here is illustrative only of the potential savings that may be realized and to provide incentive for a feasibility study.

Energy Savings	=	92,365 GJ
Cost Savings	=	Rs10,639,524/Yr