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Report on visit to Sri Lanka to evaluate performance of traditional furnace/heat exchanger systems used in the tea industry.

10 to 29 November 1992

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SUMMARY

Under a project entitled "Fuel efficient wood-fired furnace systems" NRI has developed a fuel efficient wood fired furnace/heat exchanger system suitable for application in developing countries. To gauge its effectiveness in both economic and technical terms a comparative study of a typical system used in the Sri Lankan tea industry was carried out. This was coupled to a detailed energy audit of a tea processing factory in order to assess the relative importance of process heat within the entire manufacturing operation.

This exercise was carried out in close collaboration with Browns Engineering, a long established Sri Lankan company which sells and maintains tea furnace/dryer equipment both to the Sri Lankan industry and for export. On the evidence of detailed trial results at one factory, observations in other factories, and discussion with equipment suppliers; there are clearly significant energy savings that could be achieved in the industry. Servicing of existing furnace equipment and furnace operator training should be given high priority. Production scheduling within the new factory groupings also offers scope for reduced specific energy consumption.

It was also established from the assignment that there exists a desire to upgrade furnace equipment in the tea industry. The NRI unit is competitively priced and offers significantly improved wood fuel utilization. Changes in the industry and the plans of new management groups to improve efficiency and update manufacturing techniques makes this an opportune time for introduction of the NRI design. A simple payback financial analysis shows that there are financial benefits in replacing old and inefficient units. A suitable venue for field testing and techno-economic evaluation of performance under prolonged operation has been identified.

INTRODUCTION

General

The design of the NRI fuel efficient wood fired/heat exchanger system and the visit to Sri Lanka to evaluate systems currently in operation in tea industry are part of a larger project undertaken by the NRI, entitled "Fuel efficient wood-fired furnace systems".

The efficient exploitation of wood or the substitution of traditional fuels by biomass wastes within the agro-processing industries, would alleviate the current problems of deforestation and woodfuel shortages. Reductions in woodfuel consumption would also increase process profitability and reduce pollution problems caused by under-utilized biomass wastes.

Considerable quantities of woodfuel are consumed by the agro-processing industries in developing countries to supply process heat in drying operations. Traditional systems are often inefficient in design and were developed before depletion of natural resources had created the current problems.

The dissemination of modern technologies promotes the concepts of sustainable harvesting of wood fuels and the efficient use of forestry and biomass residues for fuel. This is particularly important in countries which have little or no natural fossil fuel resources but want to maintain long term industrial development. Thus the current visit is part of a longer term program of work designed to encourage efficient use of resources on a sustainable basis which will allow continued long term development.

Project Background

NRI has developed a fuel-efficient wood-fired furnace heat exchanger system suitable for application in developing countries. This project was planned to gauge the system's effectiveness, in both economic and technical terms, through making a comparative study of a typical system used by the Sri Lankan tea industry. This work was to be coupled to a detailed energy audit of a tea processing factory to help assess the relative importance of process heat for the entire manufacturing process.

The NRI furnace system was designed for greater fuel efficiency and ease of construction using locally available materials and skills. Attention has been focused on a thermal output level of 1000 MJ/h to 2000 MJ/h, as found in many industrial process operations such as tea drying. From a broad study of typical process heating requirements found in selected key agro-forestry industries the target performance specification is:

a) heat input - 450 kW;

b) process air output - 3.2 kg/s at 140^{o}C;

c) flue gas - 0.37 kg/s at 330^{o}C;

d) fuel - typically hand-fired lump wood up to 600 mm long, 150 mm diameter. Calorific value of approximately 18 MJ/kg.

A system was built at NRI, UK and operated for commissioning trials. Its performance, in both technical and economic terms, are to be compared to that of a typical wood-fired furnace heat exchanger system as used by the tea industry. The overall findings of this work are to be incorporated in a technical project report which is to be issued separately. Terms of reference for the work in this visit report are given in Appendix 7.

Subject to a favourable prognosis a project proposal will be formulated to field test and demonstrate the system under commercially operating conditions.

Visit Background

The Sri Lankan tea industry was for many years, virtually a nationalized industry, under the control of two organizations, the JEDB and SLPC. However, it has recently undergone a major reorganization due to declining competitiveness in world markets and external donors' pressure for structual change, notably from the World Bank. One option proposed was privatisation open to foreign nationals but this was resisted by the Government of Sri Lanka (GoSL) due to concern over an Indian takeover of the proposed private management groups. During 1992 agreements were completed to reassign the 550 tea estates under new management. Of the 550, 51 were closed and the remainder were divided into 22 newly established plantation companies operated by private management groups. Each management group covers up to 25 plantations. Ownership of the land remains with the GoSL, but there has been some degree of ownership transfer through employee shareholding.

Amongst these new management groups are Free Lanka (Pvt) Ltd and Lankem Plantation Services, with whom the current work has been arranged. Both groups have former JEDB employees known to NRI and it was through these contacts that this assignment was set-up by Mr G Breag of the NRI during a visit to Sri Lanka in August 1992. Particular venues for investigation were identified by Browns. These were at Delta factory managed by Free Lanka (Pvt) Ltd and Abbotsleigh factory managed by Lankem Plantation Services. Delta has a traditional continuous belt dryer system, still very common in the industry, whilst at Abbotsleigh a more advanced furnace/fluidbed dryer system is installed making "Cut, twist and curl" (CTC) tea for the tea bag market.

During the assignment, effort was made to keep the management at Free Lanka and Lankem fully appraised of the work schedule and both companies were very interested and supportive of the programme.

INVOLVED ORGANIZATIONS

Browns Engineering (Pvt) Ltd

Several meetings were held with Browns to discuss the NRI designed air heater. Browns' fabrication facilities at Ratmalana were viewed and their plans for future development in the engineering field were discussed. Browns also have strong service staff in the tea growing areas of Hatton, Kandy and Badulla. New management policy has diversified the engineering activaties, centred in Colombo, to include computer based process control, management information and decision support systems. An associated company to Browns, Information Technology Services has been set-up. This is a subsidiary of Eutech Cybernetics based in Singapore. Eutech has obtained development funding from IDRC through the GoSL organization CINTEC for a programme of work on automated tea manufacturing. The experimental plant for a furnace/dryer operation which had been installed at Gikayanakanda Estate, managed by the George Stewart group, was described.

The drawings for the NRI air heater were supplied to Browns and they produced a costing for the local manufacture of the heater. Various aspects of the design were discussed including how it differed from the Davidson design used by Browns at present. Noticeable differences, apart from the cast iron structure, were the fact that their units were of an induced draught design except for the more modern CTC installations where an auxiliary forced draught fan supplying air under the fire grate was installed. This fan was controlled by a thermo-stat monitoring the process air inlet to the tea dryer and only operated when the process air fell below a given setpoint. Also on the more modern designs for CTC tea production, requiring higher process air temperatures, a flue gas recuperator which consisted of a flue gas to process air inlet heat exchanger had been added.

Regarding the NRI system, Browns agreed in principle to manufacture and/or service an experimental/prototype unit. They indicated commercial interest in the design and whilst expressing some concern over competitive marketing, accepted that NRI could not at this stage offer any exclusive manufacturing rights.

Free Lanka Management (Pvt) Ltd

Prior to the trials at Delta factory a briefing meeting was held with Free Lanka Management Co (Pvt) Ltd. to confirm the terms of reference for the monitoring exercise and to discuss any additional points that might be raised (see Appendix 7).

Free Lanka were particularly interested to see how well the NRI designed heater performed compared to those currently in operation. They also showed interest in long term trials of the NRI heater in an operating tea factory within Sri Lanka. It was agreed that a copy of the final results and report would be sent to them on completion.

The unit in operation at Delta is a indirect wood-fired air heater of Davidson design, manufactured by Browns Engineering and is approximately 8 years old. Free Lanka supplied an installation manual for the above heater. The furnace/heat exchanger is coupled to a continuous belt dryer and produces 425kg of made tea per m^3 of fuel wood.

Background information provided included the fact that there were 8 to 10 operating tea factories within a 5 mile radius of the Delta factory.

It is current government policy to increase CTC tea production from 6% to 12% and the Delta factory is about to be upgraded for CTC production. This will involve either a new indirect wood-fired air heater or a steam boiler. Mr M Wijesinghe, Director of Engineering, who worked for Browns Engineering for 7 years before joining Free Lanka in 1991 was in the process of making the decision between steam plant or a wood-fired air heater. He was visiting India to view the manufacturing equipment currently in use in the Indian tea industry.

Lankem Plantation Services Ltd

A meeting was sought with Mr R Ganapathy, Chief Technical Adviser, Lankem Plantation Services Ltd. to acquire permission for the monitoring exercise planned for the Browns Engineering air heater situated at the Abbotsleigh Factory. Mr Ganapathy is on a consultant assignment from the Indian based company Harrisons Malayalam Ltd. and he supported the planned monitoring exercise.

Experience from the Indian tea industry has been sought by Lankem to oversee the rehabilitation of their tea estates. It is felt that by simple changes to the methods of pruning the tea bushes and by application of scientific horticultural techniques it would be possible to increase the yield of made tea from 1500 to 2000-3000 kg per hectare. The traditional pruning methods used on the estates have developed as a way of supplying domestic fuel wood to the plantation workers as well as plant care. Changing the pruning methods used also means restricting workers of their fuel source. Lankem showed particular interest in waste heat technology which could supply the workers with a quality fuel source in the form of charcoal and reduce fuel wood costs for the tea drying process. A copy of a report describing NRI's Wood Carbonization Unit was provided (Breag et al, 1992).

Tea Smallholders Factories Limited (TSHF)

Information on this organization was obtained through a meeting with Mr Cecil de Silva, Managing Director. Around 40% of tea produced in Sri Lanka is derived from smallholders. A government organization called the Tea Smallholders Factories Ltd. provides an extension, purchasing and processing service to this part of the industry. TSHF operates a factory division with 1300 employees working in 11 factories which have been built or acquired. This includes some of the largest factories in Sri Lanka; three of which are described as modern. There are 6700 leaf suppliers mainly in the low country where TSHF was doing well. TSHF is less successful in the mid-growing areas but is profitable overall.

A privatisation scheme was being enacted by the GoSL which will pass control of TSHF into the commercial sector. Presently all the shares of TSHF are held by the Secretary to the Treasury. However advertisements were out for tenders to redistribute shares as follows:

- 51% to be purchased by a single private organization
- 10% passed to employees as a gift
- 39% offered to smallholders with a first option to purchase

Tenders closed on the 30 November 1992 and it was expected that successful bids were to be awarded by the end of the year.

Mr de Silva was keen to acquire a copy of the Albion factory development proposal previously compiled by NRI in association with JEDB. In his opinion it could be re-drafted in a form applicable to the TSHF. We agreed to convey this request to ODA and expressed our desire to be advised of future developments regarding TSHF. Details of the current assignment were provided and the drawings of the NRI furnace were shown to explain the design approach being adopted.

SITE VISITS

<u>Delta Factory, Free Lanka (Pvt) Ltd, Puperessa</u>

Furnace/dryer assembly

This was the main venue for the evaluation of an existing air heater in a tea factory. Monitoring of the furnace/dryer was conducted over five days whilst the unit was in use for tea production. Due to low green leaf supply, only short runs of 1 to 3.5 hours duration were being conducted. Full results were obtained for 4 days operation but only 3 days of over 2 hours firing were analysed in detail. The essential data from these trials are presented in Appendix 3.

Observations on monitoring trials

Results were derived from measurements of temperatures and gas flow rates. Temperatures were measured with thermocouples and data was logged for subsequent computer analysis. Flow rates were obtained from Pitot static tube readings according to recognised methods (BS848, 1980 and HEVAC, 1981) and checked against fan ratings. Given the inherent errors associated with such measurements made on a production system an accuracy of ± 10% is estimated for calculated results. Notwithstanding this, the results on the unit showed a low thermal efficiency of 45%. Made tea per unit wood consumption increased with the duration of runs. Previous work by NRI has shown that better performance could be achieved from such units and this was also Browns' opinion.

The low measured efficiency is due primarily to a high flue gas loss of about 40% which in turn is a direct consequence of high excess air levels. To reduce excess air levels and flue gas losses, damper settings on the flue gas ID fan and furnace assemblies needed to be adjusted. These would have been initially set-up by Browns on commissioning but clearly under the JEDB management the operation and maintenance procedures have lapsed. Damper mechanisms were in disrepair and consequently this did not enable more effective combustion control settings to be achieved during these trials. To rectify this situation Browns could be instructed to repair and rebalance the combustion flow system but there should also be a training programme with documented instruction manuals made available. It should be added that observations at other factories suggest that this situation is common throughout the industry.

Measurement procedures for flue gas losses and equipment efficiencies are described in NRI's recent publication *Biomass Combustion Systems* (Breag et al 1992). A copy of this was provided for the factory.

Energy audit at Delta factory

Wood supply Details of various wood varieties used at the Delta factory were provided as follows;

Rubber	Purchase cost:	400/- Rs per m^3
	Estate supply:	----

Provides 70% of factory consumption; dried undercover and stacked for 2 to 3 months

Eucalyptus	Purchase cost:	250/- Rs per m^3
	Estate supply:	150/- Rs

Best fuel when dried for 2 to 3 months

Grevillea	Purchase cost:	-------
	Estate supply:	175/- Rs

Low density wood, only used in minor quantities.

Albechia	Purchase cost:	175/- Rs per m^3
	Estate supply:	125/- Rs

Low density wood, only used in minor quantities.

Other varieties mentioned as available for purchase but not utilised were cyprus and jungle wood. Samples of the rubber wood gave an average moisture content of 29.2%, confirming observations that it had been moderately seasoned.

Consumption of firewood has been recorded over the past 5 years on a monthly basis. These figures show very little variation from an average of $250m^3$/month. Surprisingly there was no direct relationship between made tea and wood consumption on a monthly basis.

Electrical Supply Records of monthly electricity consumption and cost at the factory over the period 1990/92 were provided, (see Appendix 5). There has been some changes in tariff and periods during which an oil surcharge was imposed. A maximum kVA charge is levied and this represents about 10% of the total bill. The power factor was measured over the duration of the trials at 0.76. A power factor correction to 0.95 could result in an annual saving of approximately 10,000/- Rs for a initial cost of approximately 15,000/- Rs. The financial consequences due to a recent change to a tariff without a peak rate charge between 6 & 9pm could not be assessed.

Mini Hydropower Delta factory has a Gilkes pelton wheel turbine which was used to supply 60 BHP shaft power and DC electricity but this unit has been allowed to fall into disrepair and has not been operated for many years. The current factory management has sought tenders to establish the facility for AC electricity generation. The total cost for the refurbishment is estimated at around 600,000/- Rs with a pay-back period of 4-5 years. Clearly this long term independent generating capacity is worthwhile and serious consideration should be given to increasing the size of plant to 100 kW or more.

Diesel Engine The factory, at one time, obtained shaft power from a National R4A3, 150 BHP, Diesel engine but it has not been used in over 10 years. It is unlikely to be of further use and if the mini hydro scheme proceeds it could be removed and sold.

Overall Energy Pattern The overall pattern of wood and electrical energy utilization for the factory in 1991 is illustrated in figures 1 & 2 in Appendix 8. This has been derived from factory records (Appendix 9). Also through limited data of equipment schedules obtained over the 5 days of observed operation, a more detailed breakdown has been estimated (figure 3, Appendix 8). This shows that furnace heating for drying is the largest single energy cost and represents about 15% of average operating costs.

Potential for energy saving at Delta

1. Re-balancing of furnace damper settings and operator training.
2. Installation of flue gas temperature gauge with instruction manual for control procedures.
3. Install power factor correction.
4. Re-establish and, if possible, uprate pelton wheel turbine.
5. Centralised tea manufacture within Free Lanka factories to maintain higher factory production rates.

Suggested sites for NRI designed air heater.

Melfort Factory, Free Lanka (PVT) Ltd, Pussellawa

This factory has one wood fired Sirocco furnace supplying a Colombo Commercial Company (CCC) continuous chain dryer producing traditional teas. Also there is a Browns continuous chain dryer of 225 kg capacity designed for traditional tea manufacture. However the furnace system for the Browns' dryer is not in use and therefore a new furnace is required.

The proposal is to remove the current disused furnace and replace it with an NRI unit. It might be possible to use the experimental unit currently under test at NRI. Although furnace duty requirements are not known exactly at this stage the unit looked of a size compatible with the 450 kW unit at NRI. There is no fuelwood supply within the estate, but rubber wood can be readily supplied at approximately 400/- Rs per m^3. Due to its siting next to a main road, with an incorporated and highly profitable tourist tea centre, continuity of tea production is assured.

Abbotsleigh Factory, Lankem Plantations, Hatton

The Abbotsleigh factory is a CTC-type manufacturing plant with two fluidized-bed dryers; one Browns type-16 furnace/Bedi & Bedi combination and one Hambro production unit.

The Browns/Bedi & Bedi unit is the main operating plant and is the only wood-fired unit in Sri Lanka to be used for CTC production. It includes a gas recuperator and a forced draught primary air fan controlled by the process air supply temperature. It had been intended to conduct trials on this Browns furnace but due to production maintenance during the visit this was not possible. Performance figures have been previously provided by Browns.

The Hambro unit is a dual fired unit which has various operating problems including: an incapacity to operate on heavy furnace fuels, temperature control fluctuations which have excluded the use of fuelwood, and excessive stack corrosion. Also there are extreme difficulties in servicing the unit due to lack of local spares agents or engineering support. The cost of oil compared to fuelwood, which in the case of Abbotsleigh is grown on the estate, is such that the Hambro unit is only used as an auxiliary plant.

A proposal suggested by Lankem Plantations was to replace the Hambro oil burner unit with a NRI air heater but retain the 3 stage vibrating fluidized-bed dryer. This could then be used for NRI's proving trials without effecting the factory's main production line. However the thermal load required by the fluidized-bed dryer would require an uprated design of the NRI equipment.

Advantages of this proposal are the low cost of fuelwood (55/- Rs per m^3) and the availability of a CTC-type, fluidized-bed, dryer unit. However, the Hambro dryer is quite a complex unit which requires splitting the output from the air heater into 3 flows and supplying them at 3 different temperatures. The specification for the air supplies require a $\pm$ 2°F tolerance although it seems unlikely that the Browns furnace meets this on the factory's main production line.

Strathdon Factory, Lankem Plantations, Hatton

This factory is producing traditional teas using two oil fired furnaces connected to agitating fluidized-bed dryer units. The main production line consists of a Monarch oil burner connected to a 4 stage CCC dryer with a 300 kg/h Made tea capacity. The overflow unit consists of a Monarch dual fired furnace (only running on oil) and a CCC dryer with a 225 kg/h capacity.

A proposal suggested by Lankem Plantations was to replace the Monarch oil burner with the NRI air heater and use it for their main production line. Advantages of this are that traditional teas do not require such tight air temperature tolerances and there is a ready supply of fuelwood within the estate. However the size of dryer would require an uprated design by NRI. Although the estate is one of the most unprofitable within the area (under Lankem Plantation management) it will remain a tea producing base rather than a green leaf supplier for the Abbotsleigh CTC factory. As such it is likely to receive attention to improve its profitability and new management has recently been appointed.

Dickoya Factory, Lankem Plantations, Hatton

This factory is producing traditional teas from green leaf supplied by local freeholders. There was one Monarch oil burner supplying a CCC 3 stage, agitating fluidized-bed dryer of 225 kg capacity. Also there was a Sirocco/CCC combination as an overflow dryer.

The possibility of replacing the Monarch oil burner with an NRI unit was examined but Lankem Plantations felt that this would be of limited use for production trials due to the uncertainty of the green leaf supply.

CONCLUSIONS / RECOMMENDATIONS

On the evidence of detailed trial results at one factory; observations in other factories; and discussion with equipment suppliers; there are clearly significant energy savings that could be achieved in the industry. Servicing of furnace equipment and furnace operator training should be given a high priority. Production scheduling within the new factory groupings also offer scope for reduced specific energy consumption.

It has been established from the assignment that there exists a desire to upgrade furnace equipment in the tea industry. The NRI unit is competitively priced and offers significantly enhanced thermal efficiency and savings in fuelwood costs. Changes in the industry and the plans of new management groups to improve efficiency and update manufacturing techniques makes this an opportune time for introduction of the NRI design. A simple payback financial analysis shows that there are financial benefits in replacing old and inefficient units (see Appendix 6). A more detailed techno-economic appraisal should be included with any field evaluation trial.

With regard to future field testing of the NRI furnace three possible locations has been identified. These are:

i. Melfort Factory, (Free Lanka).
Existing scale furnace coupled to 85kg/h Browns continuous chain dryer.

ii. Abbotsleigh, (Lankem).
    Scaled-up furnace to replace Hambro furnace and coupled to Hambro vibrating fluidbed dryer producing CTC tea.

iii. Strathdon, (Lankem).
    Scaled-up furnace coupled to a CCC fluidbed dryer.

Of the above, Browns expressed strongest support for (i) since it would be coupled to one of their dryer units and traditional furnace/dryer installations are dealt with as combined units. Scaling-up of the existing design as would be required for options (ii) and (iii) might be more readily accomplished after field trials of the existing system. Option (i) at Melfort factory is therefore preferred on the basis that it offers an immediate prospect for field trials, in a suitable venue, where Browns support could be readily applied.

REFERENCES

G R Breag, P G Joseph and A S Tariq (1992) *Biomass Combustion Systems: Flue Gas Losses and Equipment Efficiency*. Chatham, UK: Natural Resources Institute

G R Breag, J P Coulter, A C Hollingdale, R Krishnan, A P Robinson (1992) *Wood Carbonisation Unit Design and Development of a Prototype with Recovery of Waste Heat*. Chatham, UK: Natural Resources Institute

British Standards Institution, BS848:Part 1: 1980 *Fans for general purposes Part 1. Methods of testing performance*

The Heating, Ventilating and Air Conditioning Manufacturers' Association - *Fan Application Guide,* 1981

APPENDIX 1. ITINERARY

Mon 9th Nov	Arrival in Colombo - R Lipscombe
Tues 10th	Meeting with Browns Engineering
Wed 11th	Arrival - A Hollingdale Meeting at BHC Meeting with Prof U Samarajeewa
Thur 12th	Meeting with Free Lanka (PVT) Ltd Meeting at British Council Meeting with Lankem Plantation Services
Fri 12th	Works visit and meeting at Browns Engineering, Ratmalana Meeting at Tea Smallholders Factories Ltd Meeting with Mr P D Joseph
Sat 14th	Meeting with Mr M Facer, ODA funded consultant to Browns Engineering
Sun 15th	Travel to Kandy
Mon 16th	Trials at Delta Estate Factory
Tues 17th	Delta trials Meeting with Browns Engineering, Kandy
Wed 18th	Delta trials
Thur 18th	Delta trials Meeting at Chemicial Engineering Dept, University of Peradeniya Preliminary visit to Abbotsleigh Factory
Fri 20th	Delta trials Visits to Hellbode and Melfort Factories
Sat 21st	Trials at Delta concluded
Sun 22nd	Travel to Hatton
Mon 23rd	Furnace/dryer evaluation at Abbotsleigh Visits to Dickoya and Strathdon Factories Meeting at Lankem area office, Dickoya
Tues 24th	Travel to Colombo Meeting with Lanka Refactories Ltd, Padukka
Wed 25th	Data analysis and compilation of trial results; meeting with Browns Engineering Visit to CDA
Thur 26th	Site visit to Loluagoda Mills; meeting with S A Silva & Sons (Lanka) PVT Ltd Meeting at BHC

Fri 27th	Preparation of visit report Round-up meeting with Browns, Ratmalana
Sat 28th	Completion of visit report
Sun 29th	Depart Colombo

APPENDIX 2. LIST OF PEOPLE MET

Browns Engineering (Pvt) Ltd

Mr M H A Rizwan	Executive Director Engineering
Mr J V R Dias	Senior Tea Machinery Engineer
Mr K Gengatharan	Research & Development Engineer
Mr L J Peiris	Area Engineer, Kandy
Mr S M Sapideen	Area Engineer, Hatton
Mr A C Wijesinghe	Area Engineer, Badulla

Free Lanka Management Co. (Pvt) Ltd

Mr D Samarasinha	Managing Director
Mr M Perera	Director Administration
Mr M Wijesinghe	Director Engineering
Mr M R C Peiris	Director Rubber
Mr S Canagasabey	Plantation Manager, Delta Estate
Mr Ramamouthy	Factory Manager, Delta Estate

Lankem Plantation Services Ltd

Mr Ganapathy	Chief Technical Advisor
Mr G Amarasinghe	Area Manager
Mr M Madgulla	Plantation Manager, Abbotsleigh Estate

Tea SmallHolders Factories Limited

Mr Cecil de Silva	Managing Director.

S A Silva & Sons (Lanka) Pvt. Ltd.

Mr Suresh Silva	Managing Director

Lanka Refactories Ltd

Mr L N Weragoda	Production Manager

Peradeniyia University
Dept of Chemical Engineering

Prof N Fernando	Senior Lecturer
Ms R Shanthine	Head of Department
Mr Senaratne	Assistant Lecturer
Mr R Tennekoone	Technician

Peradeniyia University
Dept of Food Science and Agriculture

Dr U Samarajeewa

Coconut Development Authority

Mr H Tillekeratne

British High Commission

Mr M Foord	Aid Secretary
D R Senanayake	Senior Commercial Officer

Mr P G Joseph	Energy Consultant, Colombo
Mr M Facer	Agricultural Engineering Consultant, Browns Engineering

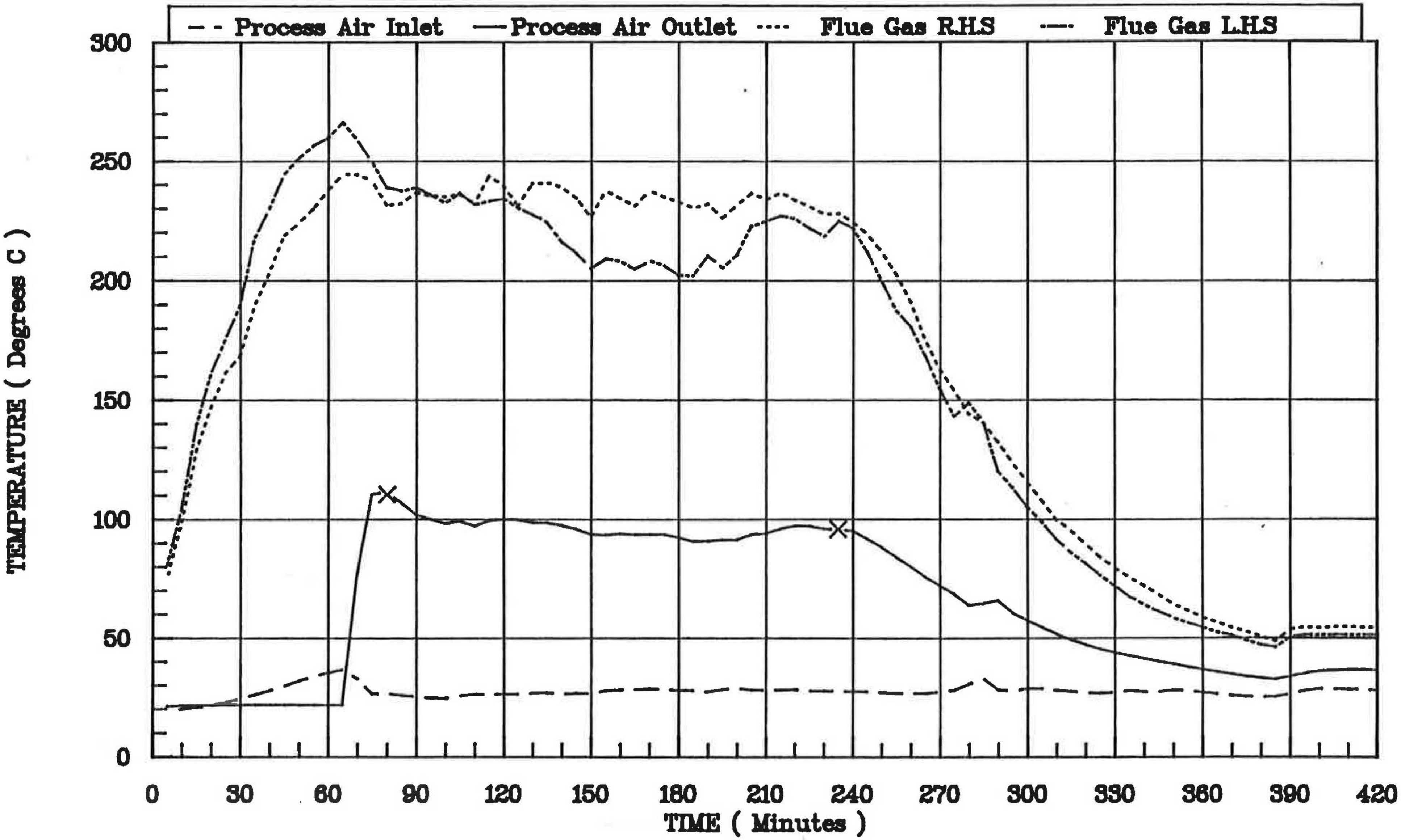
APPENDIX 3. DELTA FACTORY TRIAL RESULTS

Furnace evaluation data

		18 Nov	19 Nov	20 Nov
Duration of Firing	mins	157	145	215
Total amount of wood consumed	kg	585	563	763
Wood consumed during firing	kg	385	363	563
Fuel rate during firing	kg/h	147	150	157
Heat input	kW	571	583	610
Heat output	kW	258	266	258
Process air temperature	^{o}C	94.4	97.2	95.5
Thermal efficiency	%	45.1	45.5	42.2
Flue gas temperature	^{o}C	223	214	224
Made Tea (MT)	kg	643	586	856
Overall MT / Wood	kg/kg	1.1	1.04	1.12
Firing period MT / Wood	kg/kg	1.67	1.61	1.52

DELTA TEA ESTATE – 18 NOVEMBER 1998

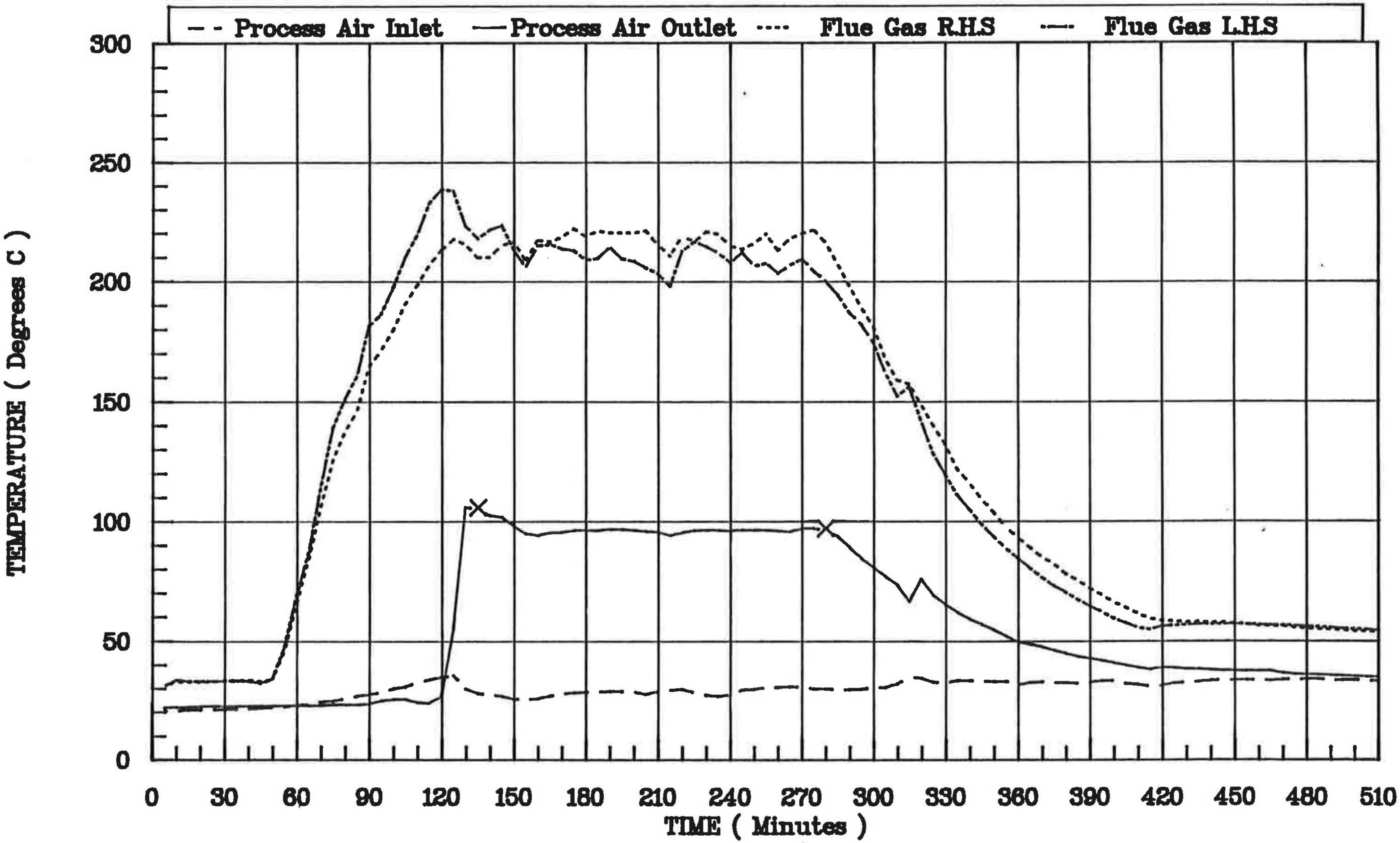
Furnace Temperature Data



Note – X marks start & finish of tea firing

DELTA TEA ESTATE – 19 NOVEMBER 1992

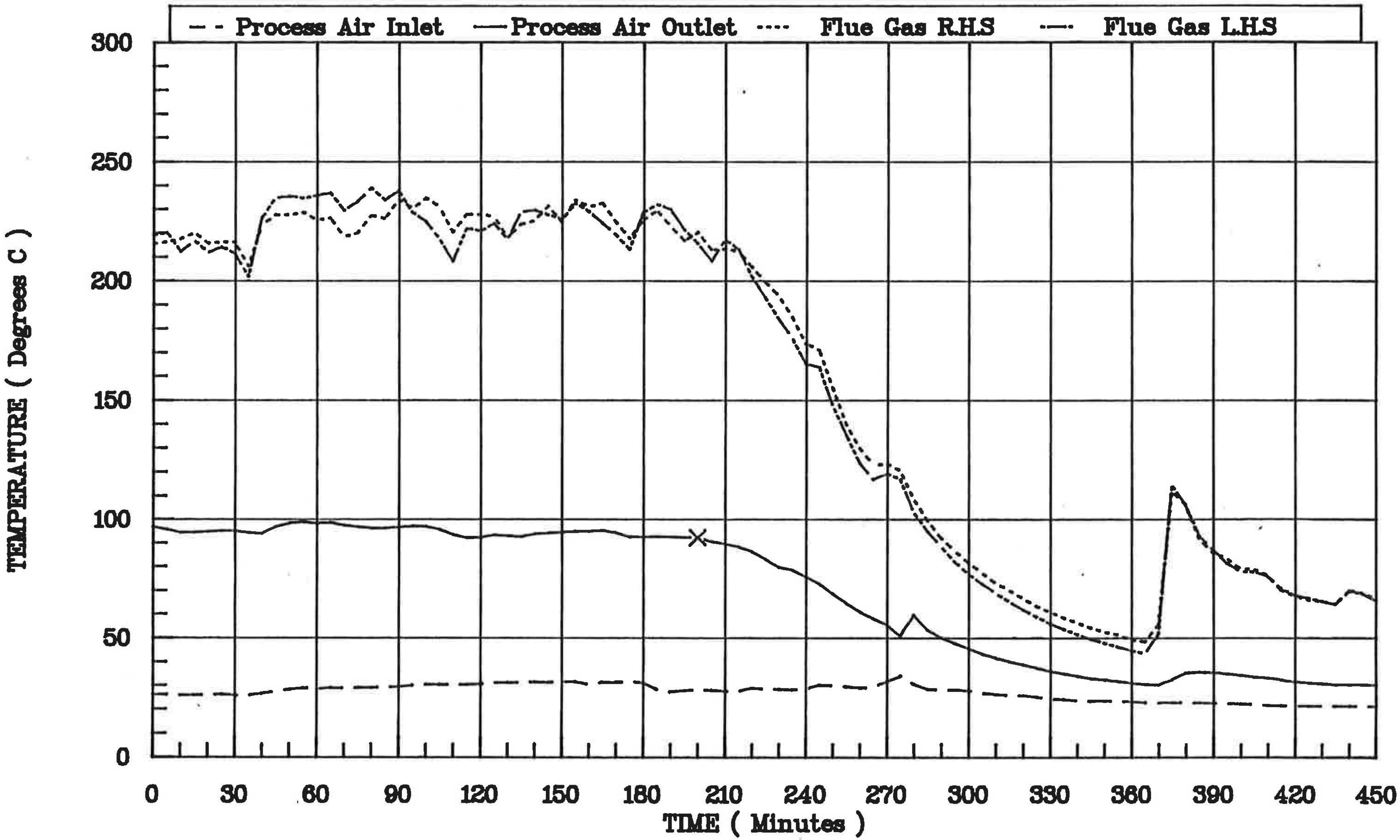
Furnace Temperature Data



Note – X marks start & finish of tea firing

DELTA TEA ESTATE – 20 NOVEMBER 1992

Furnace Temperature Data



Note – X marks finish of tea firing

APPENDIX 4. LIST OF EQUIPMENT IN OPERATION AT DELTA ESTATE

Rolling Room

	Machine	Make	Size	HP	RPM	Output
1	ROLLER1	CCC	42"	20	38	341
2	ROLLER2	WALKER	46.5"	20	43	454
3	ROLLER3	WALKER	46.5"	20	-	454
4	ROLLER4	WALKER	45"	15	43	250
5	ROLLER5	WALKER	45"	15	38	250
6	ROLLER6	CCC	34"	15	38	125
7	BREAKER1	CCC		3	140	
8	BREAKER2	WALKER		1.5	145	
9	ROTAVANE	WALKER	8"	15	145	600
10	EN	NATIONAL				

Firing Room

	Machine	Make	Size	HP	RPM	Output
1	DRYER1	SIROCCO	4'	10	560	115
2	DRYER2	BROWNS	6'	20	645	250
3	ID FAN	SIROCCO	15"	2	715	
4	D PACK	CCC		2		
5	C/SAW		30"	10		

Sifting Room

	Make	SIZE	HP	RPM	Output
1	CHOTA		2	145	250
2	MYDDLETON	3/161,7/32	2	200	250
3	MICHIE		1.5	189	300
4	TEACUTTER		.75	55	200
5	TERRY NUPPU		.75	55	350
6	WINNOWELL		3	715	250
7	CHOTA		1.5	144	250
8	S/EXTRACTOR				150
9	DUST FAN		2	4	
10	DUST FAN		2	4	

APPENDIX 5. ELECTRICAL USAGE AT DELTA ESTATE

Electricity 1989 — Charges 1989

	Made Tea kg	Elec Consumed kW	Max kVA	Fixed Charge Rs	kW Rs	kVA Rs	Total Charge
Jan	29319	22050	105	200	1.92	110	54086
Feb	23776	21060	100	200	1.92	110	51635
Mar	17845	14560	96	200	1.92	110	38715
Apr	18965	13500	95	200	1.92	110	36570
May	65253	33310	125	200	1.92	110	77905
June	29876	29820	118	200	1.92	110	70434
July	22915	19880	120	200	1.92	110	51570
Aug	16395	15750	105	200	1.92	110	41990
Sept	35084	18070	245	200	1.6	110	56062
Oct	37604	22680	*	200	1.6	110	36488
Nov	37002	25440	135	200	1.6	110	55754
Dec	39140	11370	75	200	1.6	110	26642

Annual Total = 597852 Rs

Electricity 1990 — Charges 1990

	Made Tea Kg	Elec Consumed kW	Elec Consumed Peak	Max kVA	Fixed Charge Rs	kW Rs	kW Peak Rs	kVA Rs	Total Charge Rs
Jan		17250	10700	75	200	1.5	2.45	50	56040
Feb		8760	5450	70	200	1.5	2.45	50	30193
Mar		8670	5490	75	200	1.5	2.45	50	30406
Apr		14920	2940	80	200	2.1	4.95	60	50885
May	34347	16330	3350	80	240	2.1	4.95	60	55916
June	28422	15080	3290	71	240	2.1	4.95	60	52454
July	20052	13170	2650	72	240	2.1	4.95	60	45335
Aug	27161	14810	2810		240	2.1	4.95	60	45251
Sept	24953	13200	2600	80	240	2.1	4.95	60	45630
Oct	32598	15130	3070		240	2.1	4.95	60	47210
Nov	24842	12930	2570		240	2.1	4.95	60	40115
Dec	31773	14930	2800		240	2.1	4.95	60	45453

Annual Total = 544884 Rs

Electricity 1991 Charges 1991

	Made Tea Kg	Elec Consumed kW	Peak	Max kVA	Fixed Charge Rs	kW Rs	kW Peak Rs	kVA Rs	Total Charge Rs
Jan	29293	14170	2730	70	240	2.1	4.95	60	47711
Feb	22218	8620	1790	70	240	2.1	4.95	60	31403
Mar	24709	10250	2200	65	240	2.1	4.95	60	36555
Apr	55498	13510	2350	90	240	2.1	4.95	60	45644
May	52341	15350	2770	88	240	2.1	4.95	60	51467
June	45056	19150	1600	65	240	2.1	4.95	60	52275
July	42322	16920	3350	70	240	2.1	4.95	60	56555
Aug	33093	17250	1250	75	240	2.1	4.95	60	47153
Sept	32843	7580	2980	70	240	2.1	4.95	60	35109
Oct	33704	17970	3820	86	240	2.1	4.95	60	62046
Nov	31167	13070	3980	70	240	2.1	4.95	60	51588
Dec	37161	10440	4570	74	240	2.1	4.95	60	49226

Annual Total = 566729 Rs

Electricity 1992 Charges 1992

	Made Tea Kg	Elec Consumed kW	Peak	Max kVA	Fixed Charge Rs	kW Rs	kW Peak Rs	kVA Rs	Total Charge Rs
Jan	34146	16670	4280	80	240	2.1	4.95	60	61233
Feb	26602	9290	2470	70	240	2.1	4.95	60	36176
Mar	12944	7180	1810	60	240	2.625	6.1875	60	33887
Apr	8852	5560	1260	70	240	2.625	6.1875	60	26831
May	77698	19500	3690	100	240	2.625	6.1875	60	80259
June	36772	17190	3250	100	240	2.625	6.1875	60	71473
July	22280	12770	2700	70	240	2.625	6.1875	60	54668
Aug	22852	15400	3300	75	240	2.625	6.1875	60	65584
Sept	10458	9710	2070	60	240	2.625	6.1875	60	42137
Oct	16139	12510	2710	70	240	2.625	6.1875	60	54047

Total to date = 526294 Rs

APPENDIX 6. FINANCIAL APPRAISAL

Cost savings for installation of the NRI design will be site specific, and largely dependant on the quantity of made tea produced per annum. Using the data collected at Delta and applying it to a factory of 250 tonnes MT output per annum, gives the following financial analysis.

Expected fuel use with NRI design	2.5 kg MT / kg wood
Present usage based on Delta trials	1.1 kg MT / kg wood
Wood saving per tonne of MT	.51 tonnes wood
Value of wood saved per tonne MT	581 /- Rs

At 250 tonnes of MT per annum output

Potential cost saving	= 145,250 /- Rs

Capital input

Cost of furnace	= 710,000 /- Rs
Local installation cost	= 60,000 /- Rs
Total cost	= 770,000 /- Rs

Simple payback period	= 5.2 years

Melfort

Actual quoted wood consumption at the Melfort Factory was 1 tonne Green leaf/tonne of wood which at a yield of 23% made tea to green leaf is equivalent to 0.66 kg MT/kg wood. On this basis an annual saving of 355,200/- Rs is obtained, representing a payback period of 2.2 years.

APPENDIX 7. TERMS OF REFERENCE FOR NRI EVALUATION OF A TYPICAL WOOD-FIRED FURNACE SYSTEM WITH FREE LANKA LTD.

Background

NRI is developing a fuel-efficient wood-fired furnace heat exchanger system suitable for application in developing countries. To gauge its effectiveness, in both economic and technical terms, a comparative study of a typical system used by the tea industry is planned. This will be coupled to a detailed energy audit of a tea processing factory to help assess the relative importance of process heat for the entire manufacturing process.

The NRI furnace system is designed for greater fuel efficiency and ease of construction using locally available materials and skills. Attention has been focused on a thermal output level of 1000 MJ/h to 2000 MJ/h, as found in many industrial process operations such as tea drying. From a broad study of typical process heating requirements found in selected key agro-forestry industries the target performance specification is:

a) heat input - 450 kW;

b) process air output - 3.2 kg/s at 140^{o}C;

c) flue gas - 0.37 kg/s at 330^{o}C;

d) fuel - typically hand-fired lump wood up to 600 mm long, 150 mm diameter. Calorific value of approximately 18 MJ/kg.

A system has been built at NRI, UK and is now being operated for commissioning trials. Its performance, in both technical and economic terms, will be compared to that of a typical wood-fired furnace heat exchanger system as used by the tea industry.

Subject to a favourable prognosis a project proposal will be formulated to field test and demonstrate the system under commercially operating conditions.

Terms of reference

At a selected tea processing factory:

a) obtain factory background information - eg process and production details, capacity, labour and material inputs, and equipment specification;

b) evaluate performance of wood-fired furnace drying system - measure temperatures, air flows, fuel-rate, wood moisture content and conditions;

c) from data obtained calculate convection/radiation losses, flue gas losses, combustion efficiency and energy balance;

d) detail fuelwood supply - eg source, species, distances, costs, seasoning time, preparation, and labour inputs;

e) collect or measure consumption data and costs of other energy inputs eg electricity and fuel oil;

f) identify best opportunities for thermal savings.

In addition:

g) consider other commercial applications of the NRI wood-fired furnace system;

h) obtain local manufacturing cost estimate for NRI system;

i) identify potential site for field testing and demonstrating the system;

Inputs

Visit by an NRI technologist and economist for approximately 3 weeks to tea processing factory, fuelwood supply area, engineering workshops and other industries as appropriate for evaluation work and to collect technical and economic data.

Outputs

Visit report detailing:-

* evaluation of existing wood-fired furnace drying system;
* fuelwood specification and source;
* energy audit of tea processing operation;
* typical factory fuel usage;
* diagram of process and quantified energy inputs;
* technical and financial data;
* best opportunities for thermal savings;
* details of NRI-system;
* potential test site for field testing and demonstration of NRI-furnace system;
* assessment of local furnace manufacture and cost-estimate for NRI system;
* techno-economic appraisal of introducing NRI system;
* other potential applications of NRI system.

APPENDIX 8. ENERGY CONSUMPTION AND UTILIZATION DATA FOR DELTA ESTATE

Delta Tea Factory
Energy Consumption – 1991

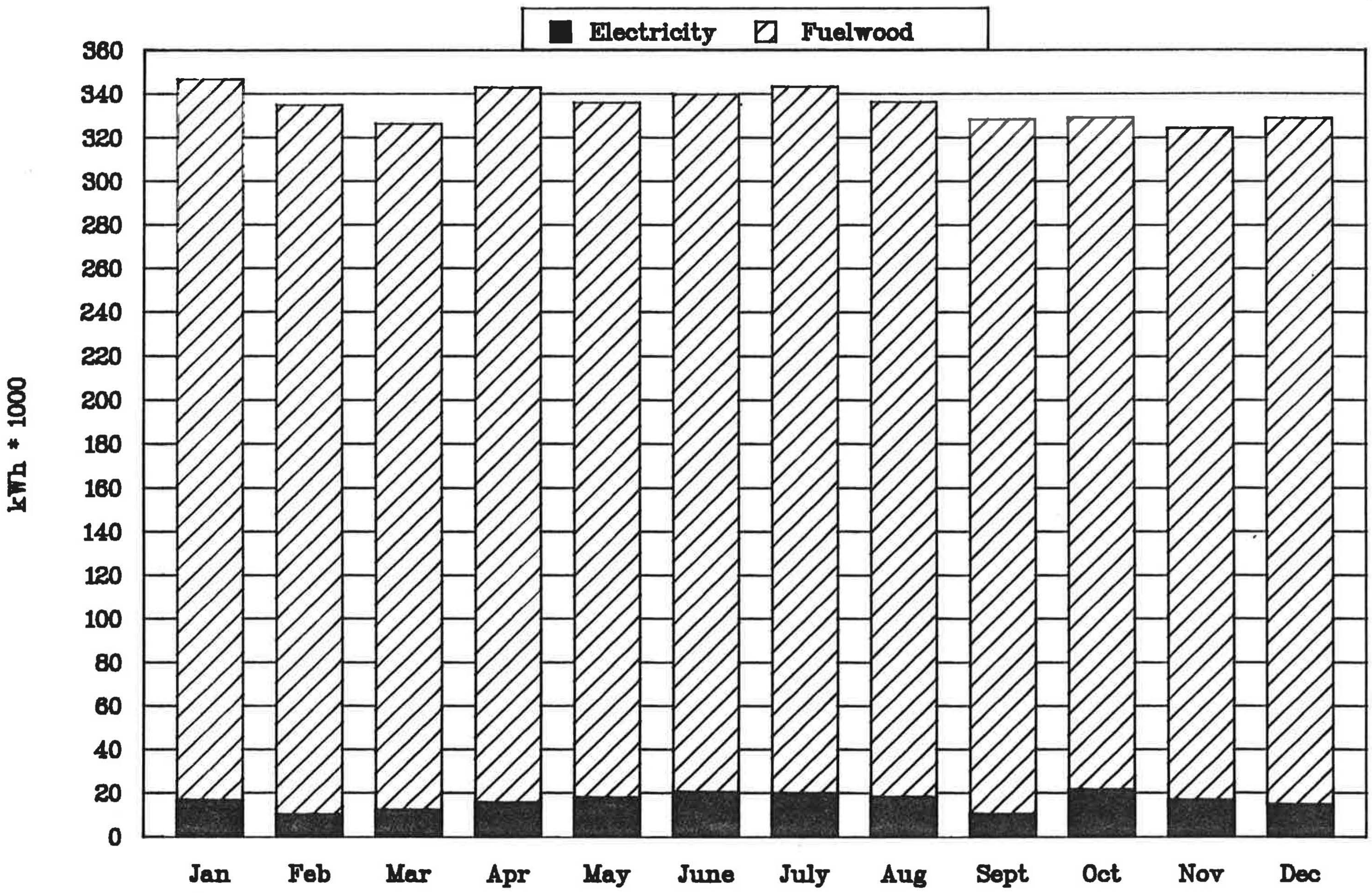


Figure 1

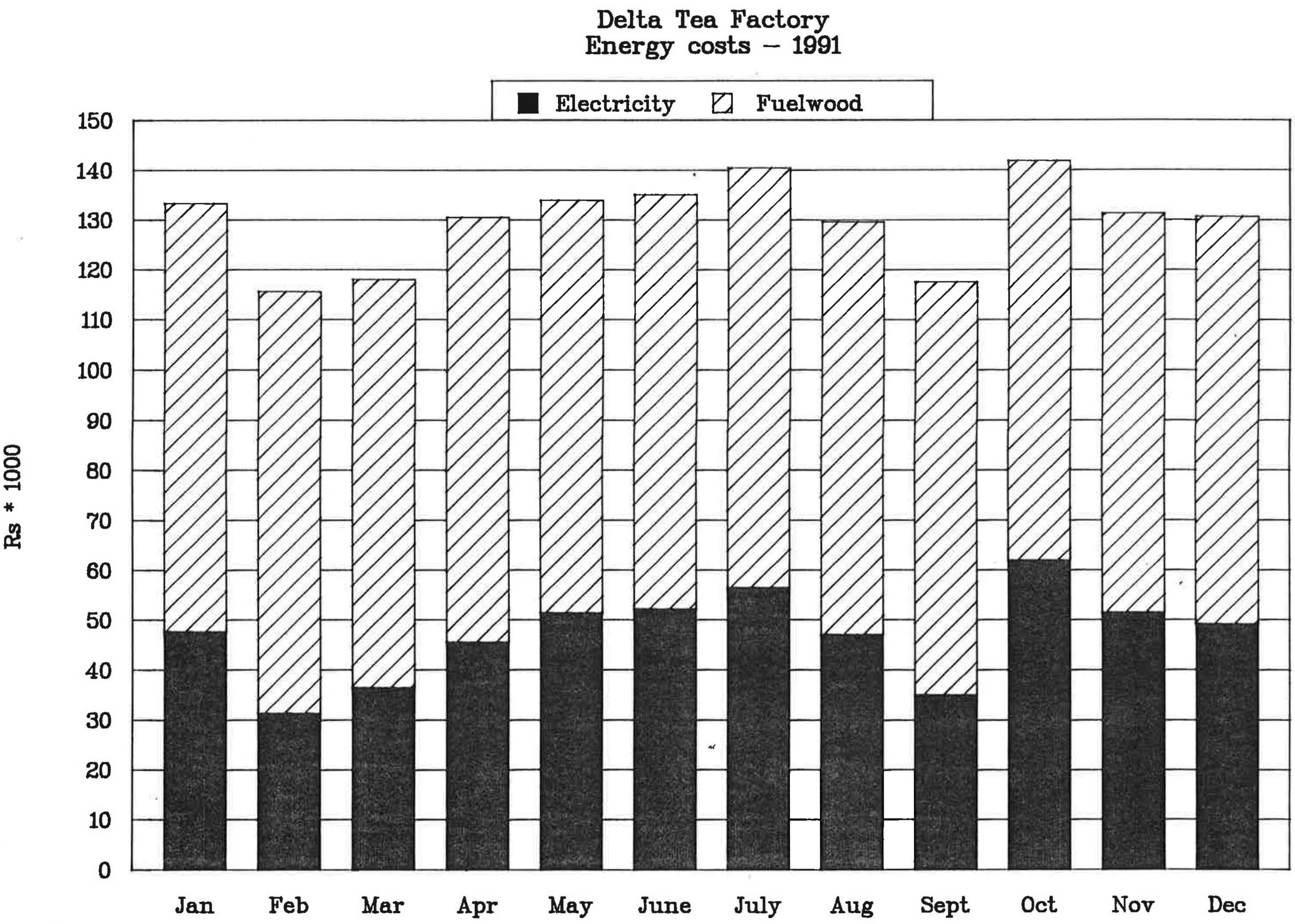

Delta Tea Factory
Energy costs – 1991
Electricity
Fuelwood
Rs * 1000
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec

Figure 2

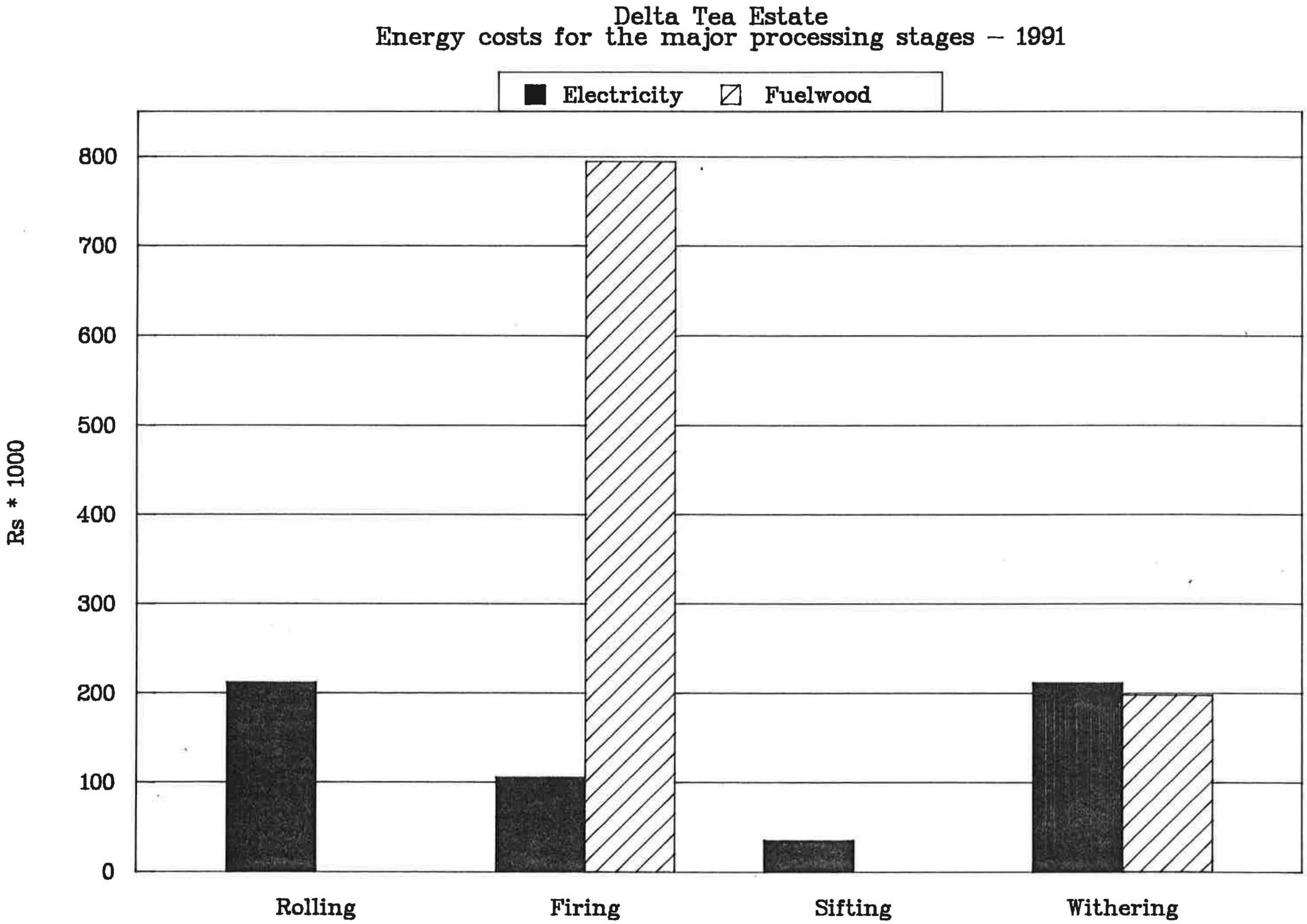

Delta Tea Estate
Energy costs for the major processing stages – 1991
Electricity
Fuelwood
800
700
600
500
400
300
200
100
0
Rs * 1000
Rolling
Firing
Sifting
Withering

Figure 3

APPENDIX 9. FACTORY DATA FOR DELTA ESTATE

DELTA TEA ESTATE - FACTORY DATA 1988-92

		Jan	Feb	March	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
RAINFALL mm	88	-	130	90.10	370	148	149	385	274	313	180	375	183	2597
	89	164	3	40	172	388	307	493	168	226	358	225.5	115	2659.5
	90	262	69	135	133	268	366	199	162	103	320	281	238	2641
	91	151	12.3	104.1	30.8	64	144.4	300	147	143	442	-	-	-
	92	87			265.4	-	-	-	-	-	-	-	-	-
GREENLEAF tonnes	88	130.0	77.8	216.5	167.6	221.5	167.8	158.9	160.9	134.7	135.3	168.0	131.4	1870.4
	89	116.2	6.5	65.4	57.6	236.4	105.3	178.2	126.5	130.7	130.0	158.3	160.0	1491
	90	123.6	105.4	124.9	202.5	145.7	122.9	89.6	120.1	100.7	131.2	105.3	97.3	1469.1
	91	121.4	86.3	95.9	183.3	172.8	152.9	146.3	141	135.3	145.6	110.8	135	1626.9
	92	109	73.4	30.2	24	279.6	-	-	-	-	-	-	-	-
MADE TEA tonnes	88	32.2	19.5	51.0	37.4	50.8	37.9	34.7	35.6	29.5	32.3	39.2	30.0	430.1
	89	28.1	22.7	17	14.3	52.8	23.5	24.1	28.0	29.3	29.4	35.3	37.0	304.5
	90	29.7	26.5	29.6	48.0	31.1	25.7	19.2	26.4	24.0	31.1	23.9	30.5	348.4
	91	27.7	21.1	23.8	52.3	49.7	42.9	40.8	31.9	31.5	31.6	25.0	30.6	373.4
	92	26.8	12.3	8.7	5.7	60.3	-	-	-	-	-	-	-	-
OUTTURN %	88	24.75	25.07	23.53	22.32	22.96	22.61	21.92	22.10	21.92	23.89	23.34	22.82	22.98
	89	24.22	26.27	26.01	24.76	22.32	22.31	20.43	22.15	22.41	22.62	22.32	23.29	22.87
	90	24.01	25.13	23.72	23.71	21.37	20.91	21.39	22.01	23.81	22.75	22.5	21.91	22.76
	91	22.81	24.43	24.82	23.5	22.81	22.16	23.08	22.64	23.26	21.67	23.46	22.7	22.93
	92	24.57	26.34	28.26	23.87	21.56	-	-	-	-	-	-	-	-
YIELD tonnes	88	89	54	142	103	141	106	96	99	81	90	109	83	1193
	89	79	69	48	40	148	66	68	79	82	83	100	104	857
	90	84	75	84	135	88	73	54	75	68	84	67	61	948
	91	80	60	69	124	113	98	97	92	91	91	99	125	1292
	92	101	70	28	18	206	-	-	-	-	-	-	-	-

Delta Tea Estate - Factory Data 1988-92 continued

		Jan	Feb	March	Apr	May	June	July	Aug	Sep	Oct	Nov	Dec	Total
FIREWOOD CuM	88	253	254	252	252	257	264	254	254	257	284	270	255	258
	89	261	264	261	264	269	265	267	255	258	263	254	265	263
	90	281	256	257	258	239	245	255	251	251	256	250	243	254
	91	252	248	240	250	243	244	247	243	243	235	235	240	244
	92	243	250	250	243	-	-	-	-	-	-	-	-	-
LABOUR Kg/man	88	43	42	42	37	38	40	43	45	42	45	42	44	41
	89	42	41	42	42	43	42	47	43	44	46	44	44	43
	90	49	44	50	43	41	43	42	40	43	42	41	39	43
	91	45	46	50	47	43	47	41	40	46	42	45	46	44
	92	46	43	45	31	-	-	-	-	-	-	-	-	-
NET SALES AVERAGE Rs/kg	88	39.58	42.77	42.71	41.43	38.16	38.45	36.11	35.12	35.04	38.38	32.76	38.68	-
	89	37.31	40.9	42.19	44.06	44.06	47.75	40.25	41.76	58.92	61.1	60.61	61.19	-
	90	64.1	69.39	66.99	62.53	62.53	53.55	49.59	54.67	58.37	61.47	61.56	57.84	58.55
	91	57.76	58.98	58.11	56.43	56.43	48.68	38.96	37.05	39.05	44.05	41.1	39.84	44.51
	92	44.47	45.77	51.01	58.88	58.88	-	-	-	-	-	-	-	
COST OF PRODUCTION Rs/kg	88	37.87	52.03	38.11	49.21	38.36	43.79	-	51.55	58.49	50.67	40.01	68.87	-
	89	53.65	56.47	62.88	78.26	38.85	76.42	57.38	57.74	53.89	63.6	53.97	56.93	-
	90	51.72	51.44	54.59	41.89	62.52	73.71	102.86	64.24	74.74	63.75	75.54	62.02	62.1
	91	60.44	66.44	63.02	54.8	53.38	56.51	64.52	66.87	62.61	65.05	64.29	61.66	60.98
	92	68.77	83.54	106.34	237.07	-	-		-	-	-	-	-	-

DELTA TEA ESTATE - FACTORY OPERATING COSTS 1991

Budget		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Mean
0.19	Upkeep	0.10	0.07	0.15	0.03	0.03	0.07	0.19	0.16	0.10	0.10	0.20	0.25	0.12
0.76	Machinery	0.21	0.33	0.24	0.23	0.33	0.37	0.23	0.53	0.35	0.29	0.41	1.66	0.43
0.60	Factory Staff	0.66	0.82	0.72	0.39	0.47	0.58	0.52	0.65	0.57	0.62	0.64	0.56	0.58
0.25	Watchman	0.35	0.44	0.45	0.17	0.17	0.21	0.23	0.26	0.26	0.27	0.25	0.25	0.26
1.39	Teahouse Lab	1.41	1.29	1.17	1.33	1.47	1.41	1.42	1.55	1.35	1.47	1.43	1.40	1.40
1.20	Fuel for Drier	1.70	1.39	1.49	1.57	1.88	1.71	1.89	1.95	2.08	2.35	2.34	1.94	1.86
1.85	Electrical Power	2.02	1.49	1.56	1.13	1.06	1.54	1.41	1.51	1.10	1.95	2.13	1.52	1.50
0.03	Factory Water		0.03	0.04	-	-	-	-	-	-	0.08	-	0.02	0.01
0.15	Teahouse Sundries	0.07	0.01	-	0.05	0.03	10.00	0.07	34.00	0.13	-	0.08	0.11	0.08
3.28	Packing Materials	2.52	3.22	2.94	3.16	3.24	3.20	3.50	3.34	3.80	2.60	3.00	3.39	3.18
0.54	Depreciation	0.63	0.83	0.73	0.34	0.35	0.41	0.43	0.55	0.56	0.55	0.60	0.49	0.51
10.24	TOTAL	9.67	9.92	9.49	8.40	9.03	7.60	9.69	10.84	10.30	10.28	11.12	11.59	9.93
	COP	60.44	66.44	63.02	54.80	53.38	56.51	64.52	66.87	62.61	65.05	64.29	61.66	60.98
	NSA	57.16	58.98	58.11	56.43	57.92	48.68	38.96	37.05	39.05	44.05	44.10	39.84	44.51