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SOME ENERGY SAVING ACHIEVEMENTS OF THE TEA INDUSTRY IN SRI LANKA

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INTRODUCTION

At the begining of the Tea Industry in Sri Lanka, micro hydro was the main source of power for its factories, and power was transmitted to machinery by line shafts and belts. As the Industry developed line shafts and belts were replaced with DC generators and with further progress by AC generators. At the peak use of Mini/Micro Hydro systems it is on record that there had been between 400-600 factories depending on the energy potential of streams and rivers.

In the independent era of Sri Lanka, with the development of large scale hydro power generating plants with excess capacity there was considerable pressure on tea estates to switch from micro hydro power to grid electricity. In the period that followed up to recent times there were no incentives to have these hydro systems in an operational state. By 1985 only 5% of these systems were operating. At about this time with costs of electricity escalating some of the abandoned systems have been rehabilitated with modern turbines having electronic load controllers (ELC). These units are operating satisfactorily on estates such as Mahawela, Hapugastenne, Uda Radella to just name a few. However, there is much more scope to harness the full hydro potential found on tea estates by rehabilitation of the olden day hydro systems.

Electrical Energy Savings Options/Achievements

The only area where energy savings seem possible lies in the unit operation of withering. As at now electricity consumption in withering is around 0.46 Kwh/kg MT and with good housekeeping it is estimated that the electricity consumption could be reduced to 0.23 Kwh/kg made tea. At a national level this represents a saving of 46 Gwh/annum.

Thermal Energy Saving Options/Achievements

Thermal energy consumed in the unit operations of withering and drying depend, as at now, on highly inefficient systems of heat generation. Savings can be achieved by R + D leading to more efficient systems and improvement of process control in both withering and drying. This is now all the more

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important for the Tea Industry in order to conserve Sri Lanka's scarce fuelwood reserves. In this context the following energy saving options have either been looked into or are under serious consideration by the Tea Research Institute as well as by the Industry.

a. Development of fuel efficient driers.
b. Development of fuel efficient air heaters.
c. Development of waste heat recovery systems.
d. Utilization of fuelwood at its maximum potential.
e. Co-generation of process heat and electricity by wood gasification.
f. Direct use of solar energy for tea drying and withering.

Fuel efficient driers

A schematic drawing of a conventional endless chain pressure drier (ECP) is shown in Fig. 1

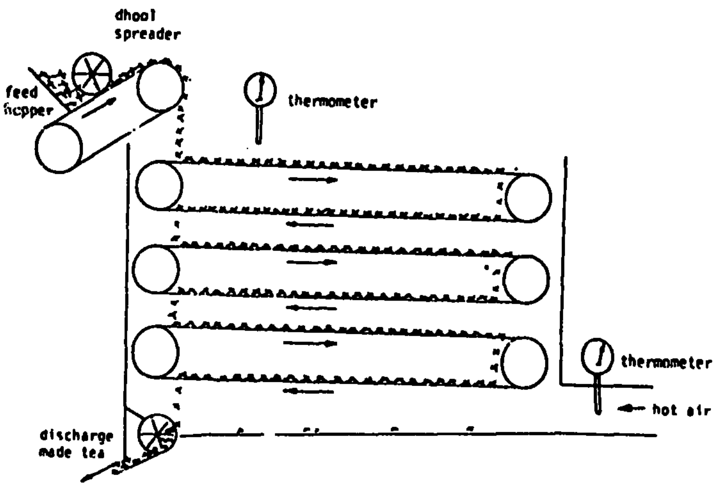

Fig. 1 – *Schematic diagram of a three stage ECP drier.*

These driers have been in use in the tea Industry for many decades and continue to be used even at present times by a very large majority of production units. Fuel efficiency-wise they are far from satisfactory. The highest efficiency that can be conceived of in relation to operating parameters is about 36% (de Silva, 1993). This prompted the Tea Research Institute to pioneer into Fluidized Bed Drying which resulted in the Fluid Bed Driers depicted in Fig. 2.

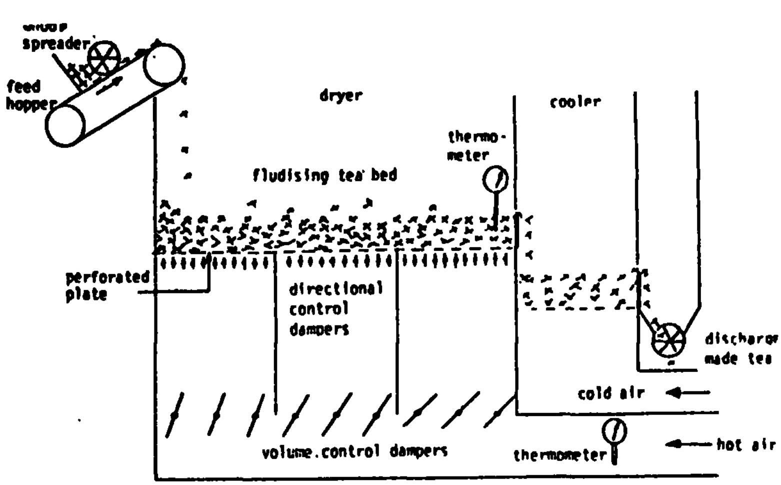

Fig. 2 - *Schematic drawing of TRI - C.C.C. Fluidized Bed Tea Drier*

Theoretically possible efficiency of TRI – CCC Fluid Bed Drier is 54% as against 36% for conventional driers. This represents a fuel saving of 33 1/3 % per unit of made tea. Further developments have since taken place and improved versions of Fluid Bed Driers are now available to the Industry.

During R + D leading to the fabrication of Fluid Bed Driers it was clear that these driers are not suitable for large leaf grades produced by the Low Grown Sector, which accounts for nearly 50% of Sri Lanka's production and this sector still depends on the age old ECP driers.

The higher efficiency in Fluid Bed Driers was achieved by drastically changing the operating parameters such as air flow rates, operating temperatures, etc. and in the case of ECP driers so long as processing techniques remain as they are now there is very little hope in improving efficiencies of these driers and the chances of using solar energy for tea drying would remain very slim. Operating parameters of conventional driers need to be re-examined and changed in order for new drier designs to emerge. This seems feasible at least for Low Growns and the Tea Research Institute is pursuing such projects.

Fuel efficient Air Heaters

The fuel efficiencies of wood fired air heaters, currently in use are at best around 65% (De Silva, 1993). A furnace efficiency of 90% is about the maximum realisable and though too good to be believed this has been achieved by a prototype Air Heater of Dutch origin installed at one of the Up Country factories, under an aid programme (Haskoning, 1989). However, even though this furnace was conceptually sound, it was mechanically defective, resulting in constant furnace failures. From the experience gained with this furnace, local fabrication of a conceptually similar furnace with superior materials is being undertaken by a domestic engineering firm. This heater is designed for an efficiency of 75%. The general construction of the heater is of three basic sections namely primary combustion chamber, secondary combustion chamber and heat exchanger. The firewood is dried, burned and gasified in the primary chamber. This process takes place just above the grate through which primary combustion air is sucked into the system. Other design features of the system are:

(i) The secondary combustion chamber completely burns the volatiles thereby extracting the total quantum of heat available in the firewood.

(ii) The secondary chamber flame heats the primary heat exchanger which is constructed using stainless steel for critical areas.

(iii) The flue gäses pass through this chamber and enters the tube banks eliminating direct flame from touching the tubes, virtually eliminating tube burn out.

(iv) Charging of fuelwood is done through a hopper which eliminates the need for stoking, an unpleasent task which is generally neglected by the estate labour. There is no special preparation for the fuelwood which can be of normal recommended sizes.

(v) Heated outlet air temperature is monitored electronically enabling the shut off of primary air automatically which retards the combustion on reaching the desired temperature contributing to high efficiencies as well as stable temperature at discharge,

and

(vi) The heater is designed both to generate and utilize the heat at optimum level. The flue gases leave the heater at a temperature less than 100°C thereby minimising the heat losses in the stack.

Waste heat recovery systems

Moist air expelled from driers, especially ECP driers, contain bulk of the energy given to hot air by the furnace. Recovery of part of this energy using a heat regenerator was thought feasible. On information supplied by the TRI a regenerator was designed and fabricated by a firm in U.K. In essence, the regenerator is a slowly rotating mass of aluminium with access to air flow through it so that at any given time part of the rotor is exposed to exhaust air from the drier and the other part to the ambient air stream of the furnace. This unit is expected to save about 20% of the waste heat. The actual performance and economic feasibility is yet to be studied.

Fuelwood utilization at maximum potential

Even though air drying over at least 12 weeks has been advocated to reduce the moisture content from about 50% (wet basis for raw wood) to about 20% (wet basis), this is hardly adhered to by the Industry for various reasons. Moisture content of fuelwood as used by the Tea Industry varies from 25 to 45% and the average is esimated at 35%. Considerable saving in fuelwood usage is achievable and if the moisture is reduced to the desired level of 20%, if the saving in fuelwood could be estimated at 22%, on the basis that LHV of fuelwood at 20 and 35% moisture are 13.3 MJ per kg fuelwood. Use of furnace flue gases for the drying of fuelwood is being popularised to achieve better utilization.

Co-generation of Process Heat & Electricity by wood gasification

As a solution ot the energy crisis that existed in mid 80's accompanied by frequent power cuts of long duration wood gasification was looked into as a total system for co-generation of Process Heat and Electricity. Accordingly a total energy system comprising of a wood gasifier, a gas burner and a gas engine cum generator fabricated by BECE of Netherlands was purchased by the Tea Research Institute for field testing.

This system included a wood processor, a gas cleaning unit and a gas cooling unit. The gasifier is of a fixed bed down draft type which is designed to convert approximately 190 kg wood per hour into 440 m^3 (20°) gas with a LHV of approximately 5000 KJ/m^3 and this gas is suitable as a fuel for internal combustion engines after removal of entrained dust particles and cooling of the gas. The unit has a rated co-generation capacity of 500 Kw thermal and 60 Kw electricity at a voltage of 220/380V, 50 Hz.

The system is installed at the Institute's Low Country Station and the general layout of the system is depicted in figure 03. The gas-burner is coupled to a conventional ECP drier/air exchanger (4'). Process heat from this system has also been utilized directly without the use of heat exchanger. The quantum of electricity generated has been tested under low, medium and full load conditions.

Steam was tested intermittantly over a long period of time from about February 1988 to about September 1990. During this period the cumulative running time of the system was 1468 hours, with the system being used for thermal generation over a period of 1165 hours and for electrical generation over a period of 324 hours generating 8874 Kwh.

Typical performance data of the system recorded during tests compared with performance data of the air heater using traditional combustion of split firewood logs are as follows:

a Thermal

	Gasifier system		*Conventional System*
	Direct firing over riding air heater	*Indirect firing via air heater*	*Indirect Firing via air heater*
Spec, fuel consumption under equillibrium conditions (kg. fuelwood/kg MT)	0.72	0.80	1.38
Moisture content of fuelwood used (%wet basis)	17	17	35 (average)
LHV of fuelwood MJ/kg	13.9	13.9	10.4
Gross thermal input to system Gross thermal input to system (MJ/kg MT)	10.01	11.12	14.35
Nett thermal requirement (MJ/kg MT) (Ref. DE, Silva, 1993)	8.9	8.9	8.9
System efficiency (%)	89	80	62
Saving of fuelwood compared with conventional system (%)	48	42	–

b Electricity generation

Specific Consumption of fuelwood (kg. fuelwood /Kwh)	– 1.85
Moisture Content of fuelwood (% wet basis)	– 25
LHV of fuelwood MJ/Kg	– 12.3
(Kwh/Kg)	– 3.417
Efficiency of Electrical Generation (%)	– 15.8

Composition of Gas

Typical composition (by volume) of the gas produced by co-generation system after cleaning and cooling compared with those reported in the literature are as follows:

Gas	TRI Gasifier	Gasifier reported in Literature
CO	16.8%	18 - 25%
CH_4	1.8%	3 - 5%
H_2	21.0%	13 - 15%
CO_2	13.4%	5 - 10%
O_2	0.8%	Nil
N_2	46.2%	45 - 54%
C_nH_m	Nil	0.2 - 0.4%
H_2O	Nil	10 - 15%

The above composition of gas generated by the system installed at TRI gives for the mixture a LHV of 5044 KJ/m^3 which is in close agreement with a value of 5000 KJ/m3 indicated by BECE, the suppliers of the system. A notable feature is the high quality of the gas indicated by the absence of heavy hydrocarbons and minimal water vapour. Above normal proportion of CO_2 with a corresponding lowering of CO content though not a serious disadvantage as far as gas quality is concerned, is indicative of malfunctioning of the system which led to serious technical problems (discussed later).

Economic considerations of wood gasification

a) **Fuel Savings**

Even though we have found no difference between teas fired directly (over riding the air heater) compared with those fired indirectly (via the air heater) we are reluctant to advocate direct firing for many well known reasons.

With indirect firing using the gasifier system, as already indicated, the specific fuelwood consumption as recorded during tests is 0.80 kg/kg MT as against 1.38 kg/kg MT for conventional method of drying - a saving of 0.58 kg fuelwood per kg of made tea. However, this saving has been questioned and attributed to higher heat value of wood (resulting from lower moisture content associated with comparatively small size of fuelwood) used in the gasifier system in comparison to the lower heat value of fuelwood used in the conventional system. The following analysis should settle the issue.

i) **At 35% moisture of fuelwood**

Specific consumption	-	1.38 kg/kg MT
Calorific Value of fuel	-	10.4 MJ/kg
Gross thermal input to convention system	-	14.35 MJ/kg MT

ii) **At 17% moisture of fuelwood (corrected to fuelwood used in gasifier system)**

Gross thermal input	-	14.35
Calorific value of fuel	-	13.90
Calculated specific consumption	-	1.03 kg/kg MT

On the basis of the above analysis the fuelwood saving of 0.58 kg/kg MT associated with the use of the gasifier system could be apportioned as follows :

On account of dryness factor	-	0.35 kg/kg MT
On account of efficient fuelwood usage	-	0.23 kg/kg MT
Total savings	-	0.58 kg/kg MT

Technical Problems

After 6 months of continuous daily operation technical problems chiefly as regards the performance of the gas reactor were encountered. Cross section of this reactor is depicted in figure 4:

The bunker section with the double valve fuel feeding system was a constant source of problems. The feed valves did not function as expected. Suspected air leaks through these valves, due to improper closure of these valves caused by deposition of tarry material led to excessively high temperatures in the region of the throat section, causing the throat ring to warp, and damaging the refractory lining. Another problem was the corrosion of the inner cylinder bottom section. Air leaks is the suspected factor for the observed high proportion of CO_2 with a corresponding lowering of the proportion of CO and also the cause of excessive temperature development in the region of the throat ring.

TRI is now engaged in finding solutions to these technical problems and if successful the system of co-generation will certainly be an attraction to the tea industry as an effective means in the rational and efficient use of scarce fuelwood and as a means to displace the use of oil altogether. However, wide

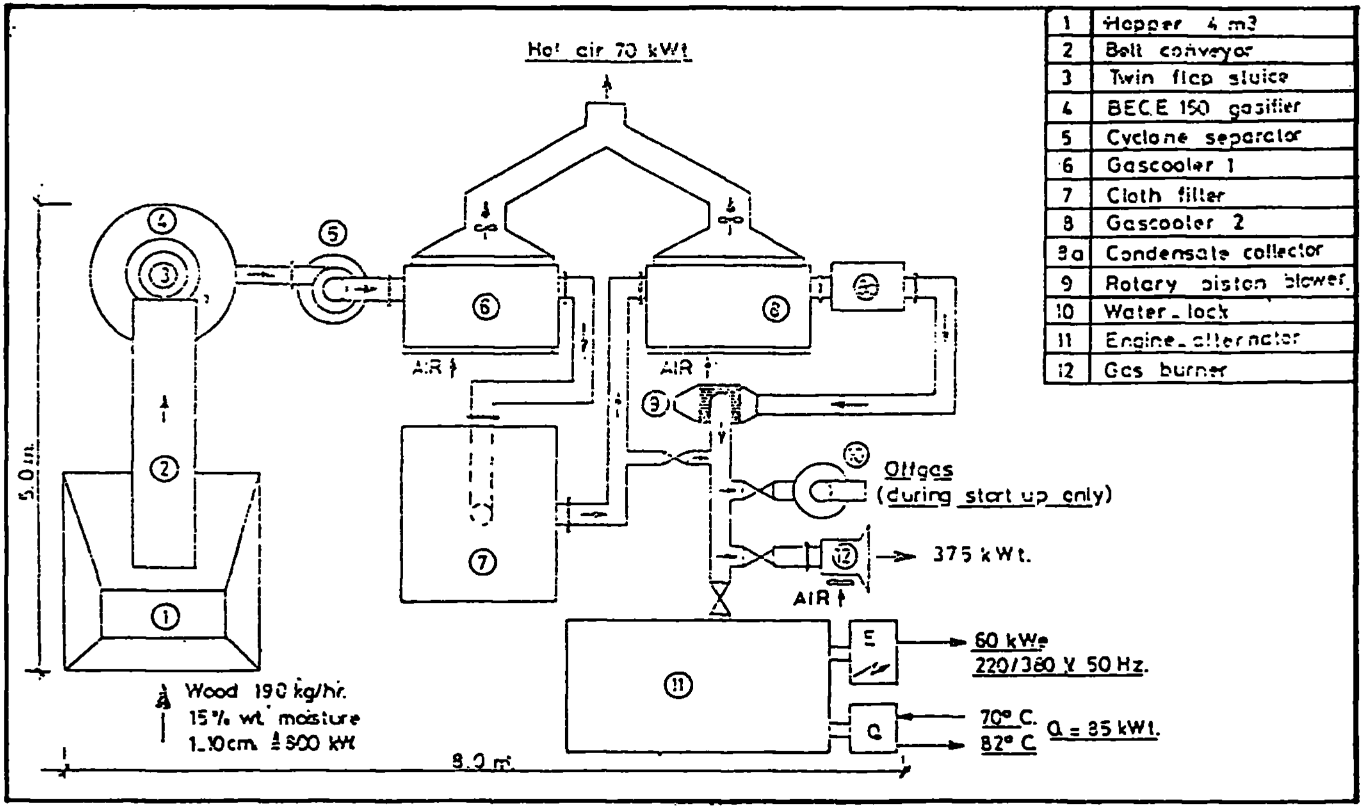

Fig. 3 – *General layout of total Energy Wood Gasification System*

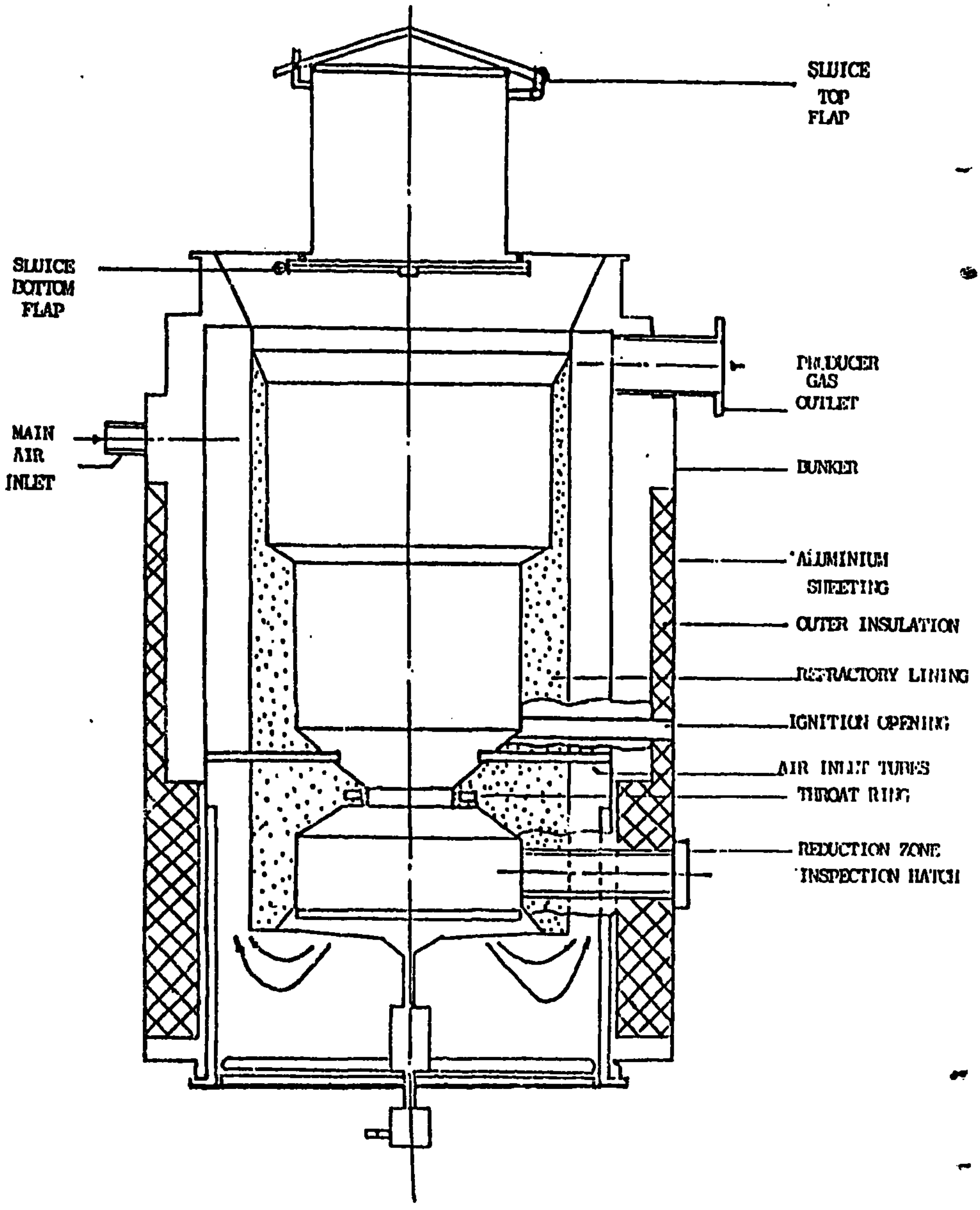

Fig. 4 – *Cross Section of Gasifier.*

acceptance of co-generation would depend on the economic viability which is difficult to assess at this stage. It would certainly depend on the technology being developed by domestic engineering entrepreneurs and this transfer of technology to gain wide acceptance, must suit local needs and conditions. The level of technology should also allow the domestics to cope easily with any maintenance and operational problems that may arise.

In the local scene, National Engineering Research & Development Centre (NERD) have pioneered in the construction of gasifiers for tea drying. These units cater to the generation of thermal energy and further development may be necessary to improve the gas quality for the generation of electricity. Even without the latter development these units worked in conjuction with existing air heaters will improve upon the efficiency of the air heater from 65% to 80% and with the development of operational safety features, these gasifiers sooner or later will find a place in the tea industry.

Direct use of solar energy for tea drying and withering

An EC funded feasibility study for the development of solar energy consumption in tea processing has already been carried out (Laing Design & Development Centre, 1983).

The relevant report concluded by proposing the construction of a demonstration unit to utilise a high proportion of solar energy in an integrated fashion for both withering and drying. Designs are already available for the fabrication of a solar energy collecting system and driers. Further R & D has to be carried out to run a commercial drier as a demonstration unit in order to make a commercial assessment of this technology. What is needed now is FUNDING.

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