SOME ASPECTS OF ENERGY UTILISATION AND CONSERVATION IN TEA FACTORIES

T. Alawattegama

(Experimental Officer, Tea Research Institute of Sri Lanka, Ratnapura, Sri Lanka)

Tea has been Sri Lanka's foremost foreign exchange earner since Independence accounting for over two-thirds of such earnings. Although this share has decreased during the last few years, 207.8 million kg tea were exported in 1986 totalling an export earning of Rs. 9,252.7 million (1). This industry, on the other hand, is also a major consumer of energy in the form of electricity, fuel-wood and oil.

ENERGY REQUIREMENTS

The output of an average tea factory is in the region of 800-1600 kg made tea per day and there are over 800 factories in the island.

At the beginning of this decade, the tea industry consumed 47,000 tonnes of liquid fuel per annum (2) and 600,000 tonnes of fuel-wood per annum (3). (With the introduction of more fuel-wood burning heat exchangers in the recent years as a measure to combat the ever increasing cost of liquid fuels, these figures may have changed considerably). The electrical energy consumption in a factory is around 0.9 KWh per kg of made tea produced. A power demand of 150 - 200 kVA is normally recorded in an average tea factory.

ENERGY COSTS

In low elevations where rubber fire-wood is available in plenty and transport cost is less, the delivered cost of a cubic yard at the factory is about Rs. 125/-. In the hill country, the delivered cost can

be as high as Rs. 250/- per cubic yard. A litre of liquid fuel costs around Rs. 8/17 while the cost of a litre of furnace fuel is Rs. 5/-. A unit of electricity is Rs. 1/45. In addition, a maximum demand charge of Rs. 100/- per kVA per month, a fixed charge of Rs. 200/- per month, and a fuel adjustment charge, when in effect, too have to be added to the electrical cost.

FUEL WOOD

The Tea Industry receives its major share of fuel wood from rubber plantations and jungles. The balance is met by shade trees and other fuel trees within tea plantations. The first two sources are limited in time and, in future, mainly the last two sources will remain the main source of fuel wood. It is, therefore, essential that a serious view is taken with regard to the establishment of fuel wood plantations (4).

Wood is mainly composed of cells and large quantities of water. The cell walls are made up of polymers like cellulose and hemi-cellulose which are bound together with glue like lignin. The low energy density of wood is due to a large amount of space in the cell structure and these spaces are filled with water and air.

When a piece of wood is burnt, the moisture present in that piece must be driven off first before ignition can take place. Energy is absorbed in this stage to keep the temperature of water (moisture) at boiling point ($100^{o}C$) in order to change it to a gas phase (steam). The moisture content of the wood determines the amount of energy and time required to complete this process. If the piece of wood is very wet (moisture content above 67%), ignition will not take place. This results from too much of water being absorbed to prevent the temperature from rising to the ignition point.

The Net Heating Value (MJ/kg) of a fuel represents the energy available in that fuel for doing work. The Net Heating Values (MJ/kg) of all woods, for a given moisture level, are nearly the same. The prime factor which changes the NHV is the presence of moisture in wood. For example, the NHV of Fir wood (5) at three different moisture levels are:

	Moisture % (Wet basis)	NHV (MJ/kg)
Fir, freshly felled	40	11.4
air dried	18	14.9
kiln dried	10	17.8

This shows that lesser the moisture content, higher is the heating value.

It is therefore, very clear that it is important to have dry firewood at the factory for efficient burning. And since, firewood is purchased on a volume basis (cubic yard, etc), it is also profitable to the factory if the most well dried as well as the heaviest wood is purchased. If firewood arriving at the factory is stored under an open sided shelter in a criss-cross manner leaving sufficient gaps between logs to promote air movement, the wood can be air dried very easily. This process however consumes time.

Another possibility is to use the exhaust gases from the firewood heater to drive away moisture from the wet firewood. As the flue gases do not contain significant amounts of sulphur, there is no risk in the formation of acids that will damage metal structures or masonry.

After removing moisture, the second phase of combustion is the break-down of wood polymers (at temperatures from about 150°C to 500°C) into gases that burn outside the piece of wood when they combine with combustion air. This is an important stage as much of the energy released in burning comes from this "flaming combustion".

The last stage of combustion, the "glowing combustion" is the oxidation of carbon present on the surface of the wood. This takes place when oxygen in the combustion air comes in contact with the exposed surfaces of the wood.

In order to promote the second phase described above, the firewood should not be in the form of large logs and in order to promote the last stage of combustion, a larger area of the wood should be exposed. Both these requirements can be achieved by splitting logs into halves or quarters. A hydraulic wood splitter can be employed for this purpose.

LIQUID FUELS

Even now a good number of our tea factories use liquid fuel to obtain their hot air requirements for processing. Although it is a much easier material to store and handle than firewood, less attention is paid to these two aspects in many factories. The result due to this negligence is (i) puddles of oil due to leaky storage tanks and pipe lines, (ii) clogged filters imposing additional duty on pumps, and (iii) poor combustion, all leading to high fuel consumption. A loss of even one drop of oil every second can cost over 4,000 litres a year! It is a good practice to check for oil leakage daily and to clean filters weekly and tanks annually.

Oil must be vaporised before combustion can take place, and atomizers are used to aid rapid vaporisation. Optimum atomization depends on the design of the atomizer and the viscosity of oil at the burner nozzle. Atomizers are the most important element of the burner and burners are often distinguished by the type of atomizer that they use such as low pressure air burners, medium pressure air burners, rotary cup burners, etc.

Since the viscosity of the oil also influences the degree of atomization, it should be maintained at the correct value. Light oils like liquid fuel are easily atomized, but heavy residual oils like furnace fuel must be heated to reduce the viscosity before atomization. The viscosity of the oil should ideally be around 100 Seconds Redwood I at the burner tip.

COMBUSTION

The essential components of a heat exchanger that is commonly used in our factories are:

i) Burner in case of oil and fire bars in case of firewood.

ii) Combustion space - sufficient to maintain necessary heat generation rate.

iii) Heat exchange surfaces - usually a mass of cast iron or bricks for absorption and transfer of radiant heat and tubular or duct like passages for transfer of convective heat, and

iv) Induced draft fan - which creates the suction effect for the entry of primary air and flow of air through the heat exchanger areas and the pressure to push the flue gases through the chimney.

All fuels, whether they are solid, liquid or gaseous, contain two elements which, in burning, produce most of the heat. These two elements, carbon and hydrogen, are present in different proportions in each fuel.

	% Carbon	% Hydrogen
Dry wood	52.0	6.3
Liquid fuel	86.0	10.5
Natural gas	76.5	23.5

Oxygen is required to burn any fuel and this is obtained from atmospheric air which is 20.9% oxygen by weight, the balance being mainly nitrogen which plays no part in the combustion process.

Combustion is the chemical reaction between a fuel and oxygen which results in the release of heat. Carbon and hydrogen in the fuel are burnt with oxygen from air as illustrated below:

Fuel (Carbon + Hydrogen) + Air (Oxygen)
$\longrightarrow$ Carbon dioxide + Water Vapour + Heat

In practice, it is not possible to provide just the right quantity of oxygen required to complete combustion as making the air (oxygen) and fuel distributed and mixed evenly is virtually impossible. An excess of air has therefore to be added to ensure that all of the fuel elements combine with oxygen to burn completely, but the amount of excess air should be kept to a minimum to avoid excessive waste of heat. The combustion equation in practice is:

Fuel + Air —— Carbon dioxide + Heat + Unburnt fuel + Un-utilized oxygen + other gases + water vapour.

It is seen from this equation that the flue gases contain unburnt fuel and un-utilized oxygen; but they have not reacted with each other as they were not available to react together at the required temperature, which is above the ignition temperature.

Higher the quantity of excess air, the lower will be the flame temperature resulting in a lower heat transfer. Maximum flame temperature required for rapid transfer of heat to the heat exchanging surfaces, is obtained only when no excess air is used.

Further, if more excess air is used, the greater will be the weight of flue gas per unit weight of fuel burnt. This increases the heat loss as air enters the burner at ambient temperature and leaves the heat exchanger at a higher temperature taking a considerable amount of useful heat with it.

On the other hand, if insufficient oxygen is supplied, some of the carbon may pass through the combustion process only partially burnt and may be seen in the form of solid deposits and/or smoke.

The intake of excess air could be controlled by adjusting the damper at the I.D. fan, and experienced operators often rely on the smoke at the chimney end, the colour of the flame or the flue gas temperature in adjusting the I.D. fan damper to control excess air.

Measuring the oxygen content of the flue gas, however, is a more objective method in controlling excess air intake. A detailed description of this aspect will form the subject of another article.

However, it is worth noting that better than 5% excess air (excellent combustion) can be achieved only with sophisticated controls and burning equipment with continuous monitoring of oxygen content in fuel gases.

ELECTRICITY

In a tea factory, motors alone consume more than 80% of the supply. Thus, a little increase in their performance will be a great step in conserving electricity.

When selecting a motor, the main factors considered are the driven equipment requirements and the initial cost. An important factor that should be taken into consideration seriously along with the other factors is the efficiency of the motor. Unfortunately, this information is not indicated by most of the manufacturers. It is simply because a less efficient motor needs more kWH to deliver a specified amount of work. Even if an efficient motor costs more to start with, it will pay back the extra cost within a short time. However, if a motor is used sparingly there may be no significant financial advantage in selecting a more efficient motor.

Over-size motors consume more energy for a constant load in comparison with a correct size motor and having an over-sized motor alone is not an insurance against burning although an over-sized motor is more capable of dealing with momentary overloads without burning. It only contributes to the lower power factor in the system. Thus, it makes the user to pay on a continuous basis. Hence, selecting a correct size motor is an important step in energy saving.

Let us now consider the economics of selecting a correct size motor by the following example. It should be noted that in this example, the comparison of the effect of the load is being made for a given quality motor and no comparison is being made between an inferior motor and a better one.

A withering trough requires a 5.7 kW motor. Two motors, a 7.5 kW and a 11 kW are on offer.

Motor Ratings	11 kW, 21A 440 V, 960 rpm	7.5 kW, 15A 440 V, 960 rpm
Load	5.7 kW	5.7 kW
Loading	52%	76%
Efficiency	82%	89%
Power factor	0.65	0.85
Input kW	6.95	6.4
Input kVA	8.48	7.53
Kwh consumption/annum (5000 hrs)	34,750	32,000
Annual saving in kWH	-	2,750
Running cost at Rs. 1/45 kWH	50,387.50	46,400
Annual saving in running cost	-	3,987.50
Annual saving in demand charges at Rs. 100/- kVA/month	-	1,140
Cost of motor	22,500	15,000
Saving in purchase cost	-	7,500

The above analysis shows that the use of the 11 kW motor instead of the 7.5 kW motor will lead to:

i) Higher consumption by 2,750 kWH/annum

ii) Higher running cost by Rs. 3,987/50 per annum

iii) Higher demand charges by Rs. 1,140/- per annum, and

iv) Higher purchase cost by Rs. 7,500/-

Load on motors can be identified with the help of a clip-on ammeter or a line ammeter and the extent of which motor is over-sized can be determined by comparing the average current drawn by the motor with its rated current.

Another grossly neglected area in a factory is the lighting system. Few simple factors that contribute to economise energy in a lighting system are:

i) Switch 'ON' when required and switch 'OFF' when not required.

ii) Provide switching arrangements so that only the required lights can be used.

iii) Dirty lamps deliver far less light than being paid for; clean them often.

iv) Light levels in over lighted areas could be reduced without affecting safety and productivity.

One cardinal rule worth noting for conserving electricity as with any other energy source is: WHEN YOU DO NOT NEED IT - TURN IT OFF.

CONCLUSION

A unit of energy saved is as good as an unit of energy produced at a lesser cost. It is very important to view the ever increasing prices of all fuels and their projected shortages seriously and take all possible steps to ensure that the commercially available energy is well used and thus bring about a reduction in production costs.

BIBLIOGRAPHY

Central Bank of Ceylon (1986).

ABDUL GAFFAR, N.M. and SAMARAWEERA, D.S.A. (1980). Energy for the Tea Industry.

HASKONING (1986). Identification of Energy Projects in Sri Lanka, Part 1, 32.

DE SILVA, R.L. (1979). Tea Q. 48, 32-40.

BAILIE, R.C. Current Developments and Problems in Biomass Gasification, Sixth Annual Meeting, Biomass Energy Institute, Canada, 1977.