Technical Session 2
Cost Reduction in Factory
Chairman N.F. Tankariwala

Mr. N.F. Tankariwala - Mr. Tanakariwala has been in the tea industry for the last 45 years. He is the Managing Director of Moran Tea Company and is the Chairman of the Tea Research Association, Kolkata.

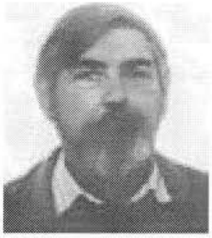
Opening Remarks by the session chairman

Distinguished guests, ladies and gentlemen I consider it as a privilege to have been invited to chair this session on reducing the costs and I thank the organisers for giving me this opportunity. The theme of this session is one of the means to achieve one of the basic objectives of the conference. The first technical session was also on the same theme whilst the first session covered field practices, in this session we are going to deal with processing. We all know that during processing quality can be enhanced or quality can be damaged due to improper techniques adopted in processing. Quality has now become the key word, we have four eminent speakers and I am glad that three of them are going to speak about quality enhancement and reduction in cost. I am sure that some very useful recommendations would emerge from the deliberations. I now have great pleasure in introducing our first speaker Mr. Nigel Melican.

Chapter 11

PROCESSING TEA FOR LOWER COST AND BETTER QUALITY

Nigel J T Melican*



Mr Nigel Melican can rightly be described as a multi faceted and international personality in the tea world. Twenty seven years of R&D with Unilever, including all aspects of tea production improvement – from planting in marginal conditions to optimization of factory and value addition. He is founder and owner of Teacraft Ltd, who provide technical support to the tea industry, particularly novel process equipment, QC instruments, and the award winning Teacraft ECM System for miniature manufacture of tea, now used by far sighted producers around the world, including TRA Tocklai. Teacraft also sells specialty teas through its mail order company Nothing But Tea Ltd, and supplies world class technical consultancy and training through Tea Technology Associates covering diverse topics from tea husbandry, processing, R&D and management, to value addition and marketing. Their consultancy clients include Bigelow, K.T.D.A, Unilever, U.S.A.I.D and World Bank.

INTRODUCTION

The outlook for tea production scene remains grim. Costs rise while prices fall. Typical reports are "auction prices have continued to remain low, even lower than the cost of production in several parts" (Tata Tea Annual Report, 2002), and "with high cost of production arising from low yield and rising operating costs Darjeeling teas are slowly being sidelined" (Goodricke Annual Report, 2002).

Over in Kenya things are little better: "recent prices are barely covering the costs - so the industry is not in a very happy position" (Nigel Sandys Lumsdane, MD of Williamson Tea Africa)[1].

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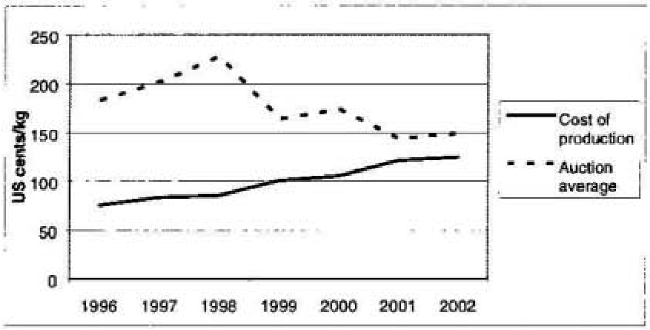
PRODUCTION COSTS

Tea prices have fallen consistently since 1998, but costs of production have risen: fuel and electricity charges up, fertilizer and agrochemical prices inputs up, wage awards up, transport costs up. This is an industry-wide phenomenon with no end in sight.

Figure 1. Tea production cost and price trend – Sri Lanka



In Sri Lanka the cost of production is converging with tea price. In 2002 (Fig. 1) the margin is 16% – combined data [2 & 3]. In south India the cost of production has risen 25% over five years while prices have fallen by 29%; in all India the auction selling price since 2001 has fallen well below the average production cost. In China this cross over point was met in 1995[4].

The sale of tea at less than the cost of manufacture cannot be sustained commercially for long. A positive margin between cost and price is a commercial necessity, yet in 2000 the World Bank predicted[5] a tea price decline of 11% in real money terms to year 2010. For the past 20 years producers (aided, it must be admitted, by tea scientists) have actively increased tea yields to bolster their decreasing margins, but this apparent success has eventually fuelled global oversupply of low quality teas. The hard choice now is to reduce production cost (by efficiency or innovation), or to increase the offered price (by better quality or novelty), or preferably both. The tea scientist has a last chance here to redeem himself.

Often it is those industries that have been forced into the position of low cost producers (or die) who are the producers of low quality tea - global oversupply of low value Argentineans, Vietnams and Indonesians bear witness to this. It may, arguably, be expedient in the longer term that the low cost producers should inherit the markets that the high cost producers are forced to abandon, thus reducing over supply and restoring a balance with demand, but the danger is that low value teas will then predominate. Is there nothing that can be done to buck this trend? Is there no way to save Darjeelings, Keemuns, and Ceylons?

This paper addresses two questions:

1. How feasible is it to reduce the cost of production of tea?
2. Need tea quality suffer if production cost is reduced?

HOW FEASIBLE IS IT TO REDUCE THE COST OF PRODUCTION?

How High is this Cost?

Cost of production of tea is notoriously difficult to compare as it is calculated on a slightly different basis from company to company and between countries, and is often a historical computation while auction prices are current. Typical costs of production are quoted here (USD/kg of made tea) from the recent Accenture report (India) [6] and/or estimated from confidential sources.

Av. Price Margin

	CoP	2003	/Loss
North India[6]	1.62	1.53	(16%)
South India[6]	1.48	1.03	(31%)
Sri Lanka[6]	1.23	1.47	19%
Vietnam[6]	0.96	0.74	(23%)
Kenya (estates) [6]	1.16	1.60	38%
Kenya (smallholders)	1.10	2.02	84%
Malawi[6]	0.84	1.26	50%
Uganda	1.09	1.40	28%
Indonesia (smallholders)	0.80	0.92	15%

The range in production cost is from 0.80 to 1.62 USD/kg whereas the range in profitability is much wider, from a 31% loss to an 84% profit. No data are available for Japan but an increasing number of Japanese manufacturers, including Mitsui and Ito En Ltd., are cultivating green tea in China, attracted by the country's cheaper labour. They are also taking increasing advantage of locally made machinery available at one-third the cost of those sold in Japan. The average price of Chinese grown Japanese green tea is 80% lower than that for tea produced in Japan[7].

How is Cost of Production Split?

Two credible sources have been used for proportioning tea manufacturing costs – the Sri Lanka Census and Statistics Department (2002)[2] and the Asian Institute of Technology Tea Sector Report (2002)[8].

	SLCS[2]	AIT[8]
Green leaf	64%	77%
Processing	6%	9%
Heat energy		3%
Electric energy		3%
Overheads	20%	7%

AIT report that in India, Sri Lanka and Vietnam the processing of green leaf into graded black tea takes about one sixth of the total cost, this is confirmed for Sri Lanka by SLCS. Within the processing sector the energy component is a massive 40% of cost, the balance being factory labour, machinery maintenance, packaging materials, and factory sundries. While strictly outside the direct scope of this paper, it is very apparent that green leaf (growing and plucking) is by far the major component of total tea cost (64-77%), and that two thirds of this green leaf cost is attributable to labour alone. Where labour is scarce, and consequently expensive, the introduction of a system of mechanical harvesting that produces an acceptable standard of leaf would be an industry saviour. Innovative R&D addressed to this aspect is long overdue. Mechanical harvesting of tea has been poorly investigated to date, and largely by people whose interest is vested in the continuance of hand plucking.

HOW COSTS BE REDUCED?

Within the tea processing sector there are four main possibilities to consider:
Reducing energy
Reducing labour
Reducing losses
Manipulating the process

Energy Use Efficiency

Tea machinery tends to be old and well worn, and tea factories tend to be under maintained. Energy represents 40% of the cost of processing, and as will be readily apparent to anyone who walks through a typical tea factory, the opportunities for saving energy are many. Yet how many tea factories have ever had an independent energy audit performed? This would pinpoint specific deficiencies and sources of loss, while providing the manager with a benchmark against which to measure future improvements.

Irrespective of the type of tea being produced, the manufacturing process is one of water removal, from around 80% initial moisture down to 3% final moisture. Product quality depends greatly on the processing skill displayed in the two energy intensive drying processes of withering and firing.

The ratio of thermal energy (fuel) to electrical energy is slightly higher in Orthodox manufacture (92% thermal, 8% electrical) than in CTC (88% thermal, 12% electrical) and the average total energy required per kilogram of tea is slightly lower for Orthodox (4.96 kWh/kg) compared with 5.10 kWh/kg for CTC. This masks a very dissimilar proportioning of electrical usage – 15% for withering in CTC, 54% for withering Orthodox; 45% for CTC cutting, but only 29% for Orthodox rolling[8].

It is one of life's amazing facts that to make a kilogram of steel requires 6.3 kWh of energy, yet to make a kilogram of tea takes on average 7.1 kWh![8] The theoretical energy required to evaporate one litre of water is two thirds of a kWh. The theoretical energy to dry one kilogram of green leaf is variously quoted from 1.9 to 2.9 kWh[8]. Comparison of these figures with the actual specific energy consumption for manufacturing one kilogram of tea measured in factories in India, Vietnam and Sri Lanka shows how much energy saving is potentially available:

Thermal energy	:	4.0 to 10.4 kWh/kg tea
Electrical energy	:	0.4 to 0.7 kWh/kg tea
Total	:	4.4 to 11.1 kWh/kg tea

Indian factories already use 25% less than the average 7.1 kWh/kg, attributable to initial attempts at technology modernisation. Sri Lanka matches the average, while in Vietnam specific energy consumption is some 50% higher. Huge cost savings would be available by matching even the lowest benchmark figure (4.4 kWh/kg).

Simple and effective ways to reduce tea processing energy use include

Dual Speed Withering

In India use of dual speed fan with dual rating energy efficient motor and suitable control panel can reduce power consumption by 50-60%[9]

Solar Withering

In Indonesia a 600 m2 Solarwall® drying system has eliminated the need for burning diesel oil to provide heat for withering saving 12,000 litres of oil annually at a payback of 1.5 years[10]. In India SHARO solar systems have reduced tea making specific energy consumption by one third with a reported improvement in quality[11]. Solar heat may also be used for preheating stove combustion air at a potential saving of 50% of fuel use during peak sunny periods. [9]

Natural Withering

In Vietnam natural withering during storage of green leaf on open trays before trough withering saved 10% of total energy cost (30,000 kWh and 90 tonnes of coal) and improved quality[12].

Cogeneration

Combined heat and power generation (CHP) can be effective where the heat is utilised from the electricity generator. For the small factory (one dryer sized) a simple diesel system is recommended; for larger factories additional thermal energy is required, this can best come from a wood gasifier[13]. In large Kenya sized factories, a steam turbine can be used as the power generator: Finlay Teas have installed this system in Kericho to conserve energy. CHP can improve energy production efficiency from the conventional 35% level to 80% with modern systems – and do away with reliance on grid power.

Direct Firing

Elimination of the heat exchanger in some factories has improved thermal energy efficiency but it requires a clean fuel to avoid taint. Wood needs a gasifier system to allow direct firing but potential savings are more than 50% (0.9 kg wood fuel/kg of made tea before gasification, 0.4kg/kg afterwards) [9].

Waste Heat Recovery

35-55% of furnace heat is lost in the flue gases; much of this can be recovered simply by using it to preheat combustion air[9]. In the 1980s Kenya Brooke Bond pioneered the use of hot exhaust air from final drying stage of FBDs as feed air for first stage and saved 15% of fuel costs. Rudramoothy et al[9] also advise the use of a heat pump method to recover heat. This reduces fuel input by 54%, with a payback of 2 years.

Energy Efficient Motors

Replacing oversized motors with the correct size, and the use of energy efficient motors will reduce power consumption.

Power Factor Correction

Installation of adequate power factor correction (capacitors) on motors can significantly reduce maximum demand by as much as 20% [9]

Labour Reduction Aspects

Labour can also be expressed as an energy cost (0.11 kWh of manpower per kg made tea) [9], but it is more normally costed in man-hours at a given wage rate.

Mechanisation

The continuous process CTC line is intrinsically less labour intensive than the Orthodox batch process. The simple hot sorting of four CTC tea grades is less labour intensive than sorting 12 or 15 Orthodox grades. Use of conveyors to link machinery eliminates much hand labour. Use of trolleys reduces the carrying of heavy loads and can decrease manning for a given task.

Factories in Argentina, Turkey and Georgia have introduced mechanised withering using moving troughs. So far these have reduced manning and wither time (typically 6 hours), but at the expense of quality.

Automation

The tea industry is slow to take up automation. In other fields, automated factories commonly operate with a handful of staff. Unilever has a fully automated tea line in Kenya with NIR moisture monitoring at four points and line speed corrected to ensure a steady flow to the dryer. Full automation with mechanisation can reduce manpower to the absolute minimum and, because the process must be fully understood for control to be applied, the product quality is optimised and is consistent.

Economy of Scale

The average factory capacity in Sri Lanka is 406 tonnes per annum (tpa), in Vietnam 667 tpa, in India 669 tpa, while in Kenya it is five times larger at 3,253 tpa. The better cost-price margins in Kenya reflect, amongst other things, the economy of scale and its reduced labour requirement.

Good Housekeeping

Reducing heat losses by proper insulation and quality losses due to product spillage from conveyors are simple measures often overlooked. A recently quantified housekeeping improvement is the keeping of fuel wood under cover. A reduction in timber moisture from 50% to 25% increases its calorific value from 8 to 13 MJ/kg. If this measure were applied throughout Sri Lanka it would reduce wood fuel use by an annual equivalent of 100,000 hectares of forest[8].

HOW ABOUT TEA QUALITY?

Need tea quality necessarily suffer if production cost is reduced? No, not if it is correctly done – in fact tea quality can often be enhanced. Consider these five examples:

Tank Withering

This labour efficient, space efficient, energy efficient example comes from Kenya, where Brooke Bond Kenya was faced with increasing yields and limited capacity. Its introduction was premised on achieving at least equal quality from traditional trough withering. When a factory is running over capacity and yields are rising the normal reaction is to build another factory. Labour laws in Kenya would require that this factory had a full complement of labour, thus doubling the payroll. For obvious reasons BBK preferred to double the capacity of the existing factory while utilising the existing labour force.

In a conventional tea factory, withering takes 70-80% of the floor space. Can withering be compressed without quality loss? It can be - by splitting traditional withering into 12 hours of biochemical wither (with no moisture loss) and 3 hours of physical wither (with rapid moisture loss), the overall wither time is kept the same. Trials with the Teacraft ECM Mini-manufacture System proved that there was no loss in quality; in fact cup quality was enhanced under some conditions.

By holding the biochemical withered leaf in deep tanks – each taking the normal weight of green leaf in a standard trough but at four times the depth, this uses only a quarter of the standard withering floor area. Air is trickled through the tank leaf to maintain temperature but not to remove moisture. Every 12 hours the leaf from one tank is transferred to a standard sized trough for 3 hours of rapid physical wither. This process uses another 25% of the floor area. Thus only 50% of the area is now required for the existing capacity and the balance is available to double the factory withering capacity. As the physical withering stage is concentrated into a three-hour period it avoids mistakes in fan control and heating losses often made during the normal night time withering.

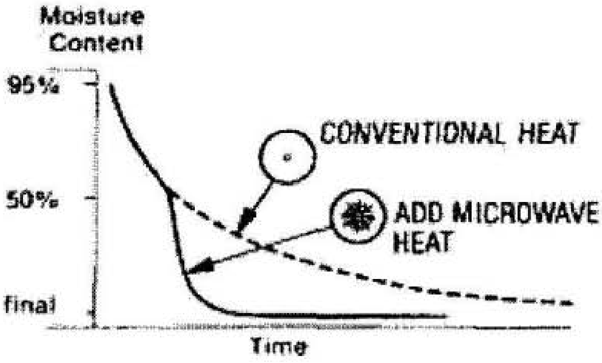
Because of tank withering the existing factory capacity could be doubled without increasing floor area or making significant labour increases. Provided that the tank withering system is correctly controlled the tea quality is the same as normal trough production, but efficiency is enhanced and operating cost per kg greatly reduced.

Fluid Bed Drying

Perhaps one of the most significant examples of the evolution of operating efficiency in the tea industry is the development of the dryer. From the static tray Venetian dryer of the 1930s returning 20% drying efficiency through the ECP dryer at 32% and the static bed FBD at 39%, to the latest vibro bed FBDs at 54% and the combined ECP/FBD dryer at above 60% efficiency[14] – plus the bonus of a rapid 15 minute drying period. There is no doubt about the energy efficiency of the FBD concept and for some teas it produces a better quality. Fermenting dhool sees the maximum temperature on entry; this ensures quick denaturing of enzymes and a brisk bright cup with no danger of stewing. For CTC teas particularly this enhances their quality.

Suspending a wet particle in the drying medium allows surface evaporation all round, thus for the initial stage of drying the efficiency of a fluidised bed is close to optimal; however, for the second stage (falling rate) where evaporation rate is determined by capillary flow through the particle to the surface, its efficiency drops away. The next innovative step in tea drying must be a combination of FBD and microwave dryer. Optimising the strength of the FBD – rapid evaporation of surface water from wet dhool, and the strength of the microwave dryer – effective at lower moisture as it speeds diffusion by vaporising the water within the particle converting 90% of electrical energy into heat – will further reduce specific energy requirement and will speed up drying times. Capacity of combined systems is much increased, reducing their per kg drying costs. Combination air/microwave drying and continuous flow microwave drying are already in use in the food industry (spices, cereal products, wheat germ, coconut, vegetables) where it reduces drying times and enhances product quality.

Figure 2. Drying curve for combination FBD and microwave dryer



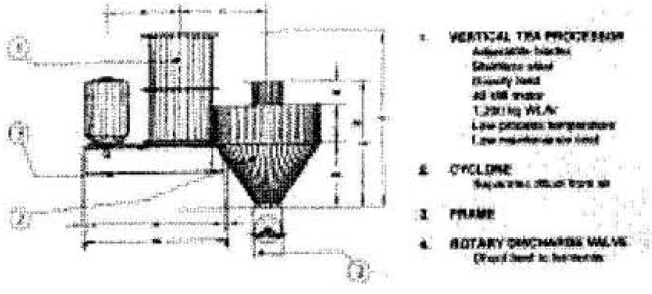
Tea drying tests so far with microwave energy have shown enhanced quality and keepability[14], doubtless due to better enzyme "kill".

VSTP - Vertical Sniechowski Tea Processor

This Argentinean successor to the hammer mill based Lawrie Tea Processor (LTP) utilises flying knives and a screen, and separates dhool from process air using a cyclone.

The unit is gravity fed and shows a useful energy reduction of 25% over the equivalent capacity triplex CTC line. This saving would gross up, for a typical African tea factory, to some US$ 7,000 per annum. It runs cooler and quieter than the LTP and cuts finer and smaller, producing better quality teas than the rotorvane orthodox method it replaces in South America. In capital cost alone it saves half the price of the equivalent Indian made CTC line, and it has considerably lower maintenance costs.

Figure 3. The vertical Sniechowski tea processor

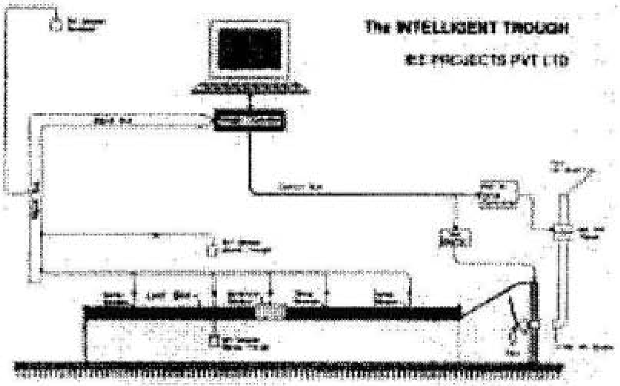


The Intelligent Trough

It is widely accepted that correct withering is the key to tea quality. On efficiency alone, with withering taking 70-80% of process time, 75% of process space, 25% of process energy, and around half of process man-hours, there must be improvements to be made. Correct withering means achieving a consistent target wither moisture in a variable time (to suit production scheduling) from a variable moisture green leaf input, using variable ambient air for drying. Human error in application of airflow (direction, volume and duration) and heat (modification of wet bulb temperature), and in recognising a consistent end-point normally combines to produce a sub optimal product using more energy than is required.

Introduction of computer control and effective condition monitoring has produced the Intelligent Trough. This automatic withering control and monitoring system was pioneered in India by TRA Tocklai and CEERI and has been commercialised by IEE Projects (Pvt) Ltd, Kolkata, so that it can be applied to existing withering troughs. The Intelligent Trough is now in operation in a dozen tea factories. The system monitors leaf moisture loss throughout withering using three different measuring methods whose outputs are combined using fuzzy logic. Also monitored are ambient air temperature and humidity, and trough air humidity above and below the bed. Manual inputs are simple: the start time and the required finish time. Target moisture, drying curve and maximum temperature can also be nominated by the supervisor, but are normally kept constant. Control after the start button is pressed is fully automatic with airflow duration and direction, and heating being calculated and applied to give the required result. The system is labour efficient – continuous human supervision and switching is eliminated, it is energy efficient, with savings of 25% in energy inputs recorded, and it gives better quality than manual wither control due to the consistency and controlled pattern of wither.

Figure 4. The computer controlled automatic Intelligent Trough



Process Manipulation to Add Value

The cost-price challenge may be met not only by reducing cost of production but also by significantly increasing the selling price. Manipulating the tea manufacturing process to produce unique added value products is a direction that smart producers should consider. Ideally, innovative process manipulation should show a very small cost increase to achieve a very large price increase.

Lipton Cold Bru tea is a recently launched commercial black tea that infuses immediately in cold water. Aimed at the huge US iced tea market it adds convenience by cutting out the necessity for the consumer to boil water and then to chill the tea. This patented invention[15] relies on two simple additions to the process at the CTC cutting stage – an enzyme (tannase or flavanol gallate esterase) and a mineral (potassium zeolite) that in combination produce a black leaf that infuses in cold water more than twice as fast as conventional leaf giving an intense colour and high extractable solids. Because the leaf is not "cleaned up" by the use of boiling water it requires a clean hygienic factory run on strict HACCPs principles to ensure product safety. This tea is produced exclusively at a Brooke Bond factory in Kericho converted for the purpose.

In another related process manipulation Unilever[16] is using a very short heat pulse (500 to 600°C) applied to initiate the fermentation of whole tea leaves which are subsequently processed to resemble an orthodox tea, but exhibiting CTC fast and strong liquoring characteristics. This gives a distinct marketing advantage, and apparently is a process that is particularly suitable for the coarse leaf standard from mechanical harvesting.

Health claims for tea centre largely on its very high antioxidant content, particularly the polyphenol theaflavins. Unilever has patented[17] a process for enhanced theaflavin production from slurry fermented teas. Extraction yields 6.4% TF on a dw basis compared with a typical 1 to 2% TF in a standard black tea. However, a conventional black tea format processed to contain significantly enhanced theaflavin levels would provide a valuable marketing claim. Applied Food Sciences LLC has just licensed a theaflavin enhancement process[18] (using mushroom tyrosinase) that can be applied in a standard tea factory. They claim black teas with high TF levels of up to 12%.

CONCLUSIONS

Far-sighted tea producers are securing their future by applying the results of their own R&D or by importing ideas from parallel industries. There are many examples where production costs can be significantly reduced while tea quality is enhanced, or at least not altered. The benefits of cost reduction are demonstrable and the payback periods on investment are short. With a few exceptions, however, the general tea industry is loath to change its ways even to seize these benefits. Reasons for this inactivity range from a professed lack of capital to a lack of will compounded by a lack of knowledge. This conservative outlook may be acceptable in times of plenty, but it is a death wish when margins are tight. In the short term tea industry survival depends on taking urgent steps to apply proven cost reducing methods immediately. The tea industry future health depends on seeking further innovative solutions to reducing costs and improving selling prices. Doubtless this will increasingly involve the exciting new area of value addition during primary manufacture.

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Comments from the Chair
Thank you very much Mr. Melican. You have presented very thought provoking discourse.

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Chapter 12

IT-ENABLED WITHERING PROCESS CONTROL SYSTEM

Pawan Kapur*

Dr. Pawan Kapur after doing his B.Tech, M.Tech and Ph.D .on control systems from the Institute of Radio Physics and Electronics, University of Calcutta, joined Central Electronic Engineering Research Institute (CEERI) Pilani in 1975 where he is currently Scientist G and Group Leader-Agri Electronics Group. He has guided several projects on process control instrumentation for various industries such as sugar, tea, mushroom, fans etc. Some of his works include technology on withering-trough automation systems developed and currently working in more than fifteen tea estates in Assam and West Bengal. Automation systems developed by Dr. Kapoor have been successfully installed at Ramgarh Chini Mills and the National Research Centre for Mushroom at Solan.

Dr. Kapur is a fellow of I.E.T.E and past Chairman of I.E.T.E Pilani Centre. He is a recipient of several awards including CSIR Technology Shield for sugar processing, Seventh Hari Ram Toshniwal Gold Medal, STI silver medal and many others. He has to his credit over 75 research papers in scientific journals and conference proceedings, four patents and six book chapters. His areas of interest are process control instrumentation, soft computing, modeling and simulation in electronic perception analysis.

ABSTRACT

Withering of green leaf has been a critical unit operation in black tea manufacturing which occupies most of the factory floor area and consumes major share of electrical energy. Moreover, good withering sets a pace for subsequent unit operations for quality tea production. This requires judicious control of conditioned air movement in troughs through fan control to provide direction and duty cycle regulation (open trough) or damper-shutter movement for air up/air down control (enclosed trough). Till recent past, this was all done manually with subjective judgment of green leaf moisture during the course of withering and providing above controls manually.

CEERI and TRA, through a joint R&D project carried out at Mohurgong and Gulma Tea Estate in Siliguri, India for more than 5 years, have come out with a computer controlled monitoring and control system which was perfected through continuous operation in about 15 gardens processing green leaf under different agro-climatic conditions. The system acquires process parameters like leaf moisture, leaf loading per unit area, leaf-bed temperature, relative humidity of ambient air, conditioned air and air above the trough, hot air temperature, fan/damper-shutter status etc. and regulates fan and air delivery to the trough automatically to achieve desired pre-set moisture profile resulting in enhanced throughput and energy saving. The paper highlights the system configuration, performance results and techno-economic benefits achieved.

INTRODUCTION

Withering involves controlled removal of moisture without cell damage and comprises two phase operations: (a) chemical wither that sets in immediately after plucking through a large number of biochemical reactions and ultimately decides the quality of tea, and (b) physical wither that decides the surface characteristics of the leaf. Withering is strongly influenced by three primary variables viz.

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leaf moisture, leaf temperature and airflow rate, and hence has to be measured on-line. Reliable and suitable gadgets for on-line measurement of various process parameters had been a long felt necessity and design of an appropriate automatic process monitoring and control system warranted incorporation of these on-line measuring gadgets.

During initial stages the instrumentation systems were developed for measurement of temperature and leaf bed moisture content. Dielectric behavior of the leaf was taken as one of the characteristics for measurement of leaf moisture. Different sensors were tried for measurement of RH and the hygroscopic technique was found to be most reliable. All relevant sensors and transducers were developed for initial testing to study the interrelationships among various parameters. After developing the necessary hardware and software for the above measurement, PC-based monitoring system was developed to log the parameters like leaf bed temperature, ambient temperature, ambient RH and capacitance of the leaf bed. Circuits for indicating fan on/off position and direction status were designed, developed and interfaced to the PC.

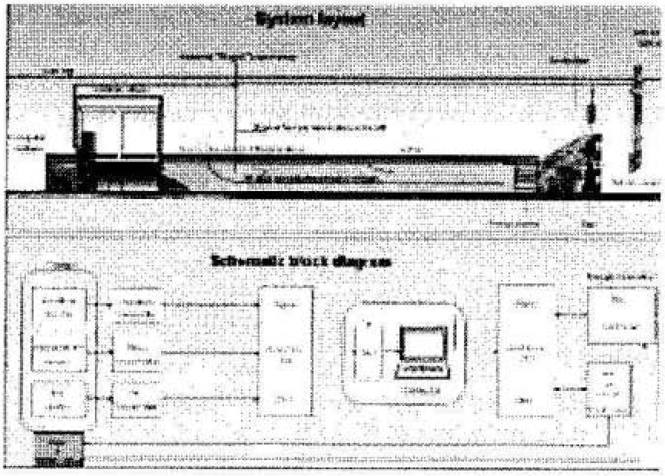
Erection and commissioning of the system were first done at Mohorgong & Gulma Tea Estate in Darjeeling District, W. Bengal and later extended to 15 other tea estates in Assam. The system description, parameter settings, software features and performance results along with techno-economic benefits achieved are discussed below.

The paper presents the highlights of intelligent withering trough controller, which has been perfected through a series of trials carried out at various commercial tea factories in North East India. Results obtained through the introduction of this gadget and techno-economic benefits achieved are discussed.

SYSTEM DESCRIPTION

Figure 1 shows the block diagram of withering trough automation system with the monitoring and control parameters as given below.

Figure 1. System configuration



Monitoring parameters:

- Moisture content of green leaf
- Temperature along the leaf bed height
- Temperature and relative humidity of ambient, conditioned and air above the trough
- Fan status (air direction)
- Leaf loading per unit area
- Hot air temperature

Control Parameters:

- Air direction control
- Hot air control

The system has following objectives:

- Achieving desired rate of loss of moisture profile in minimum possible time under varying ambient conditions
- Master-Slave configuration for cost-effective solution

Salient features of the system are:

- User configurable for parameter selection

- Target moisture, blow factor, maximum allowable leaf temp, optimum leaf temp, RH above which hot air is required, RH below which no hot air required, preferable blowing/sucking pattern, maximum withering time
- Auto start, auto shut
- Rule-based control strategy with facility to add/modify new rules
- Soft-computing technique to estimate expected blow time (air up), expected suck time (air down), drying capability of air, expected withering time, extended withering period, if required.
- Dynamic duty cycle control of fan operation
- Auto termination of process by generating withering complete signal
- Auto reset after trough unloading
- Time independent auto/manual changeover without interfering the decision making routine
- Continuous control and data storage facility
- In-built error sensing and debugging
- On-line real time graphics and parameter display
- Annunciation alarm panel for status indication

SYSTEM CONFIGURATION AND ITS SUB-MODULES

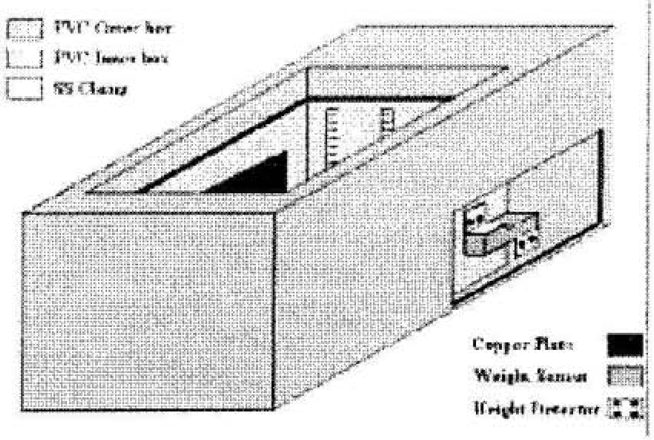
The line diagram of intelligent withering controller is given in Fig. 1 and various sensor modules and controller units comprising the total system are discussed below:

Moisture Sensor

A plate type moisture-sensing probe was developed based on dielectric principle. The vector impedance of the tea leaves was measured, out of which the resistive and capacitative components were extracted. After establishing a suitable relation between moisture content of the leaf and electronic parameters it was found that the packing density affects accuracy. Level measurements were incorporated in the system to minimize the above errors and initial loading measurement was also taken into account.

The moisture sensor consists of a rectangular box made of water resistance bakelite structure fitted with two (film coated) parallel copper plates fixed on the opposite inner walls for measuring the capacitance of the tea leaves. IR based LEDs are fixed on the corner of the box at different heights to detect the level of leaf bed. The inner box rests on the outer case through four load cells to progressively monitor the weight of the leaf. The information obtained from these sensors is connected to the matching transmitters and interfaced to a PC for recording of data and taking corrective measures whenever necessary. Figure 2 shows the block schematic of the moisture sensor.

Figure 2. Moisture sensor for green leaf



The broad specifications of the moisture sensors are:

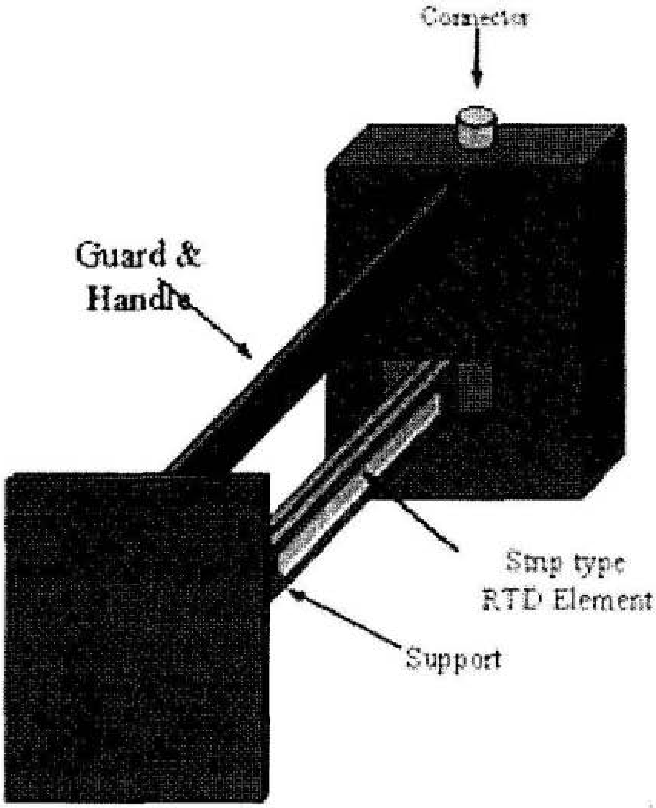
- Input: capacitance cell containing tea leaves
- Output: Voltage 0-10V (adjustable)
- Optional output for direct parameter read out
- Auto ranging for different range of measurements
- Accuracy: ± 1% of full scale
- Linearity: ± 1%
- Open sensor detection and display
- Provision for calibration and offset

As withering proceeds, the moisture content of the leaf decreases and hence decrease in the dielectric constant reflected through decrease in capacitance developed across the plates. The moisture content falls progressively following the capacitance profile. The packing density correction, by using the leaf bed height and initial loading information, improves the accuracy of measurement.

Temperature Sensor

The temperature transmitter module developed uses a precision RTD probe connected to XTR-100 IC, which generates a 4-20 mA current output proportional to the temperature. The platinum resistance element used provides extreme stability and reproducible results. Figure 3 describes the temperature measurement setup for green leaf.

Figure 3. Leaf-bed temperature sensor



Broad specifications of the transmitter are:

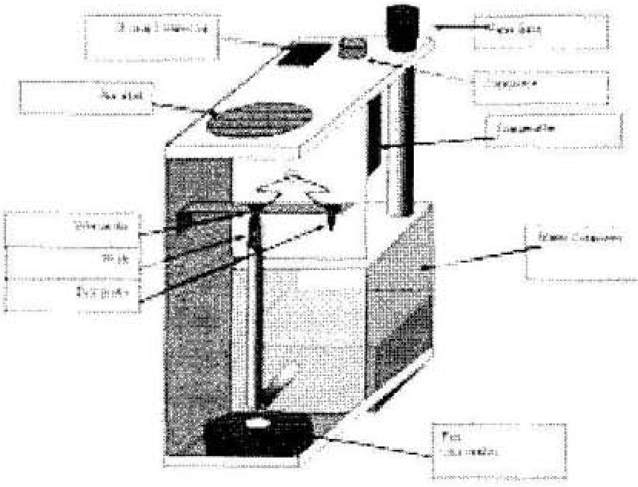
- Input: RTD Sensor
- Output: 4-20 mA
- Accuracy: ± 0.1°C
- Linearity: ± 1%
- 'Open Sensor' detection and display
- Provision for calibration and offset

The measured temperature gave stable observations and their response time was of the order of 30 seconds.

Relative Humidity Sensor

A relative humidity transmitter was specifically developed for direct continuous measurement of humidity. The principle involves measurement of the hygroscopic temperature difference of wet and dry bulbs for estimating the RH of the air. Electronic temperature probes of the type mentioned above were used and the differential output from the XTR-100 IC directly gave the temperature difference, which was amplified for connection to the PC where calculations are made for estimating the relative humidity. A self-wetting arrangement was provided to keep the wick wet through a water supply from an IL built-in container (Fig. 4).

Figure 4. Relative humidity sensor



Broad specifications of the transmitter are:

- Input: RTD sensor

- Output: 4-20 mA
- Accuracy: ± 2%
- Linearity: ± 1%
- 'Open sensor' detection and display
- Provision for calibration and offset

The hygroscopic temperature difference of 3°C was observed during the course of withering. The relative humidity estimated from the above was within 2% of the measurement.

Industrial Computer

Industrial grade PC with the following minimum specifications was selected:

- Processor: Intel 486/586
- FDD: 3.25", 1.44 MB
- Frequency: 100 MHz
- Memory: 16 MB
- Monitor: SVGA (industrial grade)
- Keyboard: Standard 101/102 key
- Mouse: Serial
- Watchdog timer and four ISA expansion slots

IPC Compatible DAS Card

The IBM-PC compatible Data Acquisition Card Type PC 818 HG was used which has the following minimum specifications:

- Bus standard: ISA
- Analog input: 16 channels, 0-10V (adjustable) single ended 12-bit accuracy
- Digital inputs: 16 TTL compatible
- Digital outputs: 16 TTL compatible

Signal Conditioning Sub-module

The signal-conditioning sub-module converts the 4-20 mA signals from all the transmitters into voltage signals for inputting to the data acquisition card. It has the following minimum specifications:

- Channels: 16
- Input: 4-20 mA
- Output: 0-10 V

Controller Part

- Fan ON/OFF and direction control from computer with both auto and manual switching facility.
- Isolated ON/OFF and direction feed back to the computer
- Auto/manual changeover switch (bypassing the computer) at the fan end
- Over-current and single phasing protection switch gear

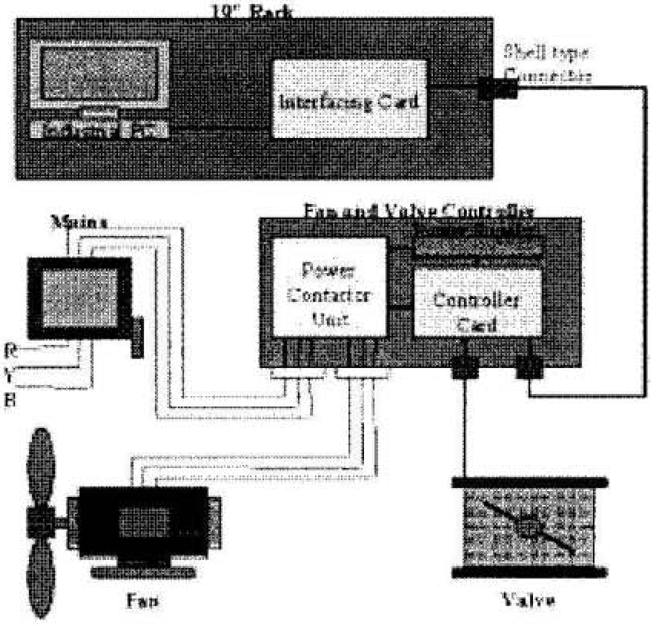
Valve Control

The hot air valve with actuator for continuous opening and closing facility has the following provision:

- Continuous opening and closing facility from computer both in auto and manual modes
- Valve reset sensing
- Hot air availability sensing
- Manual low-level control at the valve end.

Fig. 5 shows the line diagram of the fan controller and hot air valve control.

Figure 5. Line diagram of withering controller



Alarm Controller

Hooter to indicate hot-air requirement and withering completion activation signal was incorporated with the following features:

- Multi-trough connectivity
- Hooter Enable/Disable
- Hooter bypass

The operator can enable or disable hooter through the computer or using the switch on Hooter Board. The hooter signal can be bypassed to the bulb for testing purposes. Hooter circuits are designed in such a way that a single hooter can be used for the alarm purpose of multiple withering troughs.

A large number of tracks for withering based on rate of moisture removal have been incorporated taking into account the leaf and ambient conditions and the targeted wither for any particular leaf on a particular day. The withering process may be made to follow a pre-determined track from the recorded memory of the computer. Operator can also enter feasible track data for the computer to follow. From track signifies the set of rules for fan control as well as for the hot air control.

Thus, in the systems developed, the decision-making is guided by the following parameters measured:

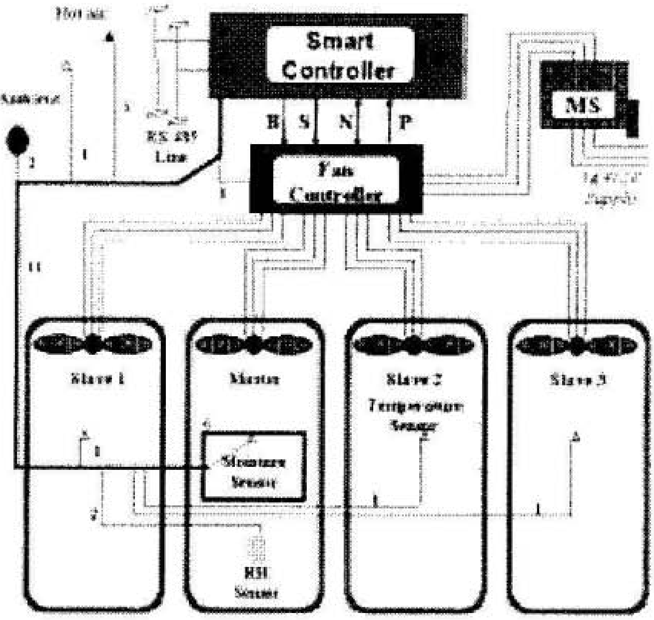
- Green leaf moisture content
- Leaf bed temperature
- Conditioned air parameters
- Ambient air parameters
- Leaf bed height
- Leaf loading per unit area

The control action, therefore, is through the timing control of the fan duty cycle so that the desired rate of loss of moisture profile is achieved.

MASTER-SLAVE CONFIGURATION

A typical withering house may have a number of troughs ranging from 20 to 80 depending upon the production capacity of the factory. For cost-effective performance the withering house can be configured as master-slave mode, with the master trough fitted with all the sensors for centralized data monitoring while each slave is fitted with fan controller and hot air controller for synchronous operation. Figure 6 shows the master-slave configuration for multi-trough control along with fan and hot air controller fitted to each individual trough. The configuration can be made from the computer, which can add or delete any trough from the network. It is assumed that leaf during given plucking time is loaded on troughs for achieving uniformity of results.

Figure 6. Master slave control system

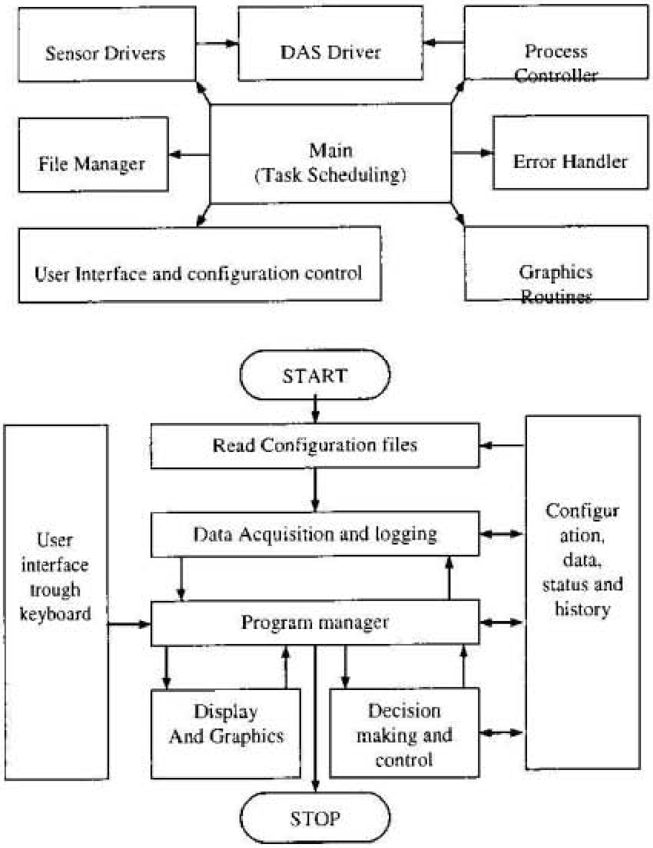


For enclosed trough the fan runs in one direction only and the direction of air flow for upward and downward movements can be obtained by adjusting the damper and shutter position. Both automatic and semi-automatic (cost effective solution) modes are available and the various actions are displayed on annunciation panel along with the alarm.

SYSTEM SOFTWARE

System software structure is shown in Fig. 7. There are seven different tasks under the command of main program that acts as a task scheduler. The broad functions are driver modules for sensors, data acquisition system (DAS) functions, process controller for carrying out various valve control actions, fan movement, air direction etc. Error handler checks status of various process conditions and activates regulatory actions as well as raising alarms. Graphic routine provides various screen functions such as mimic diagram and trend graphs. File manager controls various sub-programs, directories and data-base containing process data and finally the user-interface and configuration control for man-machine interface.

Figure 7. Software structure



Although the basic design philosophy is common in open and enclosed trough, some alterations are to be made in enclosed trough to suit garden specific requirements. The semi-automatic mode can be converted into the fully automatic mode by addition of three additional units – damper controller, shutter controller and the hot air controller. In the semi-automatic mode of operation the air flow controls signals from the computer will be terminated at the signal units, mounted at the damper and shutter ends of the trough, which consists of six bulbs each. The yellow bulb is activated from the valve control signal, which indicates the operator to open or close the valve manually. Under fully automatic mode the valve control signal will be extended to the valve controller unit, which automatically opens or closes the hot air valve. The blue bulb indicates the end of the current process. The red and green lamps indicate the required shutter and damper positions. If the system wants to put the trough in forward (blowing) mode, it checks the status of damper and shutter positions and, in case of an error the red bulb for the correct position of the corresponding signal unit will glow. For example, consider a case in which the system needs to be put in the forward (blowing) mode and both the shutter and damper are up. Here the damper position is correct while the shutter position is not. In the damper side neither green nor red bulb will glow, while on the shutter side lower red bulb will glow indicating that the shutter should be brought to the bottom. In a similar situation under semi-automatic mode, if a hooter is enabled, the system will raise it for the operator's attention. When one manually corrects the positions of shutter and damper, all the red lamps glowing will switch off and green lamps and the fan/fans will be switched on. When the system raises alarm, the operator can stop it only by pressing any of the acknowledged buttons mounted on both damper and shutter ends. The system raises alarm once for all in a particular process for indicating the hot air requirement and withering completion. The operator can differentiate the purpose of alarming from the signal unit status.

Under fully automatic mode, the signals used to drive the red and green lamps will be extended to the damper and shutter controllers to make the operation automatic. The neon lamps mounted with acknowledge-buttons are supposed to indicate the trough, which raised the alarm, under multi-trough configuration in which these lamps and the corresponding acknowledge buttons will be extended to a control panel in the main control room.

PERFORMANCE

Figures 8 and 9 show various screens for initial settings of parameters, and Fig. 10 shows the total system using Industrial PC. The system was commissioned at various Tea Estates in Terai and Assam areas in India for long-term trials. The techno-economic benefits are summarized.

Figure 8. Parameter selection

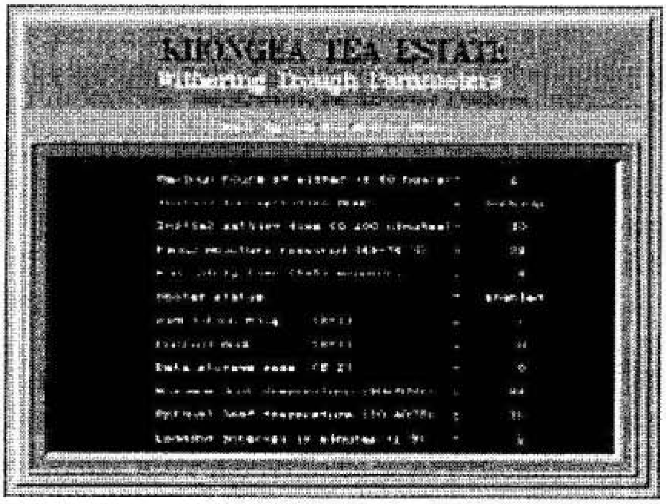
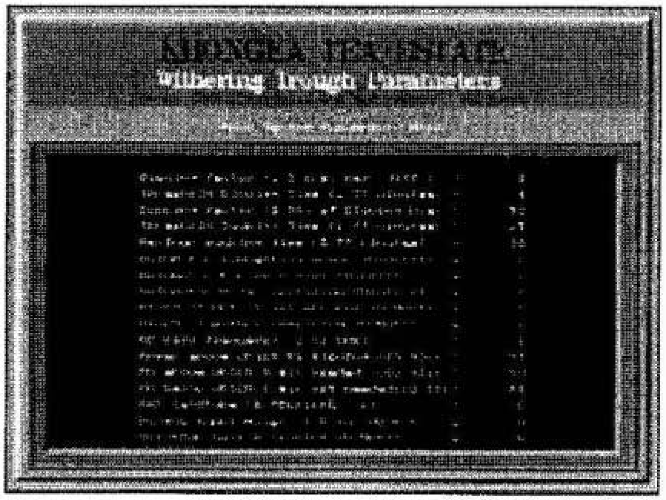
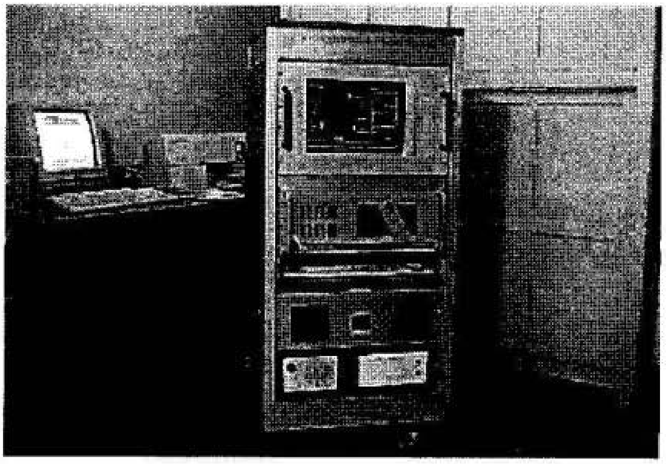


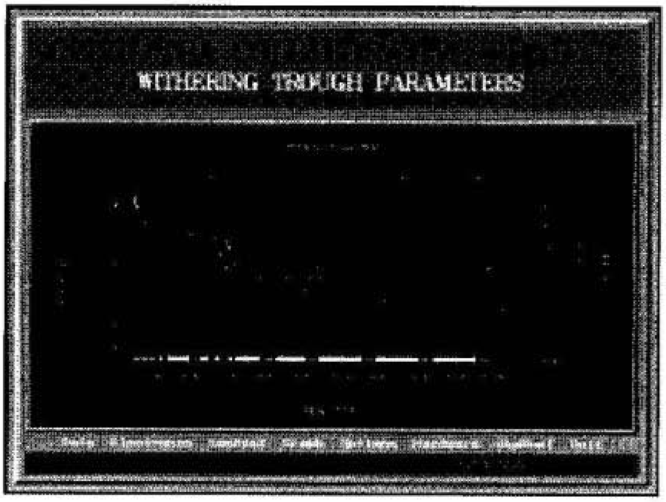
Figure 9. Parameter selection



Figures 10. Automatic tea withering system



Figures 11. Performance Graph



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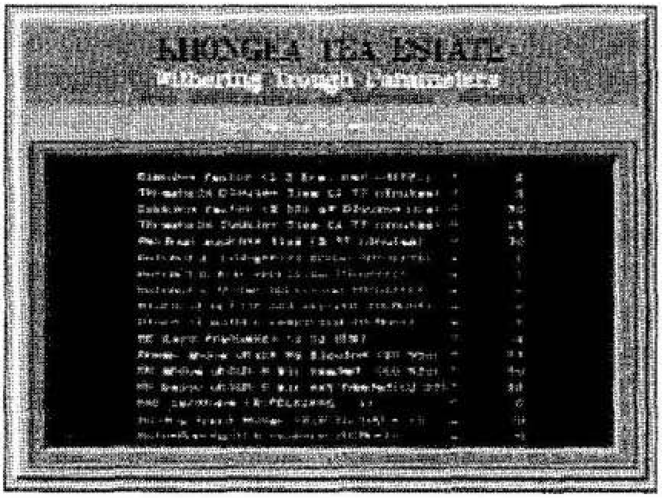

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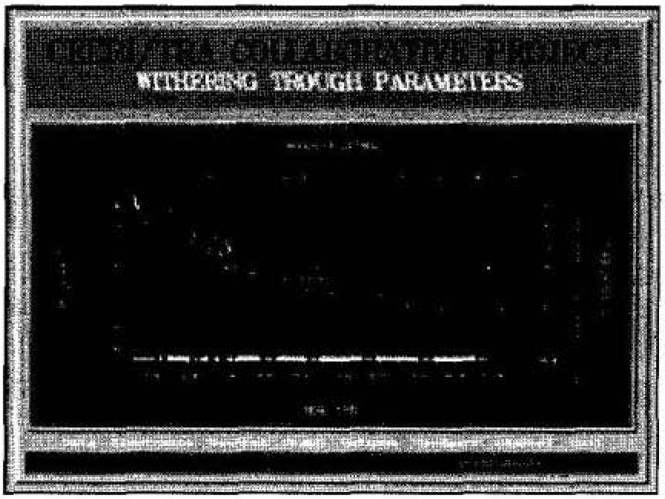
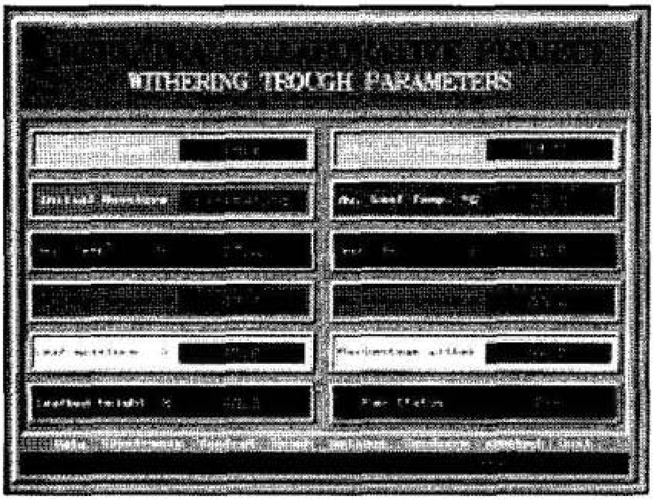
Figures 11. Performance Graph



Figures 12. Typical parameter screen



Figures 11 and 12 show typical moisture removal trend graph and electronic parameters appearing on the screen for continuous monitoring for typical data collected on open troughs at a commercial tea factory.

CONCLUSIONS

The paper has highlighted system configuration, salient features and performance results of IT-enabled withering process control system, which is user-friendly and fully configurable as per factory specific requirements. Any rate of loss of moisture profile permissible according to factory withering house setup can be set and the system tries to follow the same under varying agro-climatic conditions at the localized level. The same system, with suitable changes in the hardware setup (damper-shutter movement for enclosed trough) and parameter settings in the software, can be configured for use in open and enclosed troughs for both CTC and Orthodox types of tea under given factory processing conditions. The system monitors physical parameters and regulates fan and hot air demand to follow the pre-set moisture removal profile for achieving uniformity in the quality of wither. Various screens provide useful current and past information about the process behavior both in functioning and diagnostic purposes. New rules can be added that make the system adaptive to different situations in withering while master-slave configuration provide cost-effective solution. Through the introduction of this system, an increase in throughput (up to 25%) and saving in electricity consumption (up to 25%) with consistency in the quality of withering has been achieved with an approximate return to investment within two tea seasons.

ACKNOWLEDGEMENTS

The author expresses his thanks to Chairman, TRA and Chairman and members of Engineering Committee for sponsoring the project and site interactions, and to management of member gardens where CEERI systems were commissioned for conducting field-trials. Thanks are also given to Director, CEERI and all the team members from CEERI and TRA for their untiring efforts during the execution of the project.

LITERATURE FOR FURTHER READING

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Chapter 13

BIOMASS GASIFICATION FOR ENERGY NEEDS OF TEA INDUSTRY

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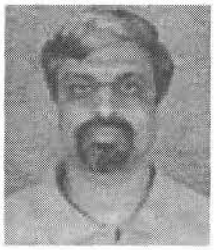

ABSTRACT

The paper addresses principles and field experience on the open top biomass gasification technology developed at Indian Institute of Science. The reactor design uses dual air entry – air nozzles and open top to help in establishing a thick reaction zone to remove the contaminants. The cooling and cleaning system is capable of generating clean gas. The technology packaging addresses total system – fuelling, water treatment, ash handling, process automation and necessary accessories for a power plant.

Diesel savings in the range of 80 % has been achieved in dual fuel mode of operation in the entire power range. In the case of producer gas engines, natural gas engines have been adapted by employing an indigenously built producer gas carburetor along with optimized ignition timing.

Biomass gasification plants for village electrification, captive and grid applications in the range of 5 kWe to 1 MWe; interesting thermal applications for low and high temperature uses in the range of 0.2 to 5 MW thermal for drying and heat treatment applications are in operation. Cumulative experience of 80,000 hours over a dozen systems has resulted in a fossil fuel saving of 350 tons; typical daily saving is about 18000 lts of fossil fuels. This replacement of fossil fuel has resulted in a net saving of about 1120 tons of $CO2$ – a promising candidate for CDMs.

INTRODUCTION

Fossil fuel based technology has been primary source in the last two decades to meet the thermal energy required in small as well as large industries. The number of small-scale industries that uses liquid fuels in the range of 100 lts / hr to meet the heat requirements is quite large. This has led to development of efficient combustion devices for the fossil fuels over the decade, to meet both efficiency and emissions standards. Over the years, many of the solid fuel based devices have been converted to petroleum-based fuels due to the availability and the compactness of the combustion system; without serious concern on the economics of operation. With the present changes in cost of petroleum fuels, the overall economics are being affected. Economics along with the environmental considerations has resulted in looking at alternate sources of energy.

Industries have adopted the use of petroleum-based fuels for various applications, apart from their use in electricity using internal combustion engines. Some of the applications are the low temperature

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requirements like, drying of various food and non-food items, hot air for specific process requirements, etc., while the high temperature is used for, boilers for steam generation, thermic fluid heaters, furnaces in heat treatment industries, steel processing, ceramic sector, etc. This has led to the use of petroleum fuels for stationary applications, which other wise could address the transport sector.

Biomass gasifiers are devices performing thermo chemical conversion of biomass through the process of oxidation and reduction under substoichiometric conditions. These, as sources of combustible gas for energising internal combustion engines, have been in existence for nearly half a century. Gasifiers are broadly classified into updraft, downdraft and crossdraft types depending on the direction of airflow.

Fig. 1. Updraft and down draft systems

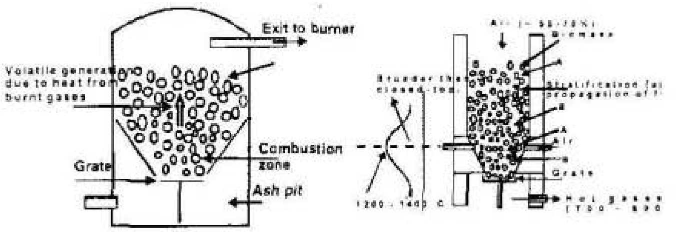


Figure 1 shows the typical sketches of an updraft and downdraft system. In the case of an updraft generator, air is taken in through a grating in the bottom of the fuel bed. Immediately above this grating a burning zone is established. The hot gas now moves through the fuel bed towards the top of the generator, to pyrolyse and dry the fuel. During this process all the volatile matter and the moisture is carried out into the gas outlet. This gas carries the higher molecular weight compounds, generally identified by "tar". The presence of this allows the gas to be used in furnaces and not generally application in internal combustion engines.

In the case of a down draft generator, air is drawn through the bed from air nozzles and the gasification proceeds in a sequence as mentioned in the above block diagram. The process of pyrolysis releases the volatiles, which further under goes fuel rich combustion near the air nozzles region. The products pass through a hot bed of char for the reduction process to generate producer gas. The gas so generated has low values of "tar", generally recommended for application in internal combustion engines. A downdraft gasifier, in which fuel and air move downwards, is widely used because it generates combustible gas with low tar content.

GASIFICATION THEORY

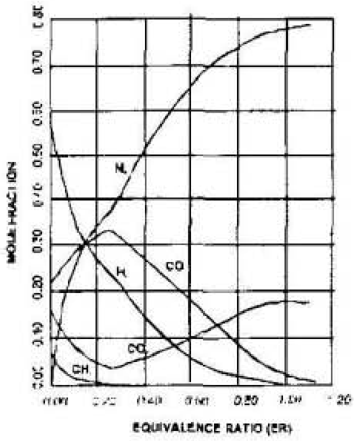
The essence of gasification is the conversion of the solid fuel to gaseous fuel by thermo chemical reactions of a fuel. Gasification involves partial combustion and reduction operations of biomass with air/oxidant under sub-stoichiometric conditions, while combustion is the chemical combination of biomass (fuel) with air or oxidizer resulting in release of energy in the form of heat. In case of combustion process complete oxidation of the fuel takes place with right amount of air/oxidiser known as stoichiometry.

For a typical biomass

$CH_{1.4}O_{0.74}N_{0.005}$ (Fuel) + $0.98\ (O_2 + 3.76\ N_2)$ (Air) $\Rightarrow CO_2 + 0.7\ H_20 + 3.69\ N_2$ (Products)

In the above reaction the air to fuel ratio is : 1 : 5.3

Fig. 2 . Gas composition with equivalence ratio

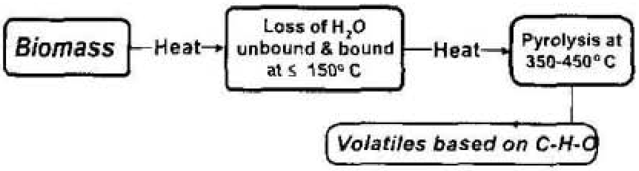


Where as in gasification

$CH_{1.4}O_{0.74}N_{0.005}$ (Fuel) + 0.337 (O_2 + 3.76 N_2) (Air) $\Rightarrow$2.7(0.211 CO + 0.18 H_2 + 0.0105 CH_4 + 0.1275 CO_2 +0.471 N_2) + 0.157 H_2O + 0.028 C (Products)

Air to fuel ratio is : 1 : 1.8

The overall A/F tends towards fuel rich condition (less amount of air) and the energy in biomass is realised in the form of combustible gases (CO, CH_4 and H_2) as a result of gasification. The above gasification process occurs in different stages, drying, pyrolysis,

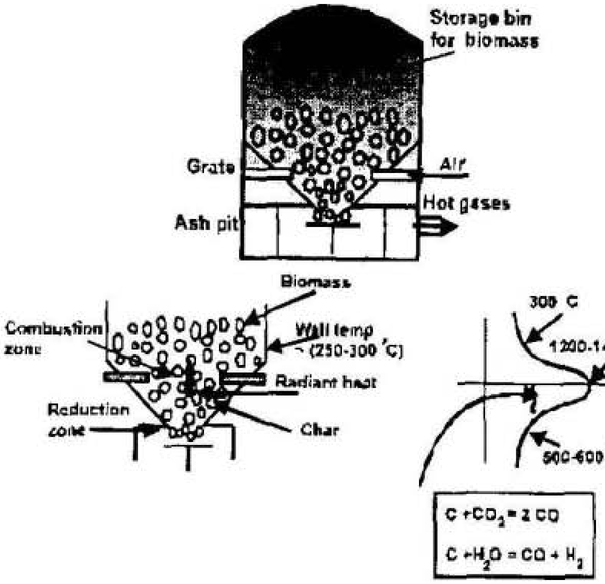


oxidation and reduction process. The block diagram indicates different stages during the gasification process. Based on the sequencing of the above process two major types of gasification systems can be identified; namely, updraft and down draft. In the case of an updraft system, the gas is carried from bottom to the top of the bed, while in the downdraft the gas is carried from the top towards the bottom.

The only reactor design available till recently was the closed top, where the upper portion of the reactor acted as a storage bin for the fuel, and air was allowed to enter at the lower part which consisted of charcoal. Developmental work at the Indian Institute of Science on wood gasifier resulted in a design (Dasappa 1989) with an open top, air entering both from the top and through the side air nozzles. This feature has resulted in a design which can handle wood chips of higher moisture content, up to 25 %, and with low tar levels (< 30 ppm) in the generated gas). This low tar level is due to the stratification of the fuel bed, which helps in maintaining a large bed volume at high average temperatures.

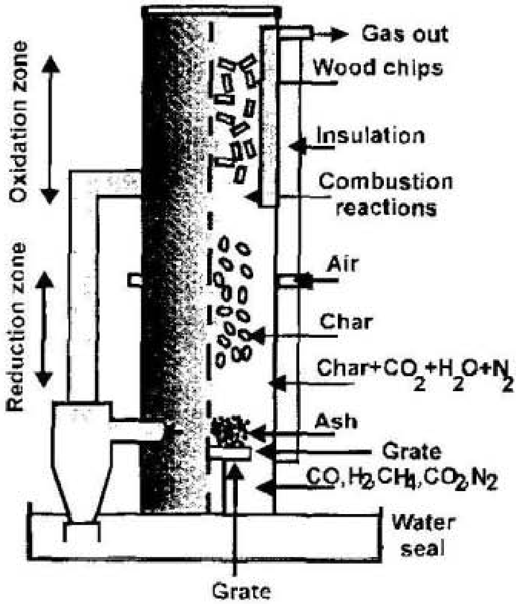
In the closed-top gasifier, the hopper region into which the biomass is loaded, is relatively large, its size being generally dependent on the time to run a single uninterrupted cycle before reloading. The ratio of reactor hopper diameter by its throat diameter is large. The throat is the smallest cross section in the flow path for both fuel and gas. Throat diameter has an influence on the tar content in the gas and is determined by the need to balance two factors: large throat diameter leading to higher amounts of tar in the gas and small diameter leading to larger carry over of fine dust and ash.

Fig. 3 a. Schematic of the closed top gasifiers



The higher the value of the diameter, the greater the risk that tar-laden gases will escape the combustion zone, smaller the throat diameter the greater the velocity of the gases that sweep through the throat and the reduction zones, collecting fine dust and ash. Another feature of the closed top gasifiers that the diameter of the hopper is so large that heat transfer from the high-temperature zone generally affects wood chips near the hopper's wall rather than its center. Another drawback of the

Fig. 3 b. Schematic of the open top gasifier



closed-top gasifiers is that generating combustible gas of reasonable quality is more difficult when the moisture content of wood is high (15-30 %).

PRINCIPAL REACTIONS

The generation of gas termed as "gasification" or partial combustion of solid fuel, is like a fuel rich *combustion; a reaction at high temperature between* the oxygen and the solid fuel. In a typical combustion process generally oxygen is surplus, while in gasification fuel is in surplus. The combustion products mainly consisting of carbon dioxide, water vapor, nitrogen, carbon monoxide and hydrogen pass through the glowing layer of charcoal for the reduction process to occur. During this stage both carbon dioxide and water vapor *oxidize the char to form carbon monoxide and* hydrogen.

The combustible substance of a solid fuel is usually composed of the elements carbon, hydrogen and oxygen. The oxygen in the fuel will, of course, be a part of the combustion products, and therefore the amount of oxygen needed is reduced.

The following are the typical reactions, which occurs during gasification;

The products of combustion of pyrolysis gases result in CO_2 and H_2O, which react with C in the char to form CO, H_2 and CH_4.

$C + O_2$ — CO_2 (combustion) (240 kJ/mole)
$C + CO_2$ — 2CO (Boudouard) (-164.9 kJ/mole)
$C + H_2O$ — $CO + H_2$ (water gas) (-122.6 kJ/mole)
$CO + H_2O$ — $CO_2 + H_2$ (water gas shift) (40.2 kJ/mole)
$C + 2H_2$ — CH_4 (methane reaction)(83.3 kJ/mole)

The char oxidation with CO_2 and H_2O are *endothermic while the other reactions are* exothermic. The reducing reactions indicated above reflect on decrease in the gas temperature during the reduction process.

The above reactions is generally divided into two different partial process. The physical process referred to the mass transfer of the reactants and products and the second, the chemical process, *the reaction itself. The first process basically* depends on the properties of the fuel such as the surface area, particle size, density, conductivity, etc., along with the fluid flow. Based on the relative rates of mass/heat transfer and the chemical rate, the above chemical reactions can be classified as either diffusion limited or reaction limited.

The composition of the gas produced by a generator depends on the degree of equilibrium attained in the various reactions. It is clear from the literature (SERI 1979) that the above reactions are far from equilibrium. In a study which is a part of the Swedish experience on closed top gasifiers (SERI 1979), some basic results concerning the reactions being near-equilibrium or otherwise are discussed. Wood gas composition similar *to the above has been presented; also the* equilibrium constant for one of the reduction reactions,

$$C + CO_2 = CO,$$
$$Kp = \frac{pco^2}{pco_2}$$

has been calculated as 0.3. Equilibrium temperature corresponding to this K_p is approximately calculated as 910 K. This is different from the measured exit gas temperature of 1200 K. Thus, the calculated equilibrium temperature being considerably below the measured temperature, they concluded that the reactions are not in chemical equilibrium in the reactor. Similar deviations are found in the $C + H_2O$ reaction. However, it is always valuable to examine the non-equilibrium situation since equilibrium results can be obtained in the limiting process. The above non-equilibrium behavior also provides the motivation for the present study, involving the kinetics of char combustion/gasification reactions.

Dasappa et al (1998) has studied the above char gasification reaction in detail. Based on the study, for the C-O_2 system, the conversion time dependence for the char oxidation is shown to be $t_c \sim d_0^2$, where n = 1.9 and 2.0 for combustion at T ~300K and 1000K respectively for particle diameters above 1mm. The importance of conductivity of char and of the $C + CO_2$ reaction during char combustion is brought out. For the range of the present study, it appears that the $C + CO_2$ reaction is not essential to explain the observed peak temperatures and burn times. Extinction of the particle during combustion occurs at an ambient oxygen mass fraction of 0.14 for T ~ 300K. The extinction of the char particle and the incomplete combustion are shown to be due to the heat loss rate becoming more important.

In the case of steam gasification, the chemical reaction is modeled using the detailed mechanism obtained by (Blackwood, 1958) and the enhanced gas conductivity in the presence of H_2O. A comparative study of the conversion process for different gaseous components indicates d_0^2 dependence in an air/oxygen environment d_0^2 & $d_0^{1.2\text{-}1.3}$ dependence in the CO_2 and H_2O environments respectively. The variations of temperature and reactant mass fractions through the reacting sphere are used to argue the role of diffusion and reaction in the conversion process. The diffusion and kinetic limits for wood char in different ambient conditions are explicitly brought out and discussed. Correlations for the burn time for different reactant fractions have been obtained based on the model analysis.

Fig. 4. Burn time for different particle diameters in air at 300 K and 1000 K and the experimental data of Simmons and Ragland (1986)

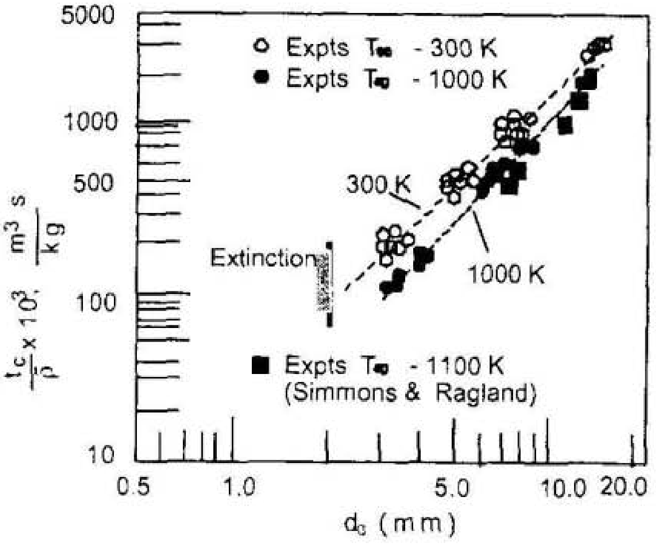
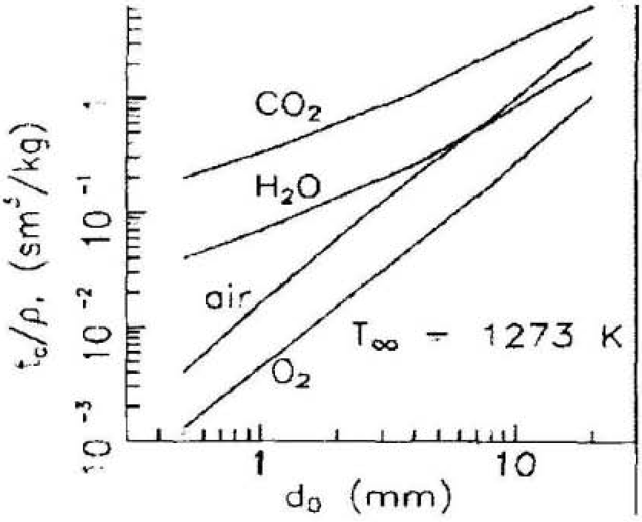


Fig 5. Normalised conversion time versus diameter for different reactants (CO_2, O_2 H_2O and air) at T_{amb} = 1273 K, from the model 10



DESIGN OF GASIFIERS

Wood gasifiers as sources of combustible gas for running internal combustion engines have been known for over five decades. In recent times, Reed et al (1982), examine the possibility of gasification in a simple cylindrical geometry where near-one-dimensional flame propagation is possible. This laboratory device has been converted into well developed production models for the field at 3-500 kW by IISc (Dasappa,1989). Generally, open top gasifiers have air being drawn only from the top (Reed and Markson, 1982). IISc gasifiers have air drawn from the top as well as from the side air nozzles (shown in the Figure2) During the developmental period it was seen that one important contributing factor for the excellent performance was stratification, as indicated by Reed and Markson (1982). Stratification is the formation of stable layers of pre-heating, volatile matter combustion and reduction zones with little opportunity for any gas to leak past any of the zones i.e. pass through without active participation. There is an upward movement of the front into the moving bed of char with air flowing in the opposite direction. The flame front moves upwards into the unburnt fuel. This is similar to the flame front moving in a premixed flame.

This movement of the front helps in establishing a larger hot zone leading to better preparation of the fuel as it moves downwards towards the second air supply zone or the nozzle zone. Studies to determine flow distribution under cold conditions indicate that the velocity distribution in a packed bed is homogeneous after a few particle diameters.This homogeneous velocity distribution results in temperature profiles which are nearly uniform across the cross section of the reactor. Thus, in the case of an open-top gasifier, the air/gas flow is homogeneous across the bed and the air/gas also passes through a long porous bed of fuel in the vertical direction. In the open top gasifier, the regenerative heating due to the transfer of heat from the hot gases (through the wall) to the biomass moving down increases the residence time in the high-temperature zone and thus leads to better tar cracking. Combining the open-top with an air nozzle towards the bottom of the reactor helps in stabilizing the combustion zone by consuming the unconverted char left and also by preventing movement of the flame front to the top. As a consequence, the high-temperature zone spreads above the air nozzle by radiation and conduction, aided by air flow from the top in the case of the open top system. The tar thus is eliminated in the best possible way by the high temperature oxidative atmosphere in the reactor itself. In the present design of the gasifiers, the heat transfer from the hot gases flowing in the annular space, makes it possible to gasify wood chips that have moisture contents as high as 25%, with consistent gas quality from a range of biomass fuels. A further feature of the introduction of the air nozzle into the open top design is that (*char conversion can be made near-complete*). In open top gasifiers not having air nozzles, complete char conversion has not been possible.

In steady operation, the heat from the combustion zone near the air nozzles is transferred by radiation, conduction and convection upwards causing wood chips to pyrolyse and lose 70-80% of their weight. These pyrolysed gases burn with air to form CO, CO_2, H_2, and H_2O, thereby raising the temperature to 1300-1500 K. The product gases from the combustion zone further undergo reduction reactions with char, as indicated below, to generate combustible products like CO, H_2 and CH_4.

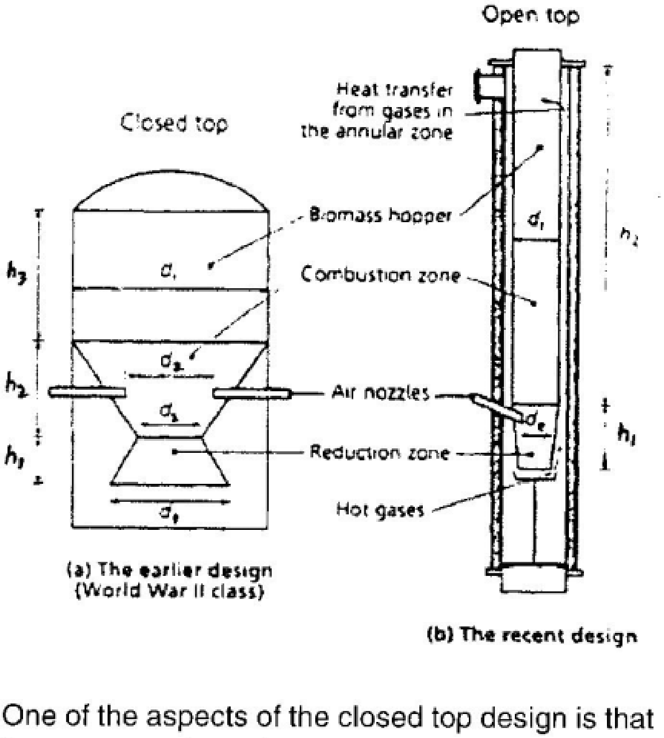
$C + O_2 \longrightarrow CO_2$ (combustion) (240 kJ/mole)
$C + CO_2 \longrightarrow 2CO$ (Boudouard) (-164.9 kJ/mole)
$C + H_2O \longrightarrow CO + H_2$ (water gas) (-122.6 kJ/mole)
$CO + H_2O \longrightarrow CO_2 + H_2$ (water gas shift) (40.2 kJ/mole)
$C + 2H_2 \longrightarrow CH_4$ (methane reaction)(83.3 kJ/mole)

The above reducing reactions are endothermic. The product gas exits from the reactor at around 1000-1200 K, below the reduction zone. Typical gas composition (dry basis) at the reactor is as follows, 19% CO, 18 % H_2, 1 % CH_4, 11 % CO_2 and the rest N_2.

TWO COMPETING DESIGNS

Figure 6 shows the details of the two geometries for the reactor - the closed top (World War II class) design and the recent open top design. Their various dimensions are shown on the line sketches. There are several variants to the reactor in Fig. 6a, but differing little in essential details. The primary dimensions of importance in the earlier reactor design are d_t, the throat diameter, d_r, the reactor diameter, d_e, the exit plane diameter, and h_1, h_2, h_3, the relative heights. Correspondingly, the dimensions of the open top reactor (Fig. 6b) are the lateral dimensions d_r and d_e and the heights h_1 and h_2. The choice of d_r/d_t, h_1/d_t, and h_2/d_t, are based on the "best" performance of some commercial designs. The size of the hopper region is decided by d_r/d_t and h_3/d_t, based on simple considerations of the time required for a single uninterrupted run - typically, 2-3 hours. For the choice of dt a few qualitative arguments are provided. Larger values of dt imply the possibility of tar laden gases escaping the high temperature zone. Smaller values of dt would mean higher velocities through the throat as well as the reduction zone. These are expected to lead to less tar, but much larger dust content. The reduced tar is principally because the gases pass through a smaller reaction volume leading to better temperatures for tar cracking and also for completion of all reactions. The larger dust content is due to the higher velocity gases picking up greater amounts of fine carbon dust and ash in the reduction zone.

Fig. 6. The two wood gas reactor designs — The earlier world war II class design and the modern open top design



(a) The earlier design (World War II class)

(b) The recent design

One of the aspects of the closed top design is that the upper region where the fuel is stored has a thermodynamic function which it is not properly designed for. The diameter is so large that heat transfer from the high temperature zone, into the upper region generally affects the wood chips near the wall rather than the central region. Some designs use an outer chamber where hot gases are passed to enable the heat to be pumped into the wood chips and others in which the incoming air is heated. It is suggested that insulation does not help much, but preheating the air is worthwhile inspite of the low heat capacity of the air and the large area requirements for heat transfer. A few other designs like the monorator (SERI, 1979) provide an outer zone for the collection of tar. Unless regenerative heating is done, the walls of the entire upper region become with tar laden in various forms - encrusted and hard, or liquid and sticky. The latter matter can cause bridging, particularly during subsequent starting, and cause problems for material movement. Also if wood with a high moisture content (say 20-30 %) is used, problems in generating combustible gas of reasonable quality are increased significantly. These problems originating from improper design of the upper region led sometimes to a situation in which the problem was attributed mistakenly to the moisture content in the wood chips. This led to performance which was not quite repeatable unless every aspect of the feed stock was attended to with care, implying the system was less user-friendly.

In order to reduce the tar content, the air nozzles are distributed around the periphery with the expectation that all fuel vapour flow is intercepted and hence combusted. During this process the temperature is also raised. Evidence in literature shows that with increased velocities the peak temperature in the combustion zone rises and this helps in reducing tar. Rules of thumb are therefore provided to choose the number of air nozzles for a given flow rate (and therefore, for a given thermal and mechanical power). Qualitative arguments are made showing the regions of influence of air distribution around the air nozzles and the regions in between the air flow zones where the flow of volatiles can escape through the low temperature zone resulting in a gas of high tar content. It is not unlikely that earlier gasifier programmes in other countries have had problems because of inadequate attention to resolution of tar problems. One of the crucial issues is that once tar escapes from the reactor, it is not easy to eliminate it by cooling/spraying systems since the vapour will escape these processes also to a significant extent. One of the important ways to eliminate tar would be to create a correct thermal and oxidative environment for reducing it in the reactor itself.

The open top design, on the other hand provides for much better homogeneity of the air flow distribution as it passes through a long porous bed. Cold flow studies in ref. 8 indicate that the velocity distribution for a flow in a packed bed becoming homogeneous beyond a few particle depths. Wall heat transfer from regenerative heating enables better tar cracking as the residence time in the high temperature zone is substantially increased. Many of the configurations of the open top design including the laboratory model study of Reed et al do not have air nozzles as used in gasifiers of earlier classical designs. The present design, (Fig. 6b) on the other hand, provides for an air nozzle as well as an open top. As such, air is shared between the nozzle and the top and this has many advantages. The air nozzle help in quick lighting with a simple wick flame. It helps stabilise the combustion zone which might move to the top because of the phenomenon of ``stratification " in which the flame front moves in a direction opposite to the air flow. The high temperature zone, consequently, spreads more above the nozzle in comparison to what would the case with the closed top design in which the spread is governed by radiation, thermal conduction and weak convection processes. In the present open top configuration forced convection heat transfer from the hot gases flowing in the annular gas passage also contributes to upward flame propagation. These aspects enable use of wood chips with moisture contents as high as 25 %. The heat pumped in by the hot gases makes the fuel chips in contact with the wall heat up and loose moisture. Generally, the air being drawn through the top is about 40-70 % of the total flow taken in depending on the pressure drop conditions due to the size of wood chips and gas flow rate. The ability of the reactor to dry the wood chips within itself allows for a possibility of reliable operation with varying conditions of moisture in the wood chips. Further, the insulation provided makes a significant difference to reliable operation the lack of which would mean significant amounts of tar and unreliable gasifier operation. Figure 2 shows the temperature variation from the air nozzle region in the classical closed top and the present open top design. It is clear that the width of the high temperature region, 600 K and above is about 1 m for the open top design whereas it is constant at about 0.4 m for the earlier design. What is more it can be controlled by decreasing the air flow through the air nozzle in the current design.

The size of the wood chips is important for the successful operation of the reactor. The SERI report emphasizes it but does not provide guidelines for lower power levels. It is indicated that wood chips for power levels of 15-75 kW should be about 60-80 mm long and 50-60 mm in diameter at the most. There are arguments about size in relation to time for gasification and hence increased bed depth for increased chip size. In view of the lack of a precise description of the thermodynamic requirements of the fuel storage region (alluded to earlier) the need for a larger depth of fuel chips is unclear. Most of the arguments, however, seem relevant to the open top system. For this case, the major dimension of the wood chip should be about one-sixth to one-seventh the diameter of the reactor to meet the requirements of flow ability with not too-high a porosity and time for gasification. The last point is addressed with more precision by Reed et al, who take advantage of the near one - dimensional character of the geometry and set out the design principles on a rational basis. The time for conversion is split into two parts, namely the flaming time and the char conversion time. During the flaming period occurring with the air drawn largely from the top, the pyrolysis process is completed and char is produced. The results are rightly expressed in terms of a volume based mean diameter so that the results apply to other geometries as well. The time required for char conversion with CO_2 alone is treated by an appropriate kinetic expression. The effect of the presence of H_2O as well as the parallel reaction path of char with H_2O, which is a faster reaction when compared with CO_2, seems to have been ignored in this work. This is an important aspect that needs future attention. For any assumed reactor diameter the required heights for flaming pyrolysis and char conversion are then obtained from the given properties of the woody biomass, namely, its density, specific heat and heats of phase change with a simple model for heat balance. The height of the reactor is then determined by requiring that the downward distance travelled by the woody biomass must allow for the residence time equal at least to the sum of the flaming (pyrolysis) and char conversion times. Reed et al do not provide any argument for the choice of the diameter of the reactor. Because of the assumption of one-dimensionality the L/D of the reactor should be large, typically 6-8. Once the height is determined, the diameter can be obtained from the choice of a value for L/D. Qualitatively, smaller diameters are preferred in order to make the reactor compact and to permit the wall heat transfer to affect the entire cross section. Too small a diameter would necessitate the use of smaller wood chip size and cause higher-pressure drops at reasonably high flow rates. One needs to optimize these factors for which there are no precise guidelines at present. In the present design, the choice of diameters and other parameters are as in Table 1.

Table 1. The reactor diameter and related parameters for various power levels

Power kW	Gas flow rate g/s	Air flow rate g/s top, g/s	Air flow rate from rate, kg/h	Wood consum- -ption	Diameter mm	Air flux kg/m²s
3.7	2.5	1.9	0.76 (40%)	3.8	150	0.043
20.0	15.0	9.5	4.8 (50%)	20.0	250	0.10
100.0	70.0	42.0	21.0 (50%)	100.0	350	0.21

The superficial mass flux of the air drawn from the top is shown in the last column. One can clearly see that as power level is increased the mass flux increases implying that the design is more compact. It is possible that the diameter can be increased by a substantial margin with equally good performance as long as the heights provided allow for chemical reaction time discussed earlier. Very large diameters cause a loss of one-dimensionality and the central region of the reactor may not receive the same benefit as that of the region near the wall where heat transfer would result in better flaming pyrolysis. The number of air nozzles is one for both 3.7, and 20 kW systems and six for the 100 kW system. The last option is due to the large diameter of the reactor. By this argument the reactor for the 20 kW system may have to use more air nozzles if the diameter is to be increased. The height and volume requirements can be related mathematically as follows. The velocity of movement of the wood chips, v_w is expressed in terms of mass consumption rate of wood chips, $\dot{m}_w$ & , the superficial density of wood chips, p, and the cross-sectional area of the reactor, A_r as

$$v_w = \frac{\dot{m}_w}{\rho A_r}$$

If it is taken that during the transit of wood chips from the top to the air nozzle the wood chips essentially undergo heating and flaming pyrolysis, and this time, t^f can be expressed in terms of the diameter of the wood chips, d_w (understood as a mean diameter based on the volume or simply the diameter if the shape is a long cylinder) as

$$t = K_C d_w^{1.8}, \quad K_C = 3.5 s/mm^{1.8}$$

where d_w is in mm and tf is in seconds. The above equation is indicative of the diffusion limitedness of the flaming pyrolysis process and the exponent on dw obtained from simple theory works out to be 2. The present value of 1.8 is a curve fit of the data obtained in the laboratory and accounts for the influence of 16 convection in the experiments. The height of the reactor above the air nozzle, h_2, is obtained as

$$h_2 = v_w t_f = \frac{4K_c \dot{m}_w d_w^{1.8}}{\pi \; \rho \; d_r^2}$$

In the above equation K_c is about 3.5 s/mm$^{1.8}$ for d_w upto 25 mm size. It was argued earlier that the wood chip size is about one - sixth to one - seventh the diameter of the reactor. It is also true that the wood chips would undergo a size reduction of 10 - 15 % during flaming and that chips above 25 mm diameter have a tendency to crack into smaller pieces. At large diameters, the wood chip size is nearly constant. In such a case the height decreases with the square of the reactor diameter.

The height h_1 is governed by the reduction reactions of char with CO_2 and H_2O. The rate limited reaction $C + CO_2$ would govern the residence time of the gas compared to the $C + H_2O$ reaction for a given temperature. The time for char conversion with CO_2 is to be obtained from chemical kinetics.

Despite the discussion of a rational basis for design as noted above, it is not possible to generate a design, with fixed target of the final composition, for a given set of operating conditions. With the basic work on the extraction of basic kinetic parameters and modeling there is fair understanding of the process in the gasifier.

In the case of reactor modeling, rigorous independent analysis on each of the gasification reactions is combined. Modifications are made to represent the ambient conditions around the particles at different heights in a packed bed. The additional equations to be solved are for axial transport of heat and mass through the bed. The bed is divided into a number of computational cells and conservation equations are solved for a typical particle representing each cell.

Results from the gasification process modeling are compared with experimental results for the char reactor system. The predicted propagation rates for varying mass flux match well with the experimental data. The model predictions for the exit gas composition from a wood char reactor are satisfactory. Beyond a certain mass flux, i.e., 0.3 kg/m² s, propagation ceases and reaches extinction. This feature has been examined using the analysis proposed in the literature (Dosanjh (1987)).

Fig. 7. Experimental set-up for the packed bed reactor

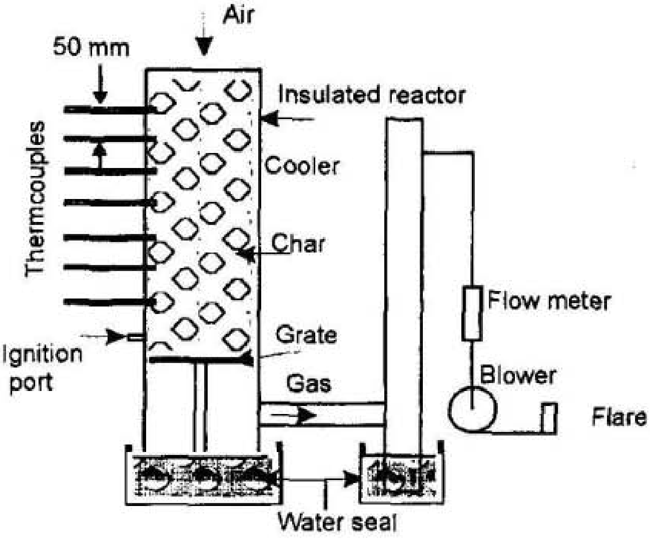
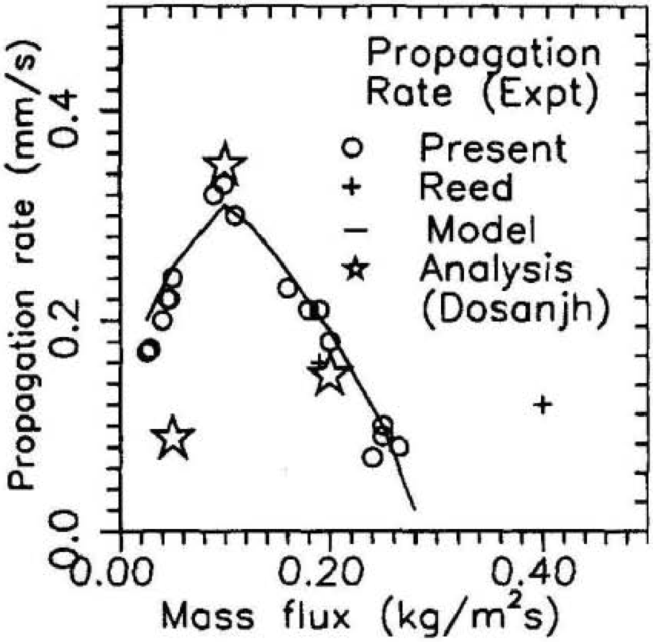


Fig. 8. Propagation rate with mass flux in a packed char bed from experiments, model and analysis



From the analysis it is brought out that extinction occurs when all the energy released in the reaction zone is used in heating the incoming gas. It is also shown from the model that the propagation front can be sustained by increasing the heat release in the reaction zone from the increased oxygen mass fraction in the ambient. Thus a comprehensive model analysis addresses several aspects related to packed char bed gasification.

ENVIRONMENTAL CONSIDERATIONS

In these industries the fossil fuels are totally replaced by technologies using only biomass as the fuel. The benefit on the environment is significant. The amount of CO_2 saving that has resulted in these industries is about 6500 tons; which is substantial at a micro scale. Along with the CO_2 saving, a large amount of other pollutants like sulphur oxides and nitrogen oxides is also in much lower concentration. The emissions from the gasifier based system are ; CO – 0.6 to 2.2 g/MJ , NOx – 0.3 to 0.7 and particulates less than 0.15 g/MJ. The lower level of NOx is related to the lower peak temperature in the gaseous flame compared with that of the fossil fuel based system.

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Concluding Remarks of Session Chairman Mr. Tankariwala

Technological changes are taking place fast to meet the end-use requirements. I would like to mention over here that jute can yield 8 metric tones of bio mass in 3 months in Assam. Dr. Dasappa has also highlighted the use of Ipomoea, which grows very commonly in Assam and is known as Nilagi Loth. I am told that in Kenya tea plantations grow eucalyptus whose chipped wood is fed into the gasifiers to generate gas. I don’t know whether we will be able to get the kind of biomass that would be suitable to generate electricity or power or gas. One other point that has been focused here amongst all the details is that we need 0.56 kg gasified biomass to process one kg tea. He has also shown the conversion factors to us as to how much fossil fuel by way of LD Oil and TD Oil can be saved. All the speakers are available for questioning and I am sure you will pick their brains during the lunch hours. May I once again thank each of you gentlemen for your very-very good discourse on all these subjects and with this I would like to close this session and thank the organizers for giving us the opportunity.

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Chapter 14

SHOOT PRECONDITIONING FOR ENHANCED WITHERING

Ravindranath

Dr. S.D. Ravindranath obtained his doctorate from I.I.Sc, Bangalore. He has 36 yrs of research experience in biochemistry and 24 yrs in tea chemistry and manufacture. He has published over 50 research papers in national and international journals and also has 6 patents to his credit. His main interest are regulation of biochemical pathways in plants, tea biochemistry applied to tea manufacture, biogenesis of flavor of tea and also diversifying the uses of tea like ready drink tea, enzyme system for making food grade tea pigments.

Withering of tea shoots is an essential step in black tea manufacture. It is a long and time consuming process taking 12-20 hrs. We wanted to hasten the process of wither and hence went into the details of the mechanism. Wither, as the industry knows, has two components viz Physical and Chemical withers. Physical wither can be achieved with the use of warm air circulating through thinly spread tea shoots on wire mesh trays in three (3) hours but to achieve chemical wither, it still needs 10-15 hrs.

The new process is based on the principles of biochemistry inherent to the shoots. Shoots, as you know, no doubt so for the plant is concerned are dead, because they have been detached from the plant but they are still alive and metabolizing. When a person is resting or working at a slow pace, his metabolic rate is slow. Similarly the tea shoots will also be metabolizing slowly. When there is stress, the human body automatically adjusts and the metabolic rate increases and generates more heat. When we are in a hurry we walk briskly or even run. We will start feeling warm and perspiring. The same phenomenon happens to the shoots also. We have tried to use the concept of enhanced metabolic activity.

The process involves giving repeated controlled stress to the shoots. By doing this, we are triggering the biochemical reactions to take over which hastens the process of chemical wither. The chemical and biochemical reactions are increased and they also generate heat simultaneously. A little extra heat is generated. As a consequence, now the shoots need to be cooled, rather than use warm air. The simultaneous increase in metabolic rate and generation of heat both are controlled by the circulation of ambient air through the system. Extra heat is removed by the air which removes some amount of water/moisture from the shoots because warmer air has grater water removing ability. So along with heat shoots continue to lose water and we are able to achieve both physical and chemical withers needed for CTC manufacture in 4 - 4.5 hrs. If one has to manufacture orthodox tea an additional hour will give the withers needed.

To transform this concept into a machine we at the Institute of Himalayan Bioresource Technology, a CSIR Laboratory, have collaborated with MESCO Pvt. Ltd., a known manufacturing company located in Kolkata. The advantage of this enhanced withering process is that it cuts on the

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withering time but how about quantity of made tea. The process does not deteriorate/lessen the quality *per se.*

The tea will be like the normal manufactured tea. The machine gives repeated controlled stress to the shoots in quick succession to precondition them. It can handle upto 4000 kg of green leaf per hour and requires just 7'X10' area of floor space. The machine does not wither the shoots but only preconditions them and facilitates faster withering.

This means the existing withering trough area has to be used for achieving physical and chemical wither but teas has to be manufactured before the normal time. As a consequence the existing troughs/area are emptied and are now available for spreading more leaf. Assuming that the gardens increase their leaf output by 200 percent, with the new concept, it can accommodate the leaf in the existing facility available at the factory. It only needs some adjustments in manufacture schedule i.e. if a garden produces 1 million kg made tea per annum it needs to reschedule the manufacture by starting at 2.30 or 3 in the afternoon. The manufacture for the day will be over a little beyond mid-night. This spares 8 hrs. of withering space which can now be reloaded with more leaf. Subsequent manufacture needs to be done as per the availability of other machines in the factory.

With the development of this new machine, now, one can think of making a continuous manufacture schedule because the machine can be made continuous. Along with this machine, as many factories are familiar with continuous fermenting system, a conveyorised system with air circulation, ambient air I emphasize, which will run for 4 - 5 hrs. will facilitate discharge of the withered leaf at the Rotavane CTC Bank. Other steps like fermentation, drying and sorting can be linked for continuous operation. One may still be skeptical about the quality. Quality does not suffer at all. It is at par with the normal manufacture or even could be better.

We have a stall by M/S MESCO in the exhibition area where pamphlets are available for distribution and people are available for clarification.

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Chapter 15

PANEL DISCUSSION ON COST REDUCTION AND QUALITY IMPROVEMENT

Chairman P. Sivepalan
Summary by V.S. Sharma

Dr. N. K. Jain invited Dr. P. Sivepalan to mediate the discussions of the panel comprising Drs. F. Rahman, V. S. Sharma, Ms. Salwa Lubnan Dalimoenthe and Dr. Nigel T. Melican on containing the cost of production of tea without detriment to its quality.

Dr. Sivepalan threw the house open for discussions on the papers presented on the subject during the course of the first day; he advised the participants to make full use of the presence of all the speakers, seeking clarification on any point that is relevant to the subject.

To a query from the audience, Dr. Rahman explained that cost reduction at the cost of quality of tea is easy to achieve but it is not the aim; in the present context, superior quality is of immense importance to be competitive and should not be compromised upon. It is, however, possible to achieve cost control without compromising with the quality. The major component of the production cost of tea is on labour, ranging between 57 and 70 per cent. There is a limit to the reduction of inputs such as fertilizers and pesticides, which seems to have already been achieved. However, there seems to be a vast scope for increasing the efficiency of labour, while simultaneously attempting its optimal deployment so as to economize on labour cost. It is, politically and socially, a very sensitive subject but, if the tea industry is to survive, it is to be handled by appropriate negotiation and persuasion of the powers that are.

Dr. Sivepalan invited questions and clarifications on the subject of mechanization, particularly harvesting that was presented by two speakers.

Dr. Jain, during the course of interaction, mentioned about a remarkable feat of a Tanzanian worker, harvesting about 300 kg of green leaf per working day of 8 hours by hand as against Indian worker who is likely to achieve an upper limit of about 20 kg per man day. He opined that time and motion studies/ ergonomics of harvesting should be critically evaluated to optimize the workers' efficiency. In this context, it was brought out that effective harvesting time of a plucker is only about four and a half hours, the remaining time being spent on such sundry works as collection, unloading and loading and carrying the leaf to the weighment sites. All efforts should be coordinated to ensure that plucker spends most of the time only on actual harvesting, leading to an increased plucker productivity.

Dr. Sharma pointed out that due to its very nature of isolated situation, the plantation industry is oblivious of the main stream of life and breath-taking sophistication and advancement that are taking place in other industries. The plantation industry still believes in carrying materials by head loads within the fields, not giving even a thought to the possibility of using a wheelbarrow or other mode of transport for the purpose. There is no escape from mechanization of field operations, wherever possible, if the plantation industry-whether it is tea, coffee or rubber, is to survive the onslaught of competition from other producing nations. There is immense scope of mechanization of certain operations in tea such as pitting, pruning, harvesting and transport of materials within the fields.

Dr. (Ms) Salwa Lubnan and Dr. Sharma demonstrated in their studies beyond doubt that mechanization by way of hand-held, manually operated shears and motorised mechanical harvesters increase the productivity manifold without detriment to quality. They focussed on the serious constraints in the use of motorised mechanical harvesters by developing countries that produce tea, because of their price and cost of maintenance in view of high price of spare parts of the machines. It is worthwhile that a motorised mechanical harvester is designed and developed indigenously at low cost, to be accessible to the developing countries.

The mounted mechanical harvesters have limited application only in flat fields or those with gentle slopes. Teas made from the leaf harvested thus have not been reported very favourably. But the quality of teas made from the leaf harvested by shears can be maintained by optimizing the length of plucking rounds based on phyllochron (the number of days required for one leaf to open).

Dr. Sharma made an appeal to the Tea Board/ NABARD to freeze all funding for activities such as extension planting and planting in non-conventional areas; in other words any increase in the existing tea area is to be frozen till the prices are stabilized.

A suggestion also has taken shape in the course of discussion that the incentive system for harvesting of green leaf should be redesigned to make it more attractive and promoter of production.

A delegate pointed out that reduction in the cost of production while increasing or maintaining superior quality of tea, will not automatically result in reward to the producer by way of higher returns; instead, the profit margins of the middlemen only will increase with no benefit to the producer! In this context, it was pointed out by another delegate that the auction system seems to work against the producer in times of over-supply. An important solution to this problem could be direct outlet from the producer by way of selling pouches or direct sale.

Tea, like other commodity products, is unique in that it goes to the market without a price-tag, while even such an insignificant article as a pin is marketed with a price-tag! If the plantation sector, particularly tea, chooses an agricultural destiny, it is likely to meet the fate of an Indian farmer continually exploited by the middleman. If tea chooses an industrial destiny, it has to behave like an industry, exploring the possibility of value addition with its own marketing strategy attaching a price-tag to its product.

The important objective of this conference is not just cost reduction in tea production but also realization of remunerative prices and wider margins for the produce; certain avenues have been indicated towards that direction.

For live Panel Discussion on Cost Reduction, Please listen to the attached Audio-Disc

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