Tea Research Institute of Sri Lanka

Woodchip Feeding System for Efficient use of Firewood in Tea Drying

Collaborative project

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இலங்கை தேயிலை ஆராய்ச்சி நிறுவனம்
TEA RESEARCH INSTITUTE OF SRI LANKA

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Project Team

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Overview

- Introduction
- Source of Fuel
- Combustion process
- Objective
- Experiment
- Results and Discussion
- Demonstration of the System
- Conclusions

Introduction

- More than 600 tea factories, registered at SLTB
- Annual production of tea is more than 250 million kg
- Estimated fuelwood consumption is about 450,000 tons/ yr
  (at 1.8 kg/ kg of made tea)

Sources of Fuel

Rubber wood plantations

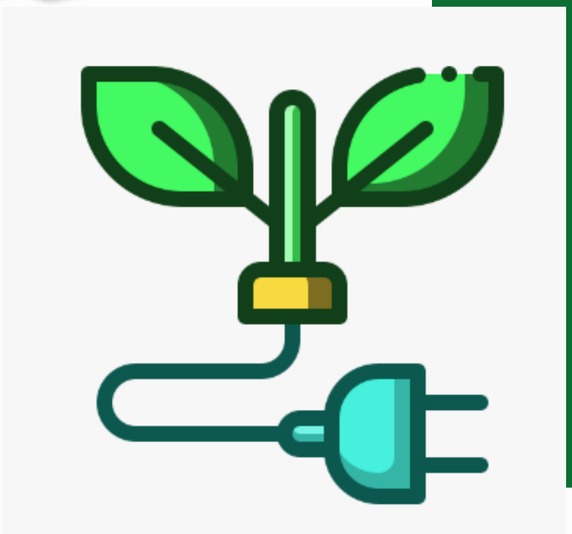
Main source is wood logs used in cut, split and dried form
This source is becoming scarce

Timber industries and Carpentries

By-products such as offcut pieces and
saw dust in briquette form

Biomass energy terminals

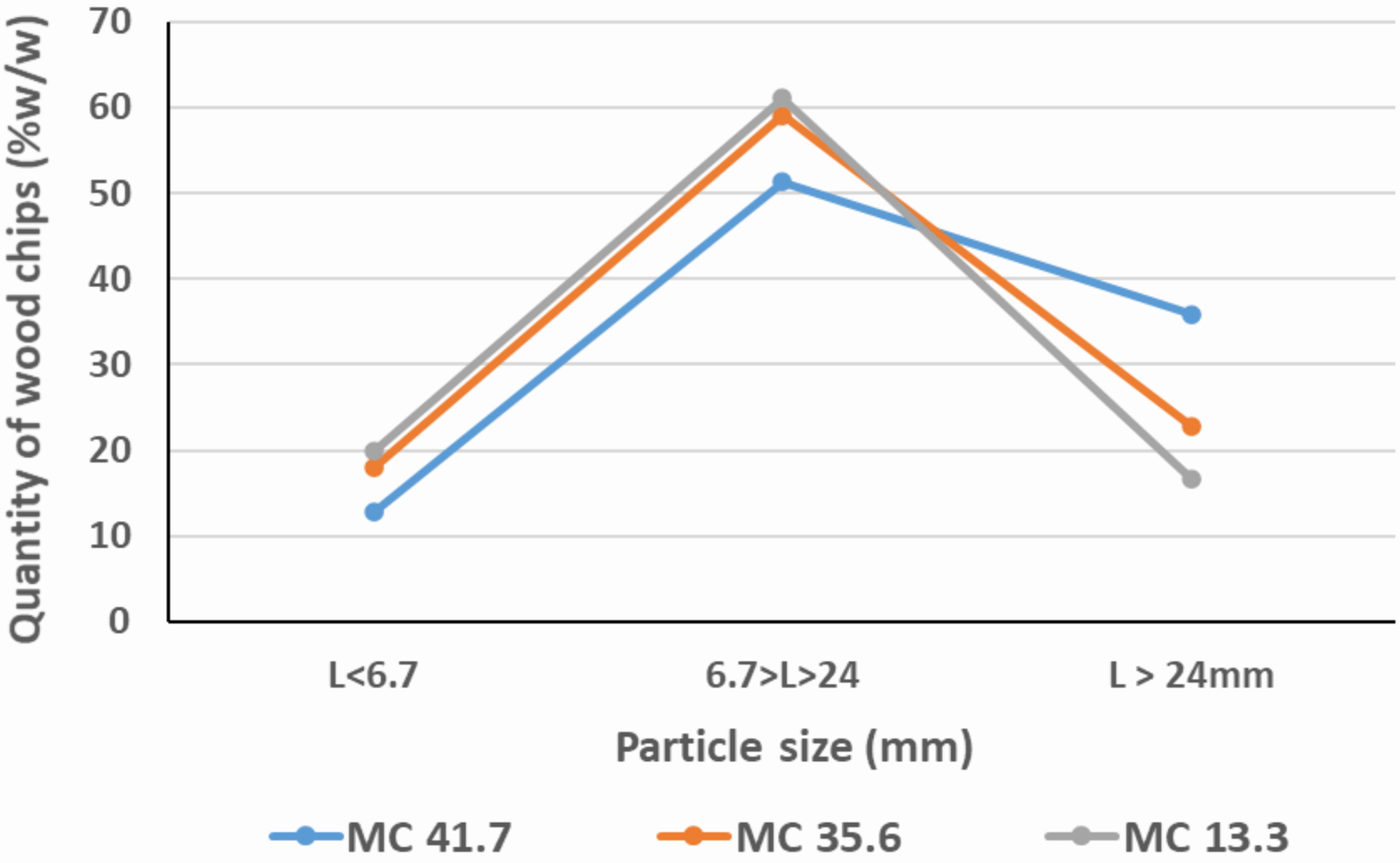
Woodchips from Gliricidia, rubber and other
locally available firewood tree species,
Briquettes and
Split & dried firewood



Woodchips

- More surface area
- Could generate more energy with less quantity
- Used in other industries such as MAS Fabric and Ansel Lanka

Particle size distribution

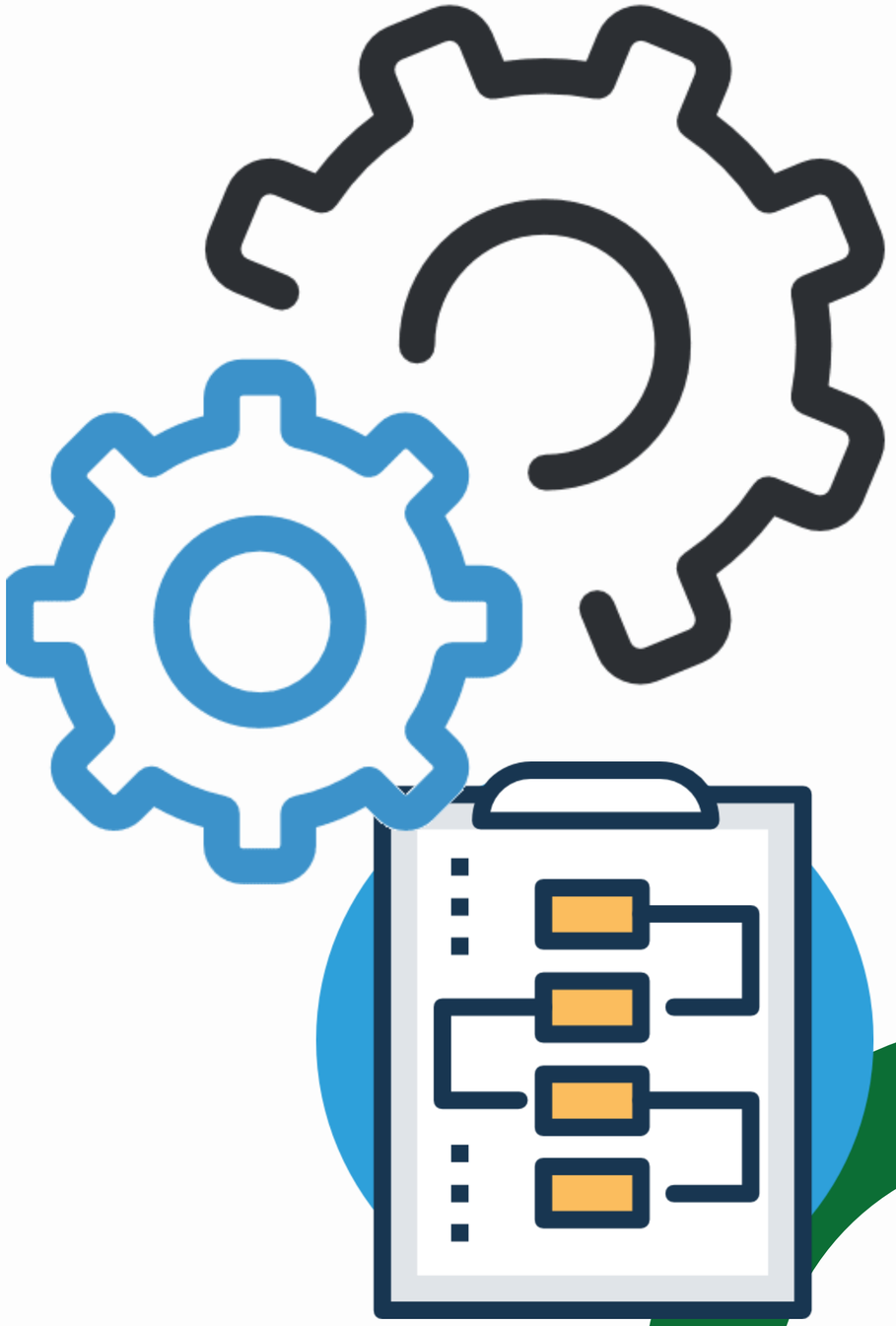


Woodchips tend to shrink as it dries.

Combustion Process

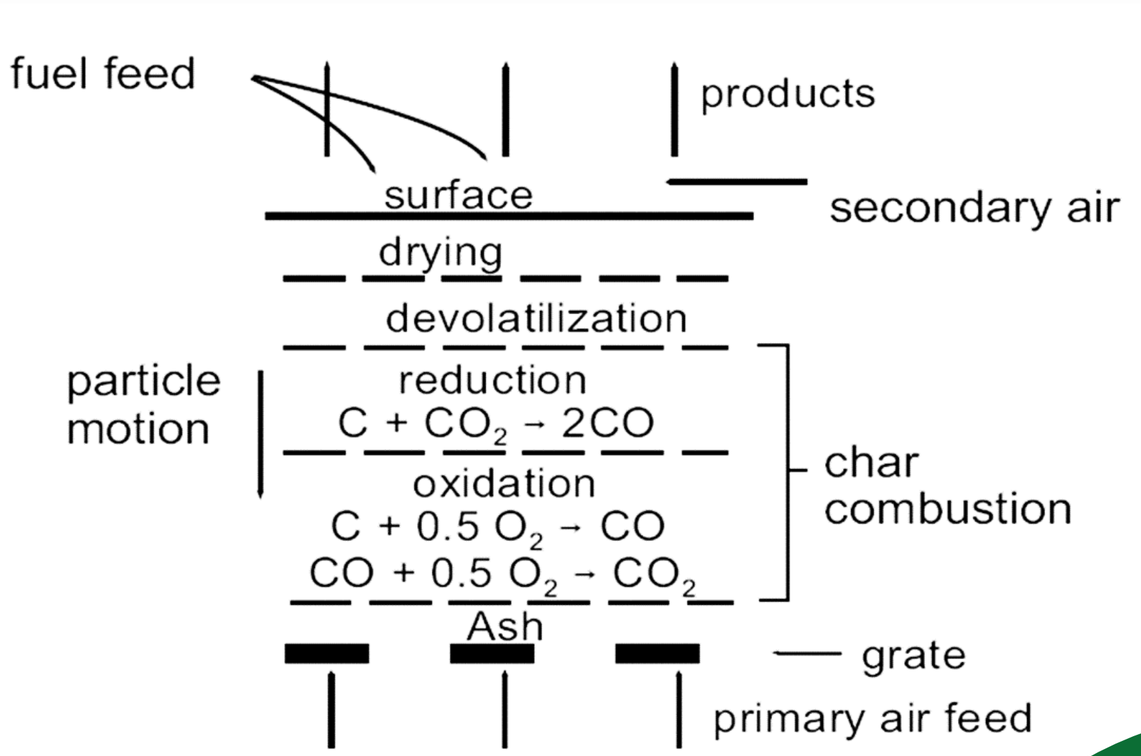
Wood combustion process,

- Heating
- Drying
- Solid-particle pyrolysis to volatiles and char,
- Gas phase volatile oxidation and
- Char oxidation



Combustion of woodchips

- Thin bed - primary product is CO_2
- Thick bed - (> 8 particles thick) – primary product is CO - essentially a Gasifier
- Volatiles almost always burn above bed with secondary air
- Stoichiometry of an overfeed bed is determined ONLY by bed thickness
- Changing air flow only changes combustion rate, not stoichiometry!



Objective

To design and develop a semi-automated feeding system for feeding of woodchips to be retrofitted to an existing conventional furnace/air heater-dryer system for generating required hot air for drying tea

Specific Objectives

- To maintain inlet drying air temperature within ± 2 °C without any accumulation of woodchips on the fire grate
- To dry teas within the acceptable moisture content of 2.5 – 3.0% (w/w, wet basis)
- To reduce specific firewood consumption below 0.8 kg/kg made tea

Experiment

Location : A Tea Factory in Ratnapura Region

Material : Woodchips

Moisture content of fresh woodchips - 50 %
(w/w, wet basis)

Degradation of woodchips was observed when the moisture content is above 30%

Machinery

Furnace/Air heater (CCC Model 3A)

To combust woodchips and generate hot air for drying

- Flat-bed fire grate of 0.9 m x 1.2 m
- Cast iron fire bars

ECP Dryer (CCC, 6ft., 3 stage)

Coupled to the **furnace/air heater** to dry tea using the hot air

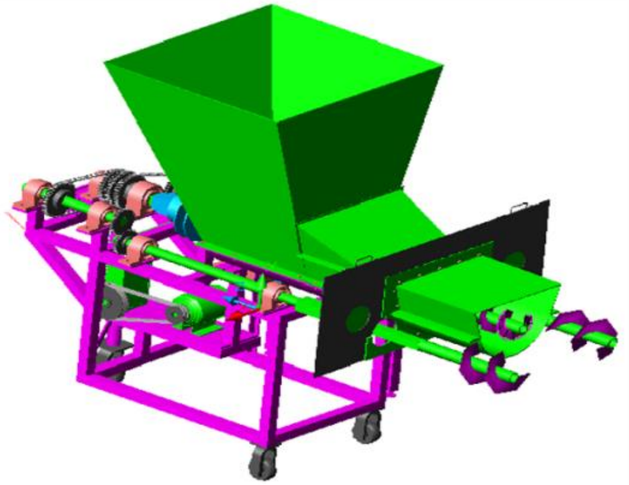
- Dried-tea output is 195 kg/hr
- Drying air temperature is 120 °C

Machinery

Screw Feeder

To feed woodchips into the **furnace/air heater**

- A VFD was coupled to the motor
- Suitable rotational speed is 7 rpm
- Feeding rate of wood chips vary as,



Developed to feed cut and dried pieces of Gliricidia fuelwood lopping ~ 25 mm ϕ x 75 mm

Moisture content of woodchips (%, w/w, wet basis)	Feeding rate of woodchips (kg/hr)
17.6	252
27	282
41.7	354

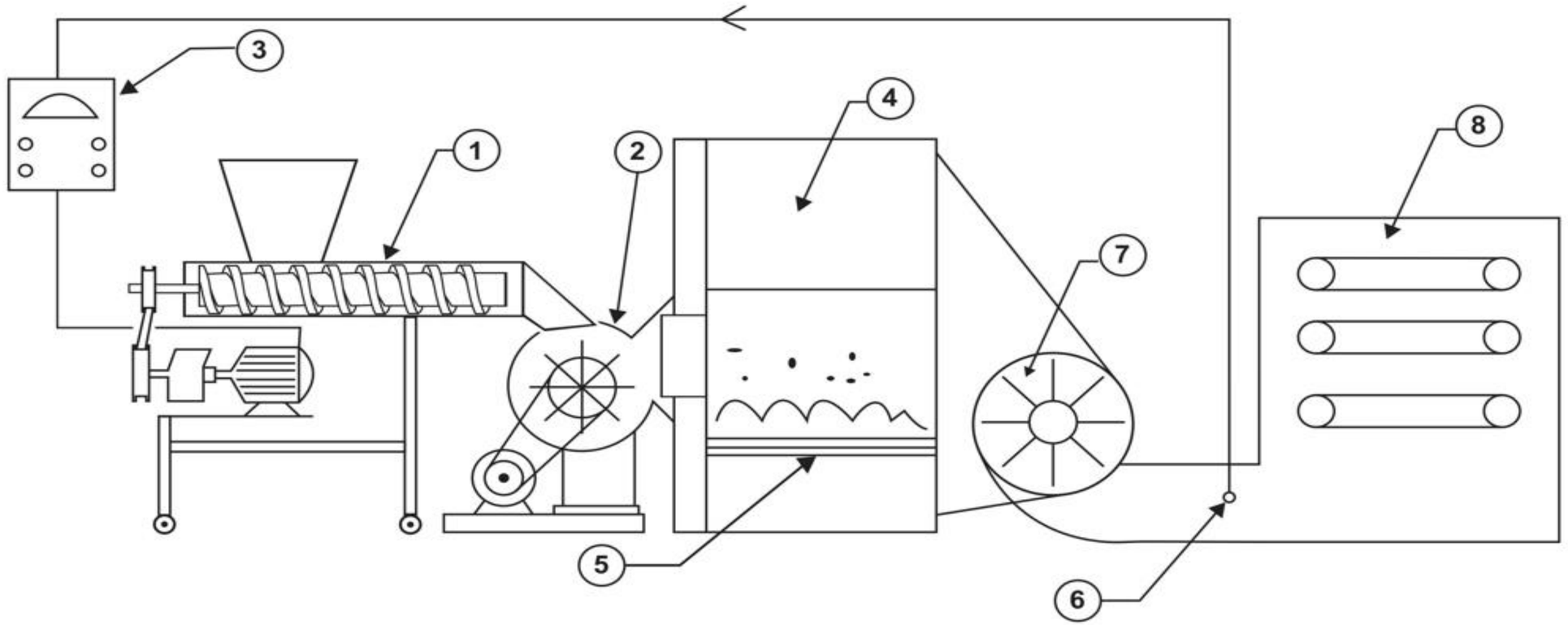
Machinery

Drum Spreader Stoker

To spread the woodchips on the fire grate

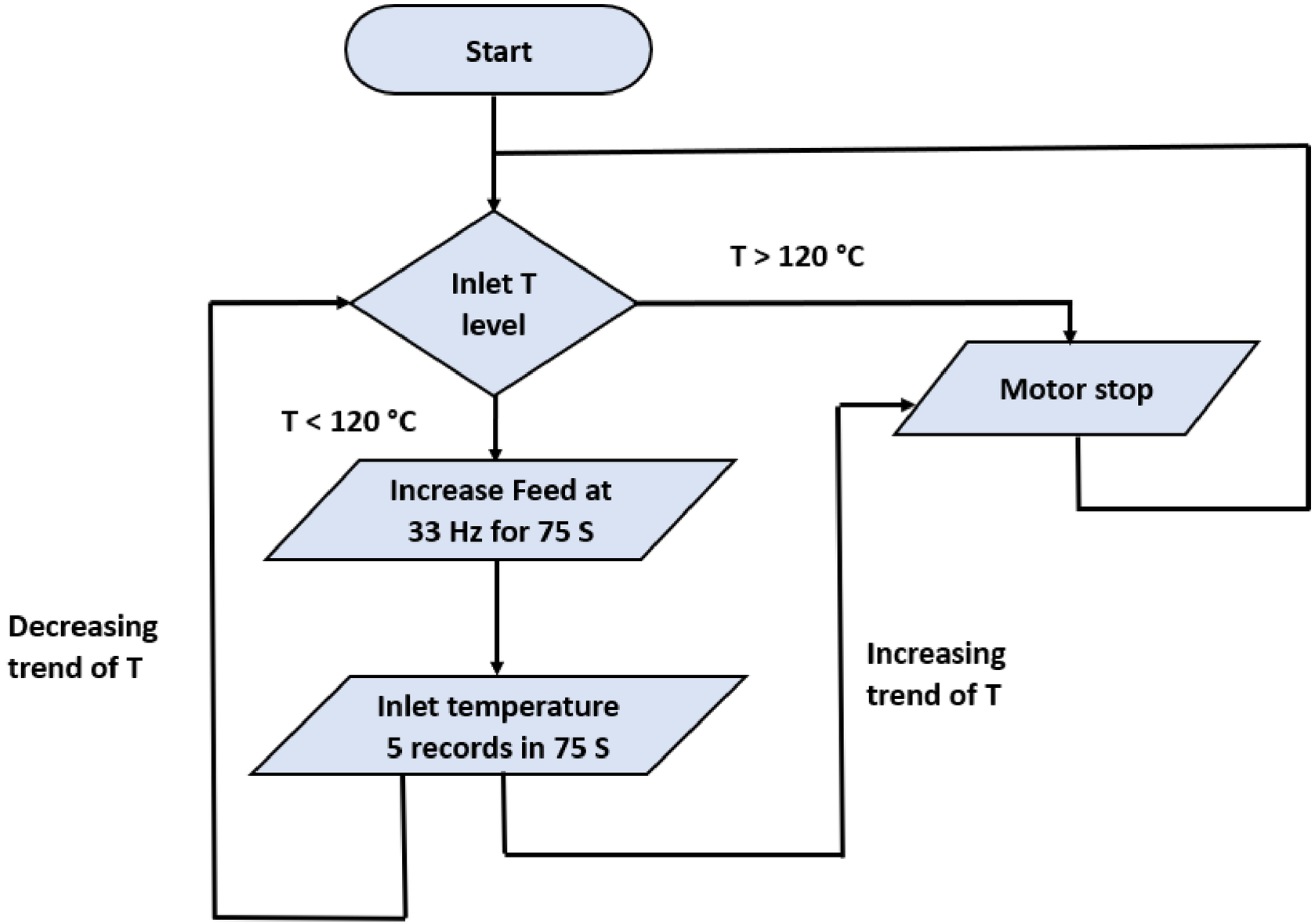
A VFD was coupled to the motor to adjust the speed and obtain even spread of woodchips on the fire grate,

Schematic Diagram of Experimental Set up with Control System



1. Screw Conveyor
2. Drum Spreader Stoker
3. Control Panel
4. Furnance / Air heater
5. Fire grate
6. Temperature Sensor
7. Main Fan
8. ECP Drier

Control Programme



Continual Feeding of Woodchips

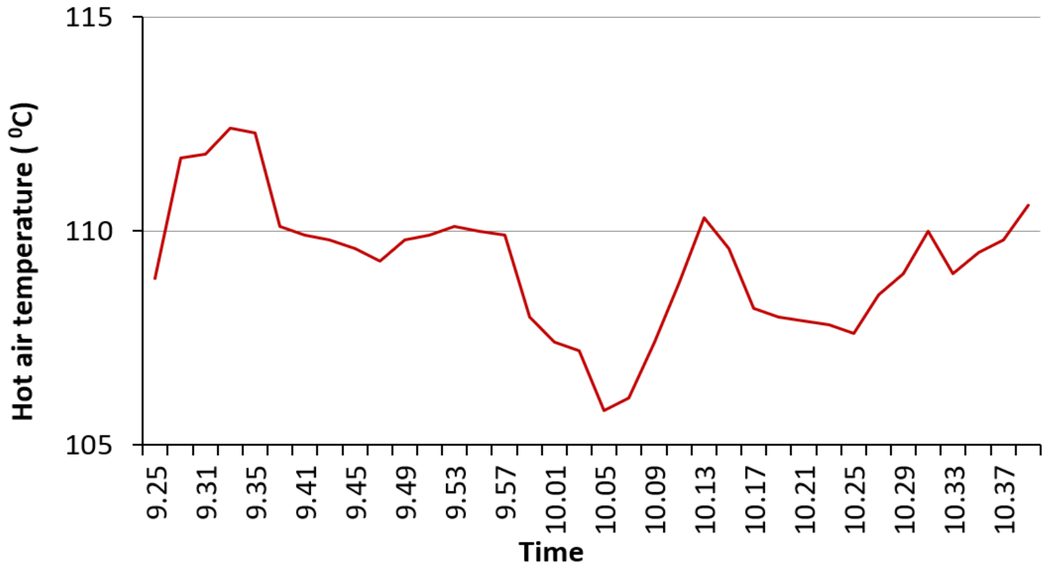
semi-automated feeding system

RESULTS AND DISCUSSION

Trial 1

- **Set point of 110 °C**
- **Moisture content – 35.6 % (w/w, wet basis)**
- **Flue gas temperature – 210 °C**
- **Auto mode after initial heating up**

- Temperature dropped after 30 minutes
- Manually increased the feeding rate resulted in accumulation of woodchips
- Sub-stoichiometric conditions occurred in the woodchip bed as a result of limited supply of oxygen and reducing reactions dominated
- When the woodchips were mixed with dry woodchips having 13.3% moisture content (w/w, wet basis), the hot air temperature increased again



MC of Woodchips

It was a challenging task to burn small woodchips on a fixed flat-bed grate.

- Grate was designed to burn wood logs.
- The combustion chamber of the **furnace/air heater** had been designed to give enough grate area and volume to pile up logs for burning

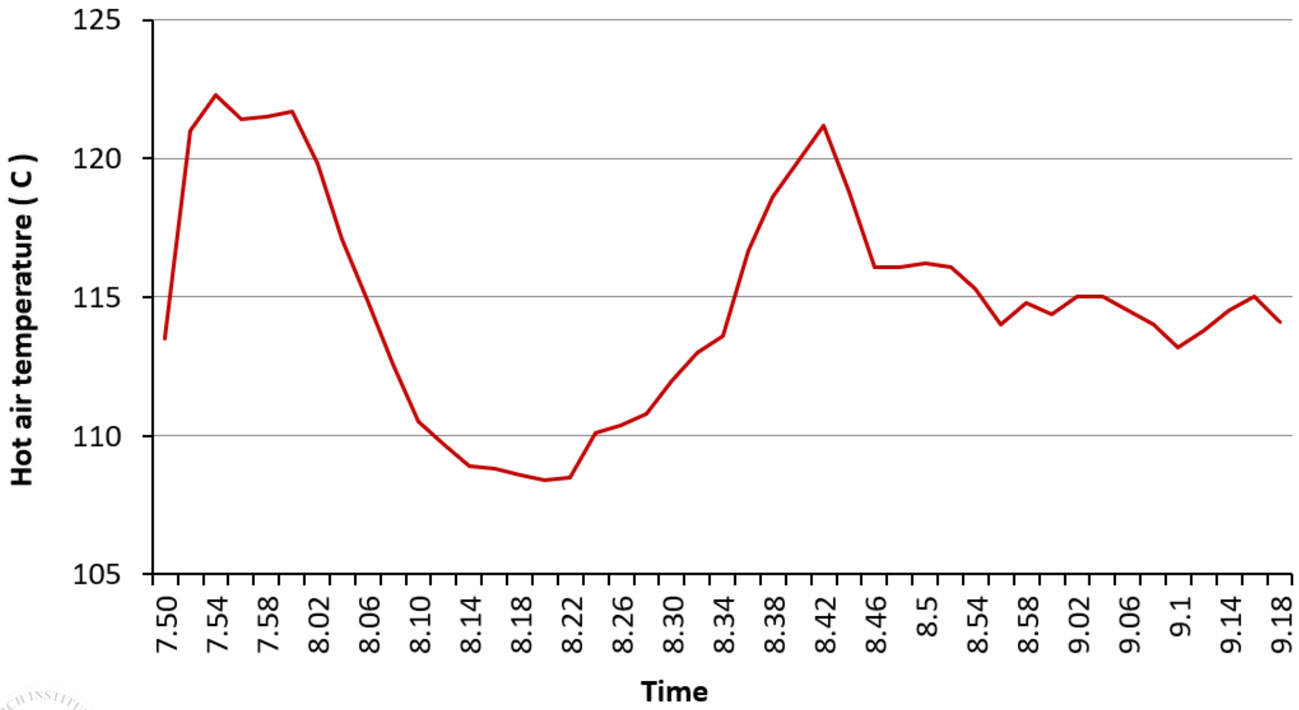
Decided,

- to reduce the moisture content of wood chips to 25% (w/w, wet basis)
- Increase the drying air set point to 120 °C

Trial 2

- **Set point of 120 °C**
- **Moisture content – 25 % (w/w, wet basis)**
- **Flue gas temperature – 210 °C**
- **Auto mode after initial heating up**

- Temperature dropped drastically within 15 minutes
- Woodchips, that were fed by the feeding system to regain the temperature, started accumulating
- An iron rod was used to level the woodchips
- Continual feeding leads to drop in the hot air temperature

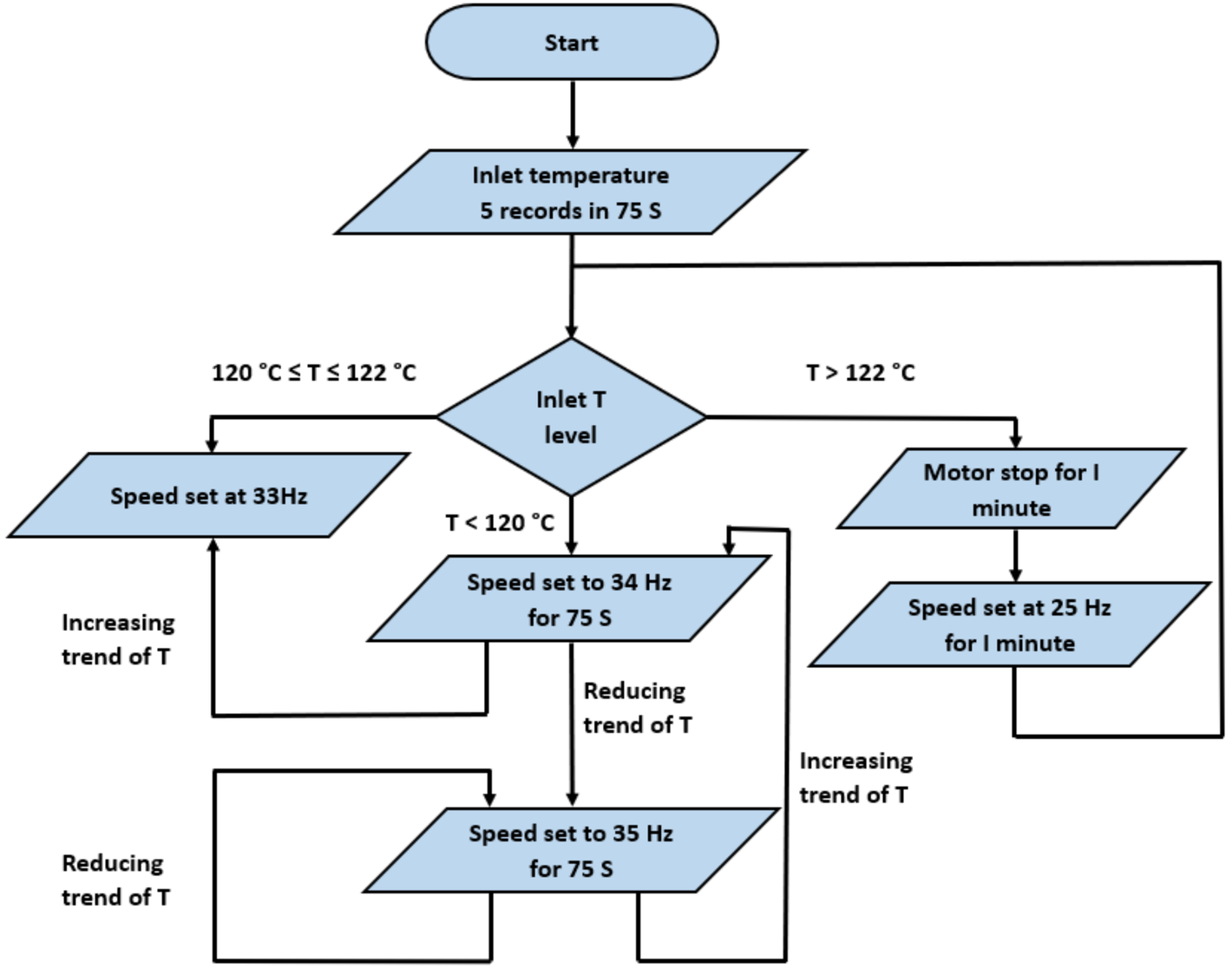


Decided to,

- Regulate feeding without accumulation of woodchips.
- Revise the control programme

Revised Control Programme

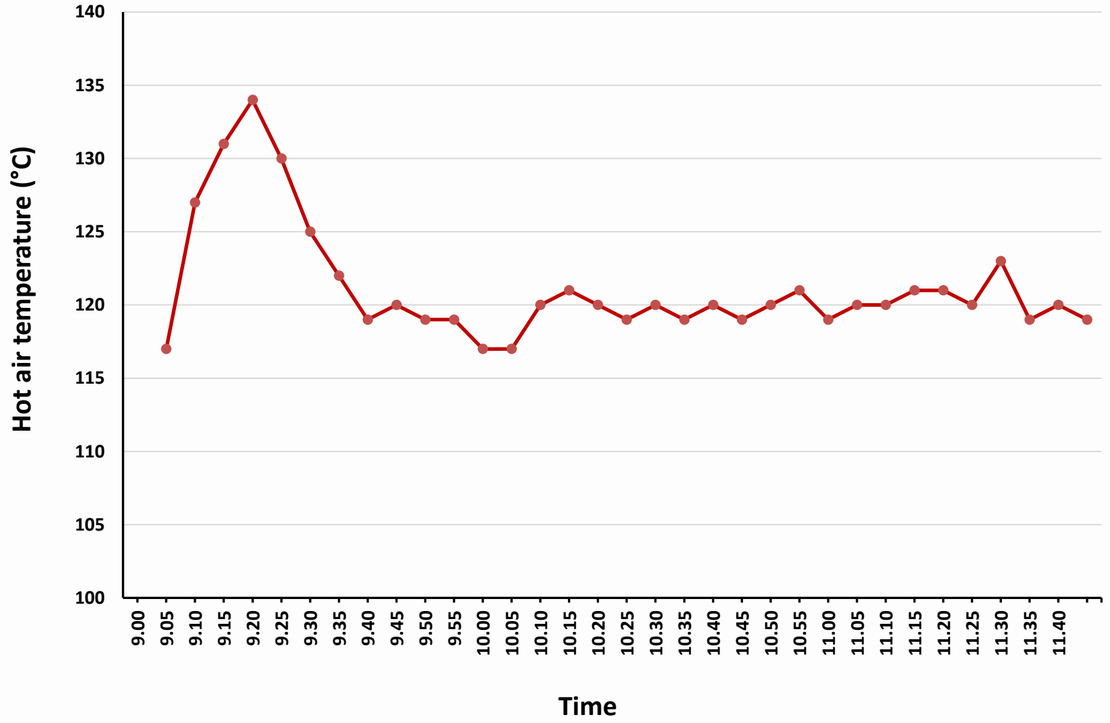
Regulating Feeding of Woodchips



Trial 3

- **Set point of 120 °C**
- **Moisture content - 25 % (w/w, wet basis)**
- **Flue gas temperature – 210 °C**
- **Auto mode with Revised Control Programme after initial heating up**

- Temperature maintained within ±3 °C
- No accumulation of woodchips on grate.



Specific Woodchip Consumption for Drying tea

Dried tea moisture content – 2.5 – 3.0%	Dryer output – 195 kg/hr.	Woodchip consumption – 227 kg/ hr.	Specific firewood consumption – 1.16 kg/ hr.

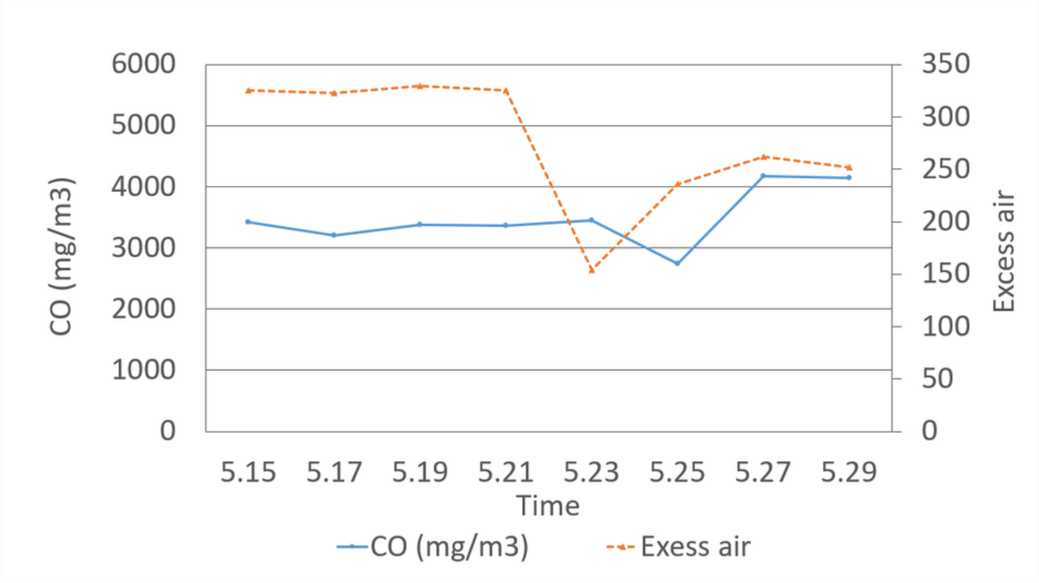
High Specific Firewood Consumption Is due to Stack Losses

Flue gas temperature was maintained at 210 °C to achieve the hot air temperature of 120 °C.

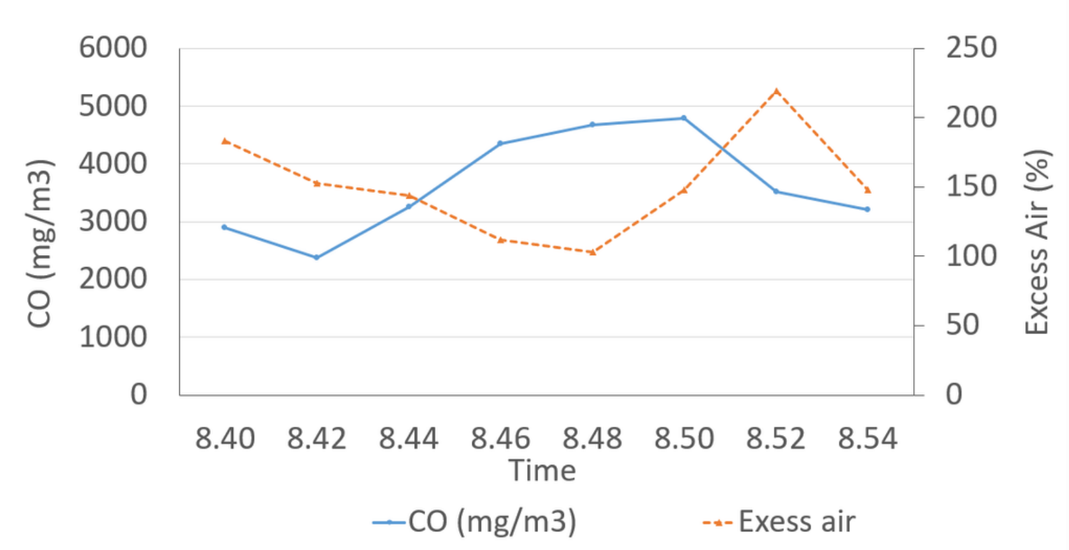
Condition of the Air heater and dryer was poor

Flue Gas Analysis

Combustion of split wood logs



Combustion of woodchips using Feeding System



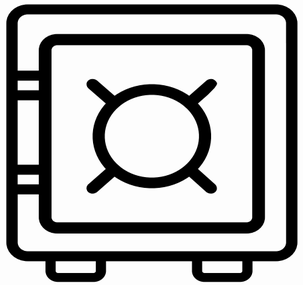
	Combustion of split wood logs	Combustion of woodchips using Feeding System
EXCESS AIR	**154 – 330 %**	**103 – 219 %**
CO	**3,206 – 4,169 mg/m³**	**2,370 – 4,791 mg/m³**
COMBUSTION EFFICIENCY	**94.7%**	**96.2 %**

Validation of the System

Institute Tea Factory at TRI Low Country Regional Centre at Ratnapura

Tempest Dryer with rated output of 250 kg/hr

Chola Air Heater 5-pass type, efficiency > 70%



Necessary Modifications to the Unit and Furnace/Air Heater

Mesh arrangement

Fire bar arrangement

ID fan and flue gas line repair

Revising control programme

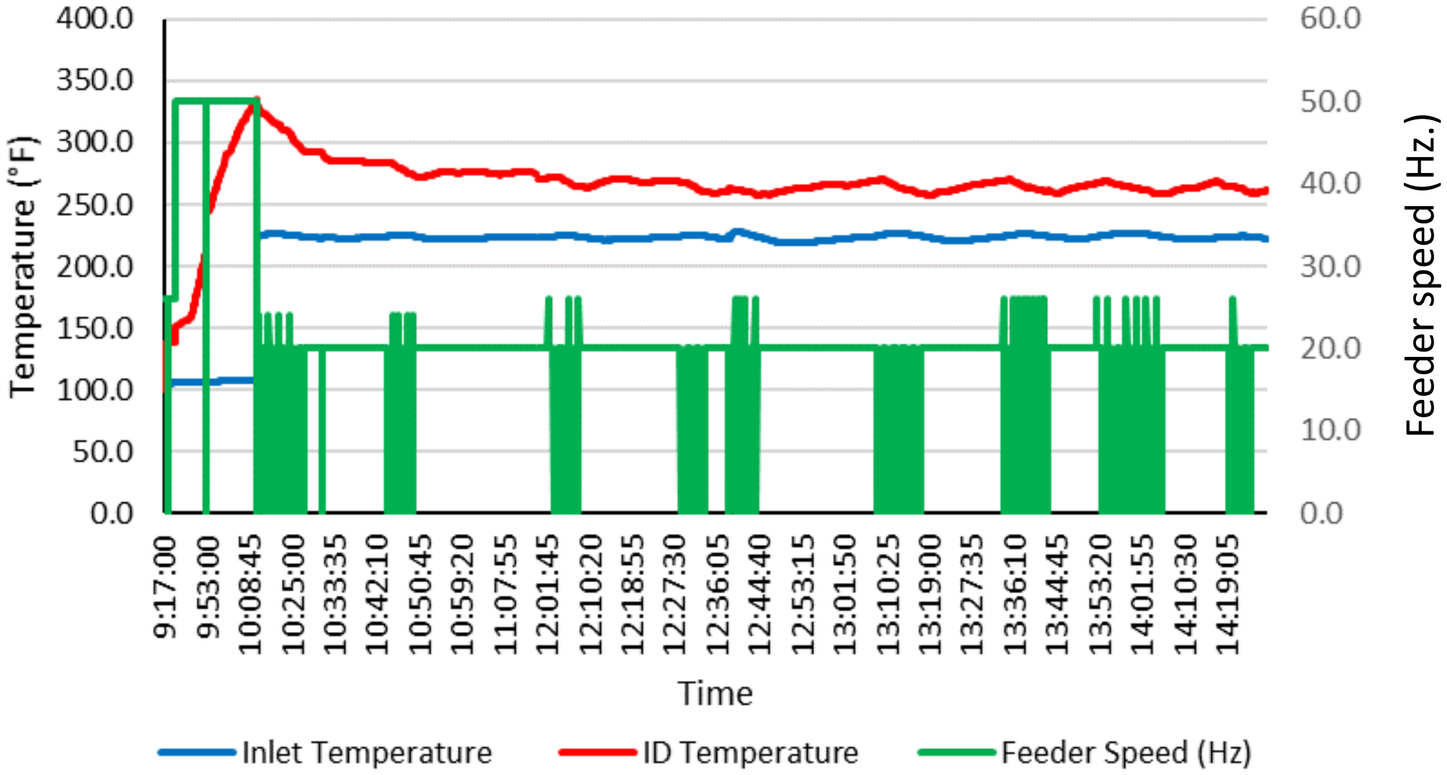
Retrofitting the unit to Air heater

Six Trials were Conducted to Establish Operating Parameters

- Woodchip consumption for heating up is 140 kg/40 min
- Woodchip consumption for drying is 153 kg/hr
- Dryer output is 255 kg/hr
- Specific woodchip consumption is 0.6 kg/kg made tea

- Reducing the moisture content of wood chips from 44% to 25%
  - less than 3 weeks

Inlet drying Air Temperature – Maintained with Minimum Fluctuation



Variation of inlet drying air temperature, flue gas temperature and screw feeder speed with time

Demonstration Activity at St Joachim Tea Factory

Cost Benefit

- Firewood cost - Rs.4,500/ cu.m
- Woodchip cost - Rs.18/kg.
- Cost of the Woodchip Feeding System - about Rs. 3.3 million.

- Drying cost with woodchips – Rs.14.72 / kg made tea
- Drying cost with wood logs – Rs.18.00 / kg made tea

Saving on cost of drying - > Rs.3.00/ kg made tea

The simple payback period - < 03 years
(for processing more than 4,500 kg green leaf per day)

Other Benefits

- Drying teas within 2.5 – 3.0% moisture content
- Reduced specific fuel wood consumption
- Easy maintenance of inlet drying air temperature and thereby achieving rated output of the drier
- Less load to air heater and reduced maintenance requirement to **air heater** and its parts

Conclusions

- A Woodchip Feeding System was successfully tested for drying tea, by retrofitting it to a conventional furnace/air heater at a tea factory. Teas were dried within the acceptable moisture content of 2.5 – 3.0% (w/w, wet basis)
- Control Program was established to maintain inlet drying air temperature within ± 2 °C without any accumulation of woodchips on the fire grate
- Acceptable moisture content in woodchips was found to be about 25% (w/w, wet basis)

Conclusions

- Specific woodchip consumption for drying was 0.6 kg/kg dried-tea
- Saving on firewood is more than Rs. 3.00/ kg made tea
- Investment on Woodchip Feeding System is Rs. 3.3 million with a simple payback period of less than 3 years for a daily green leaf intake of more than 4,500 kg

Recommendations

- **Air heater requirement**
  - Efficient & in good condition, preferably a 5-pass type or higher efficiency
  - ID fan and flue gas line in good condition without any damages/leakages
  - Proper firebar arrangement
  - Regular removal of ash and deposits on heat transfer areas

- **Dryer requirement**
  - In good condition
  - Achieve rated output

- **Operating condition**
  - Fixing the Woodchip Feeding System properly to prevent more secondary air
  - Use dried woodchips – 25% moisture content
  - Arrange firebars to minimize fall through
  - Operate manually until inlet temperature is achieved
  - Ensure, dryer is fed with different dhool properly to achieve rated output of the dryer

Future Work

Testing and Validating the Woodchip Feeding System

- In different Air heater-Dryer Systems
  such as Boiler/ Hot Water Generator-Dryer System

- With different Energy Plantation Sources
  such as Gliricidia.

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THANK YOU!

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