

AN AUTOMATED CONTROL SYSTEM FOR FLUIDIZED BED DRYING

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Introduction



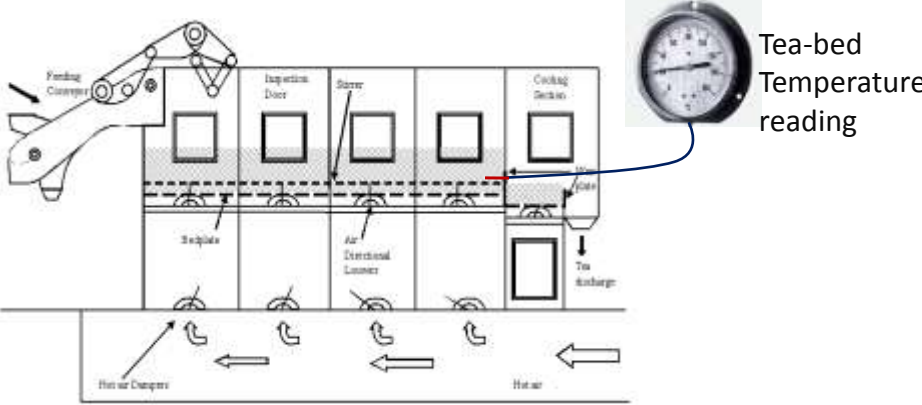
Fluidized bed drying – best method
TRI-CCC FBD – widely used for tea
Drying

Moisture is reduced and which results...
density changes &
fluidization velocity changes

Challenge – Maintaining fluidization conditions



Present method of control



If the temperature is maintained 190 - 210 °F (88 – 99 °C),
2.5 – 3.0 % Moisture Content is ensured in dried-tea.

monitoring tea-bed temperature and
adjusting spreading thickness of dhool on feeding conveyor.

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Reasons for fluctuations of tea-bed temperature

1. Time lag** for response in tea-bed temperature
2. [Manual method to adjust spreading thickness](#)
3. Spreading thickness cannot be finely adjusted
4. Varying moisture content in dhool
5. Different dhool fed into the dryer (1st, 2nd, 3rd, etc..)
6. Dryer operating condition – **very important**
7. Poor performance of Dryer thermometers

**Time lag = time gap between dhool feeding adjustment and weir-end tea-bed temperature

Problems identified

1. Discharging time from the dryer is affected and tea often get under-fired or over-fired
2. Fine tea particles are carried over by the exiting fluid stream leading to increased entrainment and blowout.
3. Re-firing of under-fired tea & Blowout
4. Varying output of the dryer
5. Effect to made tea quality



Potential Solution

controlling the feeding rate of dhool into the dryer

This could facilitate minimizing of fluctuations in tea-bed temperature

- thus drying tea within 2.5 – 3.0 % Moisture content.



Objectives

Primary objective

To develop an automated control system for fluidized bed drying of Orthodox-Rotorvane tea.

Specific objectives

1. To monitor process parameters and develop mathematical model/s.
2. To develop effective control system using the mathematical model/s
3. To validate the control system



Study approach

1. Installing data acquisition system for monitoring dryer operating parameters
2. Developing mathematical models for controlling the operating parameters
3. Installing necessary control panels and actuators to control the operating parameters according to the model/s
4. Validating the control system for fluidized bed drying of tea



System components

I. Main control panel



II. PLC as the main controller



III. Sensors for sensing parameters



IV. Actuators for executing commands from the controller



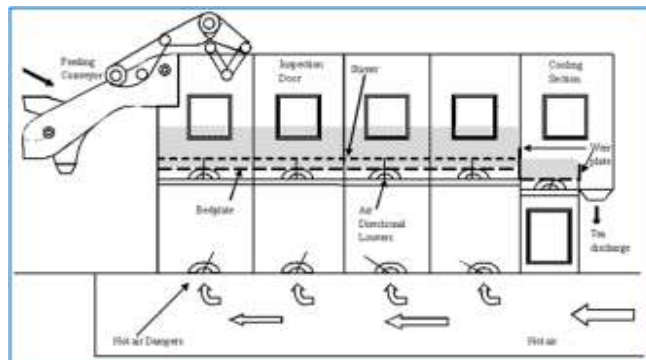
V. Other accessories



Cost of Installation = Rs.1.2 – 1.5 million



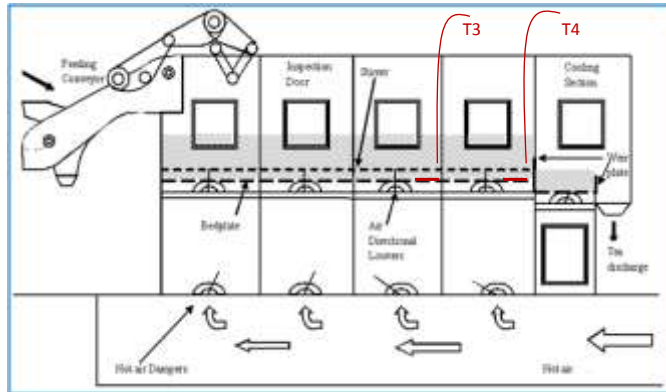
Data acquisition



1. Tea-bed temperatures (all 4 sections)
2. Feeding conveyor speed
3. Air directional louver positions in 3rd and 4th sections



Developing mathematical model

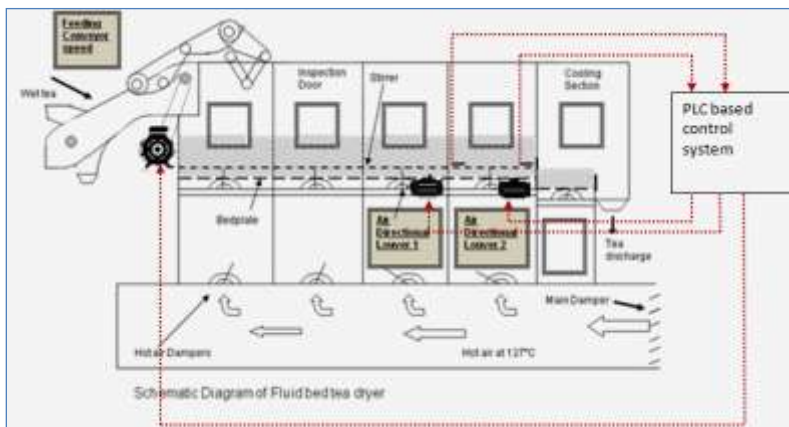


Data on final moisture content (MC) and tea-bed temperature in 3rd section (T_3) and 4th section (T_4) were analyzed.

Best fit equation, $MC = 12.1 - 0.0398 T_4 - 0.0731 T_3$



Integration of Data acquisition and control system



- feeding conveyor motor is connected to the control system to adjust feeding rate of dhool according to the control programme
- motorized operating mechanism controlled by the programme is connected to directional louvers in 3rd & 4th drying sections to change retention time of dhool



Control programme

- How to control feeding of dhool

step increase and step decrease of feeding

recovering feeding rate for steady dryer operation & rated output

recovering after disturbances such as power failure

- How to control air directional louvers

change louver positioning to reverse, forward and upright

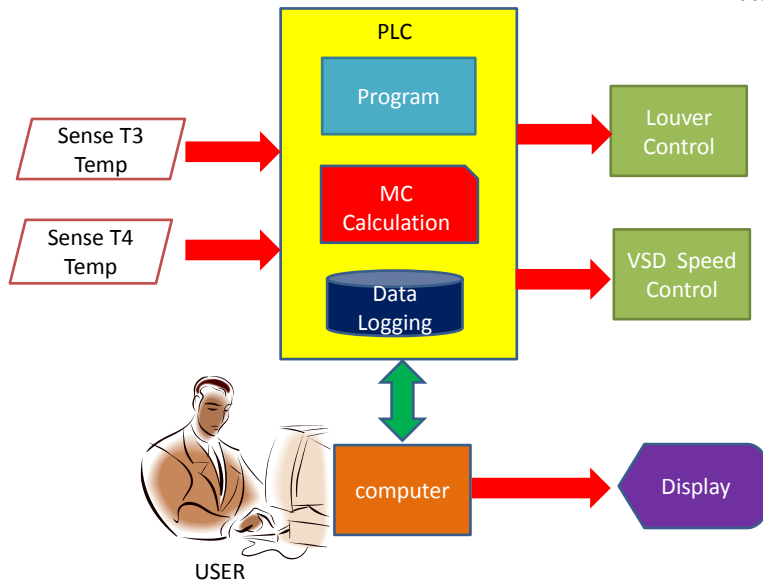
This results...

weir-end temperature within 97 ± 2 °C



System Architecture

**Patent Pending



Comparison of Moisture content & Evaluation

Monitoring variation in dryer operating parameters

– tea-bed temperature and Moisture content

1. Manual operation &
2. Automation

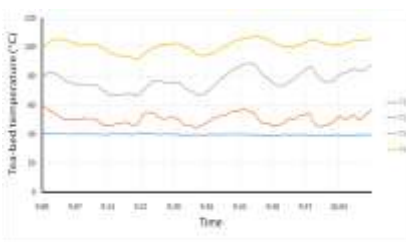
6 dried tea samples were collected at 10 minutes interval

Samples were sent to professional tea tasters for evaluation

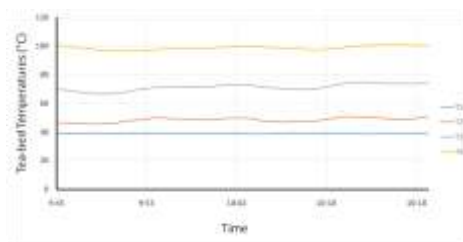


Tea-bed temperature and moisture content variation

Tea-bed temperature at drying sections



Manual



Automation

Sample No.	Dried-tea Moisture Content (%)	
	Manual	Automation
1	2.6	2.6
2	3.1	2.9
3	4.5*	3
4	2.3	2.8
5	3.5*	2.7
6	2.5	2.9

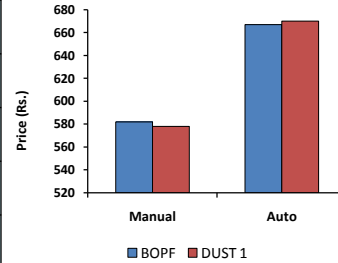
* Exceeded acceptable
limit of 2.5 – 3.0 %



Tea Taster's evaluation

Mean score values regarding quality characters of graded tea

Quality parameters	Manual		Automation	
	BOPF	Dust 1	BOPF	Dust 1
Blackness	12.3	13	24.6	23.9
Infused leaf	11.7	11.3	25.3	25.6
Liquor Color	17.1	17.5	19.8	19.5
Liquor strength	15.2	13.6	21.7	23.3
Liquor Quality	13.3	15.3	23.6	21.6



Automation – Higher graded tea prices



Comparison of Moisture content & Evaluation

Monitoring variation in dryer operating parameters
– tea-bed temperature and Moisture content

1. Manual operation – 3 separate days
2. Automation – 3 separate days

dried tea samples were collected from two batches, graded and sent to professional tea tasters for evaluation



Moisture variation

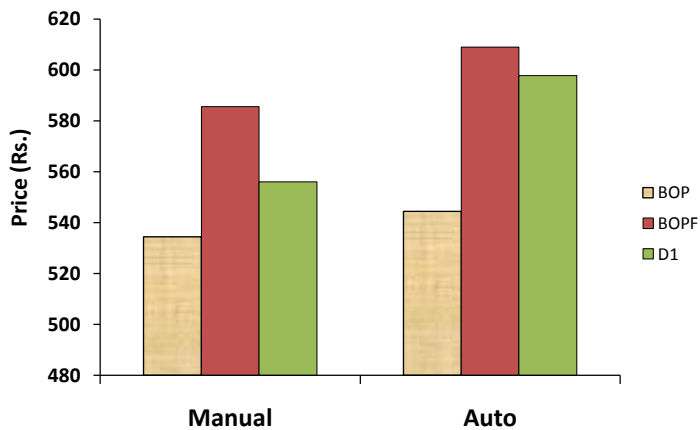
Moisture content in dried tea samples (%)					
Manual			Auto		
Day 1	Day 2	Day 3	Day 1	Day 2	Day 3
2.8	2.7	3.0	3.0	2.5	2.6
2.7	3.0	2.2	3.0	2.6	2.7
2.8	3.6	1.8	2.9	2.6	2.8
3.8	3.7	2.2	2.8	2.8	2.5
3.7	4.0	2.4	2.3	2.7	2.6
4.1	4.4	2.5	2.6	2.6	2.7
3.8	5.0	2.4	3.1	2.6	2.8
3.6	4.3	3.6	3.0	2.5	2.5
3.4	4.1	3.7	2.8	2.4	3.1
3.3	3.9	4.1	2.7	2.5	3.0
3.2	3.3	3.9	2.7	2.7	3.0

Manual operation

– Moisture content is not within acceptable limit of 2.5 – 3.0 %



Tea Taster's evaluation



Automation – Higher graded tea prices



Features of the system

1. steady dryer operation – *improves blackness and fibre removal*
2. auto/ manual mode - *uninterrupted dryer operation*
3. facility to monitor and record dryer operating parameters
 - *inlet temperature, tea-bed temperatures, direction of air directional louvers, conveyor speed variation*
4. maintaining the rated output of the dryer
 - *improve the productivity & made tea quality*



Features of the system contd.

5. minimizes blowout of tea – *reduce wastage and re-drying*
6. manages the variations in the inlet drying air temperature
7. can be retrofitted to existing Fluid Bed Dryers with minimal modifications and cost.



Advantages

The control system could

1. Ensure moisture content within the acceptable limit
2. Ensure black appearance and tea character.
3. Facilitate to increase of Net Sale Average (*required black appearance and tea character*).
4. Facilitate to increase of productivity and reduction of cost of labour and energy (*rated output of the dryer and by avoiding re-drying of under-fired tea and blowout*).



Advantages contd.

5. facilitate to a pleasant working environment by reducing dryer blowout into the working space of the dryer
6. facilitate to reduction of grading operations by increased blackness and removal of fibre during drying.
7. facilitate monitoring and recording dryer operating parameters (*continual improvement*).



Requirements

Dryer condition

1. no side plate damages
2. proper function of blow-hole suppressor
3. even perforation size in bedplates
4. no blocks in the perforations
5. proper function of hot air dampers and directional louvers
6. smooth operation of feeding conveyor



Summary

1. Control system for drying tea in fluid bed dryer facilitate minimizing fluctuation in the weir-end tea-bed temperature and ensures that the tea are dried within the acceptable limit of 2.5 – 3.0 %.
2. The control system facilitate enhancing blackness and tea character and NSA.
3. The control system can be retrofitted to existing Fluid Bed Dryers with minimal modifications



