Detailed ENERGY AUDIT REPORT

Ludhua Tea Factory

CAG
Citizen consumer and civic Action Group

Detailed Energy Audit Report on Ludhua Tea Factory

Ludhua Cha Bagan Sramik Samabaya Samiti Ltd

Sabroom, Tripura (South)

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CAG

Citizen consumer and civic Action Group

Authors

Prof. R Sethumadhavan, Energy Expert, Consultant, CAG

Mr. G. Srikrishna, Energy Expert, Consultant, JM Energy

Mr. Vishnu Mohan Rao, Senior Researcher, CAG

Mr. B. Kirubakaran, Researcher, CAG

About CAG

Citizen consumer and civic Action Group (CAG) is a 38 - year - old non - profit, non - political and professional organization that works towards protecting citizens' rights in consumer and environmental issues and promoting good governance processes including transparency, accountability and participatory decision - making.

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A C K N O W L E D G E M E N T

We wish to place on record our thanks to the Tea Board of India, Kolkata for giving us the opportunity to conduct a Detailed Energy Audit in Three Tea Factories in Tripura State run by the Workers Co - operative Society and aided partially by the Tripura State Government.

This work would not have been made possible without the advice and guidance of **Dr.R Sethumadhavan**, **Consultant** (C A G) who is the lead author of this report. We would like to express our sincere gratitude to **JM Energy** for their valuable contributions and expertise in this project.

We extend our wholehearted thanks to

1) **Mr S Soundararajan, Director of Tea Development, Kolkata**
2) **Mr B Pagalavan, Asst Director of Tea Development, Kolkata**
3) **Mr Tuhin Debnath, F A O - Head, Tea Board, Agartala**

Our thanks are due to **Mr. Sujit Sil, Manager, Ludhua Cha bagan Sramik Samabaya Samiti Ltd, Sabroom Dt** who rendered all necessary technical and manpower support towards the execution of this assignment.

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Further, **Mr. Birendra Sharma,** Electrician - cum - Mechanic, deserves special thanks for the assistance offered to the energy audit team members.

The remarkable rapport, cooperation and clear understanding shown by the concerned supporting staff of this tea factory are thankfully acknowledged. We are pleased to place on record our appreciation for the same.

We are privileged to submit this ***"Detailed Energy Audit Report" on*** **Ludhua Tea Factory** to the management of the tea factory. The Energy / Cost Conservation Proposals identified in this report - when implemented - are expected to bring in lasting benefits (savings) in terms of energy as well as cost to the tea factory.

We request the concerned authorities to take up the energy - cum - cost conservation suggestions for implementation on priority basis. Any omission of names in the acknowledgement is purely unintentional and we ask that it be pardoned.

LIST OF ABBREVIATIONS

BEE	Bureau of Energy Efficiency
BLDC	Brushless Direct Current
BQ	Booked Quantity
CCP	Cost Conservation Proposals
CD	Contracted Demand
CFM	Cubic Feet per Minute
CNG	Compressed Natural Gas
CTC	Crush, Tear, Curl
DG	Diesel Generator
DISCOM	Distribution Company
ECP	Energy Conservation Proposals
EE	Energy Efficient
FEDCO	Feedback Distribution Company
GCV	Gross Calorific Value
GL	Green Leaves
HAF	Hot Air Fan
HT	High Tension
IETA	International Electrical Testing Association
LT	Low Tension
MD	Maximum Demand
MT	Made Tea
PF	Power Factor
RESCO	Renewable Energy Service Company
SC	Service Connection
SEC	Specific Energy Consumption
SEEC	Specific Electrical Energy Consumption
SFC	Specific Fuel Consumption
SPV	Solar Photo Voltaic
T&D	Transmission and Distribution
TREDA	Tripura Renewable Energy Development Agency
TSECL	Tripura State Electricity Corporation Limited
VFD	Variable Frequency Drive

EXECUTIVE SUMMARY

PREAMBLE

- The Ludhua Tea Factory, established in the year **1979**, is owned and operated by the Tea Estate Workers Co - operative Society with **170** shareholders.
- Located in the southern part of Tripura State in Sabroom District, the factory has a total built up area of **2.5 acres** and predominantly manufactures Organic CTC tea for which it uses both electrical and thermal energy. The factory has the provision to make Orthodox and Green Tea as well, but the demand for these tea types is a lot lesser compared with that for the CTC tea.
- The factory's estate at Sabroom (**95.3 ha**) caters to its production requirements

ENERGY ASPECTS

- The electricity is sourced through Feedback Energy Distribution Company Limited (FEDCO) as per the agreement with TSECL. The consumption of electricity for the period from **Sep 23 to Aug 24** is **60282 kWh**.
- Since the tea manufacturing is a continuous process, a DG set is put into service to supply energy whenever the FEDCO supply is not available. However, the DG sets are sparingly used (in terms of diesel consumed / units generated) and their operation period - on an average - is less than 25 hours in a month. Since, it's usage is quite insignificant, its contribution is ignored in the computation of the Weighted Average Cost of Electricity.
- The cost of FEDCO energy has been computed as **₹ 11.61 / kWh** (that includes all charges) for the period Sep '23 - Aug '24. However, the electricity cost considered in the commercial evaluation of the Energy and Cost Conservation Proposals is **₹7.73 / kWh** ((accounting only for the kWh charges as a realistic estimate).
- The fuel used in this factory for producing thermal energy is Coal which is sourced from Meghalaya. The 2 year average quantity of coal consumed is **141 tons / y** costing close to **₹ 24 lakhs / y.**

SPECIFIC ENERGY CONSUMPTION

- The basic energy data that formed the backbone of energy audit study is the **S**pecific **E**nergy **C**onsumption (**SEC**). It is defined as the energy consumed for producing one kg of Made Tea.

- The study shows the following figures for this factory.
    - Electrical = **0.61 kWh / kg** of Made Tea
    - Thermal = **41.76 MJ / kg** of Made Tea

  (equivalent to 1.58 kg of coal / kg of Made Tea with a coal GCV of 6323 kcal / kg or 26 430 kJ / kg)
- As the basic raw material is green leaves, the specific energy consumption has been computed w.r.t green leaves [G L] also and presented below :
    - Electrical = **0 .12 kWh / kg** of GL
    - Thermal = **8.04 MJ / kg** G L (equivalent to **0.32 kg** Coal / kg G L)
- The above figures give an indication on the efficiency levels at which the factory is operating. The total energy cost works out to about 65% of made tea production cost, indicating the existence of reasonable prospects for energy & cost conservation through adoption of various recommendations that are suggested in this report.
- This report is the outcome of the detailed technical study carried out in various energy consuming utilities of the factory for 2 days in Sep 24 (12 & 15) by the Energy Audit Team.
- The study details out the cost & energy saving opportunities identified in various sections of the tea production and indicates the economic viability of each one.
- The cost conservation proposals can be taken up for implementation at the earliest as the cost economics of these recommendations are highly favourable. Further, these cost saving proposals are quite simple to understand and are capable of saving cost right immediately upon implementation.

Table 1: Cost Conservation Proposals [CCPs] : 3 Nos

No	Cost Conservation Proposals	Cost Savings ₹ / y	Invest ₹	Payback Period Months
1	Switching over to Chipped Wood from Coal as the source of thermal energy for combustion in the furnace to cut down the cost of coal incurred in tea drying operation	**6 74 760**	**3 00 000**	**6**
2	Rationalization [Reduction] of Contract Demand of the factory HT Service Connection with a view to optimise the demand charges payable to TSECL	**57 456**	**Nil**	**Immediate**

No	Cost Conservation Proposals	Cost Savings ₹ / y	Invest ₹	Payback Period Months
3	Installation and Commissioning of 40 kW_p On - Grid Solar Roof Top PV Power Plant adopting "RESCO" model towards attaining self - sufficiency in electricity requirement in a sustained fashion & simultaneously going green	**1 73 250**	**Nil**	**Immediate**
Total		**9 05 466**	**300000**	**< 6**

Table 2: Energy Conservation Proposals [ECPs] : 7 Nos

No	Energy Conservation Proposals	Cost Savings ₹ / y	Invest ₹	Payback Period Months
1	Operation of Electric Motors at the rated / near rated voltage in order to effect optimum energy drawl and to contain the damage to Motors	14 000	Meagre	immediate
2	Downsize and usage of Energy Efficient Motor in the **Cut 1 of CTC Section** aiming for reduced energy consumption and improved " PF " and thereby cost savings	13 915	40 000	35
3	Usage of Closed Shed for the storage of Coal from the view point of achieving efficient combustion in the furnace [on account of avoiding moisture pick up by coal due to its storage in open]and save on coal consumption	67 200	80 000	14
4	Fitment of V F D to the Hot Air Forced Draft Fan - whose operation shall be controlled by exiting moist flue gas temperature - enabling energy efficient operation of the fan resulting in electricity conservation and cost saving	23 190	40 000	20
5	Partial Recirculation of the Dryer Exhaust Air back into the Furnace along with conventional atmospheric air from the view point of enhancing combustion air enthalpy resulting in conservation of coal.	94 080	90 000	12
6	Downsize and usage of Energy Efficient Motor in the **Drier / Sorting Section** aiming for reduced energy consumption and improved " PF " and thereby cost savings	16 235	60 000	44

No	Energy Conservation Proposals	Cost Savings ₹ / y	Invest ₹	Payback Period Months
7	Replacement of Conventional V - Belts with Cogged V - Belts in the identified motors to reduce belt slip thereby enhancing the transmission efficiency and save on electricity	60 294	40 000	12
Total		288 914	350 000	15

HIGHLIGHTS

- **The specific energy consumption on electricity front appears only 10 % higher than the benchmark values as we could evolve. Therefore, the scope for electrical energy conservation thereupon subsequent cost conservation appears a bit limited and not enormous.**
- **The Specific Coal Consumption stands at 1.58 kg coal / kg of Made Tea as against a benchmark value of 1 kg coal / kg of Made Tea [applicable to Meghalaya coal as it has a higher GCV]. Hence, a couple of proposals have been suggested to bring down the coal consumption in the tea processing operation of this factory**
- **Further, it was felt that the factory a) should opt to install solar power plant to meet its electrical needs and b) switching over to wood chips as the furnace fuel in replacing the coal as the thermal energy source to save enormously on cost spent on energy.**
- **The cost savings - through adoption of these 2 above cited measures - could be as high as ₹ 8.5 lakhs / y which is about 28 % of the present energy cost. This is quite revealing.**
- **Hence, the factory management may initiate action to implement these 2 CCPs on priority basis and reap the benefits at the earliest.**
- **In addition, 7Energy Conservation Proposals [ECPs] have been identified that are capable of dishing out a cost saving close to ₹ 3 lakhs / y with a one - time investment of ₹ 3.5 lakhs only. The Return on Investment [R o I] works out to only 15 months.**
- **Therefore, these suggested Encon Measures shall also be taken up for implementation in a phased and time bound manner without delaying much.**

Important Note :

- The coal consumption is quite high at **1.58 kg / kg of Made Tea** as per the factory record.
- However, the experiments conducted by the Energy audit Team for a duration of 10 hours on 15th Sep 2024 has revealed a ratio of only **1.15 kg coal / kg of Made Tea** which is very reasonable.
- It is felt that the Specific Coal Consumption of 1.58 kg / kg of Made Tea is unacceptably high considering the Gross Calorific Value [G C V] of coal which is **6323 kcal / kg** as per our laboratory records.
- Hence, it is recommended to the management to have a regular checking of inventory and proper accounting of coal consumption.

CONSOLIDATION

No of Conservation Proposals		Electricity Savings kWh / y	Cost Savings ₹ / y	Invest ₹	P P Months
Cost CPs	Energy CPs				
3	**7**	**16 512**	**11 94 380**	**650 000**	**< 7**

Overall Reduction

1) Electrical Energy : **27.3 %**
2) Electrical Energy Cost : **18.3 %**
3) Thermal Energy Cost : **34.2 %**
4) Overall Cost Savings : **38.0 %**

[The above assessment considers the baseline as the average consumption / cost for the period Sep 23 – Aug 24]

1 INTRODUCTION

1.0 PREAMBLE

- Ludhua Tea Factory is run by Tea Estate Workers Co-operative Society that had started its operation [tea production] in the year 1979
- The factory has its own tea estate covering an area of 95.33 Hectares.
- The total built up area of the factory is 2.5 acre.

2.0 GREEN LEAVES PROCUREMENT & TEA PRODUCTION

- The factory manufactures 2 grades of CTC, namely, Leaf Grade and Dust Grade

1) Leaf Grade : 4 Grades

i.	Broken Orange Pekoe (Small)	(BOP - S)
ii.	Broken Orange Pekoe	(BOP)
iii.	Broken Pekoe	(B P)
vi.	Orange Fannings	(O F)

2) Dust Grade : 1 Grade

i.	Pekoe Dust	(P D)

- It also produces limited quantity of Green Tea (whole leaf) and Orthodox tea but the primary production is CTC tea.
- It uses tea leaves grown **organically** without using any synthetic fertilizers. This is the only organic tea producer in the state of Tripura.
- This factory typically operates for 265 to 275 days in a year - leaving out the lean season period - with 12 working hours in a day [7 am to 7 pm].The average annual operating period has been computed as 3000 hours on the conservative side.
- The factory provides direct employment to 15 workers and indirect to more than 100.
- The Green Leaves processing capacity is 5 **00 000 kg / y** resulting in a Made Tea production close to **1 00 000 kg / y.**
- The quality of tea leaves obtained from the tea garden is good and hence the quality of tea produced is also equally good and fetches reasonably high rates in tea auction.

Fig 1.1 : Ludhua Tea Factory Premises : A Photographic View | CAG

3.0 ENERGY DATA

- As it is well known, the CTC tea production is fairly an energy intensive process requiring both thermal and electrical energy in substantial quantities.
- The thermal energy requirement is met by the combustion of **Coal** procured from Meghalaya coal mines.

- The electrical demand is met by drawing power from the private DISCOM - known by the name **FEDCO** [**F**eedback **E**nergy **D**istribution **Co**mpany Ltd] - through a High Tension Service Connection.
- Additionally, the factory has Diesel Generator (D G) sets that operate as and when required. These are pressed into service whenever the FEDCO / TSECL power fails.
- The state of Tripura is a power surplus one and hence the power outages are quite a rare occurrence. The DG Sets are operated for about 20 hours in a month as a part of the maintenance protocol.

4.0 ASSIGNMENT CULMINATION

- This assignment of *Energy Accounting & Auditing* is a part of the **C**itizen consumer and civic **A**ction **G**roup's **(CAG)** ongoing project titled "*Accelerating Clean Energy Transition by improving stakeholder participation for Electricity Governance in India*", operating across 5 states of India viz., Tamil Nadu, Telangana, Karnataka, Chhattisgarh and Tripura.
- This assignment aims at promoting energy conservation, energy efficiency, renewable energy usage, advocating consumer's energy interests, etc.,
- The state of Tripura has many tea industries that consume a significant quantum of both thermal and electrical energy. Therefore, it was decided to perform Energy Audits in a couple of specimen tea factories in this State to identify energy conservation opportunities. The ultimate goal is the enablement of energy conservation in tea processing operations and spreading this message to all other tea factories located across the state of Tripura.
- Keeping this objective in mind, the CAG had approached the Tea Board of India, Kolkata to identify suitable tea factories for this proposed study. Based on discussions with officials of the Tea Board in Kolkata and in Tripura, it was decided to target the tea factories run by Cooperative Societies of Tea Garden Workers, as these are direly in need of conservation of energy / cost towards making the tea processing operation profitable for the sake of workers in particular and society in general.
- Accordingly, 3 tea factories run by Cooperative Societies, viz., **1) Durgabari Tea Factory 2) Leelagarh Tea Factory and 3) Ludhua Tea Factory** - were identified for conducting energy audit.

- A detailed energy audit was conducted in these 3 factories to identify opportunities to reduce energy consumption and improve energy efficiency in various processes operations. Also, identified was the scope for cost conservation in the tea production process.
- During the audit, various thermal and electrical measurements were recorded to identify the processes and equipment that consumed the most energy and determine the scope for energy conservation.
- In this respect, all the required data have been collected from the factory.
- The performance of the Utilities has been evaluated and presented in Chapters 7 & 8. This report is prepared based on the present energy consumption pattern and indicates the scope for energy conservation in various processes and equipment.
- 10 Cost and Energy Conservation Proposals have been identified and elaborated in the ensuing Chapters 9 & 10 respectively.
- An overall cost reduction of **38%** is anticipated that will demand a one - time investment of **₹ 6.5 lacs** and fetch an annual return of **12 lakhs** perennially.
- The Return on Investment [**RoI**] is **< 7 months** and the Carbon Foot Print reduction shall be 60 tons of CO_2 / y if solar power drawl is also resorted to.

Fig 1.2 : CAG Energy Audit Team : Ludhua Tea Factory | CAG

5.0 SALIENT FEATURES

- The salient features gathered in respect of this Tea Factory are summed up below :

Table 1.1 : Salient Features : Ludhua Tea Factory

Name / Address of the Factory	:	Ludhua Cha Bagan Sramik Samabaya Samiti Ltd, Sabroom, Tripura (South) - 799145
Key Officials	:	1) Sujit Sil - Manager 2) Deepak Majumdar - Factory In charge 3) Birendra Sharma - Electrician / Mechanic
Year of Establishment	:	1979
Total Factory Area	:	2.5 acres
Total Estate Area	:	95.33 hectares
Type and Grades of Tea Manufactured	:	1) CTC tea (Primary production) a) **Leaf Grades**: BOP, BOP (S), BP, Orange Fannings b) **Dust Grades:** P D 2) Orthodox and whole leaf Green Tea (only a limited production)
Number of Full Time Workers	:	15
Factory Operating Period	:	265 to 275 days in a year (Jan, Feb and March: Nil production)
Operating Time	:	12 h / d [7 am to 7 pm]
Green Leaf Processing Quantity	:	2 000 kg / d [5 00 000 kg / y]
Made Tea Production Quantity	:	500 kg / d [1 30 000 kg / y]
Thermal Energy Source	:	Coal procured from Meghalaya Mines
Electrical Energy Sources	:	• 1 H T SC from FEDCO (A private DISCOM in Tripura) for factory • Diesel Generator Sets

2 PROCESS DESCRIPTION

2.0 PREAMBLE

- Green Tea Leaves serve as the primary raw material for various types of tea production.
- The tea industries resort to three primary modes of tea production, namely,
  1. C T C (Cut, Twist, and Curl),
  2. Orthodox
  3. Green Tea

  ⇒ CTC Tea: The CTC Tea, having over 85 % of the market demand, undergoes a mechanized process that Cuts, Tears and Curls the leaves into small and uniform sized pieces. This method yields a strong, bold flavor with a higher caffeine content and a distinctive dark powder appearance.

  ⇒ Orthodox Tea: In contrast, Orthodox Tea Production involves a more artisanal approach, using traditional machinery or even manual techniques. This process results in a delicate, nuanced flavor with lower caffeine levels. Orthodox teas are typically sold in loose - leaf or whole - leaf form, often used for premium black teas.

  ⇒ Green Tea: It is produced by steaming or pan - frying leaves immediately after plucking - to prevent oxidation. This method preserves the leaves' natural color and flavor, resulting in a fresh, vegetal taste with a higher antioxidant content. Green tea is often characterized by its slightly curled leaf appearance.
- Ludhua Tea Factory primarily produces CTC tea and to a limited extent the Orthodox and Whole Leaf Green Tea.
- The final product coming out from the process is termed as “Made Tea”. Typically, 5 kg of green leaves are required to produce one kg of Made Tea.
- The tea production process demands both thermal and electrical energy.
- There are 8 major operations involved in the production of CTC tea that are briefly described below with relevant photographs.
  1. **Collection of Green Leaves**

2. Withering (partial removal of moisture by atmospheric air drying)
3. Shredding
4. Cutting, Tearing and Curling (C T C) (Size reduction)
5. Oxidation / Fermentation (Bio - chemical reactions in the presence of oxygen)
6. Drying (moisture removal and termination of fermentation)
7. Sorting (fiber removal; grading based on size)
8. Packing & Transportation

- The typical flow chart of tea manufacturing is shown below:

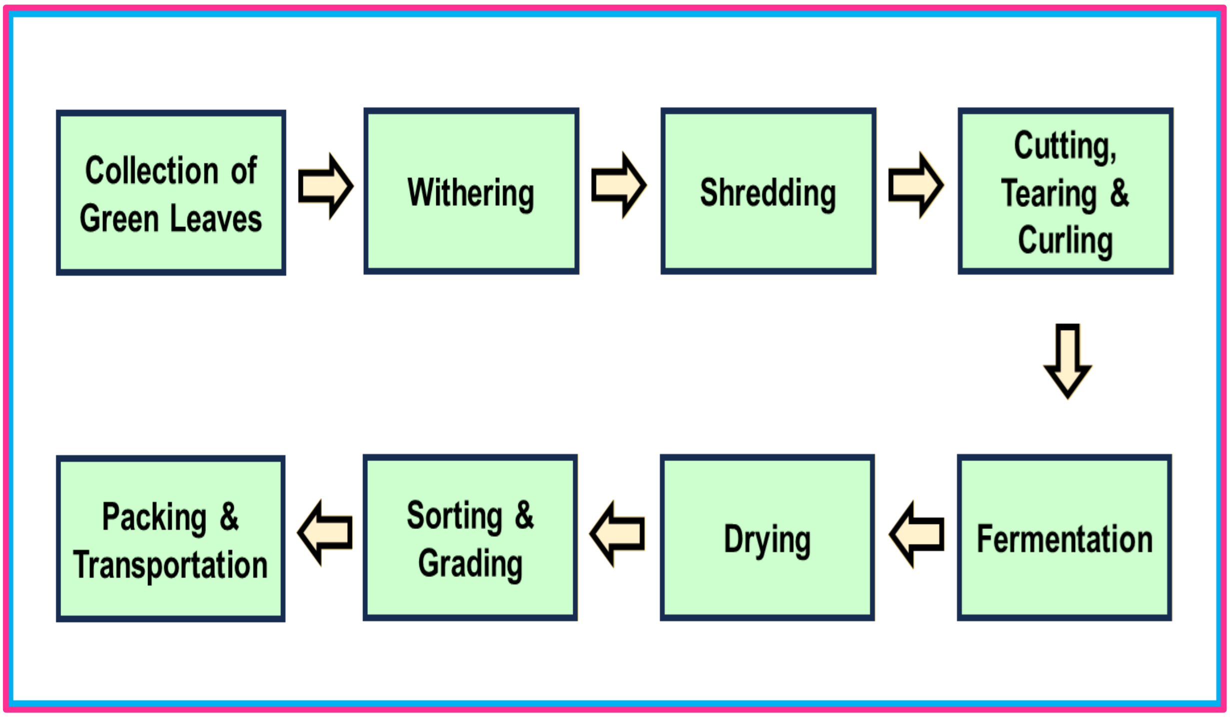


Fig 2.1 : Tea Production Process : Typical Flow Chart | CAG

- Of these 8 processes involved, chemical changes occur primarily In Withering, Fermentation and Drying operations and these in turn influence the quality of tea produced.

2.1. COLLECTION OF GREEN LEAVES

- The factory has its own tea garden spread over **95.33 hectares**. The green tea leaves are transported to the factory site through trucks. While this factory processes leaves from external sources when their own gardens cannot meet demand, their primary focus remains on processing their homegrown leaves. Plucking of green leaves is primarily done by hand.

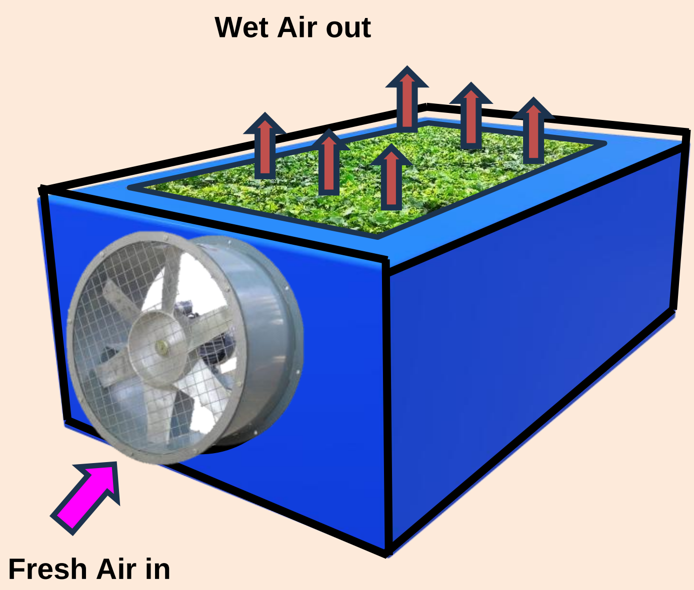
Fig 2.2 : Tea Production Process : Typical Flow Chart | CAG

2.2 WITHERING

- Withering is a crucial step in tea processing that prepares the freshly harvested green leaves for subsequent process stages like Rolling and Fermentation.
- By carefully removing the surface moisture while retaining some internal moisture, withering creates the ideal physical conditions for these processes.
- The withering process involves both **biochemical** and **physical** reactions. These reactions help to soften the leaves and prepare them for the enzymatic changes that occur during fermentation.
- Green leaves are placed on **Withering Troughs** for a period of 8 hours for withering depending on the season. There are 4 Withering Troughs installed in this factory measuring 86' x 12' and each can hold approx. 2 000 kg of leaves.
- Air is circulated through the leaves spread on the troughs over a wire mesh for the removal of excess moisture. This **Physical Withering** process is aided by blowers that pass the air through the leaves from the bottom. In addition to physical changes, **Chemical Withering** also occurs during withering.
- This withering process is typically influenced by time and temperature that play a vital role in determining the quality of the final tea produced.
- The aim of withering is to reduce the moisture content of the green leaves to around 70 %. Proper withering enhances the **flavor index and aroma** of the tea.

- Axial Flow Fans are used in Withering Troughs (2 blowers per trough) to ensure effective air supply and subsequent moisture removal.
- Thus, there are 8 Withering Fans installed and have a power rating of 5 hp each with an air flow rate of 35 000 cfm.
- The pictorial representation of Withering Troughs is depicted below:

Fig 2.3 : Withering Troughs Employed | CAG



Withering Fan

No of Fans : 8 (2 per trough)
Diameter : 4.4 ft (6 fans)
3.3 ft (2 fans)
Motor Rating : 5 HP (6 fans)
3 HP (2 fans)
CFM : 35,000

Trough

No of Troughs : 4
Dimension : 100 ft x 12 ft
Green Leaf Capacity : 2,000 kg / trough
Operating time : 8 to 12 h / batch

Fig 2.4 : Withering Trough : Layout and Technical Specifications | CAG

2.3 SHREDDING AND ROLLING (CTC)

- Upon withering, the leaves become flaccid. These flaccid leaves are crushed by means of rotor vane shredder. A reconditioned powder (made of pulverized fly - off from dryer or fiber removed during grading) is added to compensate for any loss of juice from tea leaves during shredding. Rolling is carried out to crush the leaves into small bits and to press out the juice for coating the same over the leaf particles.
- Good quality crushing is achieved when the speeds of rotation of the two rollers are maintained in the ratio 1: 10. During Rolling, the heat generated through friction reduces the moisture of the leaves to **55 %**. Depending on the quality of leaves and grade of tea needed, 3 to 4 CTC cuts are used. In this factory, a single line of C T C Line - employing 4 Roller Machines (4 cuts) are used. The green leaf handling capacity is ca.600 kg / h.
- Apart from twist and curl, the enzymes released during rolling help in fermentation. Through this process of crushing and rolling, the polyphenols and enzymes get mixed and coated over the leaves in the presence of the oxygen. When these 3 elements (Polyphenol, Enzymes & Oxygen) are mixed in proper proportion, fermentation gets activated. The extent of fermentation determines the quality of the tea.
- In this factory, 7 motors are employed in CTC Line comprising a Rotor Vane, Blower, CTC Roller 1st ,2nd, 3rd and 4th Cut and a Rotary Shifter / Ghoogy.
- The Rotor Vane, 3 Nos of CTC roller motors have power rating 20 hp each. The 1st cut has a motor with a power rating of 25 hp. The Blower and Ghoogy Motors have power ratings 2 hp & 3 hp respectively.
- The typical lay out / pictorial view of CTC Line are shown in Fig 2.5 & 2.6 respectively.

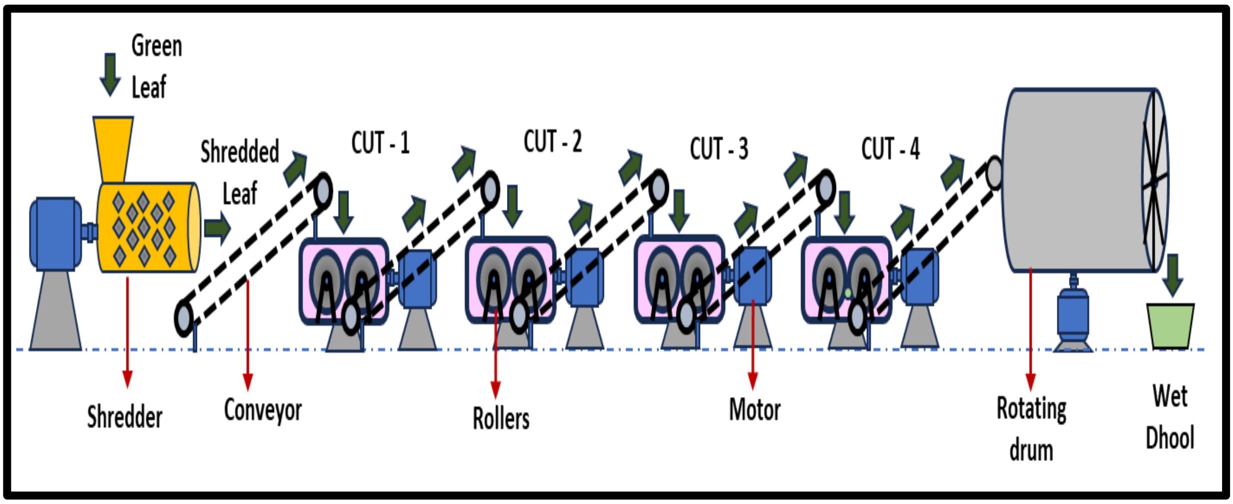


Fig 2.5 : CTC Line : A Typical Layout | CAG

Fig 2.6: CTC Machine: A Pictorial View | CAG

C T C Line

Capacity	: 500 to 600 kg / h (Green Leaf)
No of Cuts	: 4 cuts
No of Motors	: 7
Motors rating	: Rotary Vane : 20 hp
	CTC 1st cut : 25 hp
	CTC 2nd cut : 20 hp
	CTC 3nd cut : 20 hp
	CTC 4nd cut : 20 hp
	Blower : 2 hp
	Ghoogy : 3 hp

Fig 2.7 : CTC Machines : Technical Information | CAG

- Periodic sharpening and machining of the CTC Roller Surfaces, Roller Teeth are important for maintaining the quality of CTC tea and as well ensuring lesser energy consumption.

- The factory has its own workshop accommodating a Lathe Machine, Milling Machine and a Grinding Machine for periodically machining the CTC Roller Surfaces.
- The maintenance activities are carried out in - house

2.4 FERMENTATION

- Fermentation is an oxidation process through which the polyphenols in the leaf get oxidized with the help of endogenous enzymes. The fermentation process is done naturally (floor fermentation) or in a slow speed rotating drum. Fermentation of rolled tea leaves turns them to brown in color.
- Short or light fermentation gives more flavor and aroma rich tea, while long or deep fermentation provides a rich color in tea brewing.
- The factors that influence good quality fermentation are time, temperature, humidity, aeration, spreading thickness and the cleanliness.

Fig 2.8 : Adoption of Natural Floor Fermentation | CAG

- In this factory, natural floor fermentation is resorted to, in which the rolled leaves are spread over the floor and humidifier fans (8 numbers each with a power rating 0.5 hp) are operated to maintain the humidity of the rolled leaves.

2.5 DRYING

- The product obtained on completion of fermentation is called wet dhool.
- This dhool is subjected to drying for eliminating the surface and core moisture thereby arresting the fermentation activity.
- In this factory, continuous flow type dryers known as Endless Chain Pressure [ECP] Dryers are used for tea drying. The conveyors / tray containing the wet dhool moves inside the drying chamber. The capacity of the drier is 140 kg / h of Drier Mouth Tea.
- The quality of tea produced strongly depends on the drying technique practiced and the final moisture content of the product.
- Normally, the fermented dhool entering the drier has a moisture content of 70 -75 % and the final product coming out of drier i.e., dryer mouth tea contains 3 - 4 % moisture.
- In drying operation, moisture is removed from the fermented wet dhool indicated by the change of color of dhool from coppery red to black. This color change indicates the stoppage of the fermentation process
- The drying operation is an energy intensive one requiring both thermal and electrical energy for its effective operation.
- The main equipment consuming electrical energy is the Hot Air Fan (which sucks the atmospheric air and delivers into the dryer) that has a motor power rating of 15 hp and a tray carrying Conveyor Motor of 3 hp
- The hot air - generated by heat exchange between the flue gas produced by combustion of coal in the furnace - is blown over the wet dhool at a temperature of 110°C.
- Further, 2 fans (one FD Fan and the one ID Fan) are used in coal combustion that have a power rating of 3 hp and 5 hp respectively.
- On the thermal side, coal is burned for generating hot air for tea drying.
- The specific coal consumption is 1.58 kg per kg of made tea produced as per the factory records.
- The coal is purchased from Meghalaya coal mines and its grade varies between batches and affects the efficiency of heat generation and, consequently, the specific coal consumption.

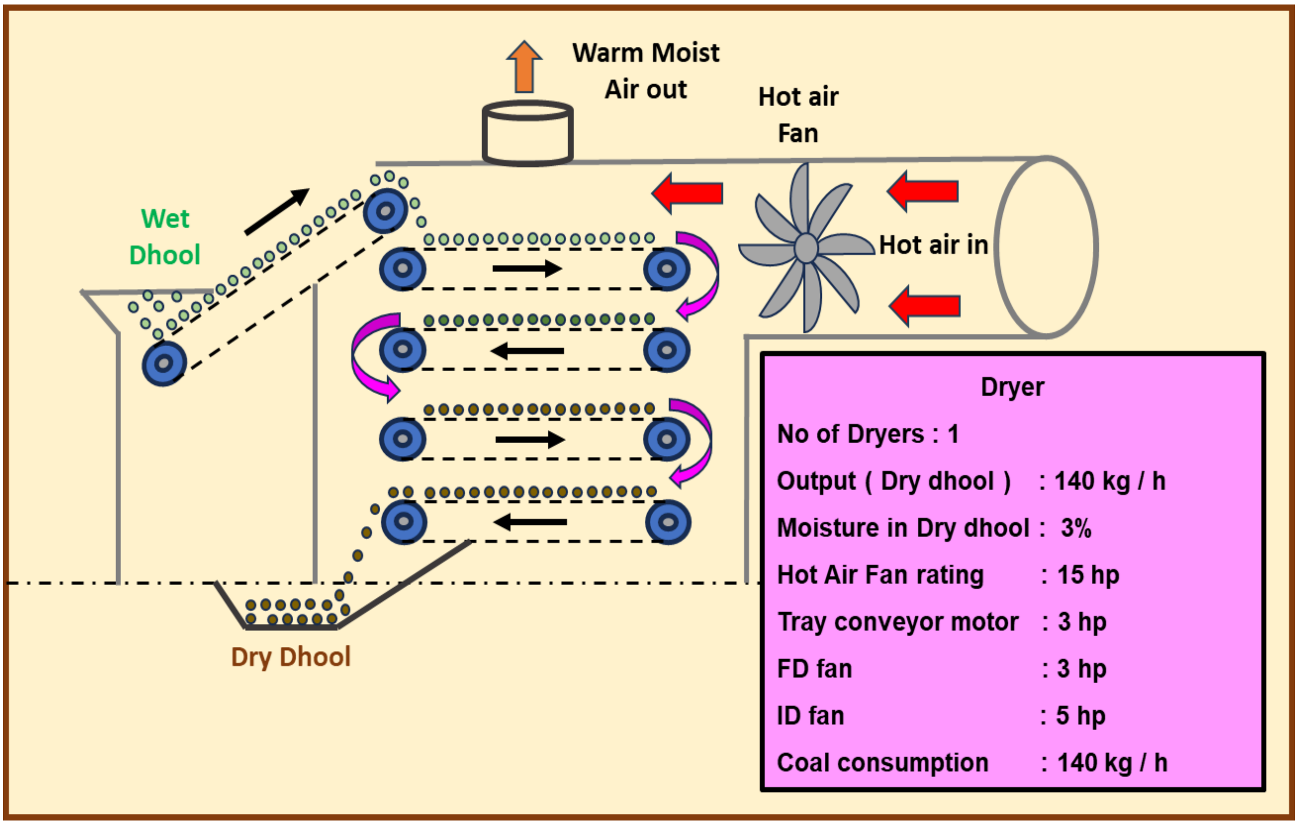


Fig 2.9 : Tea Drier : Layout and Technical Details | CAG

Fig 2.10 : Tea Dryer : E C P Type | CAG

Fig 2.11 : Tea Dryer : Furnace : Frontal View | CAG

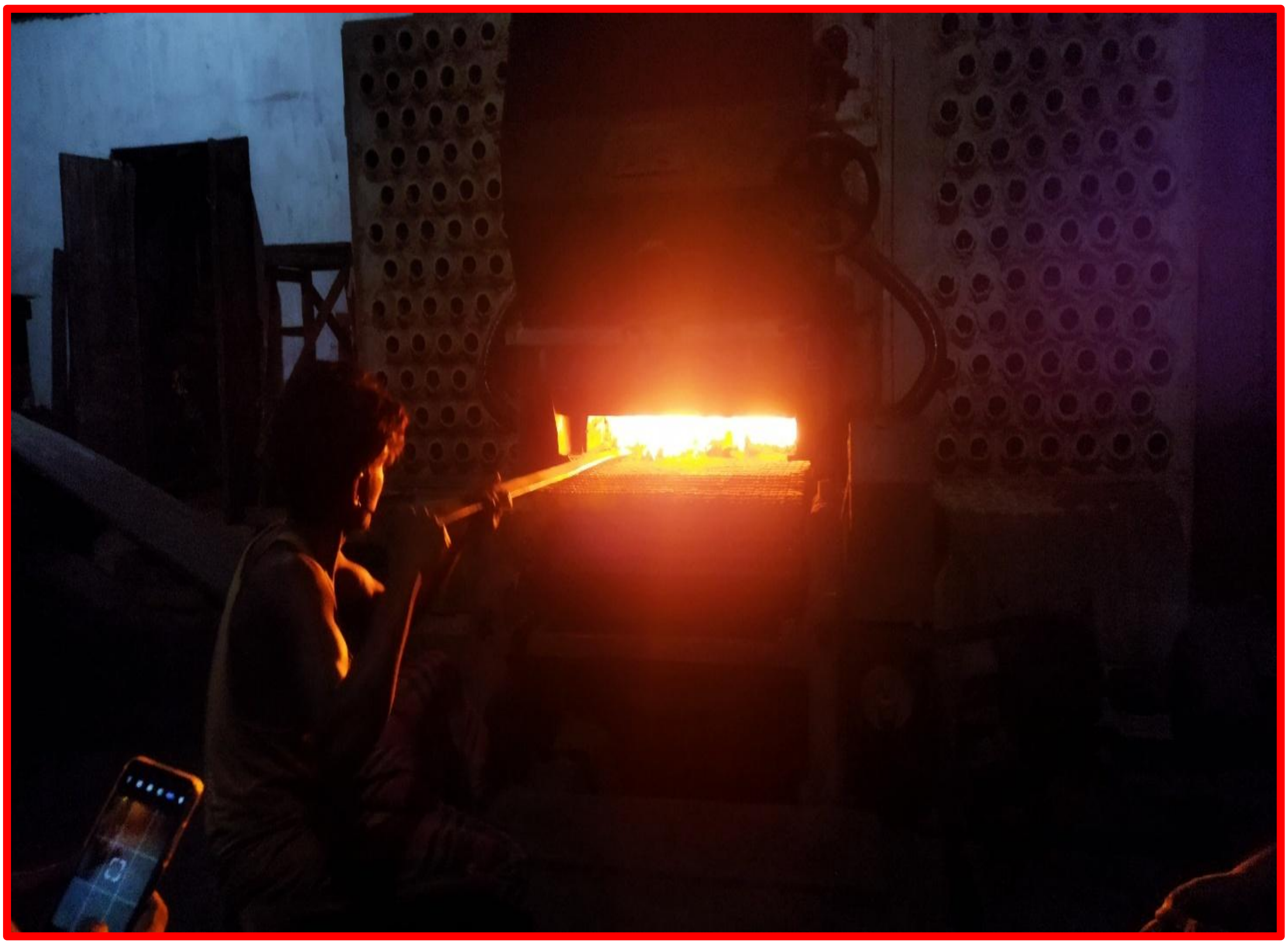


Fig 2.12 : Coal Firing inside the Furnace | CAG

Fig 2.13 : Coal Dumping / Storage Yard | CAG

2.6 SORTING / GRADING

- Sorting is an important step in tea processing that separates bulk tea obtained at the dryer mouth into different grades based on size. This process is achieved using machines equipped with different sized meshes.
- Sorting machines require several small motors to power the vibration of the meshes and as well the movement of conveyors.
- Different grades of tea are obtained by passing the Drier Mouth Tea through these meshes in a sequential fashion.
- In this factory 5 to 6 motors of each rating 2 hp are employed in the sorting machine

Sorting Machine

No of Motors : 6

Motor Rating : 2 hp x 3 Nos

: 1.5 hp x 1 No

: 1 hp x 2 Nos

- The BOP - Small (Broken Orange Pekoe Small) grade is sold at a higher price due to its superior taste and aroma, while the fine dust is the least expensive grade.

Fig 2.14 : Sorting Section : A Pictorial View | CAG

Fig 2.15 : Fiber Removing Machine | CAG

Table 2.1: Different Grades of Tea: Derived from Process Records

Type	Grades	Nomenclature	Wire Mesh (SWG)
C T C Broken Leaf	F P	Flowery Pekoe [Large size dhool]	18 to 20
	B P S	Broken Pekoe Souchong	18 to 20
	PEKOE	Pekoe	20 to 22
	B O P - L	Broken Orange Pekoe (Large)	22 to 23
	B O P	Broken Orange Pekoe	23 to 25
	B O P - S	Broken Orange Pekoe (Small)	24 or 26
	B P	Broken Pekoe	24 or 26
	B P - S	Broken Pekoe (Small)	27 to 28
C T C Fanning	O F	Orange Fannings	28 to 30
	P F	Pekoe Fannings	28 to 30
	B O P F	Broken Orange Pekoe Fannings	28 to 30
C T C Dust	P D	Pekoe Dust	28 to 35
	D	Dust	35
	C D	Churamaul Dust	37
	R D	Red Dust	30 to 35
	G D	Golden Pekoe	36
	S R D	Super Red Dust	36
	F D	Fine Dust	37
	S F D	Super Fine Dust [Small size Dhool]	38

Fig 2.16 : Different Grades of Tea: A Pictorial Representation | CAG

2. 7 PACKING & TRANSPORTATION

- The made tea – final product - thus produced is packed (based on their grades) in food grade quality bags and transported for auction / sale.

Fig 2.17 : Packing Section | CAG

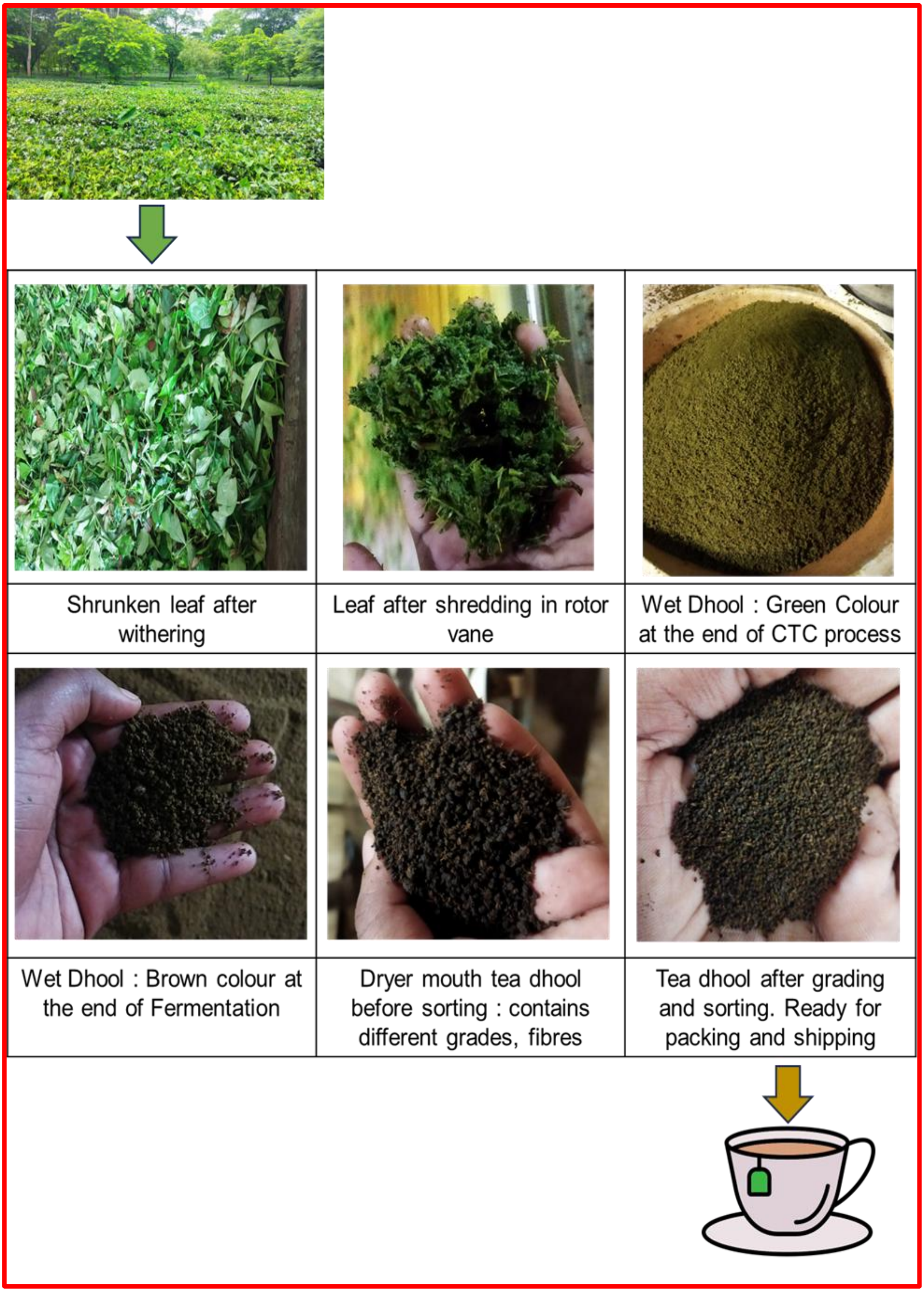


Fig 2.18 : From Garden to Cup : Tea Leaf Transformation Process | CAG

2.8 PROCESS EQUIPMENTS

- The technical details of the equipment used in tea manufacturing - along with the numbers used - are listed below in Table 2.2

Table 2.2 : Summary of Process Equipment Used

No	Process Equipment	Specifications	No of Motors / [Total Rated hp]
1	Withering Trough Fan	No of Fans : 8 [2 per trough] Motor Rating : 5 hp x 6 Nos ; 3 hp x 2 Nos Diameter : 4.4 ft x 6 Nos ; 3.3 ft x 2 Nos Air Delivery : 35 000 cfm	8 [36]
2	CTC Machine	Capacity : 600 kg / h (Green Leaf) No of CTC Machines : 1 Row No of Cuts. : 4 Motor Rating: Shredder : 20 hp. Blower : 2 hp CTC Roller 1st cut : 25 hp CTC Roller 2nd cut : 20 hp CTC Roller 3rd cut : 20 hp CTC Roller 4th cut : 20 hp Ghoogy : 3 hp 7 Motors :cumulative power rating of 110 hp	7 [110]
3	Fermentation - Humidifier Fans	No of Humidifier Fans : 8 Power Rating : 0.5 hp each	9 [13.5]
4	Dryer	Drier Type : ECP No of Dryers : 1 Output : 140 kg / h of D M T Moisture in Wet Dhool : 70 % Moisture in Dry Dhool : 3 % Hot Air Fan Motor : 15 hp Tray Conveyor Motor : 3 hp ID fan for Coal furnace : 5 hp FD fan for Coal furnace: 3 hp Coal Consumption : 140 kg / h	4 [26]

5	Sorter	Number of Motors : 6 Power Rating : 2 hp x 3 Nos : 1.5 hp x 1 No : 1 hp x 2 Nos	6 [9.5]
Total			**34 [195]**

∉ Thus, it can be seen that there are 5 major sections / equipment involved in the direct tea processing

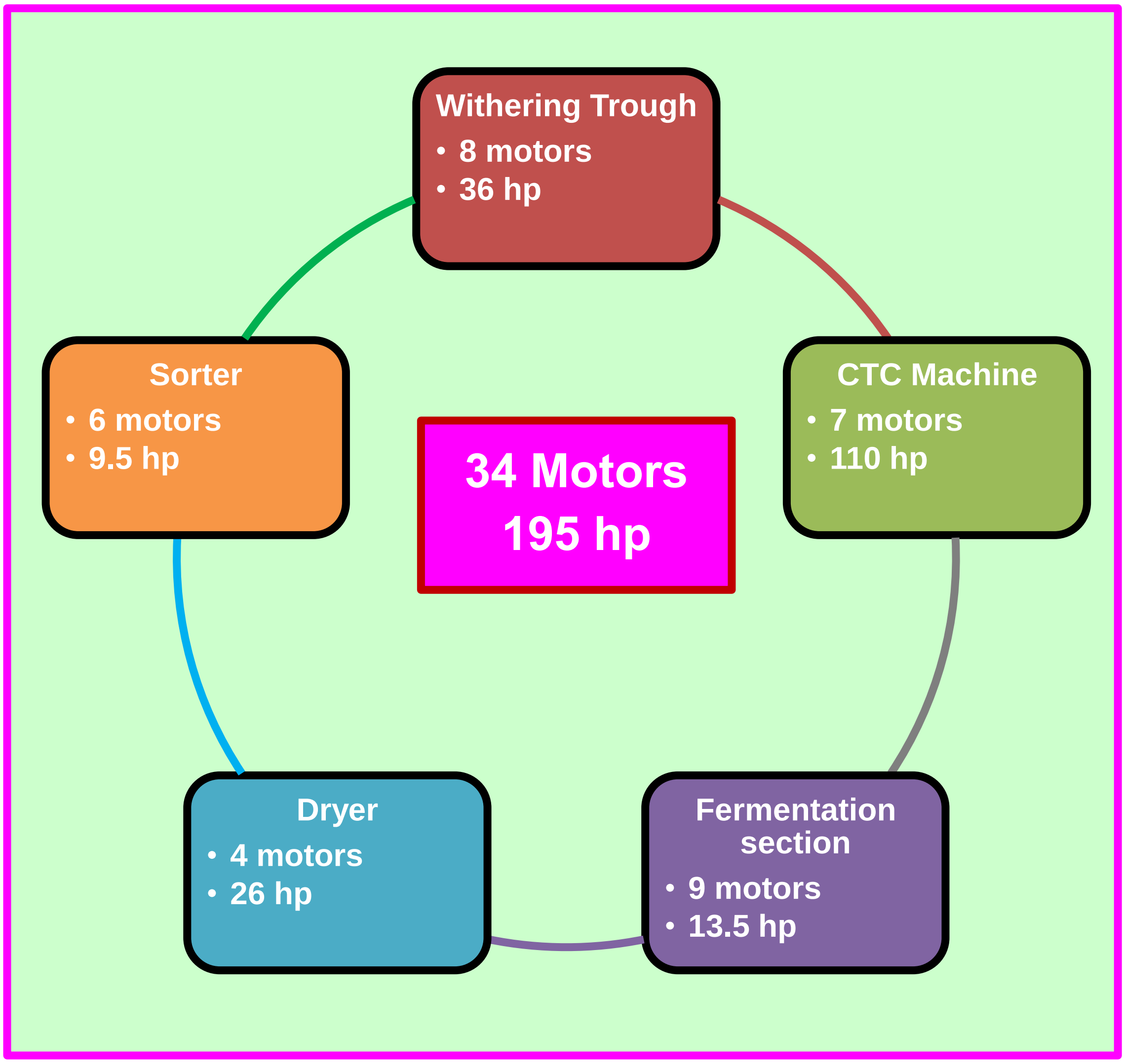


Fig 2.19 : Details of Motors Used in Process Equipment | CAG

- There are **34 motors** involved in the tea manufacturing activity with a connected load of **195 hp**

3 ENERGY CONSUMPTION – A CONSOLIDATION

3.0 INTRODUCTION

- The factory uses both thermal and electrical energy for its various process requirements.
- Thermal energy usage is restricted to the drying section while the electrical energy is used in all the sections. The factory employs a ECP dryer fitted with a coal furnace for drying operation. The hot air is produced by heat exchange from the flue gas produced by combustion of coal in the furnace. The hot air ID fan enables the circulation of hot air through the dryer.
- The electricity is supplied by the FEDCO, a DISCOM in Tripura and during the power outage period, electricity is generated through factory's own Diesel Generator (D G) sets.
- The energy details (both electrical and thermal) for the past 24 months (Sep '22 to Aug '24) period have been gathered and summarized in the ensuing sections.

3.1 ELECTRICAL ENERGY

3.1.1 Consumption

- The factory has availed 1 HT Service Connection [S C] for carrying out the operation related to tea production.
- The details are as below:

Table 3.1: Service Connection Details

No	S C Details	Consumer No	Old A/c No.	C D kW	Energy Charges ₹ / kWh	Demand Charges ₹ / kW / m
1	**Type :** H T **Category :** Tea, Coffee and Rubber Garden	1068022911305912523	000220000100	145.6	7.73	105

- The electricity consumption details (as gathered from FEDCO Bill) are given Table 3.2

- It was realized that the electricity bill does not furnish details regarding Maximum Demand (MD) attained in kW on a monthly basis. This makes it difficult to analyze the MD drawn pattern, to justify the optimality of Contract Demand agreed upon with FEDCO.
- Hence, an attempt was made to capture the load pattern during this energy audit activity, which could throw light on matters related to energy drawl as well as the peak power demanded during the factory operation period.
- This is presented in Chapter 7 [Fig 7.1]

Table 3.2 : Electricity Consumption (Sep '22 – Aug '24)

Period : Sep '22 – Aug '23		
No	**Month**	**Energy Consumption kWh**
1	Sep 22	5 312
2	Oct	6 522
3	Nov	6 401
4	Dec 22	1 700
5	Jan 23	129
6	Feb	78
7	Mar	1 156
8	Apr	1 696
9	May	1 484
10	Jun	3 674
11	Jul	5 548
12	Aug 23	9 544
Total		**43 244**

Period : Sep '23 – Aug '24		
No	**Month**	**Energy Consumption kWh**
1	Sep 23	7 210
2	Oct	7 070
3	Nov	6 728
4	Dec 23	4 652
5	Jan 24	6 150
6	Feb	476
7	Mar	850
8	Apr	3 714
9	May	2 506
10	Jun	6 096
11	Jul	5 286
12	Aug 24	9 544
Total		**60 282**

Electricity Consumption : (Sep '22 to Aug '23) = 43 244 kWh

: (Sep '23 to Aug '24) = 60 282 kWh

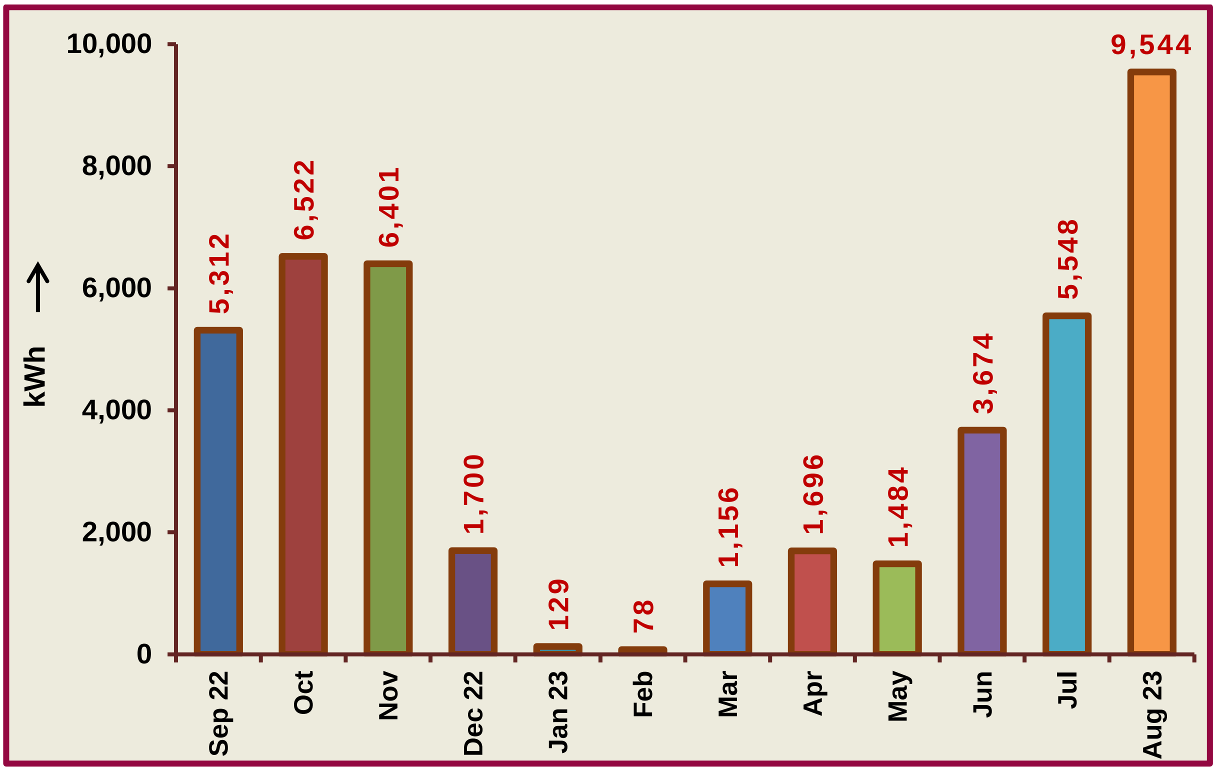


Fig 3.1: Electricity Consumption - Month wise (Sep '22 – Aug '23) | CAG

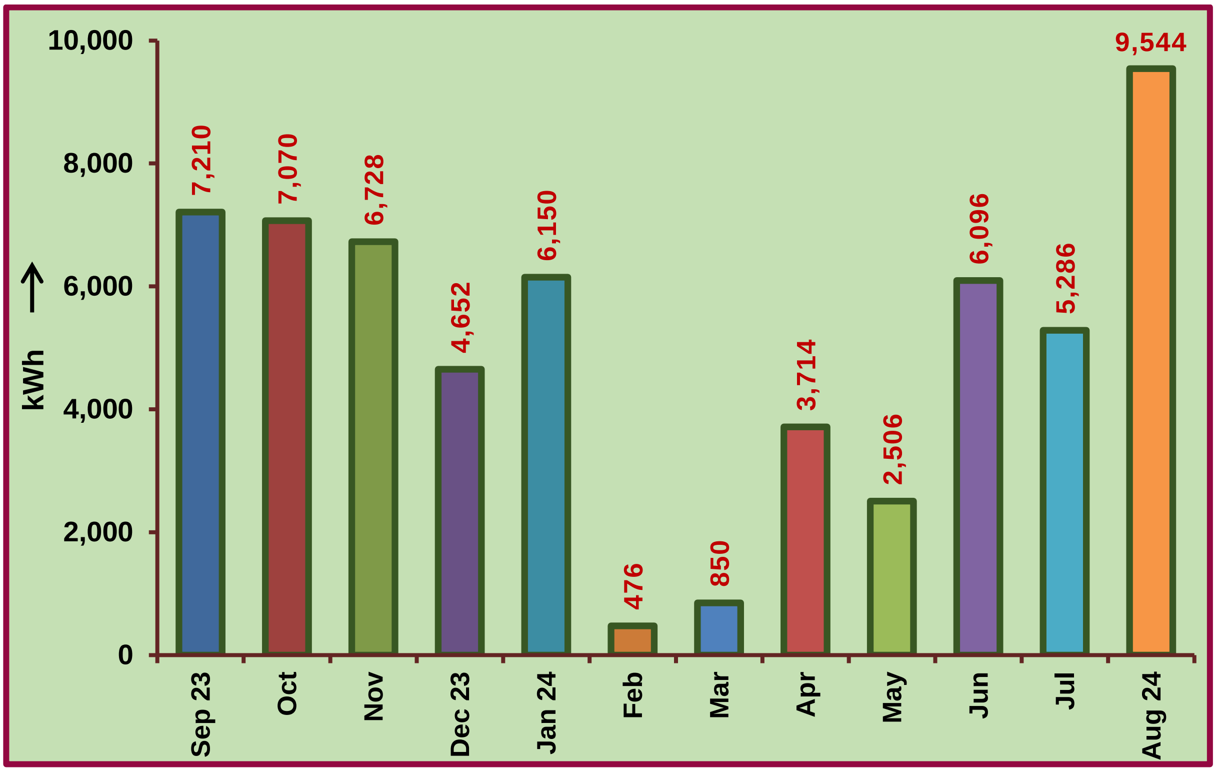


Fig 3.2 : Electricity Consumption - Month wise (Sep '23 – Aug '24) | CAG

- The month wise variation in electricity consumption across the year indicates seasonal dependence of tea production. The similarity in electricity consumption profile in the 2 years considered reaffirms the seasonal nature of the operation of this industry.

- Electricity is drawn from the DG sets during power outage period. Based on our interaction with the factory manager, it was considered justifiable to account for about 30 minutes per day of DG set operation - on an average - that does not impact the weighted average cost of electricity utilized.
- DG electricity delivery is therefore not considered in the evaluation of unit cost of electricity and going further - in our analysis - we have used FEDCO electricity cost only.

3.1.2 Cost Incurred

- The electricity cost details (as gathered from the FEDCO Bill) are given below.

Table 3.3 : Electricity Cost incurred (Sep '22 – Aug '24)

Period : Sep '22 – Aug '23		
No	**Month**	**Cost incurred ₹**
1	Sep 22	54 697
2	Oct	63 500
3	Nov	62 621
4	Dec 22	28 420
5	Jan 23	16 990
6	Feb	16 620
7	Mar	24 462
8	Apr	28 819
9	May	27 178
10	Jun	44 228
11	Jul	58 634
12	Aug 23	90 653
Total		**5 16 823**

Period : Sep '23 – Aug '24		
No	**Month**	**Cost incurred ₹**
1	Sep 23	71 497
2	Oct	75 281
3	Nov	72 383
4	Dec 23	53 488
5	Jan 24	67 580
6	Feb	21 121
7	Mar	23 538
8	Apr	48 874
9	May	38 962
10	Jun	68 418
11	Jul	61 772
12	Aug 24	96 709
Total		**6 99 622**

Electricity Cost : (Sep '22 to Aug '23) = ₹ 5 16 823

: (Sep '23 to Aug '24) = ₹ 6 99 622

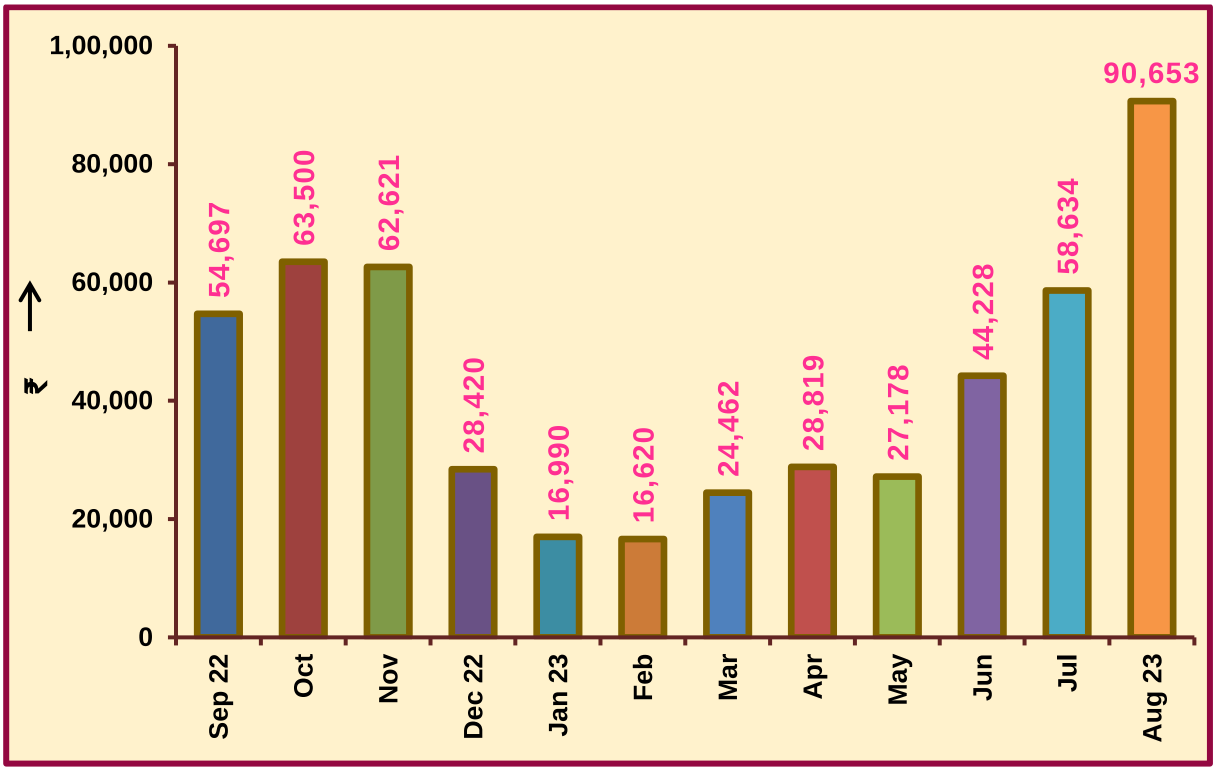


Fig 3.3: Electricity Cost - Month wise (Sep '22 - Aug '23) | CAG

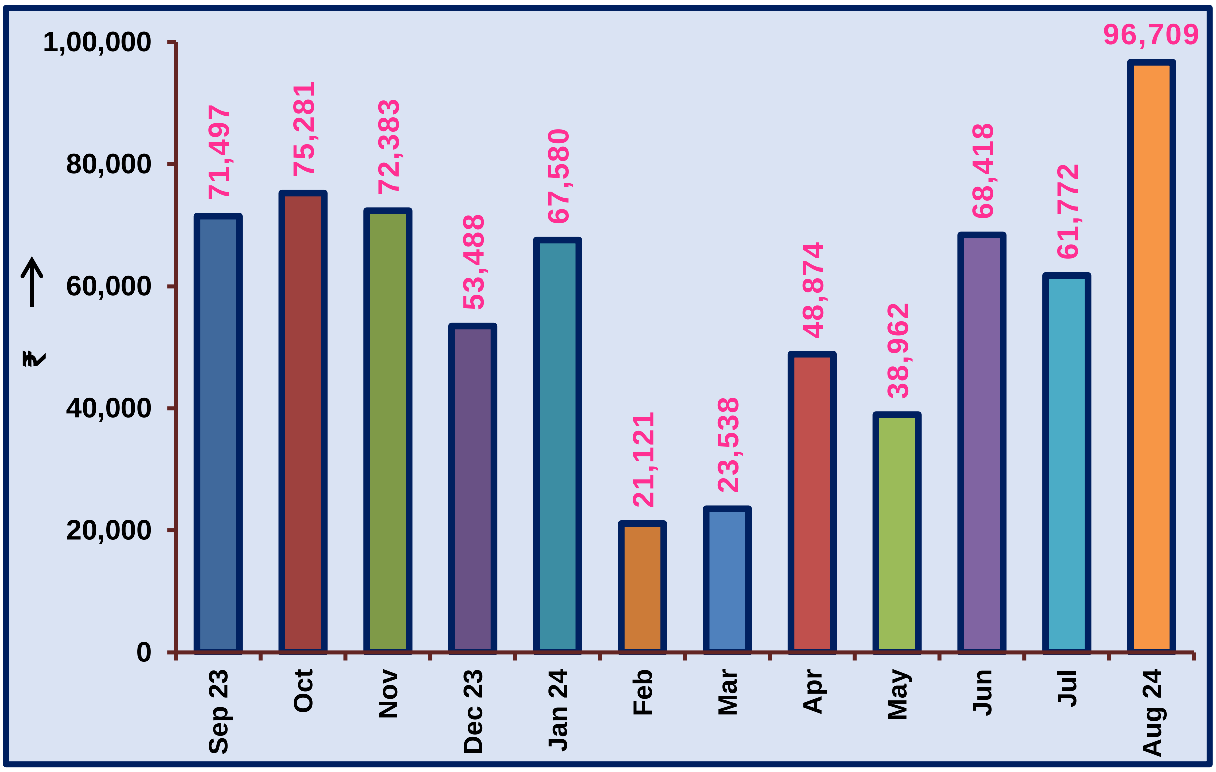


Fig 3.4: Electricity Cost - Month wise (Sep '23 - Aug '24) | CAG

3.1.3 Cumulation

- The unit cost of electricity has been computed for 2 - year period considered in our analysis and depicted in Figs 3.5 & 3.6

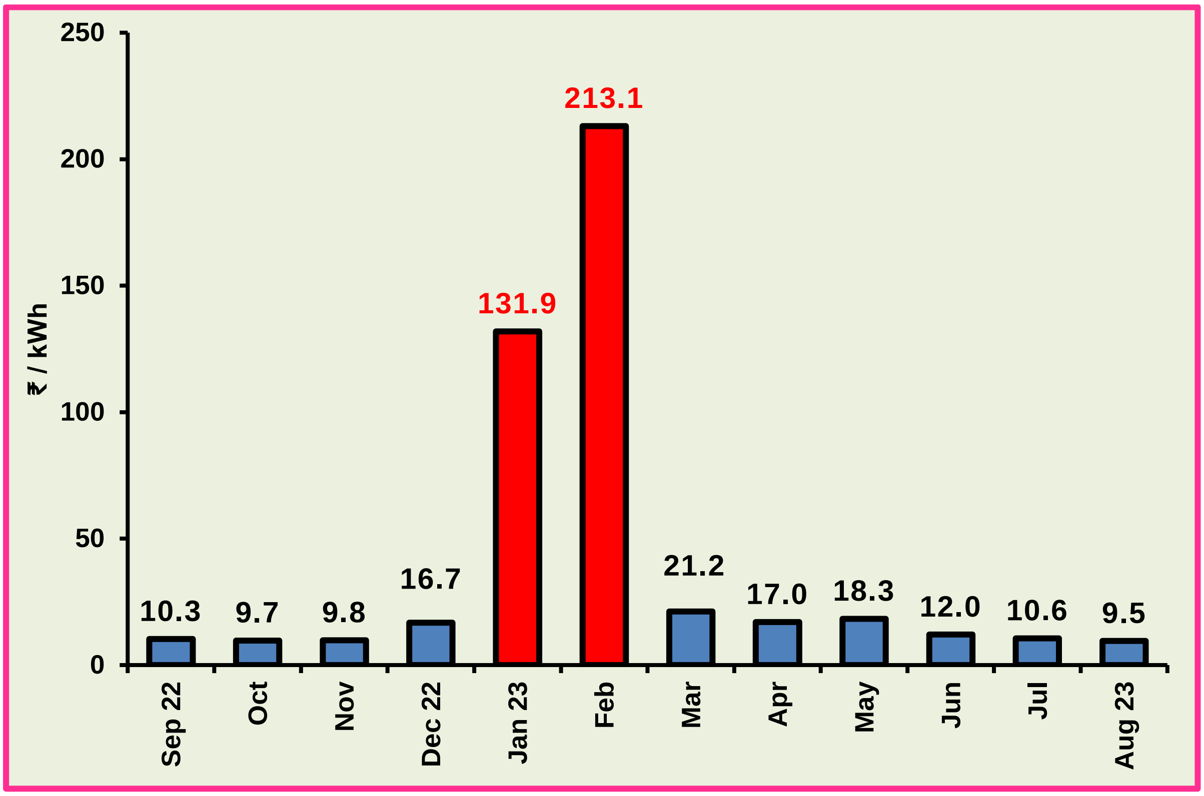


Fig 3.5: Unit Cost of Electricity: Month wise (Sep '22 - Aug '23) | CAG

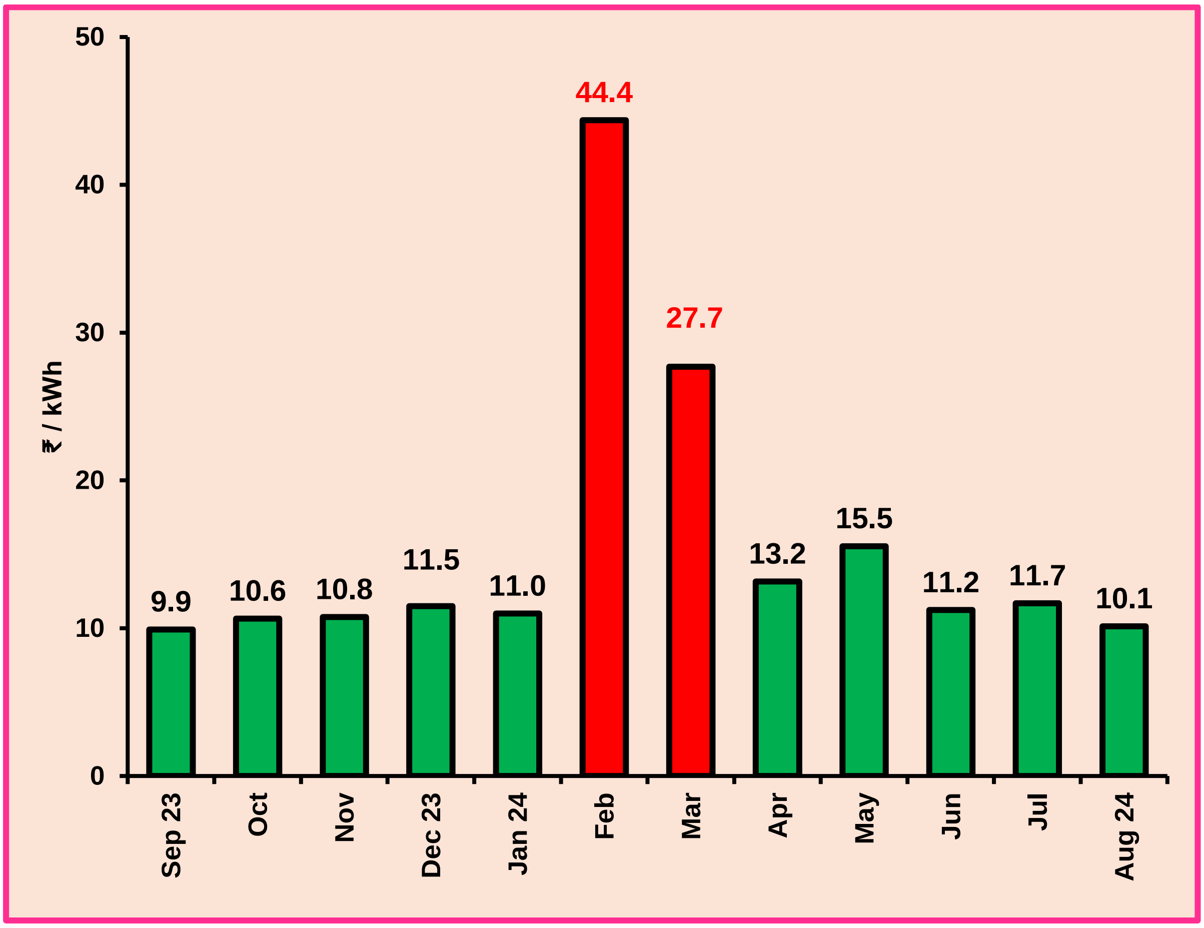


Fig 3.6 : Unit Cost of Electricity: Month wise (Sep '23 - Aug '24) | CAG

- It can be inferred from above charts that the overall cost of electricity per unit is greatly influenced by production. It is clear that when tea production is minimum / almost NIL, the unit cost of electricity skyrockets by multiple times in comparison with other production months.
- This is typically influenced by the fixed cost component of the electricity bill, specifically the demand charges. Optimal choice of CL / CD - in line with the requirement - would help bring down this disparity in unit cost of electricity between production and non - production days by levelling down it to a certain extent.
- The consolidation of electricity cost is shown below:

	Unit Cost of Electricity ₹ / kWh	
Service Connection	**Sep '22 – Aug '23**	**Sep '23 – Aug '24**
H T	**12.0**	**11.60**

3.2 THERMAL ENERGY

3.2.1 Coal Consumption

- Coal - procured from Meghalaya - is used for tea drying application in the dryers.
- The quality of coal varies with the season so also the cost of it.
- The coal consumption significantly goes high during high production season as well as during rainy season. The consumption goes up in rainy season because of the moisture pick up by the coal.
- The consumption details of the coal are depicted month wise in Table 3.4 and presented figuratively in Figs 3.7 & 3.8

Coal Consumption : (Sep '22 to Aug '23) = 1 24 530 kg

: (Sep '23 to Aug '24) = 1 56 620 kg

Table 3.4 : Coal Consumption (Sep '22 – Aug '24)

Period : Sep '22 – Aug '23		
No	**Month**	**Coal Consumption kg**
1	Sep 22	19 240
2	Oct	20 380
3	Nov	15 500
4	Dec 22	5 580
5	Jan 23	-
6	Feb	-
7	Mar	2 840
8	Apr	6 240
9	May	5 020
10	Jun	12 530
11	Jul	15 400
12	Aug 23	21 800
Total		**1 24 530**

Period : Sep '23 – Aug '24		
No	**Month**	**Coal Consumption kg**
1	Sep 23	19 240
2	Oct	20 740
3	Nov	17 660
4	Dec 23	12 920
5	Jan 24	-
6	Feb	-
7	Mar	5 520
8	Apr	13 500
9	May	14 060
10	Jun	16 860
11	Jul	18 440
12	Aug 24	17 680
Total		**1 56 620**

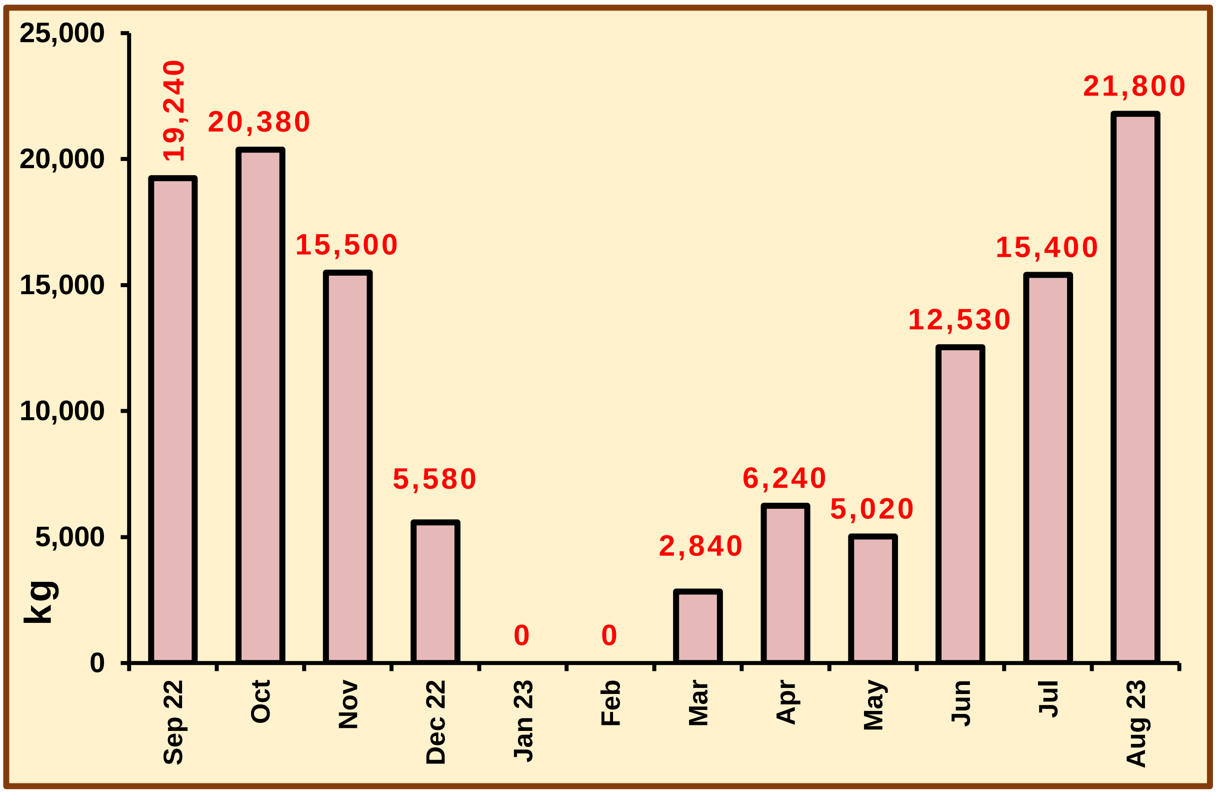


Fig 3.7: Coal Consumption - Month wise (Sep '22 - Aug '23) | CAG

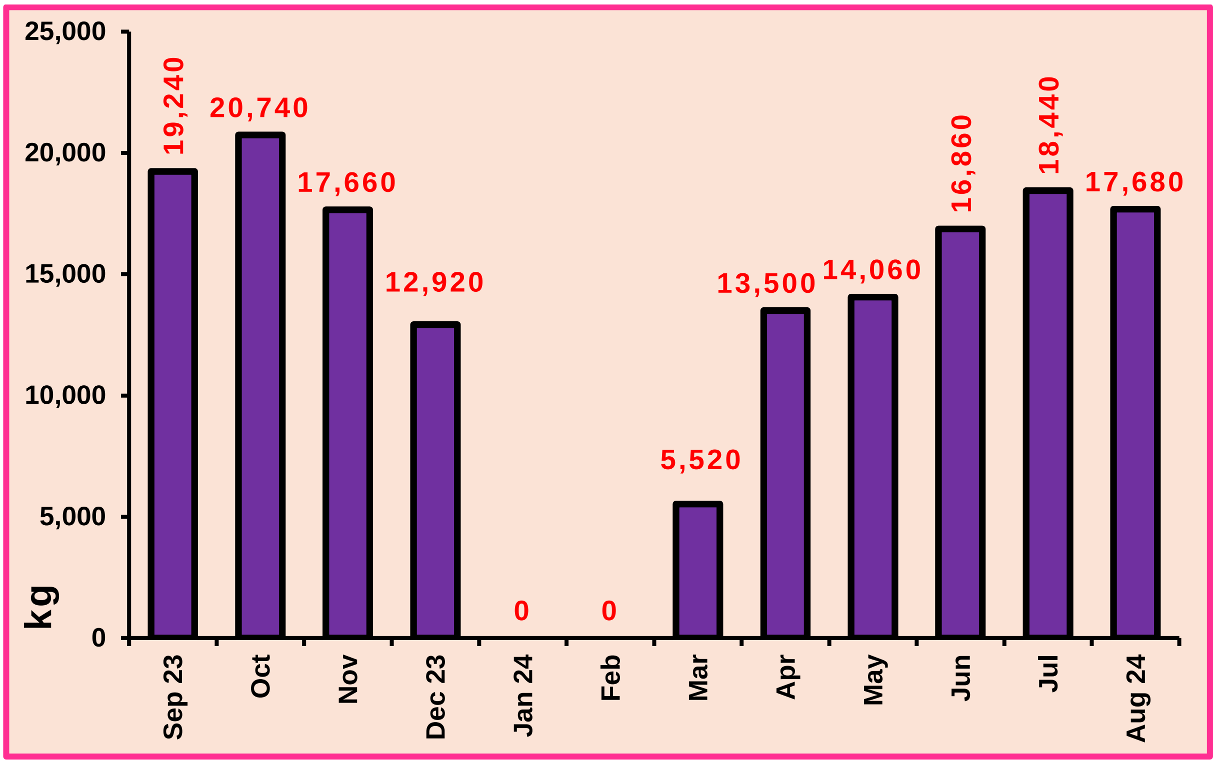


Fig 3.8 : Coal Consumption - Month wise (Sep '23 - Aug '24) | CAG

3.2.2 Cost Incurred

- The coal is being procured in batches from the coal mines of Meghalaya state. The grade of the coal varies significantly in every batch and hence the cost too varies accordingly.
- On an average, the landed cost of coal varies from **₹ 12 500 / ton** to **₹ 19 500 / ton** that includes transportation, loading, unloading and other sundry charges.
- The cost incurred towards the purchase of coal for the 2 year period is depicted below

Table 3.5 : Coal Cost Incurred : 2 year Period

No	Month	Coal Cost ₹	
		2022 - 23	2023 - 24
1	Sep (22 / 23)	3 27 080	3 75 180
2	Oct	3 46 460	3 83 690
3	Nov	2 63 500	3 26 710
4	Dec	94 860	2 39 020
5	Jan (23 / 24)	-	-

No	Month	Coal Cost ₹	
		2022 - 23	2023 - 24
6	Feb	-	-
7	Mar	48 280	79 488
8	Apr	1 24 800	1 68 750
9	May	1 00 400	1 75 750
10	Jun	2 50 600	2 10 750
11	Jul	3 00 300	2 48 940
12	Aug (23 / 24)	4 25 100	2 38 680
Total		**22 81 380**	**24 46 958**

- The cost incurred towards the purchase of coal for the 2 - year period is depicted below:

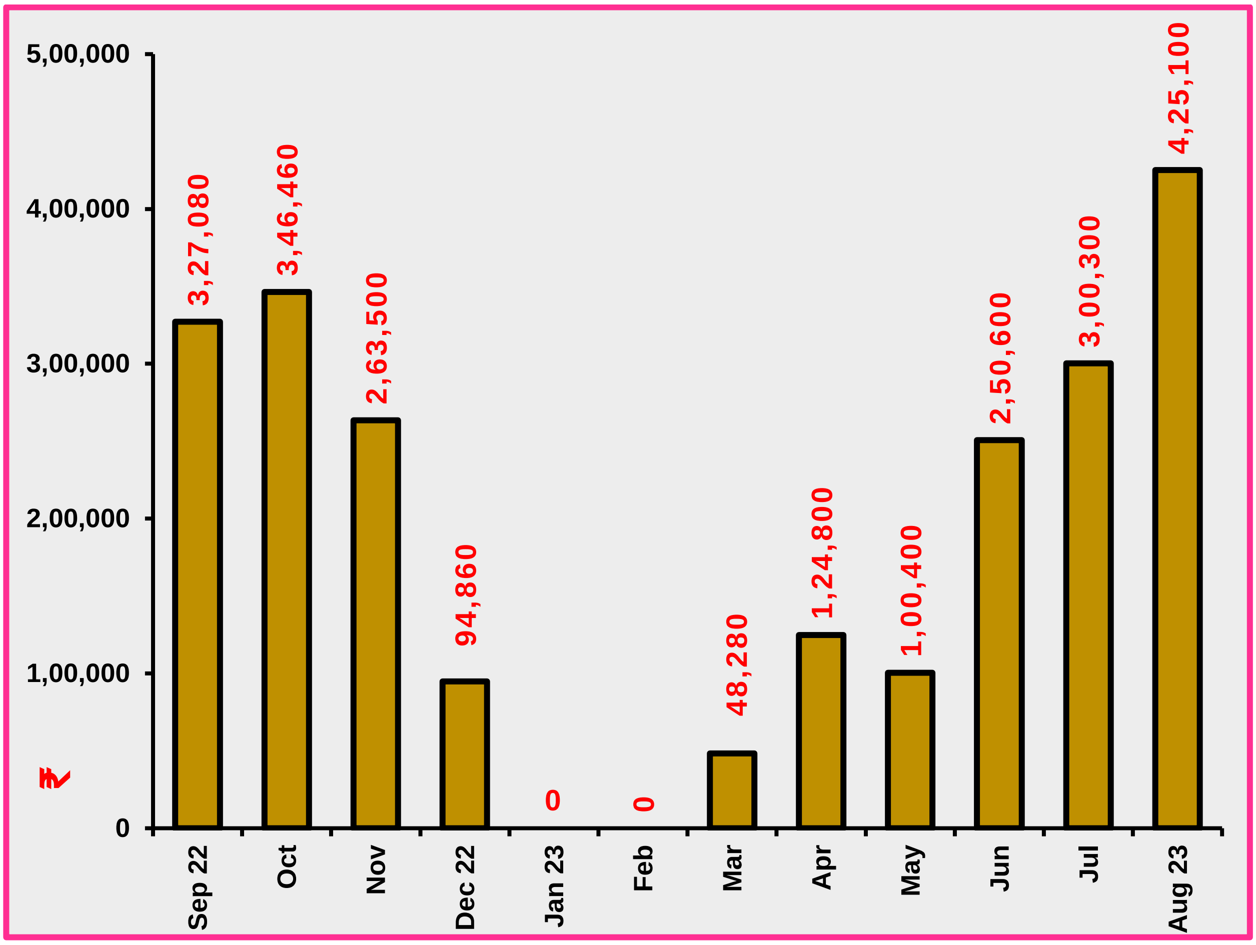


Fig 3.9 : Coal Cost incurred: Month wise (Sep '22 - Aug '23) | CAG

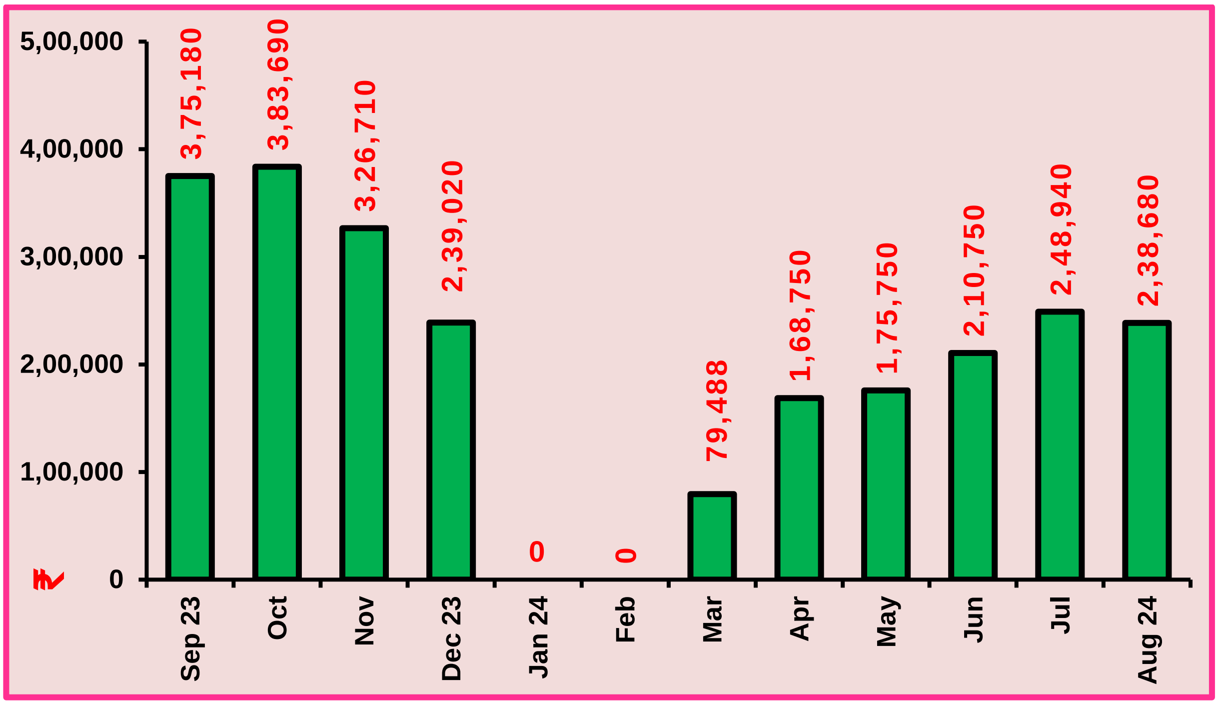


Fig 3.10 : Coal Cost incurred: Month wise (Sep '23 - Aug '24) | CAG

Coal Cost : (Sep '22 to Aug '23) : ₹ 22 81 380
: (Sep '23 to Aug '24) : ₹ 24 46 958

3.2.3 Cumulation

- The unit cost of coal - in terms of ₹ / kg - has been computed for 2 years considered in our analysis and depicted in Figs 3.11 & 3.12

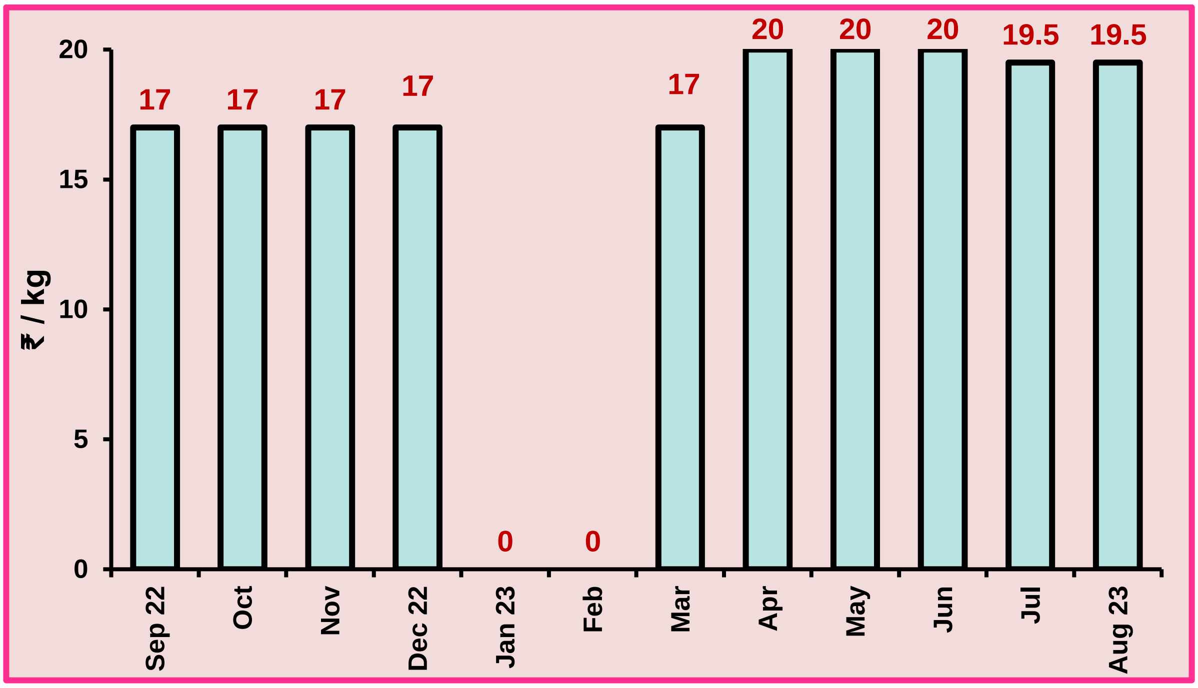


Fig 3.11 : Unit Cost of Coal : Month wise (Sep '22 - Aug '23) | CAG

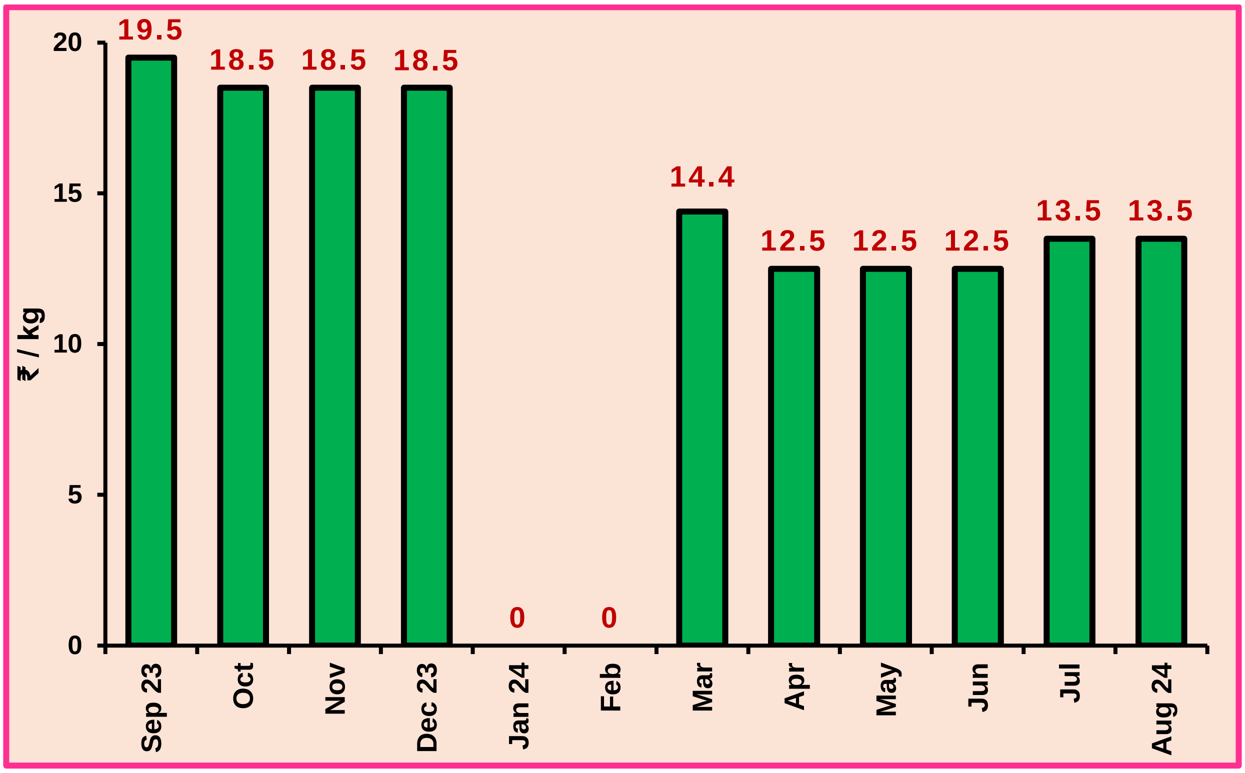


Fig 3.12 : Unit Cost of Coal: Month wise (Sep '23 - Aug '24) | CAG

Average Unit Cost of Coal :

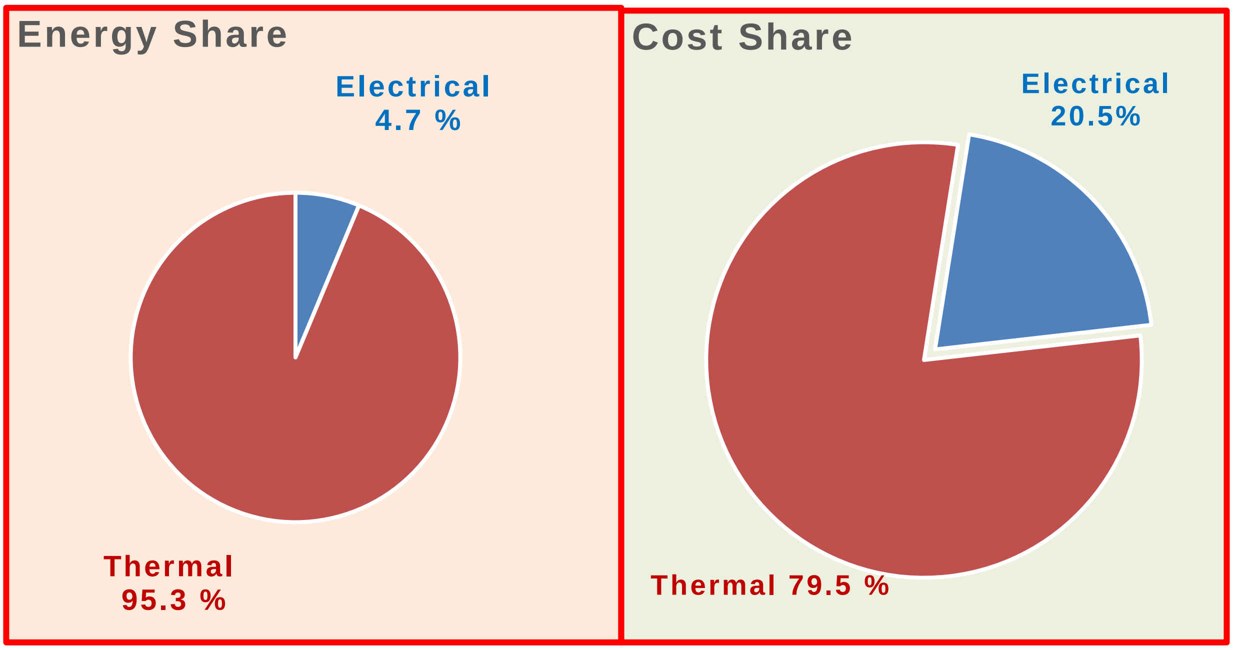
1. **Sep '22 to Aug '23 : ₹ 16.9 / kg**
2. **Sep '23 to Aug '24 : ₹ 15.2 / kg**

3.3 ENERGY & COST SHARE

- The energy and cost share details have been prepared based on the 2 - year data collected and presented in Table 3.6.

Table 3.6 Energy & Cost Share :Computed : Overall: Avg

No	Type of Energy	Energy		Cost Spent	
		MJ / y	%	₹ / y	%
1	Electricity: FEDCO / TSECL	1 86 347	4.7	6 08 222	20.5
2	Coal from Meghalaya	37 33 194	95.3	23 64 169	79.5
Total		39 19 541	100.0	29 72 391	100.0



F ig 3.13 : Energy & Cost Share: Manufacturing of Tea | CAG

- The thermal energy share is as high as 95.3 % of the total while that of the electricity is only 4.7 %. However, the cost spent on thermal energy procurement is 79.5 % and the corresponding cost of electricity is 20.5 %. This information is presented in Fig 3.13.

4.1 SUMMATION

- The annual average cost spent on energy procurement (Electricity + Coal) is estimated as **₹ 30 lakhs**.
- Thus, it is worthy an exercise to look for optimization of energy usage in the process operation and thereby containing the cost spent on energy.
- Further, the conservation / optimized usage of energy is welcome from environment view point also as it has potential to reduce the greenhouse gas emission.
- Thus, this exercise of energy auditing is the most appropriate one at this point of time

Thus, it is inferred that the factory spends a substantial amount on energy, close to

₹ 30 lakhs / year

.

4 PRODUCTION DETAILS – A PRESENTATION

4.0 PREAMBLE

- The production related details – with respect to Green Leaves processed as well as Made Tea produced – are presented in this Chapter

4.1 PRODUCTION DETAILS

- The production data (as captured from the factory records) are presented in the section.
- The period considered is 24 **months (Sep '22 – Aug '24)**

4.1.1 Green Leaves Processed

- Green leaves processed = **3 97 142 kg (Sep '22 – Aug '23)**

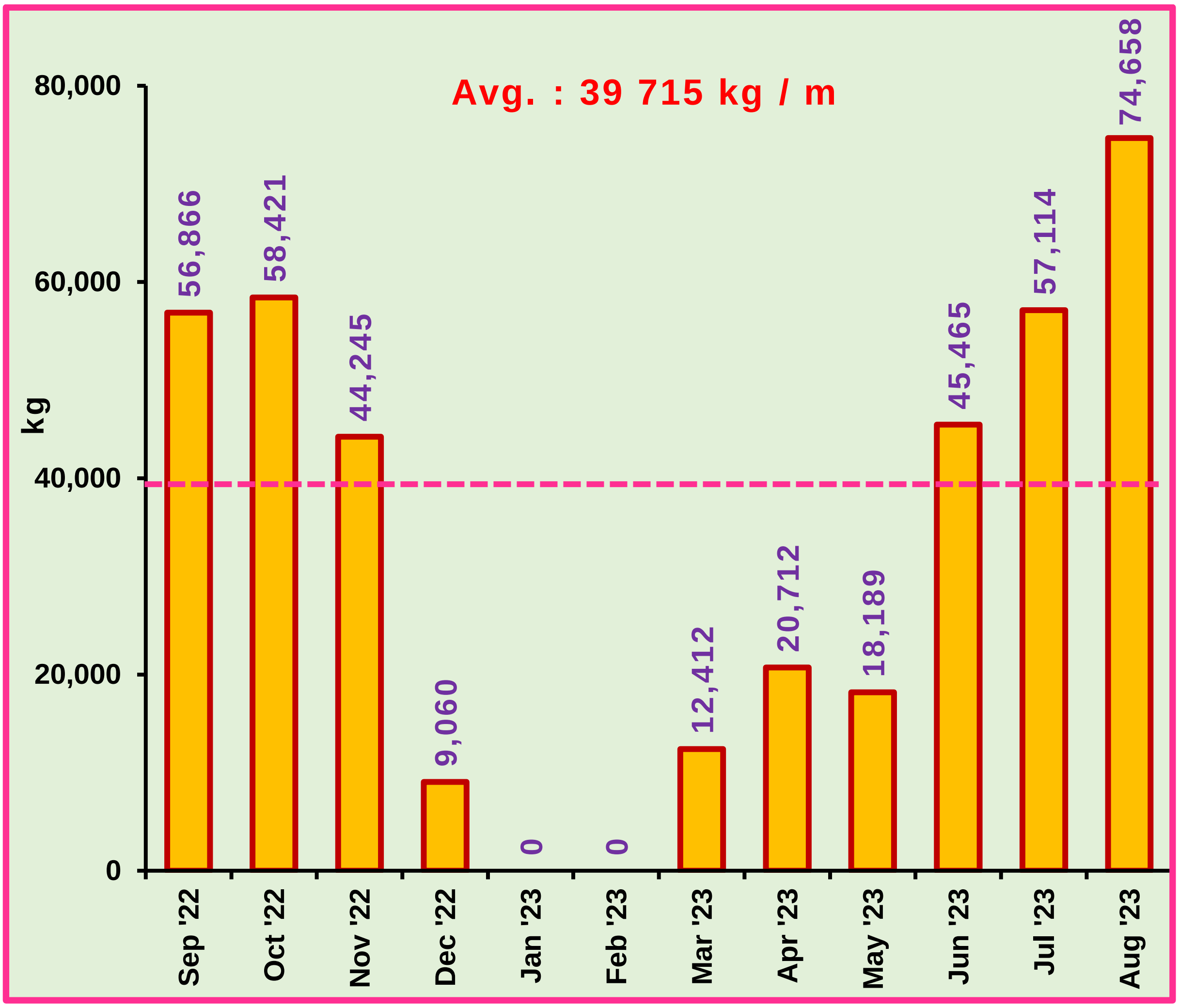


Fig 4.1: Green Leaves Processed: Month wise (Sep '22 – Aug '23) | CAG

∉ Green leaves processed = **4 80 521 kg (Sep ‘23 - Aug ‘24)**

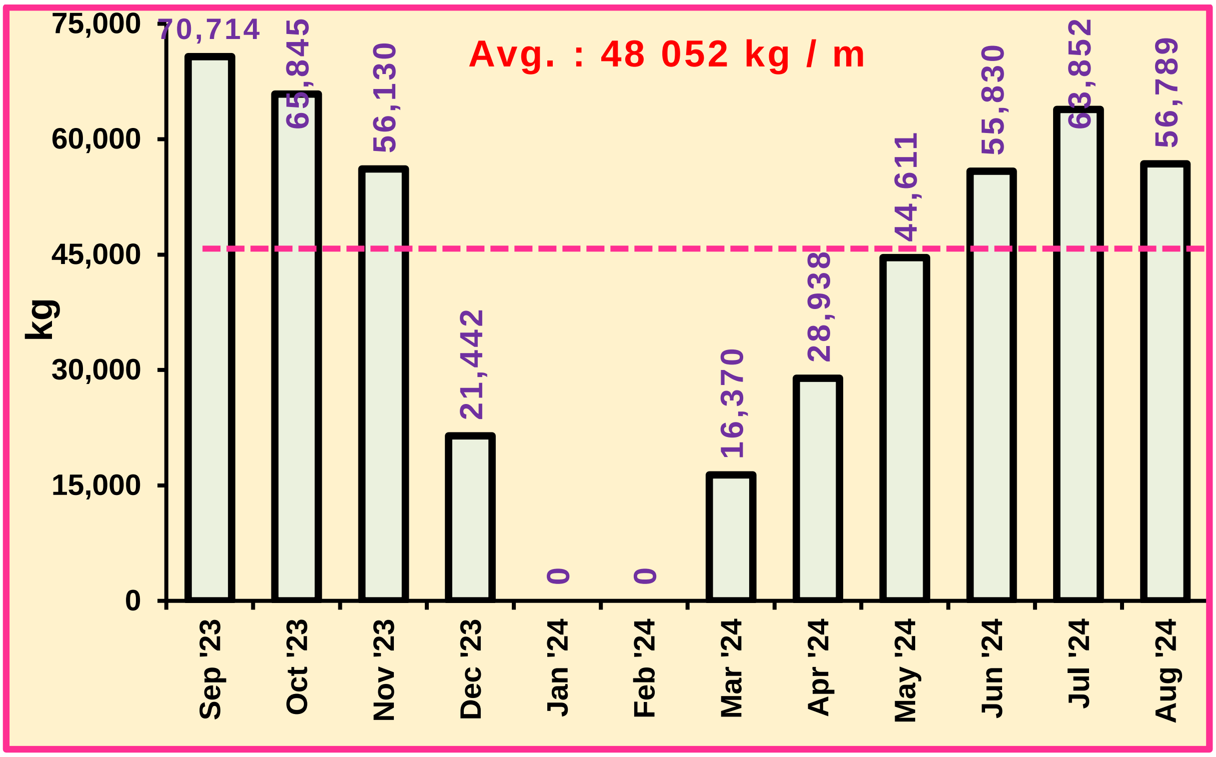


Fig 4.2: Green Leaves Processed: Month wise (Sep ‘23 – Aug ‘24) | CAG

- The processing quantity of green leaves varies with the season / arrival
- The grouping made with respect to the quantity processed is presented in Fig 4.3 & 4.4
- Typically, the months of Jul to Oct process the maximum quantity of leaves exceeding 50 tons / m. Likewise, the months of Dec - Mar experience minimal arrival of leaves (< 15 tons / m) and hence lesser processing.

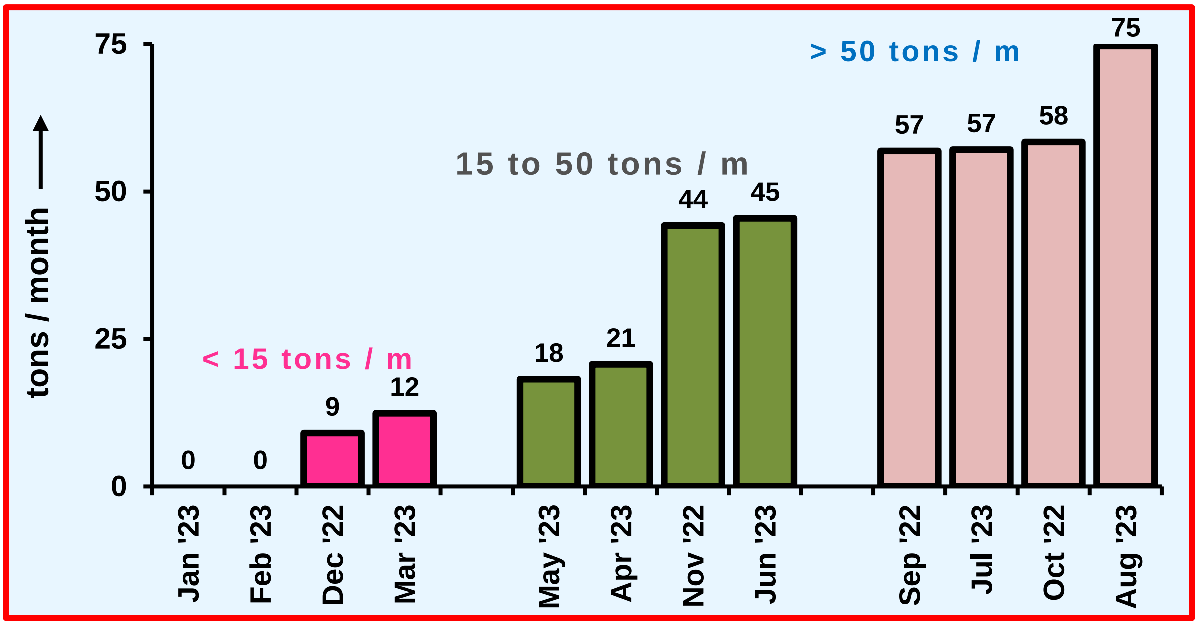


Fig 4.3 : Green Leaves Processed: Quantity wise(Sep ‘22 - Aug ‘23) | CAG

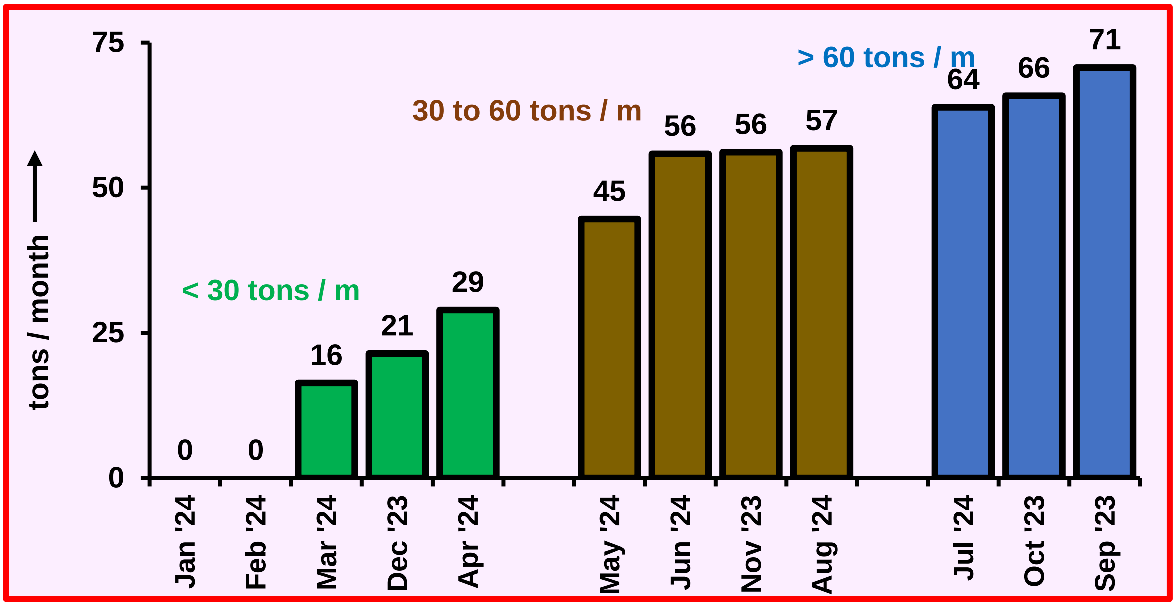


Fig 4.4: Green Leaves Processed: Quantity wise (Sep '23 - Aug '24) | CAG

- However, the period Sep '23 - Aug '24 has received / processed higher quantity of leaves compared to the same period of the preceding year [**3 97 142** kg in 22 -23 & **4 80 521** kg in 23 - 24]
- The months of Jul, Sep & Oct processed more than 60 000 kg / month of green leaves and the lowest was during Mar, Apr & Dec when the quantity processed was less than 30 000 kg

4.1.2 Made Tea Produced

- Made Tea produced

  (i) 78 997 kg (Sep '22 - Aug '23) and (ii) 99 214 kg (Sep '23 - Aug '24)

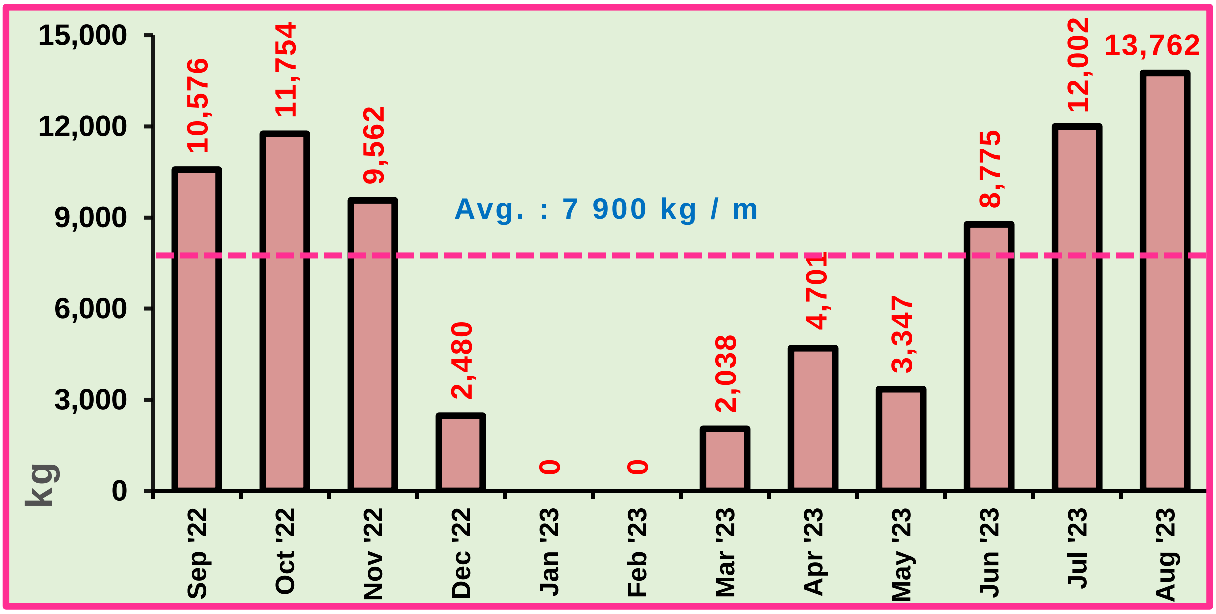


Fig 4.5 : Made Tea Produced : Month wise (Sep '22 - Aug '23) | CAG

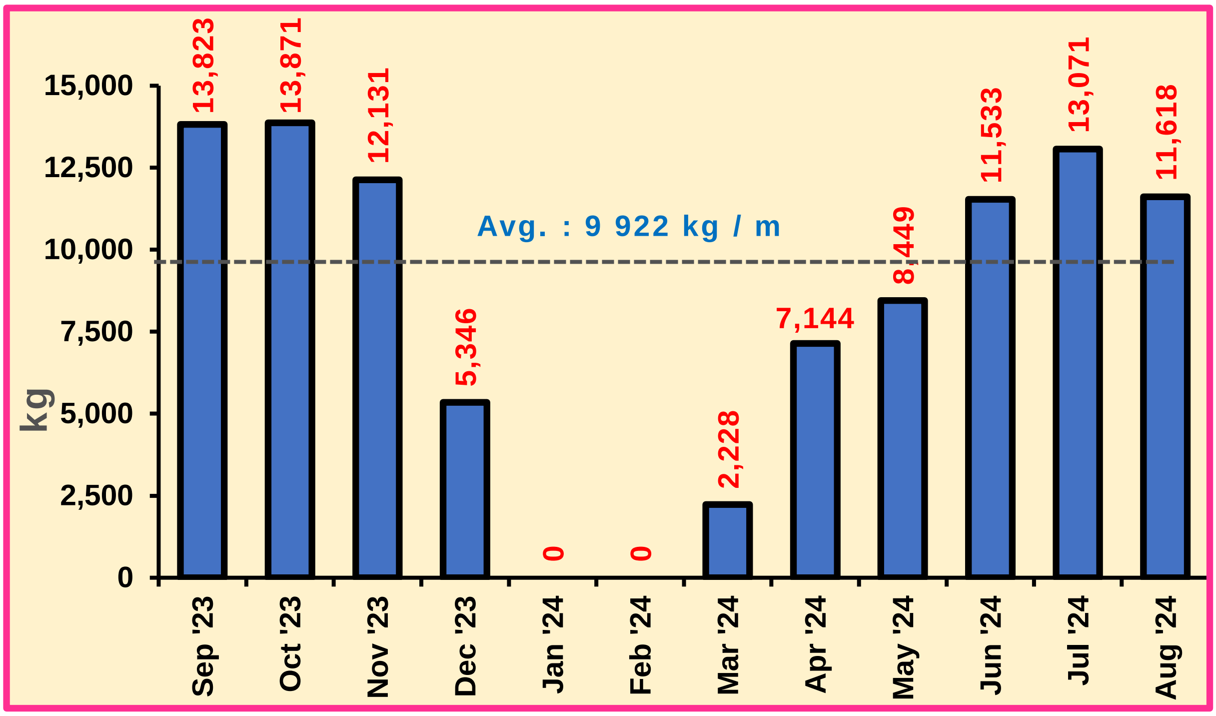


Fig 4.6 : Made Tea Produced : Month wise (Sep '23 - Aug '24) | CAG

4.1.3 Out Turn Recorded

- This parameter - Out turn - is defined as the ratio of the Made Tea produced to that of the corresponding Green Leaves quantity processed. This parameter is strongly influenced by the quality of green leaves used in the process.
- This parameter has been established month wise and presented in Figs 4.7 & 4.8

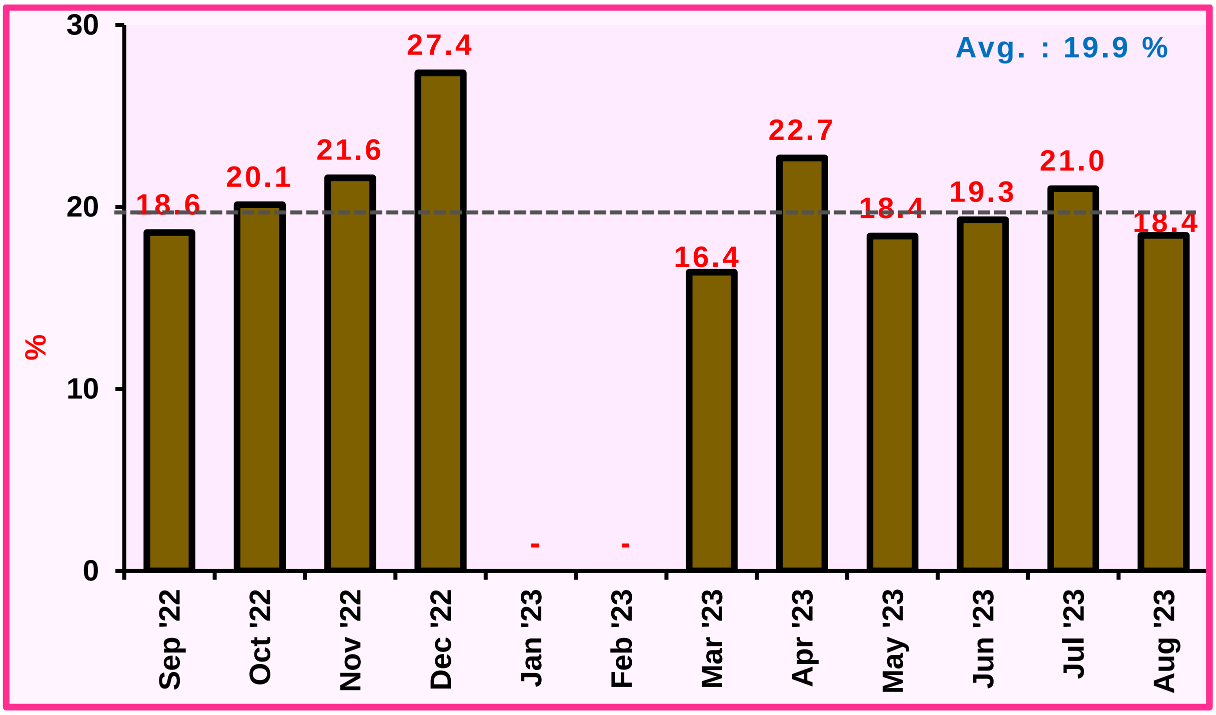


Fig 4.7 : Outturn Established - Month wise (Sep '22 - Aug '23) | CAG

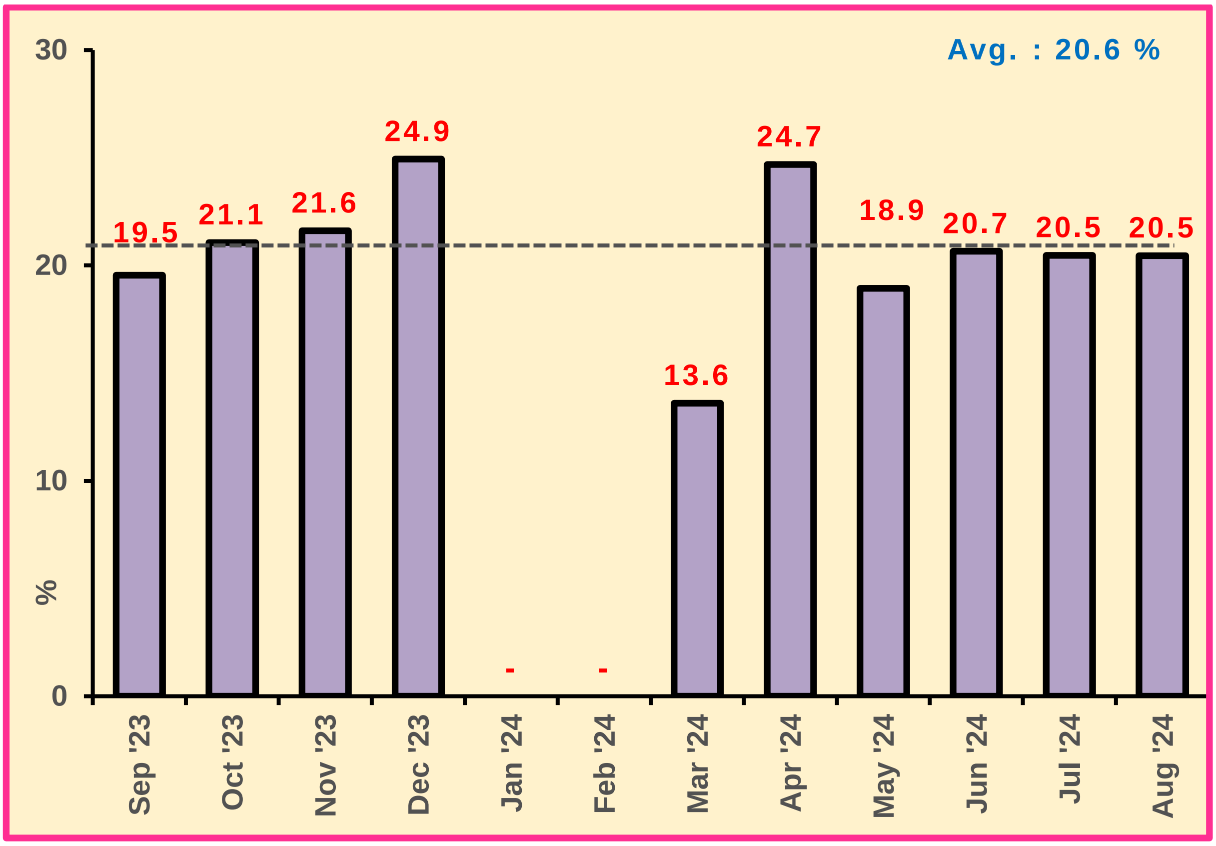


Fig 4.8 : Outturn Established - Month wise (Sep '23- Aug '24) | CAG

Average outturn in the period Sep '22 – Aug '24 = 20.3 %

4.2 CONSOLIDATION

- The consolidated production related details are provided below :

Table 4.1 : Production related Information : 2 y : Consolidated

Period	Green Leaves Processed kg	Made Tea Produced kg	Outturn %
Sep '22 - Aug '23	3 97 142	78 997	19.9
Sep '23 - Aug '24	4 80 521	99 214	20.6
Total	8 77 663	1 78 211	20.3

4.3 SUMMATION

- The seasonal dependence of tea production is quite clear - exhibiting consistent behavior in both timeframes considered - peaking during the months Jun - Oct, moderating in Apr, May & Nov and almost NIL in the months of Dec - Mar.

- A couple of inconsistencies were noted in the monthly outturn - in the month of December - showing slightly high figures; it is quite clear that this could be due to intentional year - end adjustments made (in December) to the quantities of green leaves / made tea, to account for the differences between the actual and considered quantities in the preceding 11 months. This is quite common in accounting parlance, hence ignored.
- The production of Made Tea / quantity of Green Leaves Processed in during the period 2023- 24 was higher by 20 % compared to the same period of the preceding year. This is to say that the productivity of the factory had gone up by 20 % in ‘23 - ‘24 which is welcome.
- Outturn is maintained at around **20.3 %** which is on the lower side and could be more considering the quality of the leaves received.

5 SPECIFIC ENERGY CONSUMPTION – A COMPUTATION

5.1 INTRODUCTION

- Both electrical energy and thermal energy are required in substantial quantities in the manufacturing of tea from the virgin green tea leaves.
- The energy usage locations are as below :
    1) Electrical Energy : C T C, Withering Fans, Dryer Fans, Sorting Machines, etc.
    2) Thermal Energy : Tea drying through coal combustion
- The **S**pecific **E**nergy **C**onsumption [**S E C**] is a **K**ey **P**erformance **I**ndicator [**K P I**] that measures the amount of energy required to produce a unit of output.
- The SEC determination is a very useful tool from the energy conservation point of view as it provides the information for comparison of performance of the factories in terms of energy efficiency.
- This chapter gives details on the **S**pecific **E**lectrical **E**nergy **C**onsumption (**S E E C**) and the **S**pecific **F**uel **C**onsumption (**SFC**) in terms of Green Leaves processed as well as Made Tea produced.

5.2 SPECIFIC ELECTRICAL ENERGY CONSUMPTION (SEEC)

5.2.1 SEEC: Green Leaf Basis

- The SEEC has been established on month wise basis for 24 - month period, namely, 2022 - 23 & 2023 - 24 and presented graphically in Figs 5.1 & Fig 5.2 respectively.
- As anticipated, S E E C goes lower during the season period [Jun to Sep] when the leaf arrival is plenty and it hovers around 0.08 to 0.10 kWh / kg GL.
- During off - season, the SEEC goes to as high as 0.22 kWh / kg GL as can be seen from Figs 5.1 & 5.2. This is as expected
- The overall SEEC has been established as **0.118 kWh / kg Green Leaves** processed based on the annual data of 2 consecutive years. (Table 5.1)

Table 5.1 : S E E C Established w r t Green Leaves Processed

No	Period	Green Leaves kg	Electricity kWh	kWh / kg GL
1	Sep ‘22 - Aug ’23	3 97 142	43 244	**0.109**
2	Sep ’23 - Aug ’24	4 80 521	60 282	**0.125**
Total		8 77 663	1 03 526	**0.118**

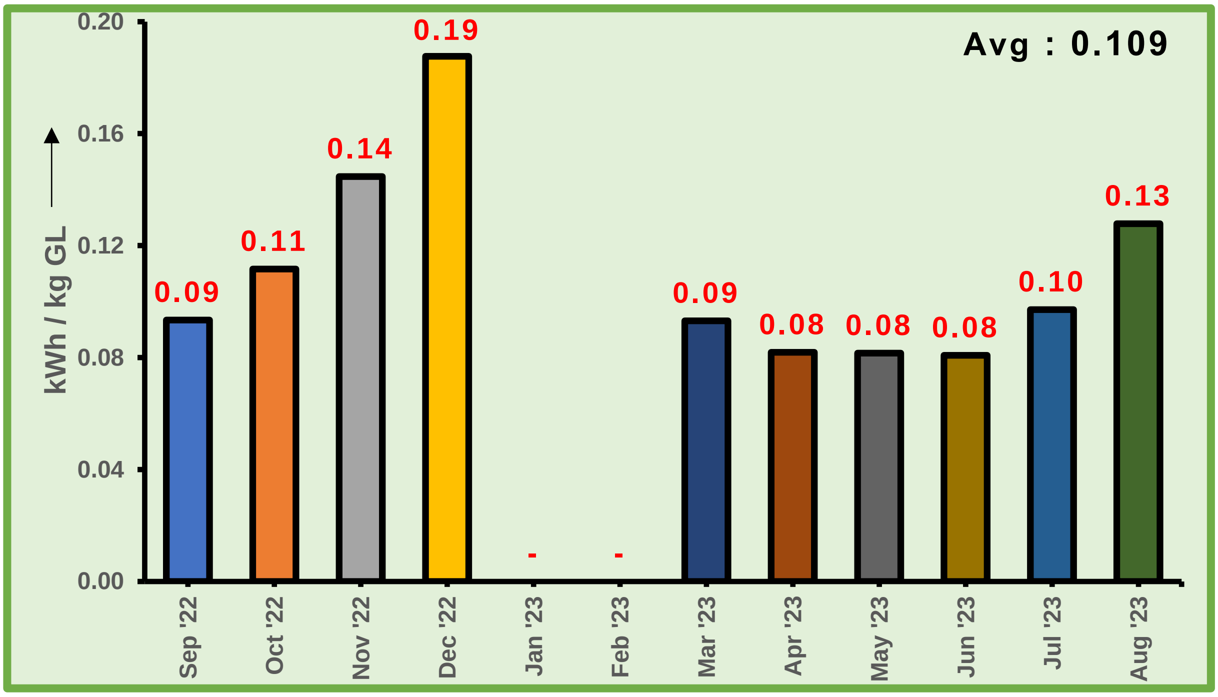


Fig 5.1 : SEEC Computed : Green Leaves Basis - Sep '22 to Aug '23 | CAG

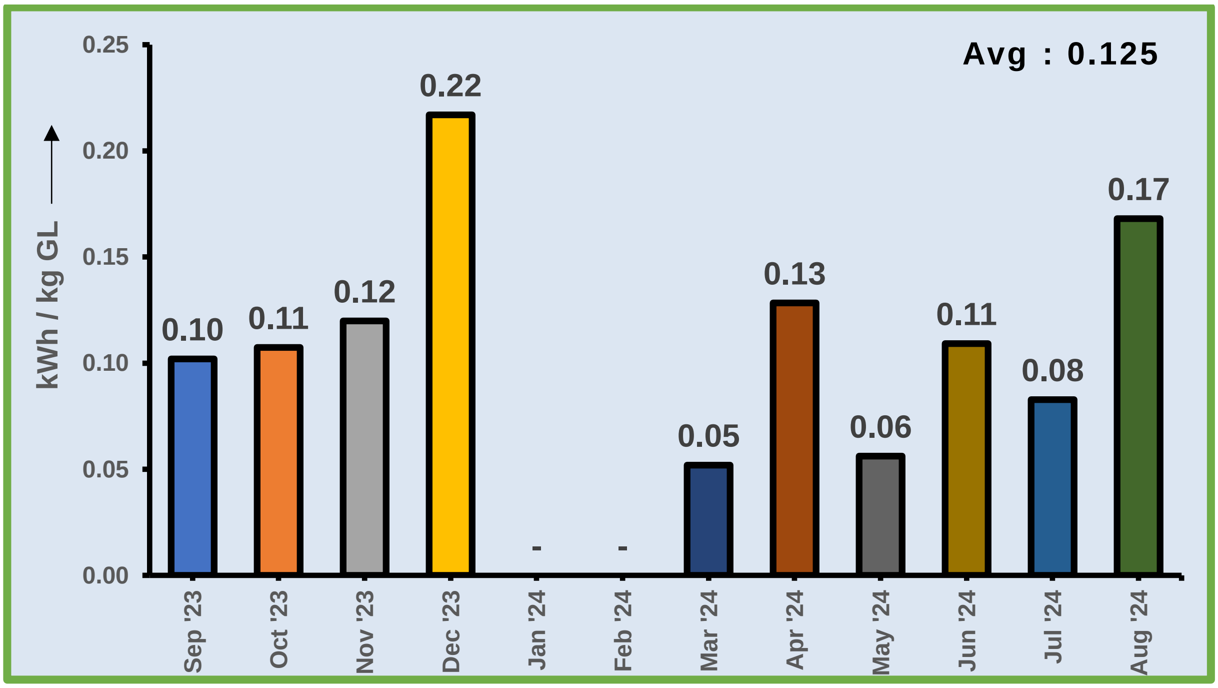


Fig 5.2 : SEEC Computed : Green Leaves Basis - Sep '23 to Aug '24 | CAG

5.2.2 : SEEC : Made Tea Basis

- The SEEC has been established on month wise basis for 24 - month period, namely 2022 -23 and 2023 -24 with respect to Made Tea and presented in Figs 5.3 & 5.4 respectively.
- This parameter is given importance due to the fact that the costing of Sold Tea is strongly influenced by this. Lower the SEEC, lesser is the energy cost of processing.

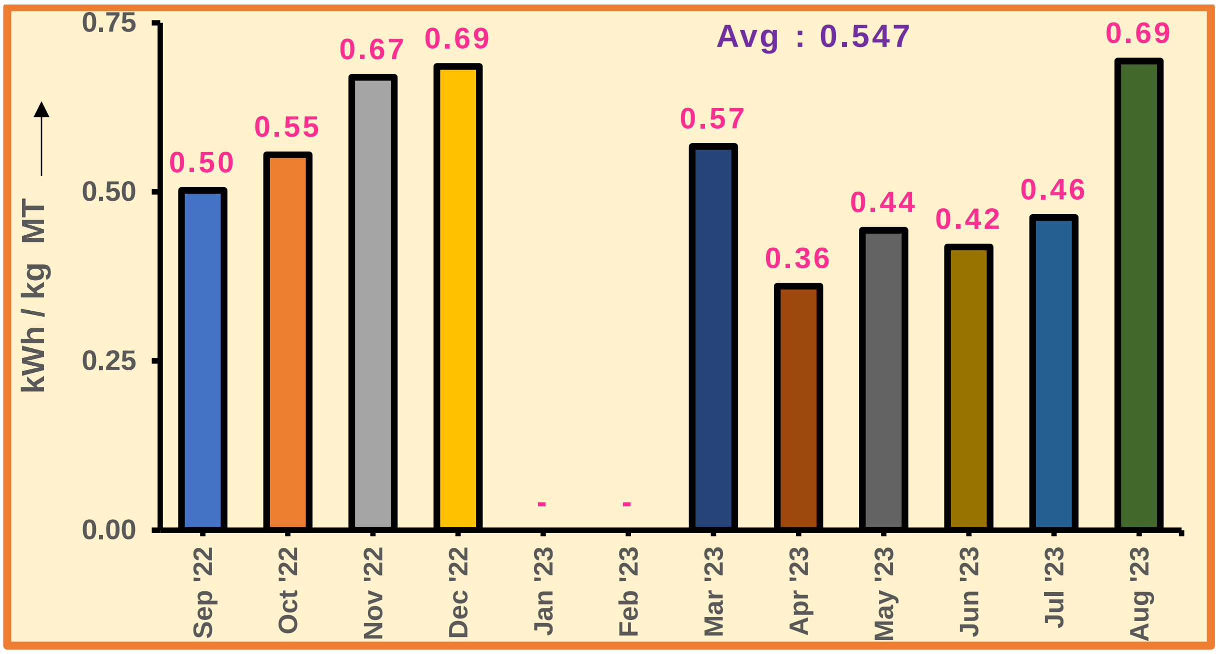


Fig 5.3 : SEEC Computed : Made Tea Basis - Sep '22 to Aug '23 | CAG

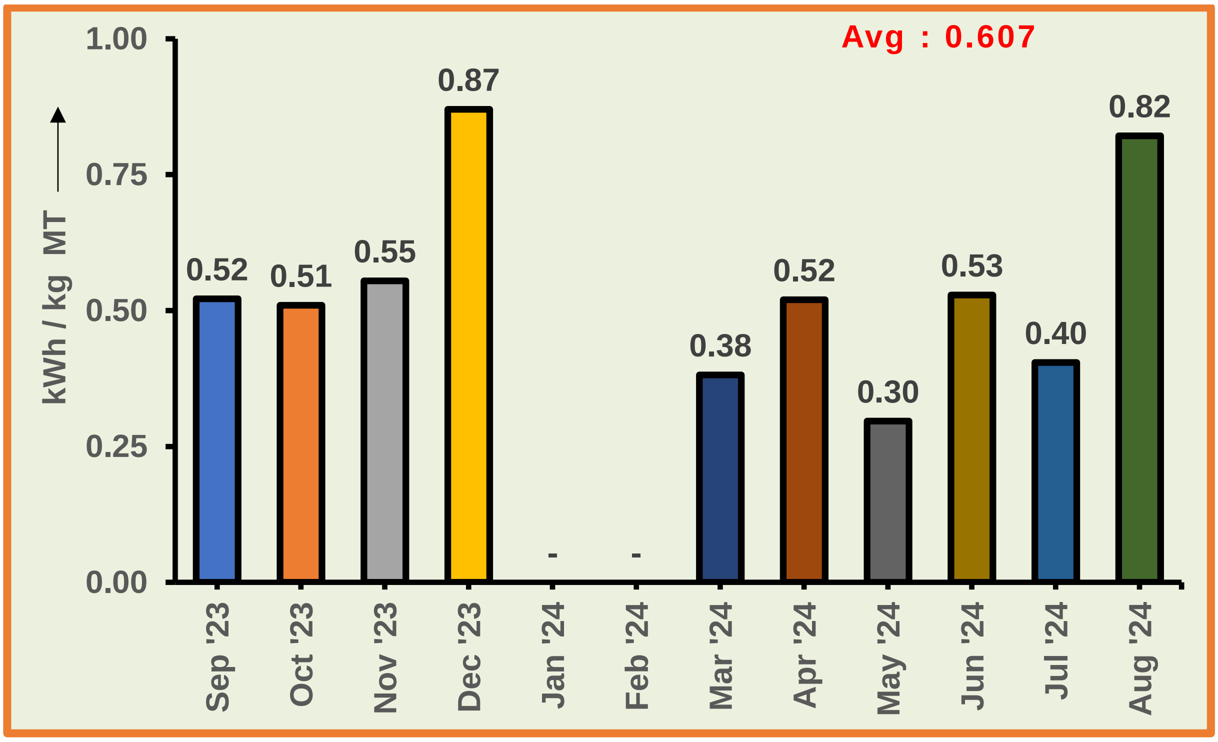


Fig 5.4 : SEEC Computed : Made Tea Basis - Sep '23 to Aug '24 | CAG

- As anticipated, S E E C goes lower during the season period [Jun to Nov] when the leaf arrival / Tea Production is higher. The SEEC value hovers around **0.50 kWh / kg Made Tea and less** during this period. During off - season the SEEC goes as high as **0.87 kWh / kg MT** which is a rare occurrence.
- The annualized data on SEEC w r t Made Tea is presented in Table 5.2.

Table 5.2 : S E E C Established w r t Made Tea Produced

No	Period	Made Tea kg	Electricity Consumption kWh	S E E C kWh / kg MT
1	Sep '22 - Aug '23	78 997	43 244	**0.547**
2	Sep '23 - Aug '24	99 214	60 282	**0.607**
Total		**1 78 211**	**1 03 526**	**0.581**

- The average SEEC has been established as **0.581 kWh / kg Made Tea** which is quite reasonable.

5.3 SPECIFIC FUEL CONSUMPTION (SFC)

5.3.1 S F C: Green Leaf Basis

- The factory employs ECP Dryers to remove moisture in the Wet Dhool to produce Tea.
- The hot air is produced by passing it through a heat exchanger heated by the flue gas released during combustion of coal in the furnace.
- The moisture laden wet air exits the drier from the top and let to the atmosphere.
- The Specific Fuel Consumption [S F C] has been established on month wise basis for 24 - month period and presented in Figs 5.5 & Fig 5.6 respectively.
- During season period, the S F C was **0.25 to 0.30 kg coal / kg GL** and is about **0.35kg coal / kg GL** during low leaf arrival period. (off - season) [*Dec 22 data is an outlier and hence ignored*]

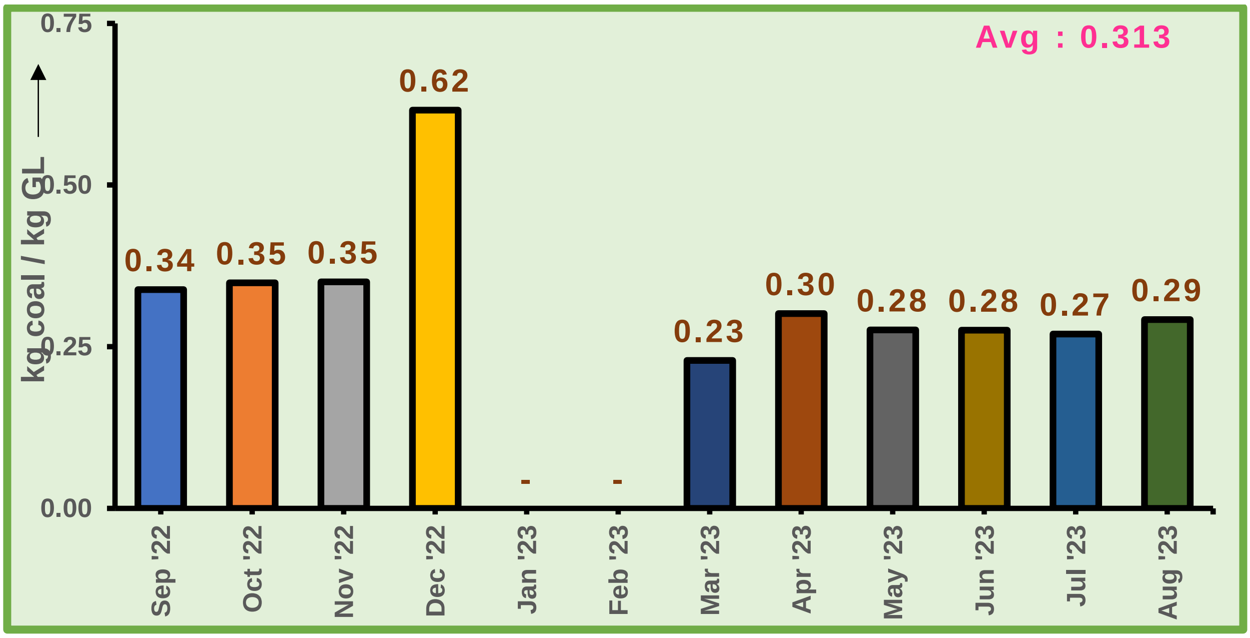


Fig 5.5 : SFC Computed : Green Leaves Basis : Sep '22 to Aug '23 | CAG

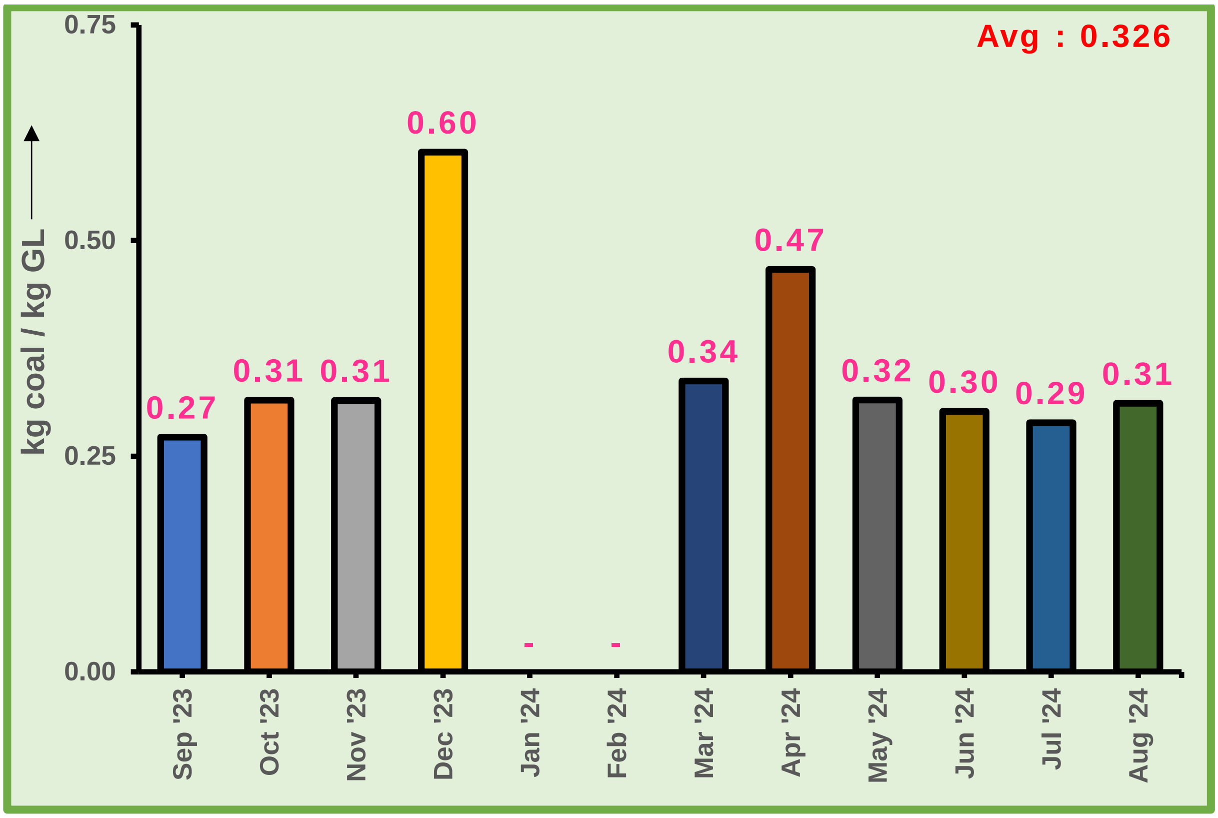


Fig 5.6 : SFC Computed : Green Leaves Basis : Sep '23 to Aug '24 | CAG

- The annualized values for 2 years are tabulated in Table 5.3 as well as the 2 - year average value.
- The SFC with respect to Green Leaves processed has been computed as **0.320 kg of coal / kg of GL** which is a 2 - year average value.

Table 5.3: SFC Established w r t Green Leaves Processed

No	Period	Green Leaves kg	Coal Consumption kg	S F C kg coal / kg GL
1	Sep '22 - Aug '23	3 97 142	1 24 530	**0.313**
2	Sep '23 - Aug '24	4 80 521	1 56 620	**0.326**
Total		**8 77 663**	**2 81 150**	**0.320**

5.3.2 : S F C : Made Tea Basis

- On the similar lines, the SFC has been established [Made Tea Basis] on month wise basis for 24 - month period and presented graphically in Figs 5.7 & 5.8 respectively.

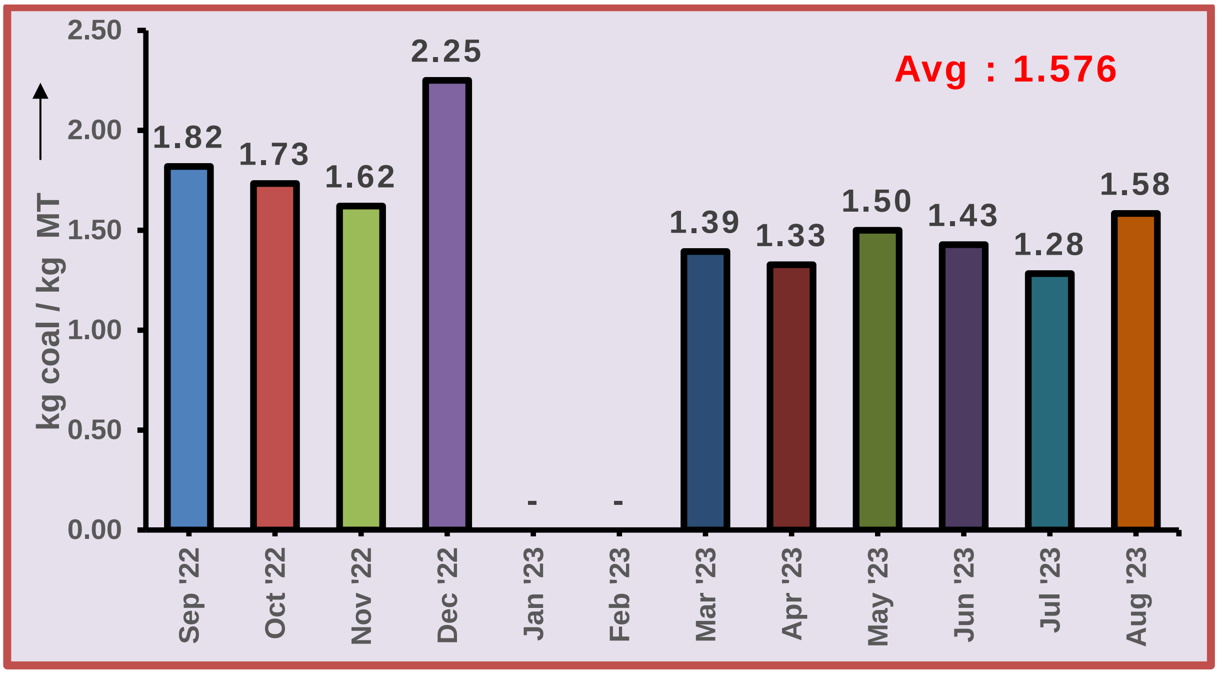


Fig 5.7 : SFC Computed : Made Tea Basis : Sep ‘22 - Aug ’23 | CAG

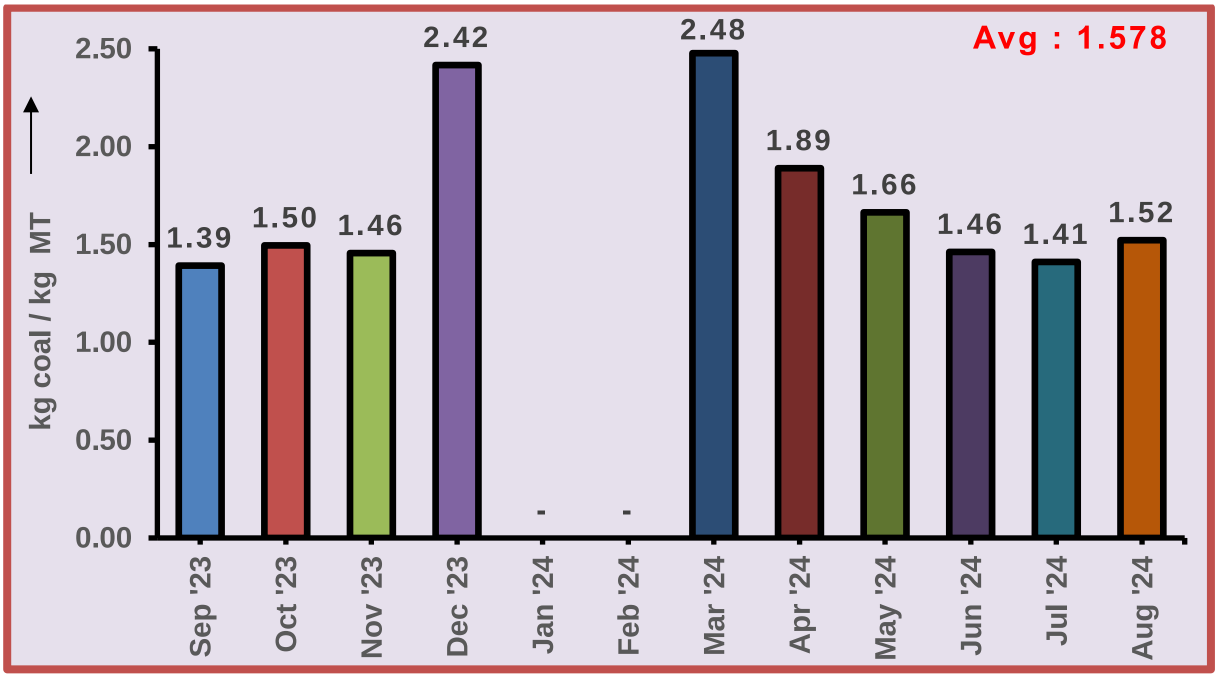


Fig 5.8 : SFC Computed : Made Tea Basis : Sep ‘23 - Aug ’24 | CAG

Table 5.4 : S F C Established w r t Made Tea Produced

No	Period	Made Tea kg	Coal Consumption kg	S F C kg coal / kg MT
1	Sep ‘22 - Aug ’23	78 997	1 24 530	**1.576**
2	Sep ’23 - Aug ’24	99 214	1 56 620	**1.578**
Total		**1 78 211**	**2 81 150**	**1.577**

- The SFC has been computed as **1.577 kg of coal / kg Made Tea** which is a 2 - year average value. This value certainly is on the higher side.
- However, it is added that this SFC value is consistent over two - year period. No variation has been noticed and this is a bit intriguing.

5.4 TOTAL ENERGY COST

- Having deduced the Specific Electricity Consumption and also Specific Coal Consumption, an attempt is made here to establish the cost incurred due to electricity and coal towards tea production.
- The aggregated cost of both the energy [electricity + coal] of tea production - Month on Month - is presented in Fig 5.9 & 5.10 for clarity's sake.

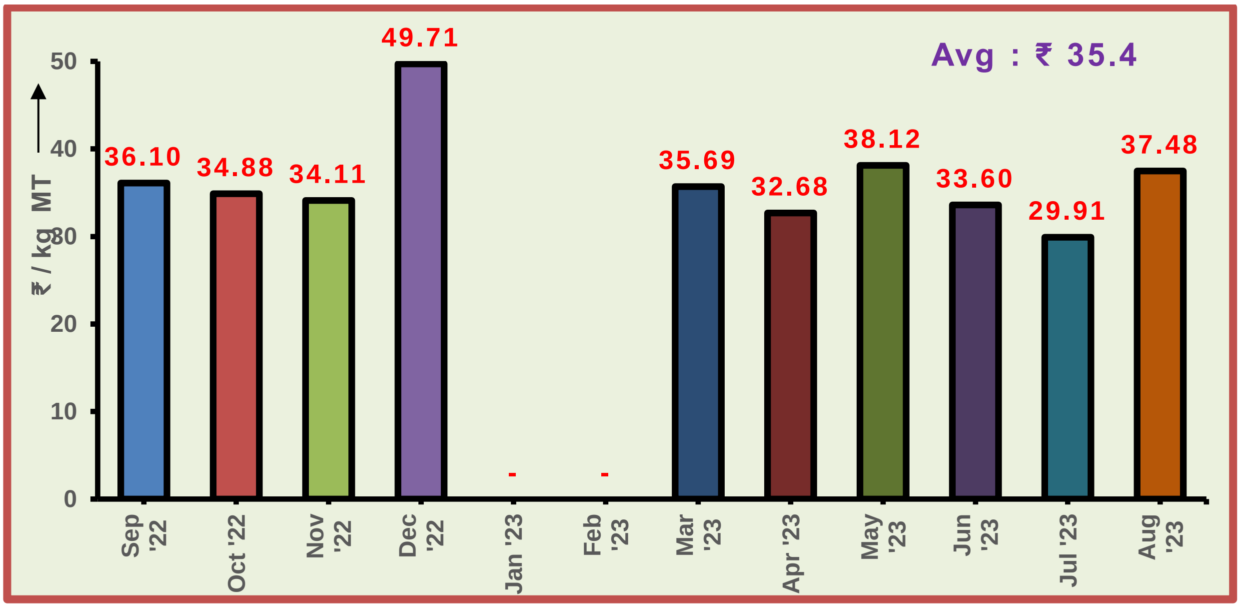


Fig 5.9 : Overall Energy Cost : Month wise : Sep '22 to Aug '23 | CAG

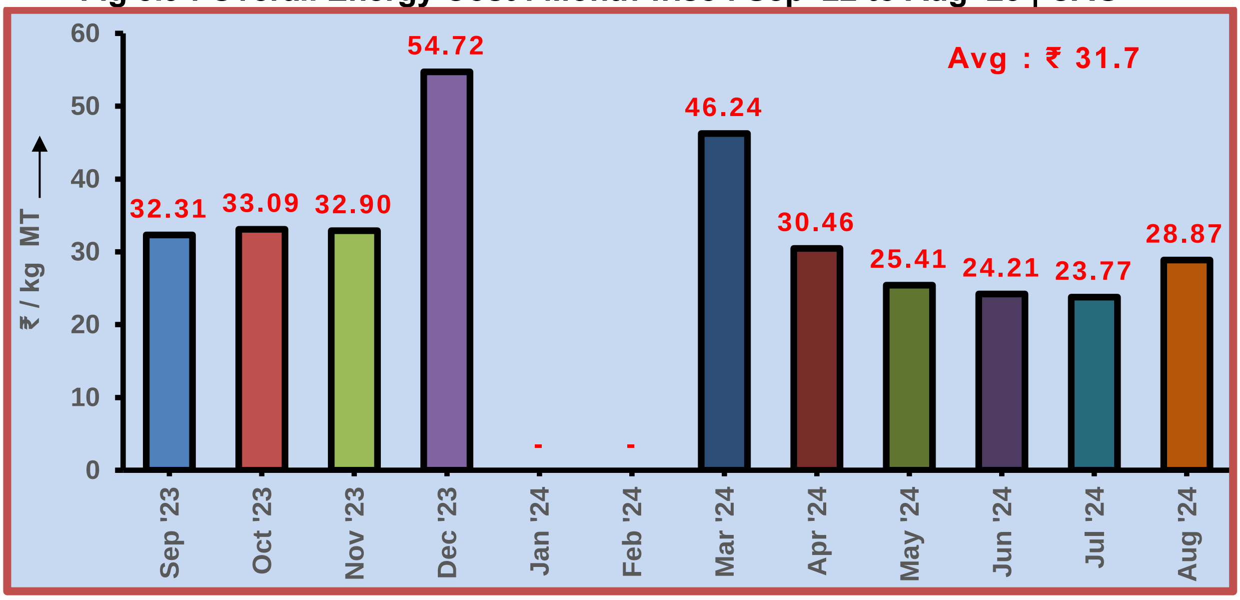


Fig 5.10 : Overall Energy Cost : Month wise : Sep '23 to Aug '24 | CAG

- Table 5.5 presents the cost details computed in respect of energy cost spent towards production of 1 kg of Made Tea.

Table 5.5 : Total Energy Cost w r t Made Tea Produced

No	Period	Made Tea kg	Electricity		Coal		Total	₹ / kg MT
			₹	%	₹	%		
1	Sep'22 - Aug'23	78 997	5 16 813	18.5	22 81 380	81.5	27 98 193	**35.4**
2	Sep'23 - Aug'24	99 214	6 99 622	22.2	24 46 958	77.8	31 46 580	**31.7**
Total		**1 78 211**	**12 16 435**	20.5	**4728 338**	79.5	**59 44773**	**33.4**

- The energy cost of tea production has been estimated as **₹ 33.4 / kg Made Tea**
- About 20.5 % of the energy cost is due to electricity and the rest 79.5 % is due to Coal.
- This is due to the higher procurement cost of Coal. This has to be optimized to bring down the specific cost of coal utilized in tea making.
- The cost share diagram is presented in Fig 5.11

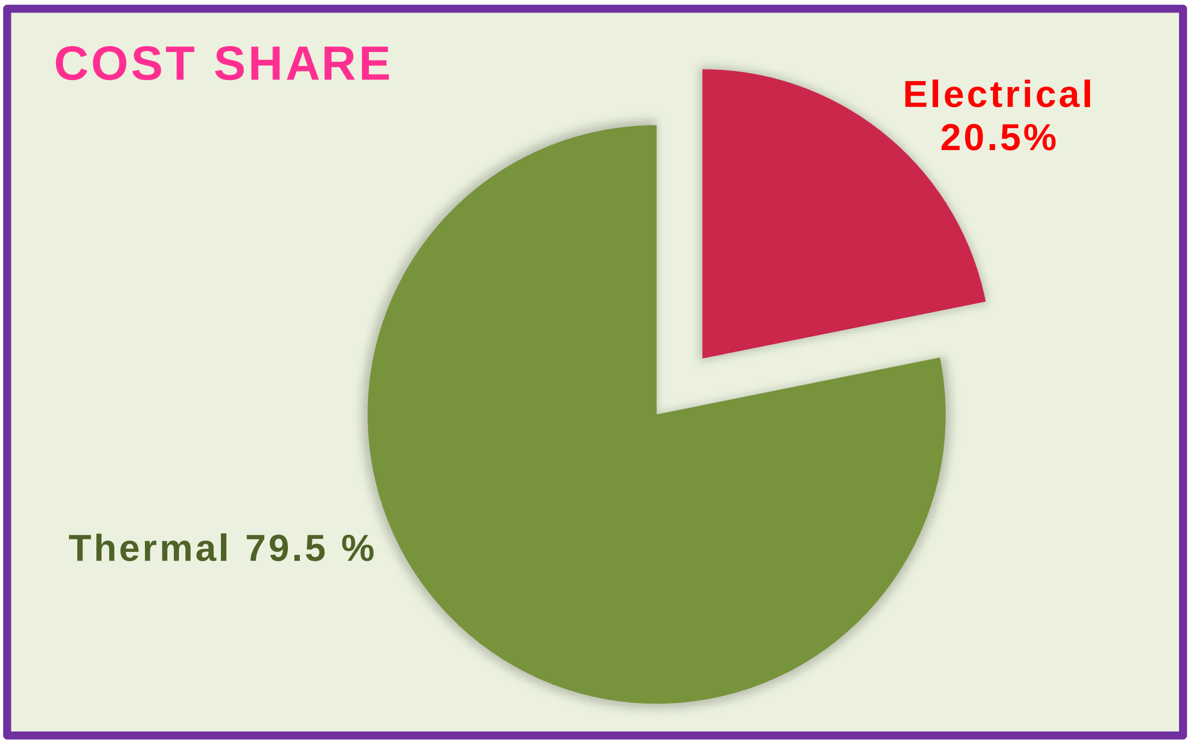


Fig 5.11 : Energy Cost Computed: per kg of Made Tea: 2 - year Avg | CAG

- In conclusion, it can be said - that on an average - ₹ 33.4 is the total energy cost for the production of 1 kg of made tea that comprises both electrical and coall cost.
- The present scope of the study lies in further bringing down the energy cost in the overall cost structure.

5.5 CONSOLIDATION

- The summary of the contents of this chapter is as below :

Specific Energy Consumption

w.r.t Green Leaves	**=**	**0.118 kWh / kg GL**
	=	**0.320 kg coal / kg GL**
w.r.t Made Tea	**=**	**0.581 kWh / kg MT**
	=	**1.577 kg coal / kg MT**
Specific Energy Cost	**=**	**₹ 33.4 / kg Made Tea**

5.6 BENCHMARKING

- The Benchmark values in respect of Specific Electricity and Specific Thermal Energy Consumption are established as

  0.6 kWh / kg MT and 1.02 kg coal / kg MT respectively

  as the present norms by the Tea Board of India.
- As far as Specific Electricity Consumption [SEC] is concerned, the factory is doing well, the value falling closely with that Benchmarked. **[0.605 vs 0.58]**
- However, on the Thermal Energy Front, the Specific Coal Consumption is higher by 55 % which is certainly on the higher side. **[1.58 vs 1.02]**
- Certainly, technical efforts are needed to bring down this to an acceptable value.
- This is to say that when the Specific Coal Consumption is brought close to the benchmark value, the cost savings can be as high as **₹ 7 lakhs / y**

6 ELECTRICAL ENERGY CONSUMPTION – AN ANALYSIS

6.0 INTRODUCTION

- A detailed presentation and analysis is made in this chapter on the electrical energy consumption pattern of motors of various sections, namely, Withering, CTC, Fermentation, Drying, and Sorting.
- The electrical measurements on the motors were logged for a period of **15 - 30** mins to establish a correct and replicable power drawl trend.
- This longer duration power logging had eliminated the possible ups & downs in the power drawl pattern of the motors and ensured the reliability of measurements recorded.
- This exercise has been undertaken as part of the energy conservation action, as it is well known that poorer the motor loading, lower is the operating efficiency and power factor, that eventually leads to higher energy consumption for the given product output.
- It has to be noted that poor loading of motors can result in higher drawl of current, thus reducing the lifetime of motor winding. In other words, the kW loading of motors - also at times - can prove to be a very relevant factor not only from power drawl but also from the lifetime operational longevity point of view.
- Hence, it was decided to record the power loading and energy consumption pattern of motors and thereby look for corrective action as well energy conservation opportunities.
- There are 5 sections identified in the factory and the load study has been conducted on 33 motors belonging to these.
- The outcome is presented in the ensuing sections

6.1 WITHERING SECTION

- The withering section has 4 troughs powered by 8 fans (2 fans per trough).
- The first three troughs are fitted with 3.7 kW fan motors (totally 6 Nos) while the 4th trough is fitted with 2 smaller motors of 2.2 kW power rating each.
- The power measurements recorded & computed on these 8 motors are tabulated below:

Table 6.1 : Motor Loading Details : Withering Section

No	Motor ID		Rated			Measured			% Loading	
			kW	Amps	η %	kW	Amp	PF	kW	Amp
1	Withering Trough Fan Motor	1 A	3.70	8.00	85.0	2.7	4.3	0.88	62.0	53.3
2		1 B	3.70	8.00	85.0	3.0	4.6	0.88	68.2	57.9
3		2 A	3.70	8.00	85.0	2.3	3.6	0.89	52.1	45.0
4		2 B	3.70	8.00	85.0	2.3	3.8	0.84	52.1	47.1
5		3 A	3.70	8.00	85.0	2.2	3.7	0.89	51.3	46.3
6		3 B	3.70	8.00	85.0	2.3	4.1	0.83	53.6	51.3
7		4 A	2.20	5.00	79.0	1.5	2.6	0.84	55.1	52.0
8		4 B	2.20	5.00	79.0	1.5	2.6	0.82	52.7	51.3
Total			**26.6**			**17.8**				

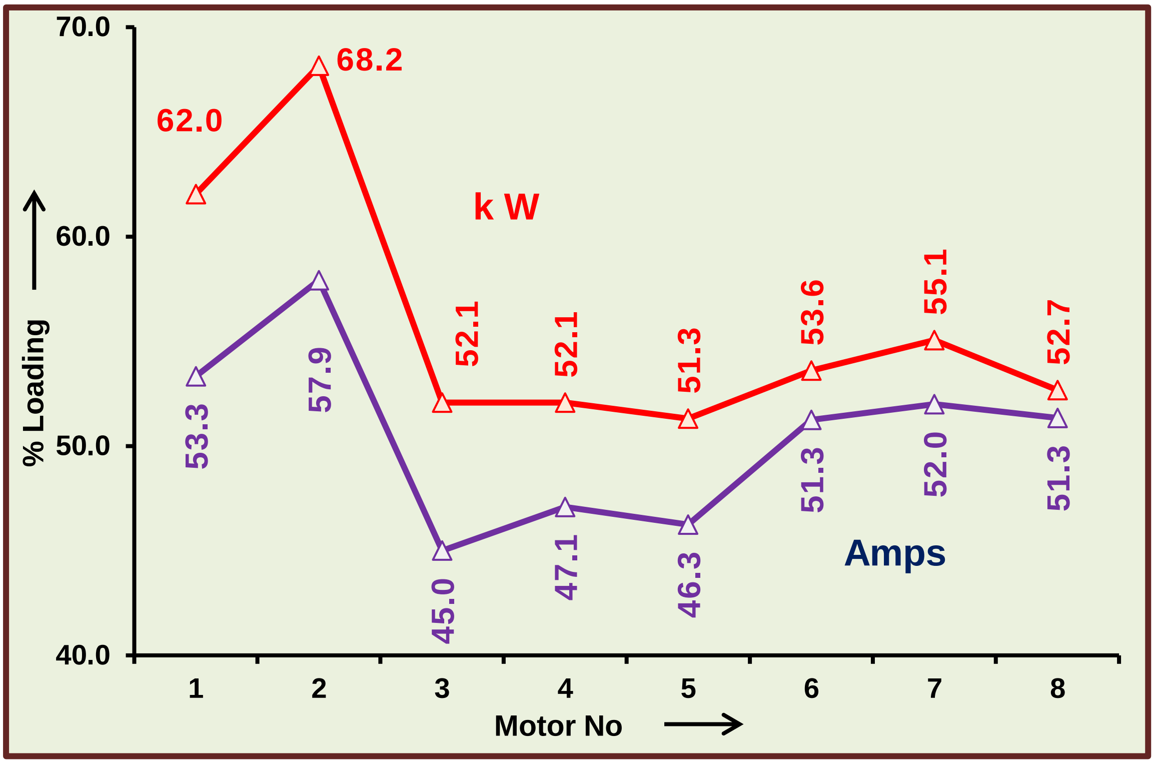


Fig 6.1: Motor Loading Details : Withering Section | CAG

Observations

- All the **8** withering trough fan motors are loaded beyond **50%** on the kW front which indicates the optimal loading of motors. This is quite acceptable.
- The power factors recorded exceeded 0.80 for all the motors which are also optimum ones.

- The ampere loading is below that of kW in all 8 motors, which is not a common occurrence.

Note :

It is to be noted that we were able to capture only the rated power output of the motors from their nameplate / based on discussion with the factory personnel, and not the full load current (F L A) or the motor's designed efficiency. The intrinsic error involved in the considered FLA and / or Efficiency could possibly be one of the reasons for this rare event. This however does not impact our assessment / recommendations in any manner.

- In conclusion, the power measurements recorded and computed show that the motors are of proper rating and loaded optimally.
- We suggest that these motors - when opportunity arises for replacement - shall be replaced with aptly sized Energy Efficient Motors (preferably IE3). This will result in the drawl of lesser and optimum power by the motors.

6.2 CTC SECTION

- The CTC section has one production line, installed with **7** motors with power ratings ranging from **1.5 kW** to **18.5 kW**.
- The loading pattern - established for the 7 motors - is tabulated below:

Table 6.2 : Motor Loading Details : CTC Section

No	Motor ID	Rated			Measured			% Loading	
		kW	Amps	η %	kW	Amps	PF	kW	Amps
1	Rotor Vane	15.0	27.0	90.0	9.7	14.4	0.98	58.2	53.3
2	Cut 1	18.5	35.0	91.2	9.0	13.7	0.97	44.2	39.1
3	Cut 2	15.0	27.6	90.0	10.4	16.0	0.86	63.0	57.8
4	Cut 3	15.0	27.6	90.0	9.0	14.0	0.95	54.2	50.8
5	Cut 4	15.0	27.6	90.0	9.9	14.9	0.76	59.9	54.0
6	Ghoogy	2.2	5.0	79.0	0.6	0.97	0.97	21.5	19.3
7	Blower	1.5	3.8	76.0	0.3	0.60	0.85	15.2	15.8
		82.2			**48.9**				

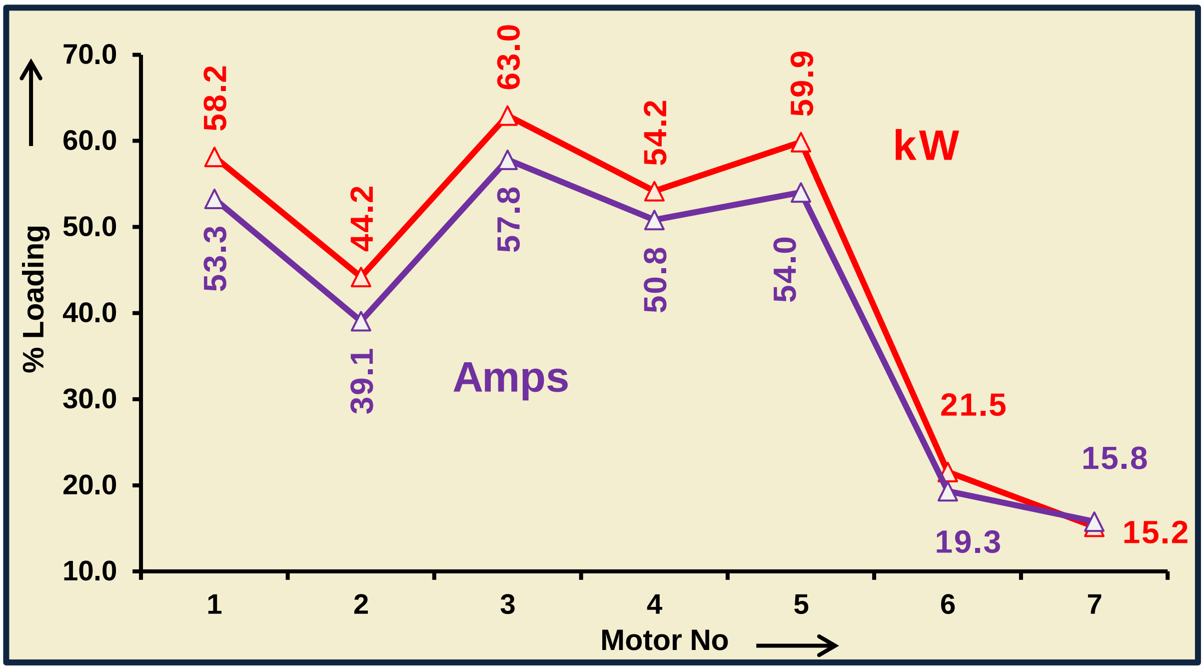


Fig 6.2: Motor Loading Details : CTC Section | CAG

Observations

- In effect, there are **7** motors for which the loading pattern has been established and **3** out of these **6** are loaded below **50%** on the kW front.
- The power factors recorded for all the 6 motors exceeded **0.75**, despite the lowly loaded characteristic of some motors, which is a good sign.
- To conclude, the loading appears to be optimum in the CTC section but for motor of Cut 1 & the lower capacity motors of Ghoogy, and Blower.This needs to be looked into.

6.3 FERMENTATION SECTION

- This section has **8** small humidifier motors whose power ratings are unknown. Hence, the loading pattern of these motors could not be established.
- However, electrical measurements have been recorded and the parameters are tabulated below :

Table 6.3: Motor Loading Details – Fermentation Section

No	Motor ID		Measured		
			kW	Amps	PF
1	Humidifier Motors	1	0.11	0.30	0.63
2		2	0.13	0.33	0.64
3		3	0.28	0.47	0.90
4		4	0.06	0.30	0.33
5	Humidifier Motors	5	0.12	0.30	0.60
6		6	0.10	0.30	0.55

No	Motor ID		Measured		
			kW	Amps	PF
7		7	0.12	0.30	0.60
8		8	0.22	0.43	0.77
Total			1.14		

Observations

- The total load in this section is only a meagre **1.14 kW** as against an anticipated connected load of 3 kW
- The Power Factors recorded belong to the lower spectrum (< 0.50 and predominantly around 0.30) in all the Humidifier Motors, which indicates that the motors are poorly loaded on kW.

6.4 DRIER SECTION

- This section has **4** motors [**2 Nos x 2.2 kW, 1 No x 3.7 kW and 1 No x 11 kW**]
- The loading pattern established for the 4 motors is tabulated below :

Table 6.4 : Motor Loading Details : Drier Section

No	Motor ID	Rated			Measured			% Loading	
		kW	Amps	η %	kW	Amps	P F	kW	Amps
1	FD Fan	2.20	5.00	79.00	0.90	1.80	0.73	32.3	36.0
2	ID Fan	3.70	7.20	83.00	0.97	2.33	0.66	21.7	32.4
3	Tray Conveyor	2.20	5.00	79.00	0.60	1.53	0.57	21.5	30.7
4	Hot Air Fan	11.00	21.3	87.5	9.15	13.7	0.97	72.8	64.2
	Total	**19.1**			**11.61**				

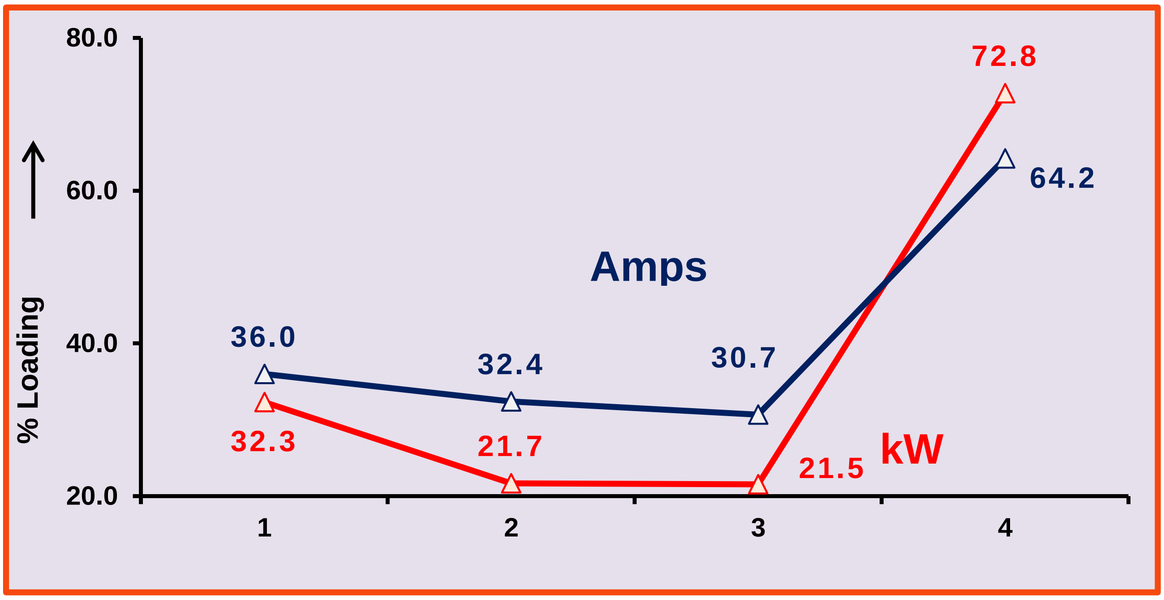


Fig 6.3: Motor Loading Details : Drier Section | CAG

Observations

- The loading of the 1st three motors is significantly low, i.e., less than **40%** on both kW and Ampere front, whereas the Hot Air Fan seems to be loaded optimally.
- The Power Factor recorded is exceedingly high - close to unity - for the Hot Air Fan - in line with its reasonable loading - and much lower for the remaining 3 lowly loaded motors, in sync with their kW loading.
- Lower loading has a detrimental effect on the operational efficiency of the motors, and the impact is more rapid below the 50 % mark of loading. The effect - decrease in motor efficiency - is more pronounced in smaller motors.
- In conclusion, it is informed that the loading of the motors in the Drier section is on the lower gamut. This needs to be taken care of from the viewpoint of enhancing the efficiency level of operation of motors.

6.5 SORTING SECTION

- This section - as expected - has motors of very low power rating.
- There are 6 motors in operation of which 3 motors are of **1.5 kW** power rating, **2** motors are of **0.75 kW** rating and one motor has a design rating of **1.1 kW**.
- The loading pattern has been evaluated for all the 6 motors and shown in Table 6.5

Table 6.5: Motor Loading Details : Sorting Section

No	Motor ID	Rated			Measured			% Loading	
		kW	Amps	η %	kW	Amps	PF	kW	Amps
1	Packing Vibro Motor	1.50	3.40	77.00	0.87	1.67	0.78	44.5	49.0
2	Sorter I/c Conveyor	0.75	1.75	77.00	0.18	0.53	0.50	18.8	30.5
3	Sorter Motor - 1	1.50	3.30	78.50	0.39	0.93	0.63	20.4	28.3
4	Sorter Motor - 2	1.50	3.30	78.50	0.32	0.87	0.57	16.9	26.3
5	Sorter O/g Conveyor	0.75	1.75	77.00	0.18	0.57	0.46	18.0	32.4
6	Penwell M/c Motor	1.10	3.00	78.00	0.41	0.93	0.64	28.9	31.1
	Total	**7.10**			**2.35**				

- The loading experienced on kW of all the **6** motors is below **50%** - predominantly around 20% and less - necessitating the need for considerable improvement [Fig 6.4]

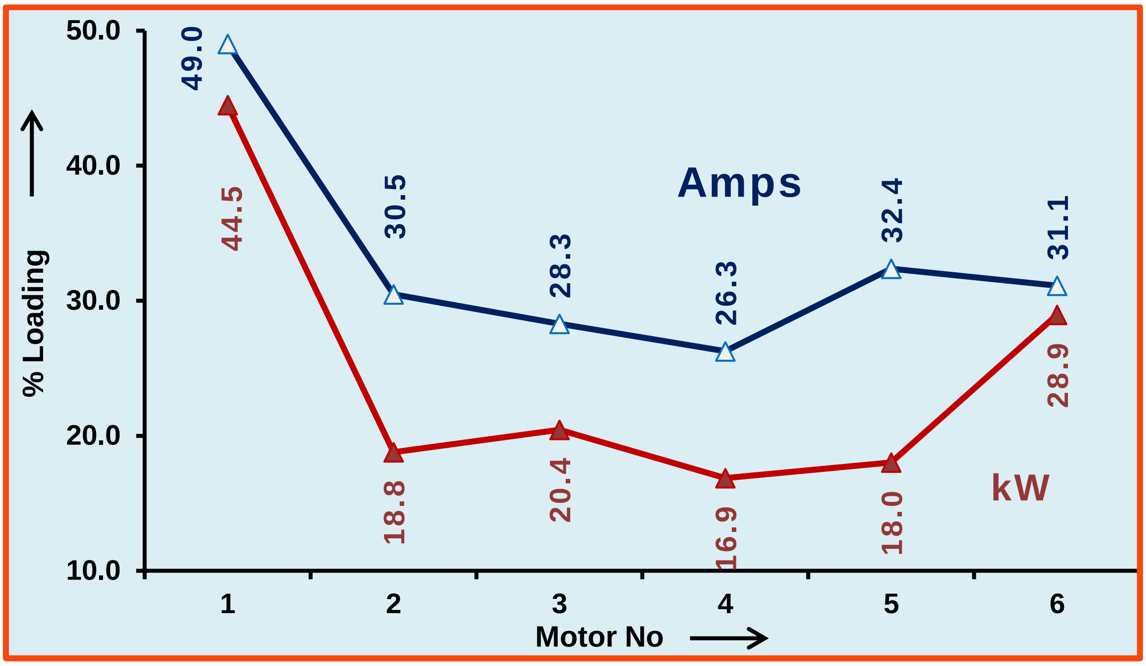


Fig 6.4: Motor Loading Details : Sorting Section | CAG

Observations

- The Power Factors recorded for majority of the motors is low at below 0.65. This is quite understandable from the low kW loading experienced by the motors.
- The unfavourable effects of loading the motors far below the acceptable levels is significantly felt on smaller size motors, as is the case with all motors in this section, compelling the management to opt for the downsizing option as soon as practicable from an energy efficiency perspective.

6.6 SUMMATION

- The power drawl contribution of each section is tabulated in Table 6.6 and figuratively shown in Fig 6.5.

Table 6.6 : kW Loading : Section wise

No	Section	Power Recorded	
		kW	%
1	Withering	17.8	21.7
2	CTC	48.9	59.8
3	Fermentation	1.14	1.4
4	Drier	11.61	14.2
5	Sorting	2.35	2.9
	Total	**81.7**	**100**

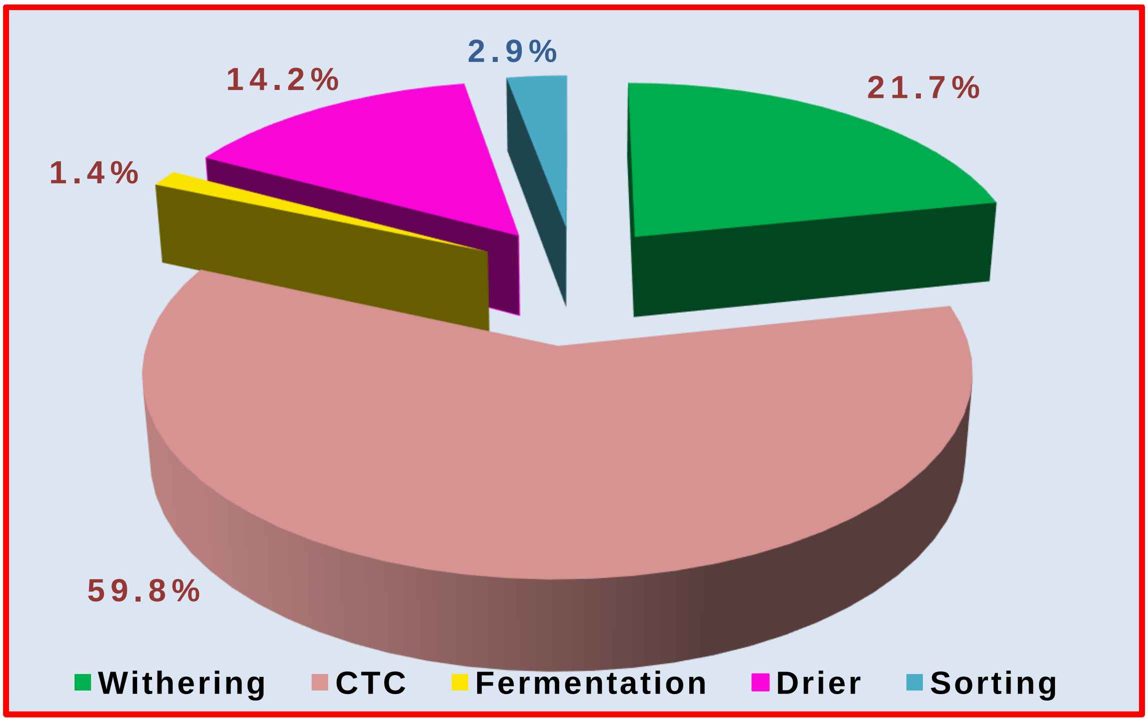


Fig 6.5: kW Loading : Section wise |CAG

- As expected, the highest power drawl is by the CTC section & the lowest is in Fermentation section.
- The power drawl / energy consumption in the CTC section is close to 60 % of the total.
- The fermentation section contributes to only 1.4 % of the total. It is not a Significant Energy Use [S E U] Section as per ISO 50001 -2018 protocol
- The order (from highest to lowest power drawl) is shown in Fig 6.6

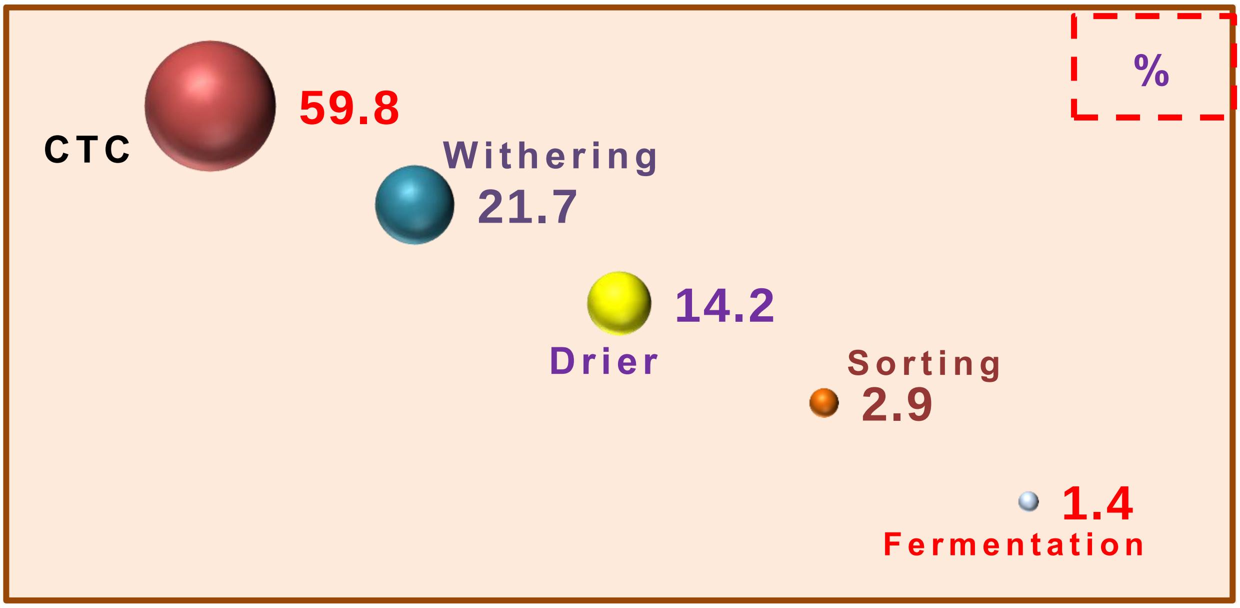


Fig 6.6: kW Loading : % Contribution : Section wise | CAG

- This makes it clear that the focus for energy consumption reduction - through incorporation of Energy Conservation / Efficiency Measures - shall be directed towards the CTC section, followed by the Withering Section, and further in that order to achieve reasonable savings in energy.

NOTE

- Considering the seasonal dependence of this industry, i.e., production being a strong function of the availability / arrival of leaves, it becomes difficult to even make a reasonable assumption for the daily operating hours of all equipment.
- This is precisely the reason why the kWh of the individual sections is not attempted here

7 PERFORMANCE STUDY ON ELECTRICAL UTILITIES

7.0 INTRODUCTION

- A performance study was conducted on the following utilities as this exercise is quite crucial to achieve reduction in energy consumption.
    1. Transformer : 1
    2. Withering Fans : 8
    3. [CTC + Drier] Section Motors : 6 (Belt Slip Analysis)
    4. Drier Section Fans : 2
- The outcome of the performance study is detailed in this chapter.

7.1 TRANSFORMER

- The factory has one transformer of rating 315 kVA installed in its premises. The manufacturer is **Siliguri Electric Works, West Bengal.**
- The loading pattern of the transformer was recorded for a period of 2 hours and this data was used as the basis for computation of its operating efficiency at the time of measurement
- The No Load Loss and Full Load Loss values have been obtained from the name plate of the Transformer.
- The designed details of the transformer are as below:

Table 7.1: Transformer Name Plate Details

No	Parameters	Unit	Values
1	Make	-	Siliguri Electric Works, West Bengal
2	Rating	kVA	315
3	H V Side	V / A	11 000 / 16.53
4	L V Side	V / A	433 / 420
5	No Load Loss	kW	0.465
6	Full Load Loss		2.440
7	Year of Mfg.	-	2013

- Table 7.2 provides the measurements made & the corresponding computed values:

Table 7.2: Transformer Operating Efficiency Prediction

No	Parameter	Unit	TR 1
1	Voltage	V	391
2	Current	Amps	100.3
3	Load	kVA	68.0
4	Power Factor	-	1.00
5	Load	kW	67.7
6	No Load Loss		0.465
7	Full Load Loss		2.440
8	Total Loss		0.58
9	Loading	%	21.6
10	Operating Efficiency		99.1

- The loading pattern of the transformer - based on our logging of its electrical characteristics for 2 hours - is provided hereunder:

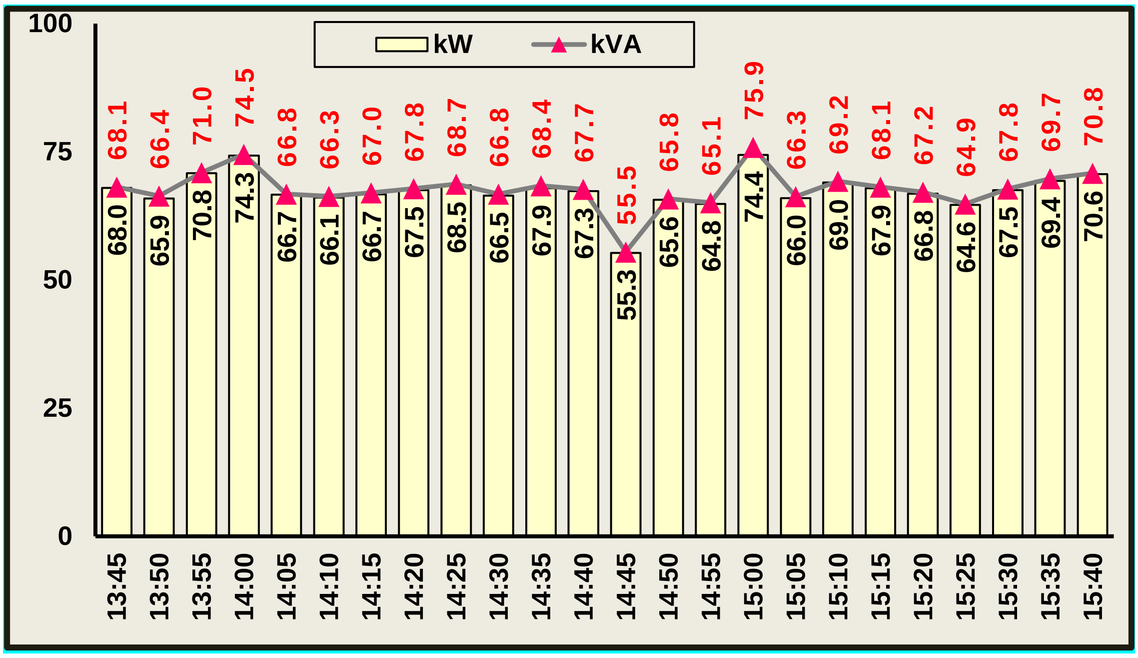


Fig 7.1: Active Power & Apparent Power Trend : Transformer | CAG

- As evident from the plot above, the closeness between the kW and kVA profiles in the Transformer (i.e., the smaller width of the gap between the two trends) is the reflection of the attainment of high power factor, close to unity.
- The total loss in the transformer is estimated as **0.58 kW**
- A loading of **21.6 %** was observed in the transformer.
- The efficiency of the transformer is computed at **99.1%**, and appears quite alright.

7.2 WITHERING FANS

- This section has 8 Withering Fans supplying air in 4 troughs for green leaf withering.
- During the audit, we were able to capture the performance of all the withering fans - with load - by instructing the leaf handling personnel to load even the empty troughs artificially by shifting the leaves in line with our requirement.
- Performance of the fans is evaluated in terms of their Specific Air Flow / Throughput.
- These details are presented in the following Table 7.3

Table 7.3: Withering Fan : Performance Assessment

No	Motor ID		Fan Power kW		Air Delivered	Specific Air Flow
			Rated	Measured	cfm	cfm / kW
1	Withering Trough Fan	1 A	3.70	2.7	27 462	10 171
2		1 B	3.70	3.0	23 908	8 059
3		2 A	3.70	2.3	28 061	12 380
4		2 B	3.70	2.3	27 537	12 149
5		3 A	3.70	2.2	28 585	12 799
6		3 B	3.70	2.3	27 275	11 689
7		4 A	2.20	1.5	18 962	12 367
8		4 B	2.20	1.5	19 109	13 029

- The cfm delivered by Fans 1 to 6 ranges from 23 000 to 30 000 (majorly in the range of 27 000 to 30 000) which is quite adequate for the fan motor rating of **3.7 kW**
- The fans in Trough 4 (Fans 7 & 8) deliver around 19 000 cfm each, which is satisfactory considering that they are coupled to **2.2 kW** motors only

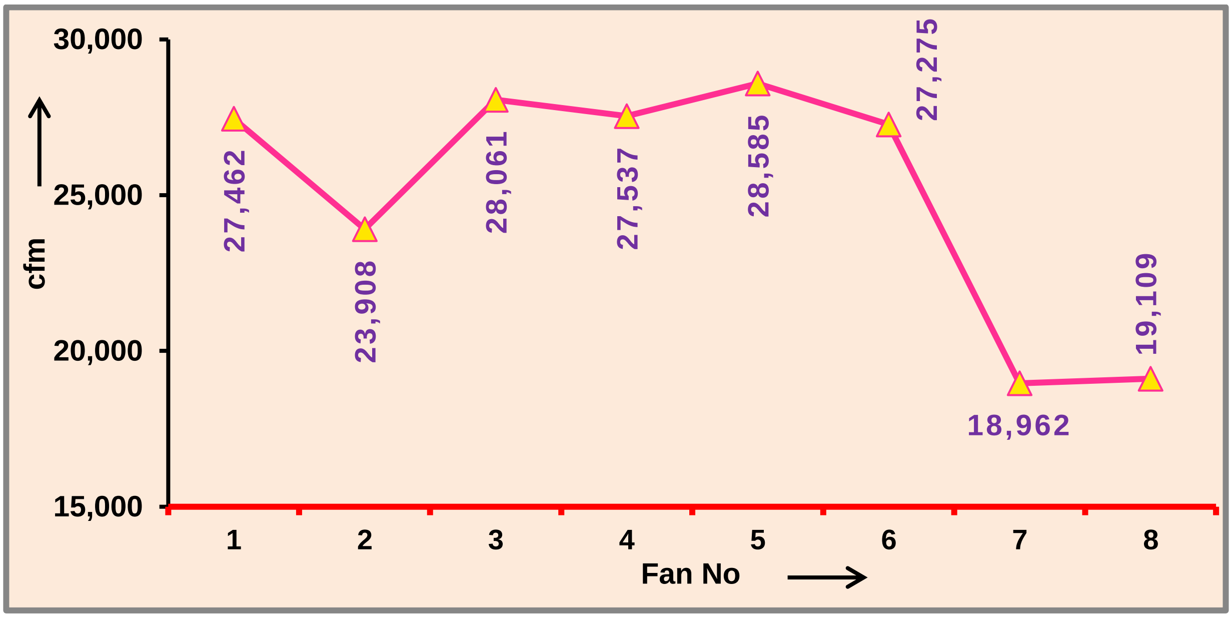


Fig 7.2: Air Flow Rate - Withering Trough Fans | CAG

- In addition to the plotting of cfm for each fan, one of the Key Performance Indicators (KPIs) that helped in the establishment of fan performance, viz., specific air flow has been computed and drawn below :

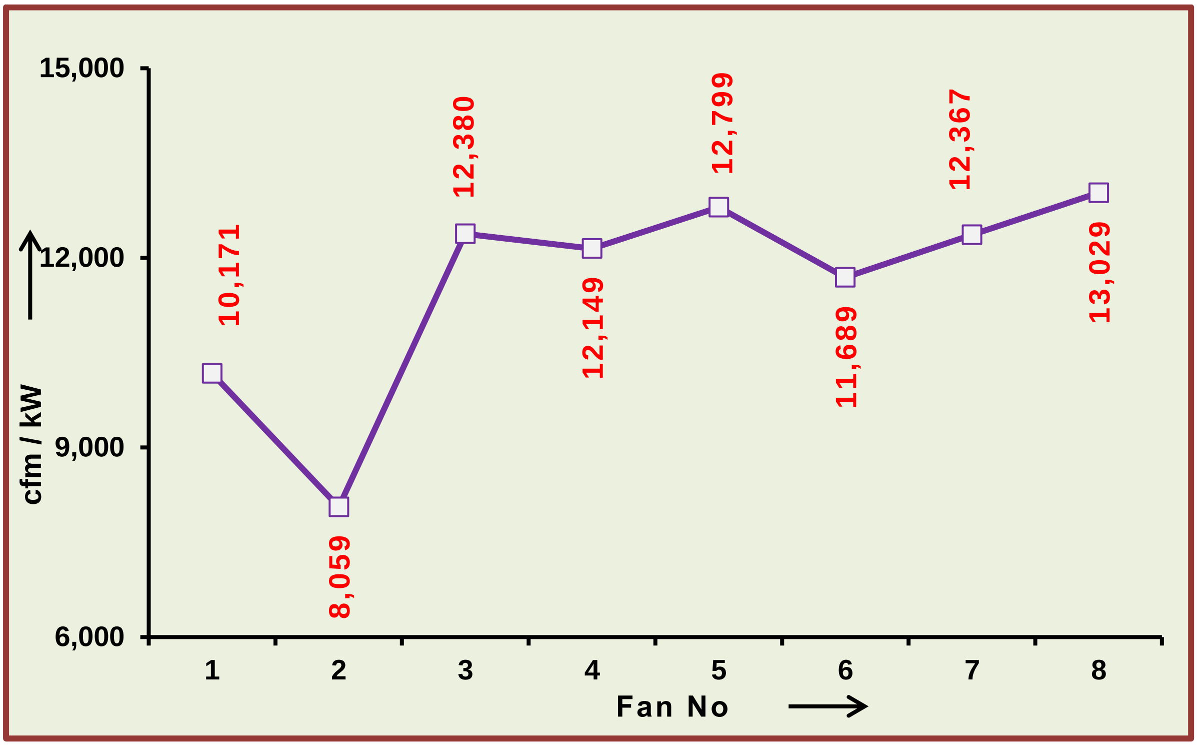


Fig 7.3 : Specific Air Flow : Withering Trough Fans | CAG

- The further breakup is as below:

Table 7.4: Withering Fan : Performance Assessment : Break Up

No	Specific Air Flow Rate cfm / kW	No of Fans
1	8 000 - 12 000	3
2	> 12 000	5

- It appears that the performance of 2 fans, namely, Fan Nos. 1 & 2 is a few notches below the mark when compared to the specific air flow rates of the remaining fans.
- To be more specific, the fans belonging to the Withering Troughs 2 to 4 (6 fans) have outperformed the fans in Trough 1 in terms of their specific output
- It is therefore advised to preferentially load the troughs 2, 3 and 4 more considering that this would improve the quality of withering, hence the tea produced. Selective loading is bound to bring in some savings in electrical energy consumption of the withering troughs as well, though not significant.

7.3 BELT SLIP ANALYSIS – [CTC + DRIER] MOTORS

- The factory processes withered leaves through its CTC line that hosts 5 major motors, of which one is coupled to the Rotor Vane / Shredder, and the rest take care of the cutting operation in 4 stages viz. Cut 1 to 4.
- Wet Dhool is conveyed through the Drier by means of a moving Tray which is actuated by the Tray Conveyor Motor of the Drier Section.
- V belts are utilized for power transmission from the drive motor to the driven element.
- A comprehensive assessment was carried out to determine the slippage level at which the belts operate, which involved measurement of the following parameters :
  1) Pulley diameter for the motor and the machine
  2) Centre - to - Centre distance between the pulleys
  3) Speed in rpm at the motor and machine end
  4) The number of grooves in the pulley, the corresponding No. of belts & belt ID.
- A tachometer was used to measure the speed of the driving and driven element
- The information collected / measured are presented below:

Table 7.5: Belt Slippage : Established thro' Speed Measurements

No	Name	Pulley Dia. mm		Measured rpm		Ideal M/c Speed rpm	% Slip	Belt - Pulley Specification	
		Motor	M / c	Motor	M / c			Groove	Belt
1	R V	120	300	994.2	386.9	397.7	2.7	5	5
2	Cut 1	150	340	1497.6	602.1	660.7	8.9	4	4
3	Cut 2	150	340	1484.3	604.6	654.8	7.7	4	4
4	Cut 3	150	340	1482.8	591.6	654.2	9.6	4	3
5	Cut 4	150	340	1488.1	605.6	656.5	7.8	4	4
6	Tray Conveyor	160	180	982.4	793.2	873.2	9.2	2	2

- The following are the notable observations made:
  1) One groove in the pulley corresponding to Cut 3 motor was running empty (i.e., it did not carry a belt), and the motor exhibited considerable belt slippage. It is advised to stay in line with the designed installation procedure always.
  2) The measured slip with all the other motors as well (other than Rotor Vane), despite staying in line with the designed operational characteristic - in terms of the number of grooves and belts - was comparable to that of the Cut 3 motor.

3) These 5 motors (Cut 1 to Cut 4 & Tray Conveyor Motor) exhibiting sizeable slippage have been chosen as target candidates for performance improvement in terms of enhancing the transmission efficiency, to optimize motor power drawl.

4) The slippage can be considerably reduced by using cogged V belt drives for power transmission

- Cogged V - belts score over standard V - belts by at least 2 % points by design in power transmission. Considering the age of the V-belts installed on the pulleys, the anticipated level of improvement in efficiency is quite significant.
- This is discussed in detail in the "Energy Conservation Measures" section of this report, with a comprehensive cost to benefit analysis.(Chapter 10)

7.4 DRIER SECTION FANS

- The following are the three fans that are connected to the Drier Section:
  1) Hot Air Fan (Induced Draft). : 11 kW
  2) Supply Air Fan / F D Fan (Forced Draft) : 2.2 kW
  3) Exhaust Fan / I D Fan (Induced Draft) : 3.7 kW

Fig 7.4 : Drier Section Fans | CAG

- Coal is utilized as the source of thermal energy in the furnace. The FD Fan supplies the air required for combustion into the furnace and the ID Fan drives the exhaustion of the combustion gases through the stack / chimney.

- The hot flue gases transfer heat - through the heat exchanger walls - to the air that is pulled into the system by the Hot Air Fan.
- This hot air eventually comes in contact with wet dhool to evaporate the required amount of moisture from it, in order that it becomes dry.
- A performance study was conducted on the Hot Air Fan and the F D Fan through :
  a) measurement of flow area and air velocity to compute the volume flow rate of air handled by the fans
  b) measurement of the power drawn by the respective motors to compute the specific air flow / throughput of the individual fans.
- The details regarding fan performance are tabulated below:

Table 7.6 : Drier Section Fans : Specific Air Flow Assessment

No	Motor ID	Fan Power kW		Air Flow Rate	Specific Air Flow
		Rated	Measured	cfm	cfm / kW
1	Hot Air Fan	11.0	9.15	14 806	1 618
2	F D Fan	2.2	0.90	1 647	1 830

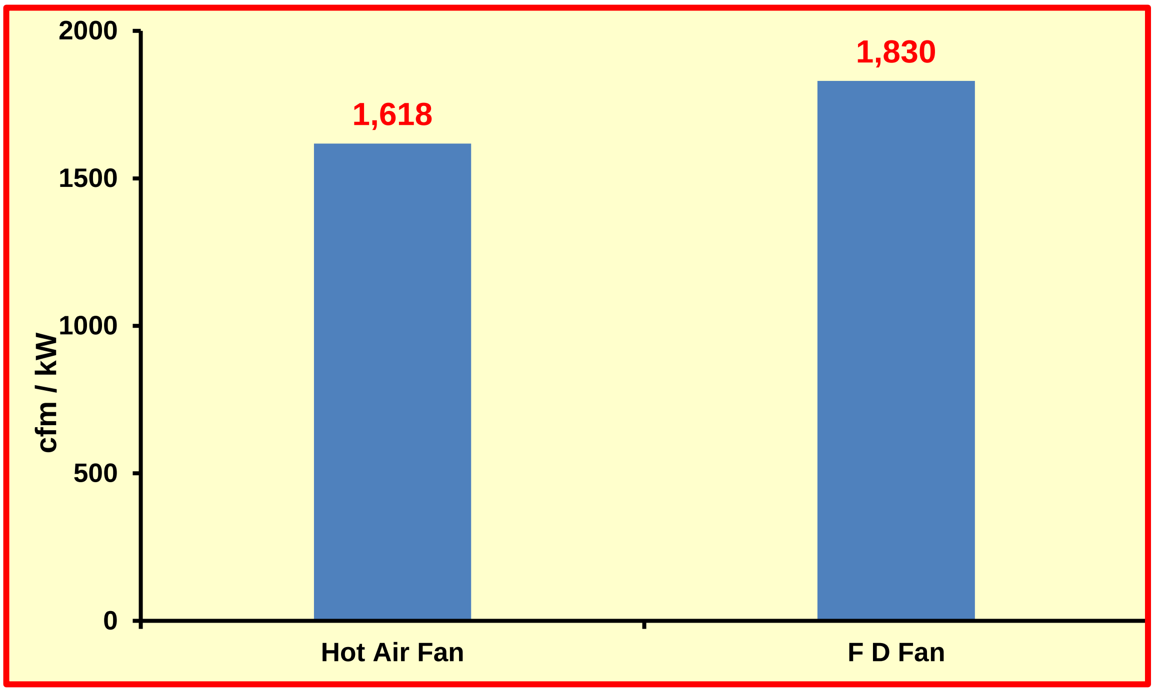


Fig 7.5 : Specific Air Flow Rates Established : Drier Section Fans | CAG

- The specific air flow computed for the Hot Air Fan and the FD Fan needs to be compared against the design / name plate data of the respective fans

- We were unable to compare the actual performance of the fans against their designed performance metrics due to the non - availability of rated parameters.
- Nevertheless, it is felt that these 2 fans may be performing sub - optimally going by the data base collected.
- The I D fan also needs fine tuning as we felt

7.5 SUMMATION

- The loading on the transformer at 21.6 % is quite low although it does not seem to have affected the performance of the transformer much. The transformer seems to have been oversized at the time of procurement.
- The performance of Withering Trough Fans is acceptable in terms of the air flow delivered as against the power drawn by these fan motors.
- As far as CTC motors drive / driven mechanism are concerned, enormous slippage has been encountered in all the motors (exception is Rotor Vane Motor) and that needs to be set right at the earliest.
- The fans of the Drier section may be performing sub optimally and a detailed performance study would reveal the truth.
- Therefore, a detailed technical study is recommended for the Drier.

8 PERFORMANCE STUDY ON THE DRIER

8.0 INTRODUCTION

- In this section, an attempt is made to establish the thermal efficiency of the Drier System comprising Furnace and the Drier, based on experimental data, viz., Coal Consumption, Wet Dhool Input and Drier Mouth Tea (DMT) output, cumulated from the respective individual load weighments on the 15th of Sep 2024.
- The moisture content of DMT and Wet Dhool was affirmed through lab measurements at **3 %** and **71.72 %** respectively and computations have been carried out using these figures.
- A sample of the coal fired was also given for lab testing, and its Calorific Value established at **6 323 kcal / kg** (**ADB** - Air Dried Basis) is used for further analysis.
- We have also tried to evaluate the overall thermal efficiency of the Drier System based on historic data to see how it compares with the experimental results

8.1 PERFORMANCE ASSESSMENT

8.1.1 Historic Data Basis

- The coal consumption for the period Sep '23 - Aug '24 is presented in Fig 8.1.
- The aggregated coal consumption has been estimated as **1 56 620 kg** for this period

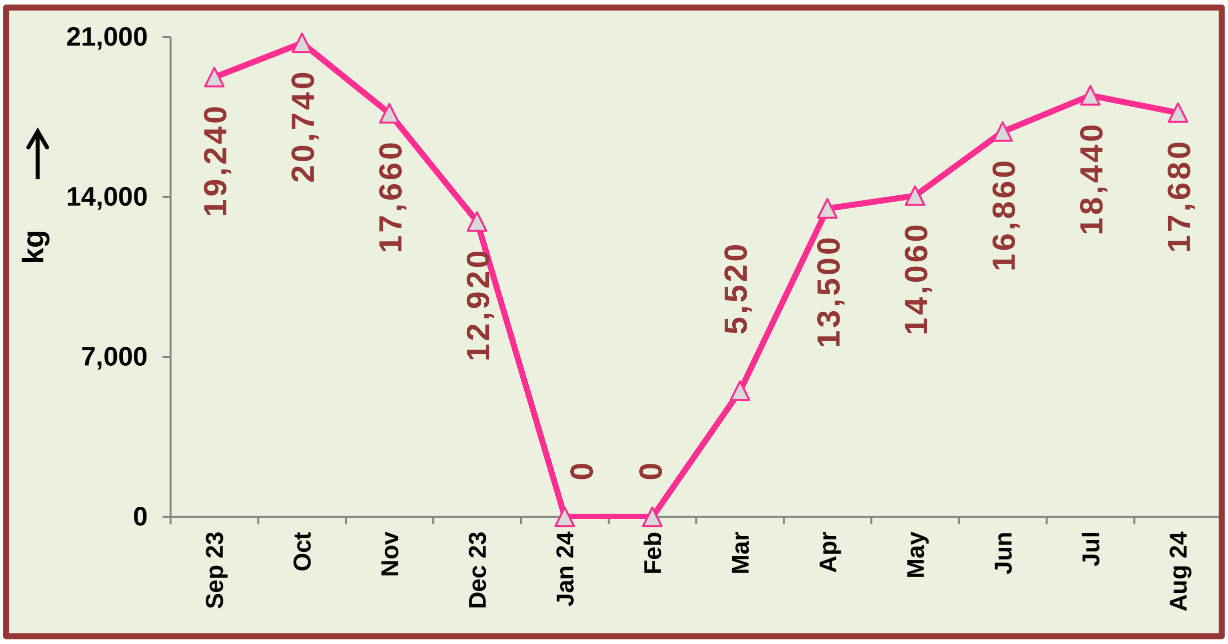


Fig 8.1: Coal Consumption : Month wise (Sep '23 – Aug '24) | CAG

- The monthly quantity of Drier Mouth Tea produced for the same period is given below to see if it correlates with the Coal consumption pattern.
- The Drier Mouth Tea Output for the period Sep 23 to Aug 24 is **99 214 kg**

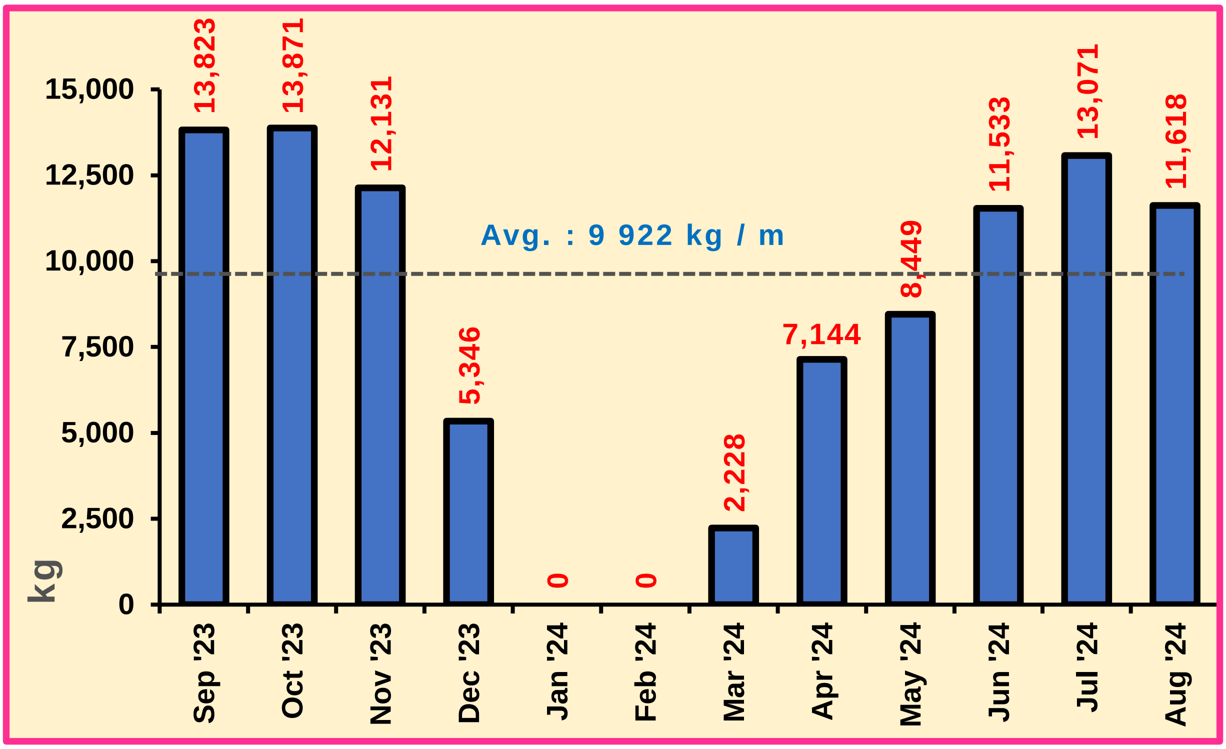


Fig 8.2: Drier Mouth Tea Output – Month wise (Sep '23 – Aug '24) | CAG

- The fuel consumption and DMT trends are majorly in sync with one another as expected.
- Now, taking into consideration the annual DMT output, the theoretical amount of heat required to evaporate the moisture contained in Wet Dhool (**71.72%**) to the level required in Dry Dhool at the Drier's Mouth (**3%**) is established.
- As a first step, the quantity of moisture evaporated is determined, which is as below.

Table 8.1: Annualised Moisture Evaporation in the Drier (Sep 23 - Aug 24)

No	Description	kg / y			%
		Quantity	Moisture	Solids (Tea)	Moisture
1	Wet Dhool	3 40 304	2 44 066	96 238	71.72
2	Drier Mouth Tea	99 214	2 976	96 238	3.0
	Moisture Evaporated		2 41 090		

- The annualised quantity of moisture evaporated in the Drier in the time period Sep '23 to Aug '24 has been computed at **2 41 090 kg**.

- The theoretical amount of heat required to evaporate this amount of moisture would be **147 million kcal** considering the heat required for evaporation of water in the wet dhool at room temperature as 610 kcal / kg.
- The quantity of coal utilized during this period is **1 56 620 kg**.
- The thermal energy input - from Coal - utilized for the process of drying is quantified as **990.3 million kcal** considering the Gross Calorific Value (**GCV**) of Coal as **6323 kcal/kg.**
- The above assessment reveals that the Drier system operates at a thermal efficiency of **15 %**.
- The results are summarized hereunder:

Moisture Removal kg	Theoretical Heat Requirement	Fuel Energy Input	Overall Thermal Efficiency
	Million kcal		
2 41 090	**210.1**	**990.3**	**15.0 %**

8.1.2 Experimental Data Basis

a) Coal Fired

- The start time for the loading of coal into the hopper - considering a base / datum level in the hopper - was fixed as **9:33 am** on the day of experiment and every load of coal that was added into the hopper then onwards was taken into account by measuring it using a weighing scale before loading.
- The end time corresponding to reaching the same datum level - as at the beginning of the experiment - was **6:35 pm**, and the aggregated coal consumption in this timeframe was computed as **1 316.8 kg** in a span of **9 hrs and 02 min**.
- Thus the coal firing rate was computed as **145.8 kg / h**.

b) Wet Dhool

- Similarly, the quantity of Wet Dhool loaded onto the Drier for moisture removal from **9:50 am** until **6:30 pm** was noted through the weighment of each and every bucket load before being dumped onto the machine for further processing.
- The total quantity of Wet Dhool added in this period of **8 hrs and 40 min** was **4 051.2 kg**, which would fix the Wet Dhool loading rate at **467.5 kg / h**.

c) Drier Mouth Tea

- The Drier Mouth Tea output from the Drier was assimilated and weighed before transferring it to the sorting section.
- The start time considered here is **9:45 am**, and the last bit of Wet Dhool added to the Drier came out as processed / dried tea at **7:12 pm**.
- The Drier Mouth Tea Output for the timeframe - **9 hrs and 27 min** - considered is **1 193.5 kg**, which establishes DMT production rate at **126.3 kg / h**.

d) Thermal Efficiency

- Based on the experimental data collected, the overall thermal efficiency of the Drier system has been predicted and the methodology adopted is described below :
  - **a.** Quantity of Wet Dhool Fed = 467.5 kg / h
  - **b.** Quantity of Dry Dhool collected at the Drier Mouth. = 126.3 kg / h
  - **c.** Hence, quantity of moisture evaporated = [467.5 – 126.3] = 341.2 kg / h
  - **d.** Heat Required for drying =

    [(126.3 x 0.97 x 0.5 x 50) + (341.2 x 610) + (126.3 x 0.03 x 1 x 50)] = 2 11 385 kcal / h
  - **e.** Coal firing Rate = 145. 8 kg / h
  - **f.** Coal G C V = 6 323 kcal / kg
  - **g.** Heat supplied by coal burning = (145.8 x 6323) = 9 21 894 kcal / h
  - **h.** Hence, Overall Thermal Efficiency of the Drier = (2 11 385 / 9 21 894) = 23 %
- The overall thermal efficiency of the drier system is established as **23 %**.

e) Heat Losses

- The thermal losses that formed around **77 %** of the heat input that comprises :
  1) Heat Lost in the Exhaust / Flue Gas,
  2) Heat Lost due to Incomplete Combustion / CO formation,
  3) Heat Loss due to Moisture and H_2 in the fuel,
  4) Heat lost in ash,
  5) Heat transfer efficiency across the heat exchanger tubes (flue gas to air),
  6) Heat in the Drier Mouth Tea,
  7) Surface Radiation and Convection heat losses,
  8) Heat Loss from the Drier Surface,
  9) Possible Hot Flue Gas Leakage to the atmosphere
  10) Other minor / immeasurable / unaccounted losses

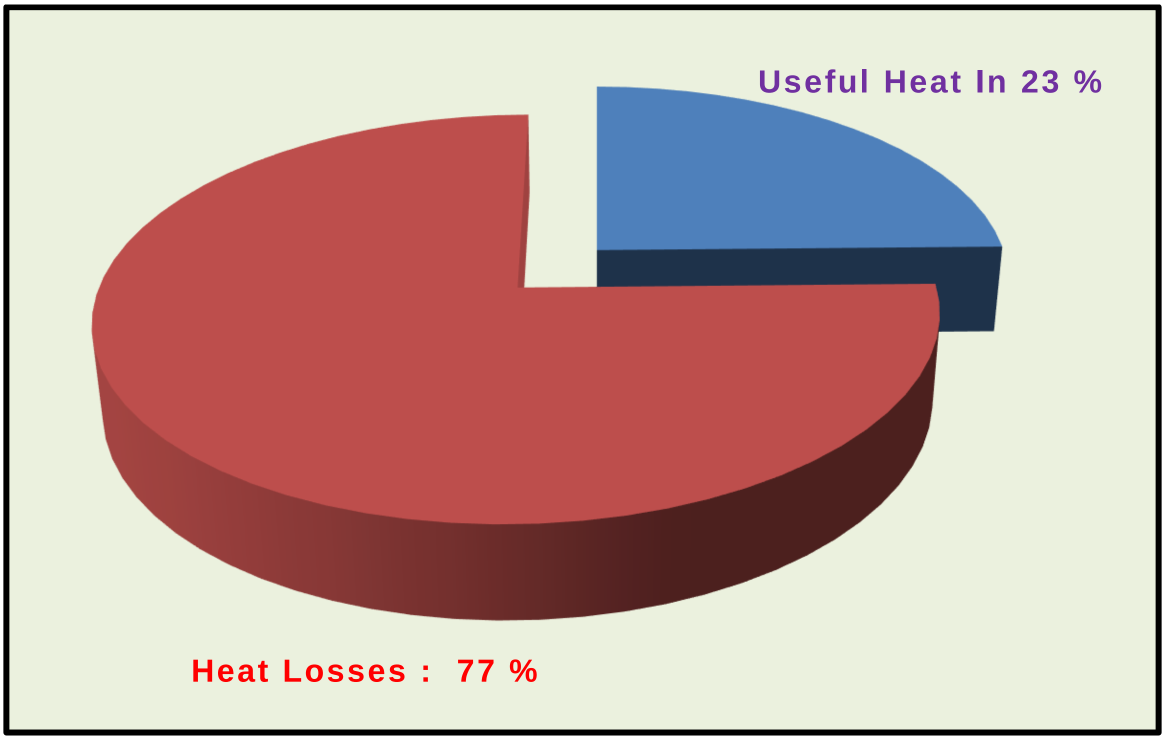


Fig 8.3: Overall Thermal Performance of the Drier | CAG

8.2 SUMMATION

- The overall thermal efficiency of the drier system established - through experiment during the time of audit - at **23 %** which is the typical value obtained in the coal fired furnace - cum - Drying system.
- The efficiency computed based on the historic data was only **15 %.**
- They may not be representative taking into account the size of historic data considered, which is 1 year, and would probably involve a significant error quotient.

It is pointed out here that the Specific Coal Consumption established through the experimental trial was **1.15 kg coal / kg DMT** as against the annual value of **1.58 kg coal / kg DMT**. This variation is too high to account.

Hence, it is recommended to the management to have a regular checking on coal consumption. We feel that the SFC of 1.58 kg coal / kg DMT is unacceptable and 1.15 kg coal / kg DMT is the right and acceptable one considering the GCV of coal which is quite high at 6323 kcal / kg.

- The thermal energy [Coal] cost works out to **₹ 26.5 / kg** of Made Tea, which constitutes about **79.5%** of the total energy cost of tea production. This is in comparison to the electricity cost share of only **20.5 %**

- The higher share of thermal energy cost is attributed to the high weighted average cost of Meghalaya coal procured by the factory management at about **₹ 16 800 / ton**.
- Efforts shall be taken to bring down the cost incurred towards satisfying the thermal energy requirements of the factory, which is discussed elaborately in the “Cost Conservation Proposals” section of this report.

9

COST CONSERVATION PROPOSALS

C C P 1	SWITCHING OVER TO CHIPPED WOOD FROM COAL AS THE SOURCE OF THERMAL ENERGY FOR COMBUSTION IN THE FURNACE TO CUT DOWN ON THE COST OF COAL INCURRED TOWARDS TEA DRYING OPERATION

Cost Savings ₹/ y	Investment ₹	Payback Period Months
6 74 760	3 00 000	6

OBSERVATIONS

- The factory utilizes Meghalaya Coal as the source of thermal energy for combustion in the Furnace. This coal is characterised by high sulphur and high energy content.
- This coal was analysed for its energy content and found to have **6323 kcal / kg** as its Gross Calorific Value**.** This is quite a high value.

Fig 9.1 : Coal Firing inside the Furnace | CAG

- Table 9.1 provides the details regarding the coal consumption and the corresponding cost incurred in procurement for the 2 year period (Sep ’22 - Aug ’24)

Table 9.1: Coal Consumption & Cost Incurred

No	Period	Coal		Unit Cost ₹ / kg
		Consumption kg	Cost ₹	
1	Sep '22 – Aug '23	1 24 530	22 81 380	18.3
2	Sep '23 – Aug '24	1 56 820	24 46 958	15.6
Total		2 81 150	47 28 338	16.8

- The aggregated coal consumption is estimated as **2 81 150 kg** and the factory had paid **₹ 47 28 338** towards the usage of coal during this period of Sep '22 - Aug '24.
- The average coal cost works out to **₹ 16.8 / kg** and **₹ 26.6 / kg Made Tea**, which constitutes about **79.5 %** of the total energy cost of tea production
- It is felt that the cost spent on fuel can be brought down considerably by switching over to cheaper fuels like Wood Chips discarding / substituting the use of coal.

RECOMMENDATION

1) It is advised to the factory management to opt for fuel switch option, i.e. to utilise cheaper Wood Chips in place of the more expensive Coal to meet the thermal energy demand of Drier operation.
2) This recommendation takes into consideration the ample availability of wood in the Sabroom area that ensure the continued availability of wood catering to the factory's requirement. Since, the wood shall be locally procured, the cost of transportation will be minimum. Thus, it will be possible to procure firewood at a much cheaper rate - compared to Coal - at the factory premises.
3) It is informed that the traveling grate fuel firing mechanism presently in use for coal burning can be adopted for wood chip burning also with equal ease. Thus, the usage of wood chips either replacing coal completely or partially at the beginning is both technically and economically viable and the present burning mechanism can take this and need no modifications. On top of all, the wood burning is a more ecofriendly option compared to coal burning as the wood burning is carbon neutral. Hence, considering all these advantages of wood burning, it is recommended that the management may take a proactive view of implementation of this suggestion.

4) Although the quantity of firewood required to provide the thermal energy equivalent of coal would be about twice that of coal - considering the heating value of the two fuels - the fuel switch option still proves to be the go to option based on the economics, which is as below :

ECONOMICS

- Calorific value of Coal = 6 323 kcal / kg
- Calorific value of Wood = 3 200 kcal / kg
- Therefore, 1 kg of Coal is equivalent to 2 kg of Wood on energy front.
- Coal Consumption = 1 40 575 kg / y
- Hence, expected wood consumption = (1 40 575 x 2) = 2 81 150 kg / y
- Landed cost Coal = ₹ 16.80 / kg
- Landed cost Wood (likely) = ₹ 6.0 / kg
- Cost Savings Possible = [(1 40 575 x 16.8) - (2 81 150 x 6.00)] = **₹ 6 74 760 / y**
- Investment Required = **₹ 3 00 000**
- Simple Payback Period = **6 months**

C C P 2	RATIONALIZATION [REDUCTION] OF CONTRACT DEMAND OF THE FACTORY HT SERVICE CONNECTION WITH A VIEW TO OPTIMISE THE DEMAND CHARGES PAYABLE TO TSECL

Cost Savings ₹/ y	Investment ₹	Payback Period Months
57 456	Nil	Immediate

OBSERVATIONS

- The factory has availed 1 HT SC for powering the operations of various utilities involved in the manufacturing of tea.
- The demand contracted is 145.6 kW and ₹ 105 / kW / month is being paid as the fixed charges for availing this CD.
- It was noticed that the electricity bill of FEDCO has no mention of MD reached during the operation and as a result the MD reached is unknown to the user. That is , the MD reached is neither informed to the user nor displayed in the electricity bill.
- It was realized that the electricity bill does not furnish details regarding Maximum Demand (MD) attained in kW on a monthly basis. This makes it difficult to analyze the MD drawn pattern, to justify the optimality of Contract Demand agreed upon with FEDCO.
- Hence, an attempt was made to capture the load pattern during this energy audit activity, which could throw light on matters related to energy drawl as well as the peak power demanded during the factory operation period.
- Fig 9.2 informs the values and variation observed in the maximum demand in kW recorded during the peak operating 2 hr period [13 45 hrs. to 15 4 5 hrs.]
- It is observed that the maximum demand recorded is lesser than the contracted demand by a
- The Maximum Demand [M D] reached was **74.4 kW** as seen in Fig 9.2 which considers a time interval of 5 min for visual clarity, whereas **87.7 kW** was the actual MD recorded based on the 5 sec time interval set on the instrument.

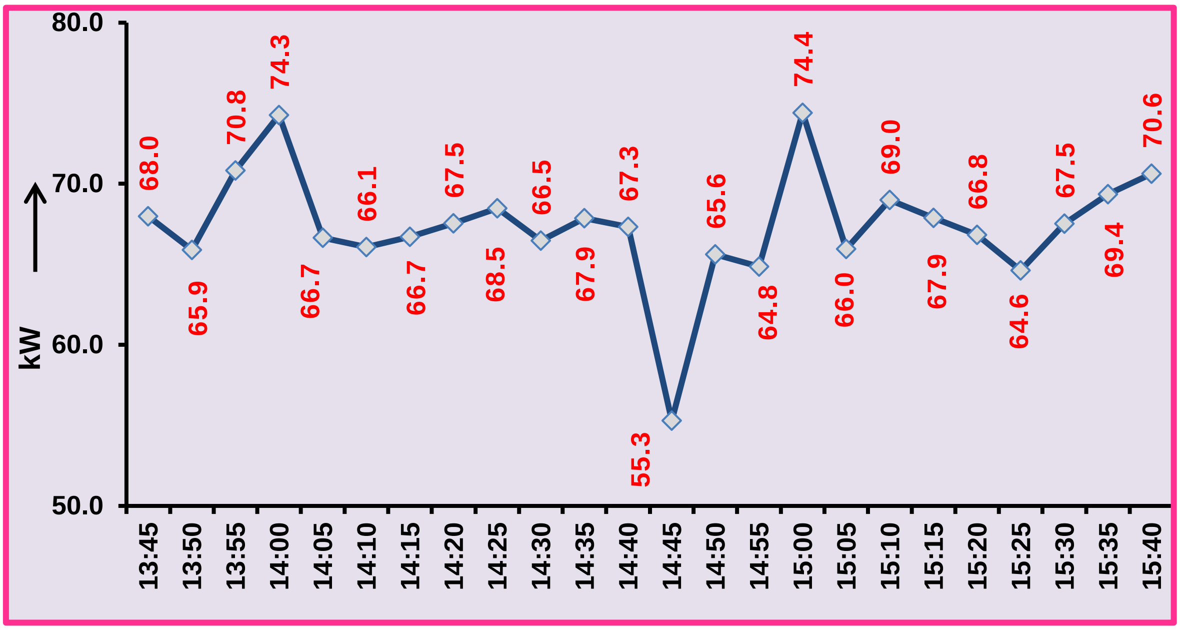


Fig 9.2 : Loading Pattern Recorded : 2 h of Operating Period | CAG

COMMENT

- In any case, it is anticipated that the maximum load on this transformer shall not exceed **100 kW** considering the possibility of simultaneous operation of some loads - that were not in operation at the time of recording - adding to the recorded maximum demand viz. withering troughs motors.
- This gives us a bandwidth of at least **45.6 kW** that can be trimmed on the HT SC
- The lowest value recorded was 55.3 kW at 2 45 pm.

RECOMMENDATION

- We therefore recommend trimming down the Contracted Demand of the **HT** Service Connection from **145.6 kW to 100 kW**.
- It is also suggested to fix a Maximum Demand [M D] Controller in order to avoid the chances of exceeding the Contracted Demand

ECONOMICS

- Contracted Demand planned to clip = (145.6 – 100) = 45.6 kW
- Demand Charges levied for CD = ₹ 105 / kW / month
- Cost Savings thro' trimming C D = (45.6 kW x ₹ 105 / kW / m x 12 m / y) = **₹ 57456 / y**
- Investment: = **Nil**
- Simple Payback Period = **Immediate**

C C P 3	INSTALLATION AND COMMISSIONING OF 40 kW_P ON - GRID SOLAR ROOF TOP P V POWER PLANT ADOPTING "RESCO" MODEL TOWARDS ATTAINING SELF SUFFICIENCY IN ELECTRICITY REQUIREMENT IN A SUSTAINED FASHION AND SIMULTANEOUSLY GOING GREEN

Cost Savings ₹ / y	Investment ₹	Payback Period Months
1 73 250	Nil	Immediate

OBSERVATION

- Tea manufacturing is an energy intensive process using both electrical and thermal energy in substantial quantities.
- As far as this factory is concerned, the Specific Electrical Energy Consumption is **0.607 kWh / kg Made Tea** for the year '23 - '24 which is reasonable enough.
- Currently 100 % of its electricity requirement is sourced from the DISCOM through one H T Service Connection.
- The electricity consumption is **60 282 kWh / y (= 240 kWh / day)** and the energy bill is close to **₹ 7 lakhs / y.**
- The average cost of electricity is estimated as **₹ 11.6 / kWh** [inclusive of all charges] and **₹ 7.73 / kWh** [only energy alone]
- During power outage period, DG sets are used which is a rare occurrence

COMMENT

- It is suggested that a On - Grid rooftop Solar Photovoltaic (S P V) power plant of right capacity shall be installed to meet the energy demand of the tea factory. This is a Green Power Generation initiative and supported and subsidized by both Central & State Govts.
- Since this factory is located remotely, Stand - alone systems are not recommended for a variety of reasons and one among them is the potential delays in fixing faults etc.,

RECOMMENDATION

- Installation of a 40 kW_p On - Grid Solar P V power plant on the rooftop of the tea factory or in any suitable location near the factory adopting appropriate RESCO

(Renewable Energy Service Companies) model is recommended. The rooftop area required for the installation is 1000 sq ft and the factory has this area.

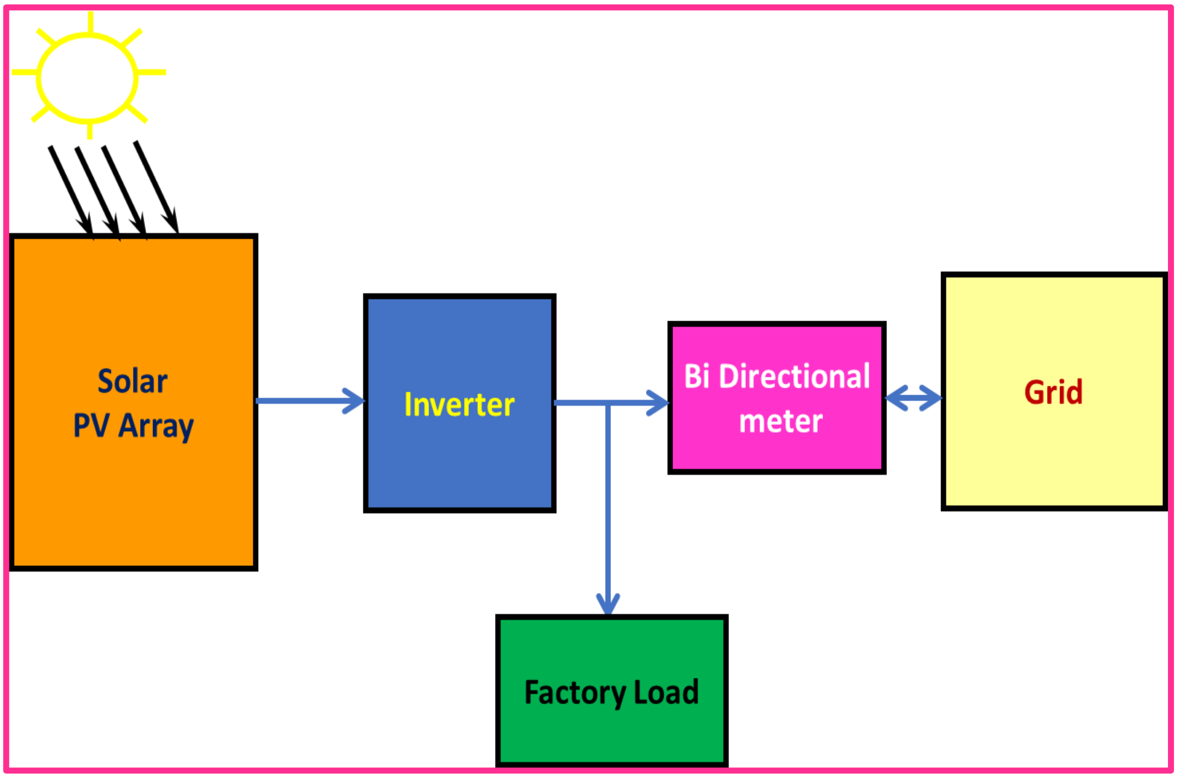


Fig 9.3 : Typical Solar "ON -GRID" System Configuration | CAG

MODALITIES

- There are many Govt approved RESCOs in the market for funding and execution of Solar Roof Top Power Plant. These RESCOs will invest on the Solar PP and integrate with the grid after obtaining necessary approval from the concerned DISCOM. The maintenance and monitoring of the Solar PP will be done by the RESCO at its own cost.
- The factory pay a pre - agreed charge (can be ₹ 4 or 5 / kWh) to these RESCOs for a pre agreed time period for the electricity supplied from the Solar PP.
- The contract period shall be usually 25 years and in any case not less than 20 years
- The support & guidance of Tripura Renewable Energy Development Agency (**TREDA**), the State Nodal Agency for implementing New & Renewable Energy Projects can be sought.
- The economics will be quite attractive

ECONOMICS

- Capacity of On - Grid SPV Power Plant suggested = 40 kWp
- Energy generation possible = 165 kWh / day
- Cost of electricity when sourced from DISCOM = ₹ 7.73 / kWh
- Cost of electricity when sourced from RESCO = ₹ 4.73 / kWh
- Cost Savings = (₹ 3.0 / kWh x 165 kWh / d x 350 d / y) = ₹ 1 73 250 / y
- Investment required in RESCO Model = Insignificant
- Simple Payback Period = Immediate

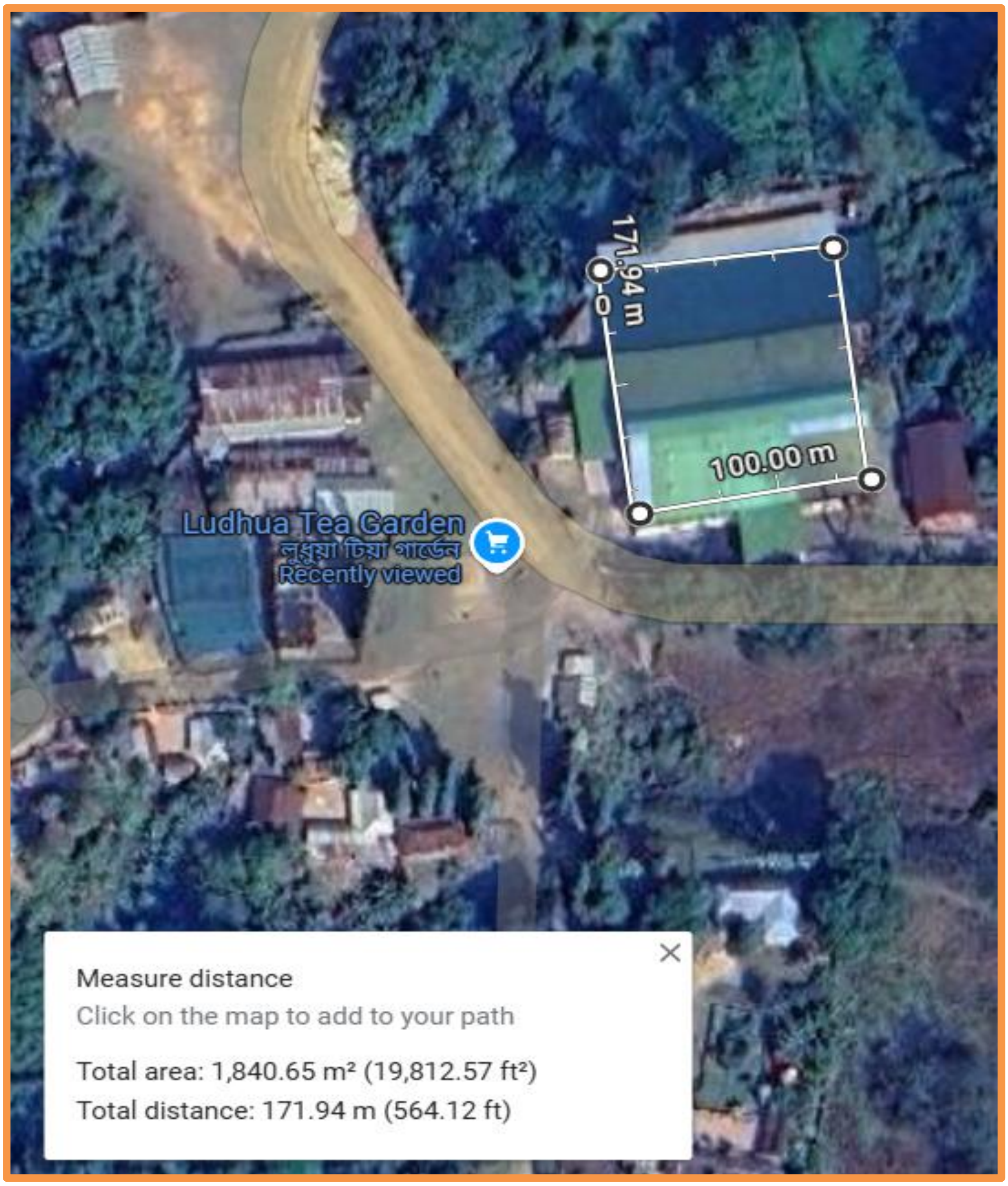


Fig 9.4 : Satellite image of Ludhua Tea Factory | CAG

10

ENERGY - CUM - COST CONSERVATION PROPOSALS

E C P 1	OPERATION OF ELECTRIC MOTORS AT THE RATED / NEAR RATED VOLTAGE IN ORDER TO EFFECT OPTIMUM ENERGY DRAWL AND TO CONTAIN THE DAMAGE TO MOTORS

Cost Savings ₹ / y	Investment ₹	Payback Period Months
14 000	Meagre	Immediate

OBSERVATIONS

- Electrical measurements have been recorded on the transformer for a period of 2 hours each when the tea processing operations were at peak of the production.
- The voltage variations tracked are shown in Fig 10.1 for the transformer.

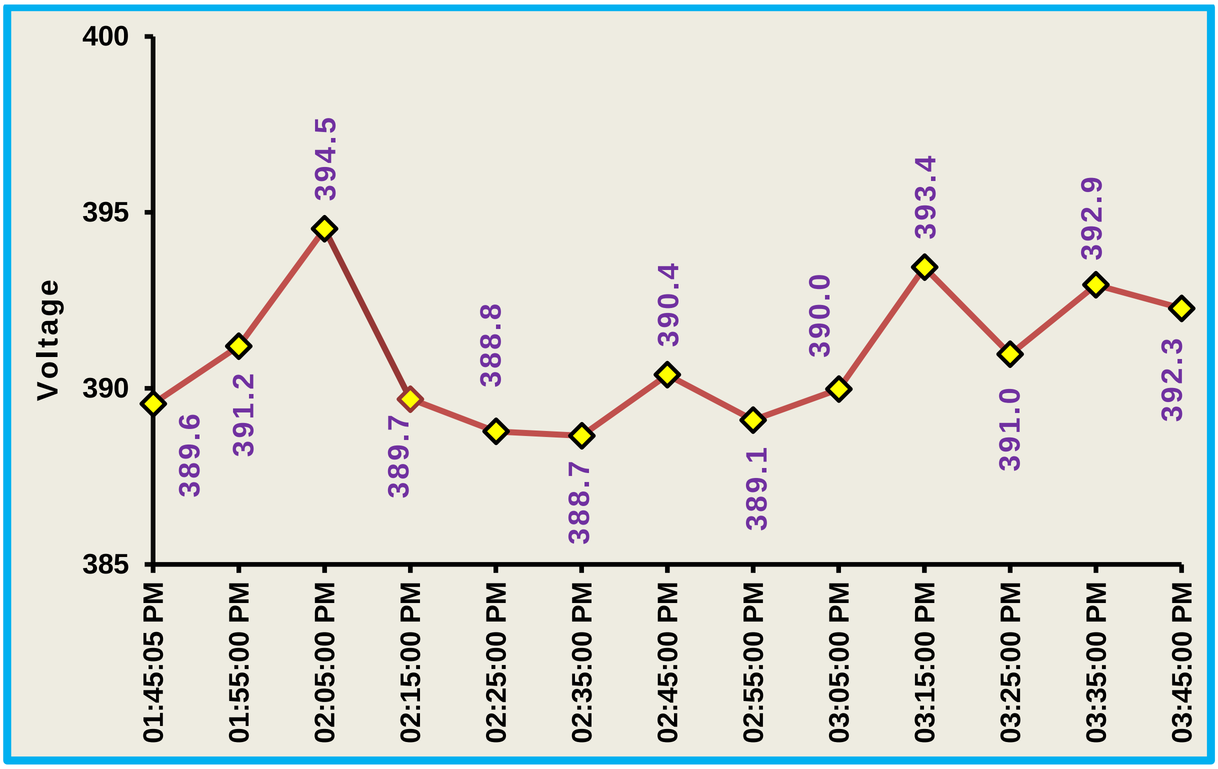


Fig 10.1: Voltage Variation Recorded in the Transformer | CAG

- The average operating voltage hovered around 380 and the voltage range recorded was **388** to **394**.
- This low voltage input to the rotating machineries - for their operation - is certain to affect not only the performance of the motors but also result in reduced life time.

- In addition, this low voltage operation also poses safety problems by way of motor getting overheated.

3 - phase, 4 - wire, 415 V, 50 Hz is the standard parameter for three phase at which the supply authorities deliver power to the consumer

ILL EFFECTS OF LOW VOLTAGE OPERATION OF MOTORS

1) Reduced Operating Efficiency

> Motors operating at low voltage will require more power to produce the same amount of power output, which can increase operating costs and reduce the overall efficiency.

2) Increased Current Draw

> To compensate for low voltage, the motor will draw more current to maintain the required power output. This increased current can lead to overheating of the motor windings and other components, potentially causing damage to motor over a period of time.

3) Reduced Lifespan

> Continuous operation under low voltage conditions can shorten the lifespan of the motor due to overheating and excessive wear on its components.

4) Reduced Torque and Power

> When the voltage is lower than that required, the motor will not generate sufficient torque and power, leading to poor performance. This can cause the motor to struggle under load or ultimately fail to start altogether.

5) Burning out

> Motors operating at low voltage may burn out because they draw more current, which is inversely proportional to voltage.

6) Stalling or Failure to Start

> Motors need a minimum voltage to generate enough force to start rotating. If the voltage drops below this threshold, the motor may not start or may stall while operating.

- The effect of voltage variation on motor efficiency as well as energy consumption is shown in Table 10.1

Table 10.1: Effect of Voltage on Energy Drawl & Efficiency

Voltage Variation	%	- 5	- 10	- 15
Efficiency Level		- 1	- 2	- 4
Energy Consumption		+ 2	+ 4	+ 5

RECOMMENDATION

- Hence, it is important that the operating voltage is maintained at the value specified by the manufacturer and in any case not less than 410 V at the motor input.
- This can happen by
  - a) Taking up the matter with the TSECL and get it rectified
  - b) regularly check the connections and wiring for any signs of wear or damage that could lead to voltage drops.

ECONOMICS

- Energy drawn through Transformer = 60 282 kWh / y
- Energy loss anticipated due to operation of motors at 390 V [7.5 % less] = 3 %

  = [60 282 kWh / y x 3 %] = 1810 kWh / y
- Energy Savings possible by setting correct the Voltage. = 1 810 kWh / y
- Cost Savings = (1 810 kWh / y x ₹ 7.73 / kWh) = **₹ 14 000 / y**
- Investment = **Meagre**
- Simple Payback Period = **Immediate**

This is in addition to all other benefits that shall accrue due to the maintenance of appropriate voltage towards the operation of motors

E C P 2	DOWNSIZE AND USAGE OF ENERGY EFFICIENT MOTOR IN THE CUT 1 OF C T C SECTION AIMING REDUCED ENERGY CONSUMPTION AND IMPROVED "PF" AND THEREBY COST SAVINGS

Cost Savings ₹ / y	Investment ₹	Payback Period Months
13 915	40 000	35

OBSERVATIONS

- The factory has only one line of CTC Cut employing a total of 5 Nos of higher rated motors for carrying out the intended activities. This line comprises 4 CTC cut motors and a Rotor Vane. It appears that all the motors are fairly old and rewound.
- The power rating of the CTC Cut 1 Motor is 18.5 kW (25 hp) and the electricity measurements carried out showed that this motor is lowly loaded on kW front.

Table 10.2 : Electrical Loading Pattern of CTC Cut 1 Motor

No	Motor ID	Rated			Measured			% Loading	
		kW	Amps	η %	kW	Amps	PF	kW	Amps
1	C T C Cut 1	18.5	35.0	91.2	9.0	13.7	0.97	44.2	39.1

COMMENTS

- It is quite clear from the above table that the CTC Cut 1 Motor is loaded to a lesser extent.
- It appears that this motor is one size oversized for the duty intended.
- Larger capacity motors have a tendency to exhibit higher efficiency values both at full and partial - load conditions and the performance / efficiency declines when the power loading goes below the 50% of the rated power.

RECOMMENDATION

- It is recommended to downsize this lowly loaded CTC Cut 1 - at an appropriate time - with Energy Efficient (I E 3) motors, rightly sized, such that the kW loading of this motor is enhanced to a plausible level.

- Though it is preferred to have loading levels as high as 75 %, the effect of loading on motor efficiency is lesser felt in the case of Energy Efficient Motors, than with standard motors. The suggested motor rating can be 15 kW (20 hp) enabling it to get loaded close to 70 %.
- The ampere loading for this motor was observed to be quite low at 39.1 % and this is bound to improve as well through appropriate sizing.

ECONOMICS

- Power drawn by the CTC Cut 1 Motor : present = 9.0 kW
- Power drawl anticipated – post replacement: = 8.4 kW
- Power Savings = 0.6 kW
- Energy Savings = (0.6 kW x 3 000 h / y) = 1 800 kWh / y
- Cost Savings = (1 800 kWh / y x ₹ 7.73 / kWh). = **₹ 13 915 / y**
- Investment towards installation of an E E Motor of 20 hp rating = **₹ 40 000**
- Simple Payback Period = **35 months**

E C P 3	USAGE OF CLOSED SHED FOR THE STORAGE OF COAL FROM THE VIEW POINT OF ACHIEVING EFFICIENT COMBUSTION IN THE FURNACE [ON ACCOUNT OF AVOIDING MOISTURE PICK UP BY COAL DUE TO ITS STORAGE IN OPEN] AND SAVE ON COAL CONSUMPTION

Cost Savings ₹ / y	Investment ₹	Payback Period Months
67 200	80 000	14

OBSERVATIONS

- Coal is burned in the furnace towards hot air generation for tea drying application.
- The scheme of hot air generation has already been illustrated in Section 2.5 / Ch 2.
- The pictorial view of the furnace is shown below:

Fig 10.2 : Coal Fired Furnace in use for Hot Air Generation | CAG

- The average coal consumption is **140 tons / y** and it is procured from Meghalaya mines.
- On an average, the landed cost of coal is **₹ 16 800 / ton** that includes transportation, loading, unloading and other sundry charges.

- A performance study was conducted on the Heater & Drier combined and the overall efficiency was estimated to be **23%**. The efficiency of the Heater alone is expected to be around **40%**.
- On an average 1.58 kg of coal is used to produce 1 kg of Made tea - as per the factory records - and that results in a lower operating efficiency of the Furnace.

> Note : This quantum of Specific Coal Consumption is too high that too for a coal having a GCV of 6323 kcal / kg

- One of the reasons identified for attaining such a low efficiency in the furnace is the moisture pick up by the coal due to its storage in open.

COMMENTS

- The Meghalaya coal has a moisture content of 10 - 15 % on ***"as received basis"***.
- At present, coal is stored in open yard inside the factory premises and consumed as per the requirement.

Fig 10.3 : Coal Dumping / Storage Yard | CAG

- The moisture content of coal was found to be more than 20 % when it was analyzed in the laboratory obviously due to moisture pick up. The moisture pick up is due to rain and mist.

- Therefore, it becomes quite important that coal is kept in a closed yard to avoid moisture pick - up in addition to the moisture it already has from the source itself.
- The quality of combustion - at present – is not up to the expected mark and one of the reasons could be the higher moisture content of the coal.
- The quality of combustion would certainly go up when the relatively drier coal is burnt. This will subsequently lead to lesser coal consumption also.
- To summarize, it is our opinion that the open storage of coal is also partly a reason for the furnace encountering a lower overall thermal efficiency and thereby consuming more coal.

RECOMMENDATION

- It is therefore recommended that the coal is stored in a closed shed and burned in order improve the quality of combustion and thereby bringing down its consumption for tea drying operation.

ECONOMICS

- Coal Consumption and Cost : [avg of 2 previous years] = 140 tons / y @ ₹ 16 800 / ton
- Coal savings anticipated by way of storage in an enclosure @ 3 %

  = (140 tons / y x 3 %) = 4 tons / y
- Cost Savings = (4 tons / y x ₹ 16 800 / ton) = **₹ 67 200 / y**
- Investment required for shed construction = **₹ 80 000**
- Simple Payback Period = **14 months**

E C P 4	FITMENT OF VFD TO THE HOT AIR FORCED DRAFT FAN - WHOSE OPERATION SHALL BE CONTROLLED BY THE EXITING MOIST FLUE GAS TEMPERATURE - ENABLING ENERGY EFFICIENT OPERATION OF THE FAN RESULTING IN COST SAVINGS

Cost Savings ₹ / y	Investment ₹	Payback Period Months
23 190	40 000	20

OBSERVATIONS

- The factory has installed a Drier and provided with a Hot Air Fan (Forced Draft wrt Tea Drier) - of a designed motor capacity of 11 kW - to facilitate the drying process.
- Coal is burned in the furnace with the aid of an FD Fan that supplies the air required for combustion and the ID Fan drives the exhaustion of the combustion gases through the stack / chimney to the atmosphere.
- This hot flue gas transfers heat - through the heat exchanger walls - to the air that is pulled into the system by the Hot Air Fan [H A F] for dhool drying application.
- This hot air eventually at a temperature of 120^{0}C comes in contact with wet dhool to evaporate the moisture from it, in order that it becomes dry.
- It was recorded through our measurement that this Hot Air Fan is loaded at effectively at 72.8 % as can be seen in the Table 10.3

Table 10.3: Motor Loading Details – Hot Air Fan

No	Motor ID	Rated			Measured			% Loading	
		kW	Amps	η %	kW	Amps	P F	kW	Amps
1	Hot Air Fan Motor of the Drier	11.0	21.3	87.5	9.15	13.7	0.97	72.8	64.2

COMMENTS

- This lower kW loading is marginally on the lower side.
- However, it is also understood that there is a possibility of this motor loading going up during peak season when the leaves arrival is more and going down during offseason.

- In order to cope up with the variation in the process operating parameters, it would be prudent to make the HAF operate as per the need that shall enable the optimum loading / operation of the motor.
- Fitment of Variable Frequency Drive [V F D] to the Motor of H A F can result in energy savings on account of the optimum operation of the motor at all loads.
- **This is a very common practice in almost all tea factories.**

RECOMMENDATION

- Hence, our suggestion is the fitment of V F D to the motor of the Hot Air Fan to optimize the kW loading.
- The input to the VFD drive shall be the moist flue gas temperature leaving the drier outlet stack. Higher this temperature, slower shall be the motor speed and vice - versa
- VFD fitted fans are expected to provide reasonable energy savings and that has been our experience.
- A 10 % savings in energy can be anticipated through this scheme of VFD installation.

ECONOMICS

- Power Drawn : Present = 9.15 kW
- Power Savings Anticipated = 1 kW
- Energy Savings = (1 kW x 3 000 h / y) = 3 000 kWh / y
- Cost Savings = (3 000 kWh / y x ₹ 7.73 / kWh). = **₹ 23 190 / y**
- Investment [Fitment of one VFD] = **₹ 40 000**
- Simple Payback Period = **20 months**

E C P

5

PARTIAL RECIRCULATION OF THE DRYER EXHAUST AIR BACK IN TO THE FURNACE ALONG WITH CONVENTIONAL ATMPOSPHERIC AIR FROM THE VIEW POINT OF ENHANCING THE COMBUSTION AIR ENTHALPY RESULTING IN CONSERVATION OF COAL

Cost Savings ₹ / y	Investment ₹	Payback Period Months
94 080	90 000	12

PREAMBLE

- Coal is utilized as the source of thermal energy in the furnace. The FD Fan supplies the air required for combustion into the furnace and the ID Fan drives the exhaustion of the combustion gases through the stack / chimney.
- The hot flue gases transfer heat - through the heat exchanger walls - to the air that is pulled into the system by the Hot Air Fan.
- This hot air eventually comes in contact with wet dhool to evaporate the required amount of moisture from it, in order that it becomes dry.
- The moisture laden hot / warm air is then let to the atmosphere

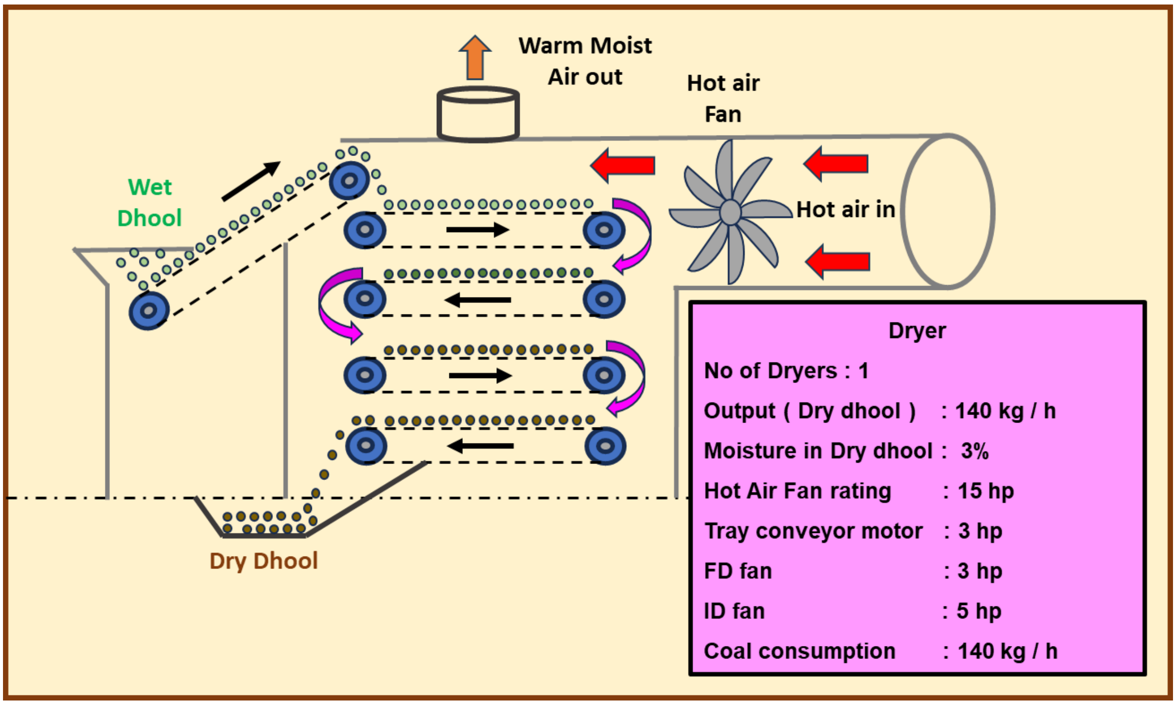


Fig 10.4 : Tea Drier : Layout and Technical Details | CAG

Fig 10.5 : Tea Dryer : E C P Type: Frontal View | CAG

- The schematic as well as the photographic views of the ECP Drier are shown above in Fig 10. 4 & 10.5 respectively

OBSERVATIONS

- At present, the exhaust humid air from the Dryer is let to the atmosphere. The temperature of this Hot Air is around **90° C** and the humidity is not very high. This air has not reached saturation humidity level as observed from measurements.
- The present scheme of operation is shown below

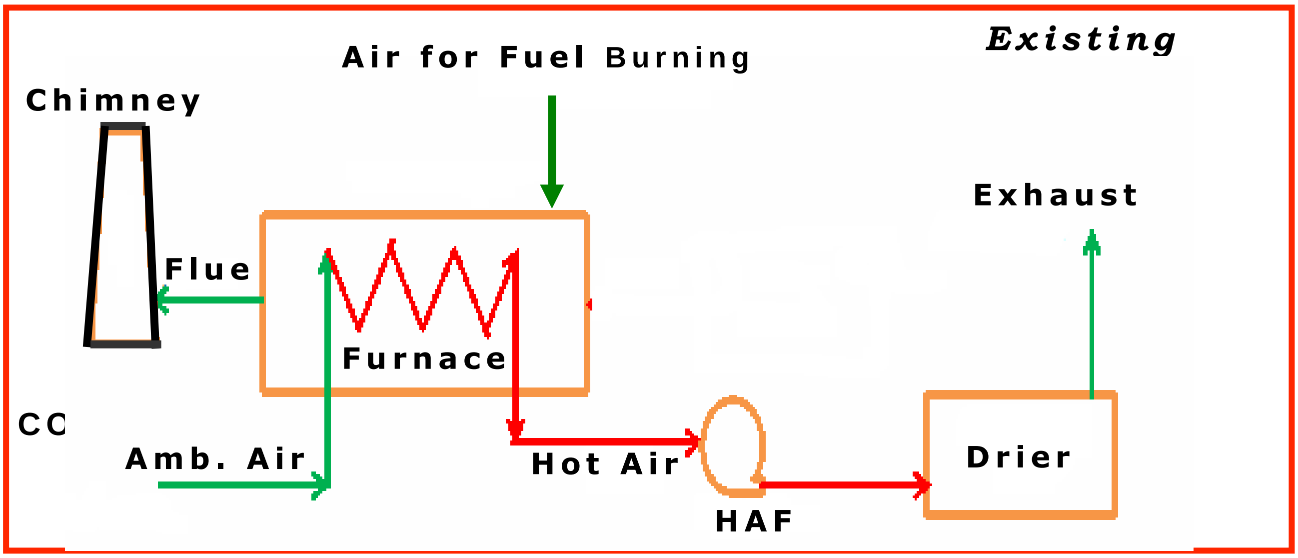


Fig 10.6 : Moist Air Exhaust Scheme : Present | CAG

- Since the Drier Exhaust Air is not only warm but also not saturated enough with the moisture, it can be put back in to the combustion chamber of the furnace along with the fresh combustion air.
- The quantity intended for recirculation can be 25 % of the total drier exhaust air and not completely 100 %.
- This is to say that a partial recirculation - to an extent of 25 % - of exhaust air quantity is recommended.

RECOMMENDATION

- It is therefore recommended to effect partial recirculation of warm / moist exhaust air back in to the coal fired furnace along with combustion.
- Since this recirculation air is warm, it brings in certain amount of enthalpy in to the furnace that is capable of conserving the fuel (coal) quantity to a certain extent.
- The proposed arrangement is as follows:

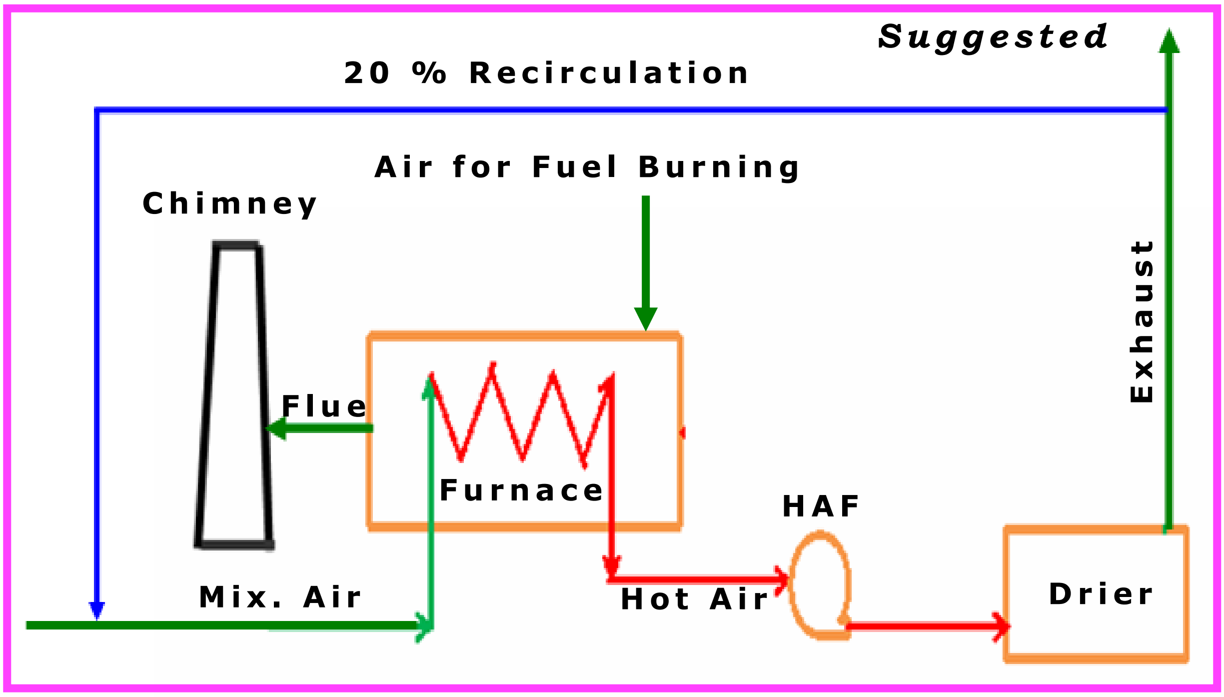


Fig 10.7 : Partial Air Circulation Scheme : Suggested | CAG

ECONOMICS

- Quantum of Hot Air leaving the Dryer = 28 000 kg / h (14 800 cfm)
- Quantity earmarked for recirculation @ 15 % = 4 000 kg / h
- Temperature of Hot Exhaust Air = 80°C

- Hence, Heat Recovery Possible = (4000 x 0.97 x 0.24 x (80 – 30)) = 46 560 kcal / h

  = 7.3 kg / h of coal equivalent (4 % reduction)
- Coal consumption = 140 tons / y
- Coal Savings possible = (140 tons / y x 4 %). = 5.6 tons / y
- Cost Savings = (5.6 tons / y x ₹ 16 800 / ton) = **₹ 94 080 / y**
- Investment = **₹ 90 000**
- Simple Payback Period = **12 months**

E C P 6	DOWNSIZE AND USAGE OF ENERGY EFFICIENT MOTOR IN THE DRIER / SORTING SECTION AIMING FOR REDUCED ENERGY CONSUMPTION AND IMPROVED "PF" AND THEREBY COST SAVINGS

Cost Savings. ₹ / y	Investment ₹	Payback Period Months
16 235	40 000	30

OBSERVATIONS

- The factory employs a total of 33 motors for carrying out various process operations related to tea production.
- Out of these 33, 6 motors have a power rating in excess of 10 hp and the rest 27 have a lower power rating, typically, 5 hp and less.
- 8 motors of humidifier fans do not exhibit any name plate information and hence the loading pattern of these could not be established.
- Thus, the loading pattern has been established for 19 motors - that have a low power rating - through the measurement of all required electrical parameters, namely, Voltage, Current, Active Power (kW), Apparent Power (kVA) and Power Factor (P F).
- Out of the 17 motors that have been analysed, majority of them were found to be loaded poorly on power, having a kW loading of less than 50%.
- This is highlighted below in Table 10.4 (motors with a power rating of 5 hp and less)

Table 10.4 : Loading Pattern of Motors : 19 Nos : < 5 hp of Rated Power

No	Motor ID	Rated			Measured			% Loading	
		kW	Amps	η %	kW	Amps	PF	kW	Amps
1	Ghoogy	2.20	5.00	79.0	0.60	0.97	0.97	21.5	19.3
2	Blower	1.50	3.80	76.0	0.30	0.60	0.85	15.2	15.8
3	F D Fan	2.20	5.00	79.0	0.90	1.80	0.73	32.3	36.0
4	I D Fan	3.70	7.20	83.0	0.97	2.33	0.66	21.7	32.4
5	Tray Conveyor	2.20	5.00	79.0	0.60	1.53	0.57	21.5	30.7
6	Packing Vibro Motor	1.50	3.40	77.0	0.87	1.67	0.78	44.5	49.0

No	Motor ID		Rated			Measured			% Loading	
			kW	Amps	η %	kW	Amps	PF	kW	Amps
7	Sorter I/c Conveyor		0.75	1.75	77.0	0.18	0.53	0.50	**18.8**	30.5
8	Sorter Motor - 1		1.50	3.30	78.5	0.39	0.93	0.63	**20.4**	28.3
9	Sorter Motor - 2		1.50	3.30	78.5	0.32	0.87	0.57	**16.9**	26.3
10	Sorter O/g Conveyor		0.75	1.75	77.0	0.18	0.57	0.46	**18.0**	32.4
11	Penwell M/c Motor		1.10	3.00	78.0	0.41	0.93	0.64	**28.9**	31.1
-	Humidifier	1	-	-	-	0.11	0.30	0.63	-	-
-	Humidifier	2	-	-	-	0.13	0.33	0.64	-	-
-	Humidifier	4	-	-	-	0.28	0.47	0.90	-	-
-	Humidifier	5	-	-	-	0.06	0.30	0.33	-	-
-	Humidifier	6	-	-	-	0.12	0.30	0.60	-	-
-	Humidifier	7	-	-	-	0.10	0.30	0.55	-	-
-	Humidifier	8	-	-	-	0.12	0.30	0.60	-	-
-	Humidifier	9	-	-	-	0.22	0.43	0.77	-	-
12	Trough	1 A	3.70	8.00	85.0	2.70	4.27	0.88	62.0	53.3
13	Trough	1 B	3.70	8.00	85.0	2.97	4.63	0.88	68.2	57.9
14	Trough	2 A	3.70	8.00	85.0	2.27	3.60	0.89	52.1	45.0
15	Trough	2 B	3.70	8.00	85.0	2.27	3.77	0.84	52.1	47.1
16	Trough	3 A	3.70	8.00	85.0	2.23	3.70	0.89	51.3	46.3
17	Trough	3 B	3.70	8.00	85.0	2.33	4.10	0.83	53.6	51.3
18	Trough	4 A	2.20	5.00	79.0	1.53	2.60	0.84	55.1	52.0
19	Trough	4 B	2.20	5.00	79.0	1.47	2.57	0.82	52.7	51.3

COMMENTS

- It can be deduced from above Table 10.3 that 11 motors have been found to be partly loaded with loading going below 30 % in 10 out of 11 motors.
- All the 6 motors in the sorter section are lowly loaded. Likewise 3 motors in the Fermentation / Drier section are loaded below 40% on kW. In the CTC section, the Ghoogy and Blower motors need improved loading.
- Hence, it is appropriate that these 11 lowly loaded motors are attended at the earliest

RECOMMENDATION

- It is recommended to replace these 11 lowly loaded motors - at an appropriate time and in a phased manner - with Energy Efficient (I E 3) motors, rightly sized, such that the kW loading of these motors is enhanced to a plausible level.
- Though it is preferred to have loading levels as high as 75 %, the effect of loading on motor efficiency is lesser felt in the case of Energy Efficient Motors, than that with standard motors.
- The P F recorded in these motors are also observed to be quite low, which relates to the poor loading of the motors. This is bound to improve as well through appropriate sizing.

ANALYSIS

- The existing scenario and our proposition have been portrayed in Table 10.5

Table 10.5 : Power Drawn : Present vs Anticipated : Low Rated Motors

No	Motor ID	Rated η	kW		% Load	Max. η at this Loading	Proposed		Anticipated	
			Rated	Measurd	kW	%	kW Rating	O/p η	kW drawn	Load %
1	Ghoogy	79.0	2.20	0.60	21.5	67.9	0.75	82.5	0.50	63.2
2	Blower	76.0	1.50	0.30	15.2	63.8	0.37	77.3	0.25	61.6
3	FD Fan	79.0	2.20	0.90	32.3	69.5	1.10	84.1	0.80	64.6
4	ID Fan	83.0	3.70	0.97	21.7	73.0	1.10	84.1	0.90	72.9
5	Tray Conveyor	79.0	2.20	0.60	21.5	67.9	0.75	78.9	0.55	63.2
6	Packing Vibro Motor	77.0	1.50	0.87	44.5	70.8	1.10	84.1	0.80	60.7
7	Sorter I/c Conveyor	77.0	0.75	0.18	18.8	63.1	0.20	71.1	0.16	70.5
8	Sorter Motor - 1	78.5	1.50	0.39	20.4	65.9	0.55	80.8	0.32	55.8
9	Sorter Motor - 2	78.5	1.50	0.32	16.9	65.9	0.37	77.3	0.27	68.4
10	Sorter O/g Conveyor	77.0	0.75	0.18	18.0	63.1	0.20	71.1	0.16	67.5
11	Penwell M/c Motor	78.0	1.10	0.41	28.9	66.3	0.55	80.8	0.35	57.9
	Total		**18.9**	**5.72**			**7.04**		**5.02**	

ECONOMICS

- Total Power Drawn presently by the identified 11 motors = 5.72 kW
- Anticipated Power Drawl – post replacement = 5.02 kW
- Power Savings = (5.72 – 5.02) = 0.7 kW
- Energy Savings = (0.7 kW x 3 000 h / y) =. 2 100 kWh / y
- Cost Savings = (2 100 kWh / y x ₹ 7.73 / kWh). = **₹ 16 235 / y**
- Investment = **₹ 40 000**
- Simple Payback Period = **30 months**

E C P 7	REPLACEMENT OF CONVENTIONAL V-BELTS WITH COGGED V-BELTS IN THE IDENTIFIED MOTORS TO REDUCE BELT SLIP THEREBY ENHANCING THE TRANSMISSION EFFICIENCY AND SAVE ON ELECTRICITY

Cost Savings. ₹ / y	Investment ₹	Payback Period Months
60 294	60 000	12

PREAMBLE

- The speed of the CTC Roller / Rotor Vane Shredder / Tray Conveyor shall normally be lesser than that of the driver, namely, the motor. Hence, a speed reduction is applied between the driver and the driven mechanism
- The speeds of the motor and the driven mechanism are normally fixed and hence only a single speed reduction mechanism is employed
- The commonly used one is the pulley driven mechanism. Based on the speed requirement at the driven location, the diameter of the pulley is sized.
- The power delivered at the driven element's shaft is a function of motor efficiency and the transmission efficiency of the pulley + belt
- The transmission efficiency of V - belt would be a maximum of 95 % whereas it shall be more than 97 % for the cogged V - belt drives with a very meagre 'Slip'
- In addition, many - a - times, non-effective number of belts are used for transmission (ex 3 belts instead of 4 and so on) that adds to the transmission inefficiency

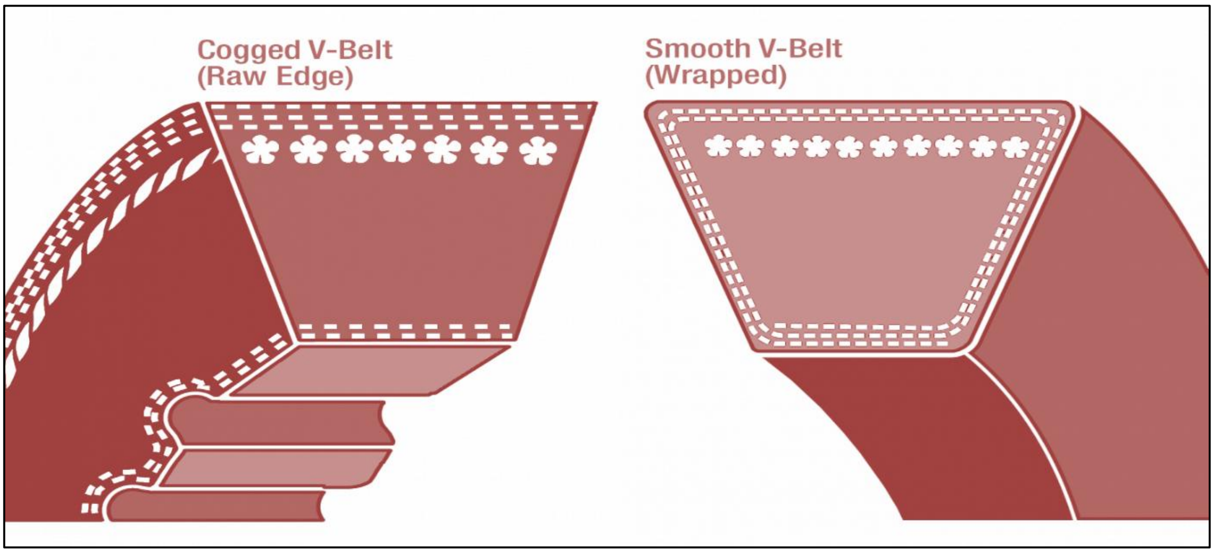


Fig 10.8 : Cogged V belt and Taper lock pulley, Baart Group | CAG

OBSERVATIONS

- The factory has installed one CTC line for the processing of withered leaves. This line consists of 5 major motors, of which one is for the Rotor Vane, and the rest are for the 4 cuts (Cut 1 to 4) of the CTC machine. These motors, along with the Tray Conveyor motor of the Drier section are considered in this evaluation for belt replacement due to the high slip encountered.
- V - belts are utilized for transmission of power from the drive motor to driven element.
- A comprehensive assessment was carried out to determine the slippage of / efficiency level at which the belts operate, which involved measurement of the following parameters:
    1) Pulley diameter for the motor and the machine,
    2) Centre - to - centre distance between the pulleys,
    3) Speed in rpm at the motor and machine end,
    4) Number of grooves in the pulley, the corresponding No. of belts and belt ID.
- The information collected / measured are presented below :

Table 10.6: Belt Slippage – An Analysis

No	Name	Pulley Dia mm		Measured rpm		Ideal Machine Speed rpm	% Slip	Belt - Pulley Specs	
		Motor	M / c	Motor	M / c			Groove	Belt
1	RV	120	300	994.2	386.9	397.7	2.7	5	5
2	**Cut 1**	150	340	1497.6	602.1	660.7	**8.9**	4	4
3	**Cut 2**	150	340	1484.3	604.6	654.8	**7.7**	4	4
4	**Cut 3**	150	340	1482.8	591.6	654.2	**9.6**	**4**	**3**
5	**Cut 4**	150	340	1488.1	605.6	656.5	**7.8**	4	4
6	**Tray Conveyor**	160	180	982.4	793.2	873.2	**9.2**	2	2

COMMENTS

1) The CTC Cut 3 motor was missing a belt (i.e., one out of the pulley's 4 grooves that should have been carrying a belt, was running empty), and exhibited considerable belt slippage. It is advised to stay in line with the designed installation guidelines.
2) The measured slip with the remaining 3 CTC Cut motors, namely, Cut 1, Cut 2 and Cut 4 motors, and the Tray Conveyor motor, despite staying in line with the designed operational characteristic - in terms of the number of grooves and belts - was on the higher side too. Rotor Vane, the only exception, recorded a slip of 2.7 % which is within permissible limits as of now.
3) Five candidates, namely, the **Cut 1 to Cut 4 motors of the C T C Section and the Tray Conveyor motor of the Drier Section**, are chosen for replacement with cogged V - belts, from the viewpoint of reducing slippage and enhancing power transmission efficiency.
4) Cogged V - belts score over standard V - belts by at least 2 percentage points by design. Considering the age of the V - belts installed on the pulleys, significant improvement in efficiency level is anticipated.
5) Further, it was also noticed that the Pulley and Belts were found to be in a worn - out condition.

RECOMMENDATION

- We therefore recommend replacement of the V - belts on Cut 1 to 4 of the CTC section (Cut 1, Cut 2, Cut 3 & Cut 4) and the Tray Conveyor Motor of the Drier Section with cogged V-belts, in a phased manner starting with the CTC Cut 3 motor, in the descending order of slippage.

- Based on the success of this implementation - effectiveness of which shall be established with power drawl measured before and after retrofit installation, as a way of validating the measure - this concept could be extended to other Cuts as well.

TECHNICAL ANALYSIS

Table 10.7 : Power Drawn vs Anticipated

No	Motor ID		Power Drawn kW	Measured Slip %	Energy Saving %	Anticipated Power Drawl kW
1	CTC Cut	1	8.97	8.9	7	8.34
2		2	10.42	7.7	6	9.80
3		3	8.97	9.6	8	8.25
4		4	9.91	7.8	6	9.32
5	Tray Conveyor		0.60	9.2	8	0.55
Total			**38.87**			**36.26**

ECONOMICS

- Power Drawn - at present - by the identified 5 motors = 38.87 kW
- Anticipated Power Consumption - post retrofit = 36.26 kW
- Anticipated power savings with the incorporation of Cogged V-belts = 2.61 kW, say 2.6 kW
- Energy Savings = (2.6 kW x 3 000 h / y) = 7 800 kWh / y
- Cost Savings = (7 800 kWh / y x ₹ 7.73 / kWh) = **₹ 60 294 / y**
- Investment = **₹ 60 000**
- Simple Payback Period = **12 months**

11 CONSOLIDATION AND CONCLUSION

11.1 COST AND ENERGY CONSERVATION PROPOSALS

- The Detailed Energy Assessment engagement at Ludhua Tea Factory, Sabroom has revealed the availability of decent scope for optimisation of the electricity usage pattern.
- Also, identified are a couple of Cost Conservation Proposals (CCPs) which are capable of bringing in significant cost savings with attractive economics (simple payback period within 5 months). Two of these CCPs are NIL investment proposals, while the other shall bring in considerable savings in comparison with the investment to be incurred.
- At present, 3 Cost Conservation Proposals and 6 Energy Conservation Proposals have been identified, the details of which are presented below:

Table 11.1: Cost Conservation Proposals : 3 Nos

No	Cost Conservation Proposals	Cost Savings ₹ / y	Invest ₹	Payback Period Months
1	Switching over to Chipped Wood from Coal as the source of thermal energy for combustion in the furnace to cut down the cost of coal incurred towards tea drying operation	6 74 760	300 000	6
2	Rationalization [Reduction] of Contract Demand of the factory HT Service Connection with a view to optimise the demand charges payable to TSECL	57 456	Nil	Immediate
3	Installation and Commissioning of 40 kW_p On - Grid Solar Roof Top P V Power Plant adopting "RESCO" model towards attaining self - sufficiency in electricity requirement in a sustained fashion and simultaneously going green	1 73 250	Nil	Immediate
	Total	9 05 466	300000	< 6

Table 11.2: Energy Conservation Proposals : 7 Nos

No	Energy Conservation Proposals	Cost Savings ₹ / y	Invest ₹	Payback Period Months
1	Operation of Electric Motors at the rated / near rated voltage in order to effect optimum energy drawl and to contain the damage to Motors	14 000	Meagre	immediate
2	Downsize and usage of Energy Efficient Motor in the **Cut 1 of CTC Section** aiming for reduced energy consumption and improved P F and thereby cost savings	13 915	40 000	35
3	Usage of Closed Shed for the storage of Coal from the view point of achieving efficient combustion in the furnace [on account of avoiding moisture pick up by coal due to its storage in open]and save on coal consumption	67 200	80 000	14
4	Fitment of V F D to the Hot Air Forced Draft Fan- whose operation shall be controlled by exiting moist flue gas temperature - enabling energy efficient operation of the fan - resulting in electricity conservation and cost saving	23 190	40 000	20
5	Partial Recirculation of the Dryer Exhaust Air back into the Furnace along with conventional atmospheric air from the view point of enhancing combustion air enthalpy resulting in conservation of coal.	94 080	90 000	12
6	Downsize and usage of Energy Efficient Motor in the **Drier / Sorting Section** aiming for reduced energy consumption and improved P F and thereby cost savings	16 235	40 000	30
7	Replacement of Conventional V - Belts with Cogged V - Belts in the identified motors to reduce belt slip thereby enhancing the transmission efficiency and save on electricity	60 294	60 000	12
	Total	2 88 914	3 50 000	15

- The overall anticipated savings is computed at **₹ 11 94 380 / y** at an investment of **₹ 6 50 000** which shall be paid back in about **7** months.
- On the energy front, the overall savings is expected to be **16 5120 kWh / y** on Electrical, equivalent to a cost saving of **₹ 1 27 634 / y**.
- Of the **10** schemes identified in total, **2** schemes do not call for any investment.
- All proposed recommendations can be implemented with ease.

11.2 AUDIT OBSERVATIONS

- The table below sums up our observations - section wise - during the comprehensive energy audit carried out at Ludhua Tea Factory, Sabroom.

Table 11.3: Audit Observations

No	Section	Remarks
1	Thermal System	• The operational efficiency of the drier system is on the lower spectrum at **23%** • The thermal energy cost works out to **₹ 26.6 / kg** of Made Tea, which constitutes about **79.5%** of the total energy cost of tea production; this is quite significant & needs to be brought down • The thermal insulation tightness of the drier system seems to be okay, with few sections - around the furnace - where there is scope for improvement • Fuel switch from coal to cheaper, more affordable wood chips shall result in significantly lowering the coal cost paid. [CCP 1]. • Coal consumption is quite high and calls for proper measurement and accounting.
2	Withering Section	• The loading of all the motors in this section seemed optimal, which indicates good overall performance. • Preferential operation of the troughs in line with the specific flow rate / throughput is advised to improve the quality of Withering and as well electricity saving to a reasonable extent.
3	CTC Section	• 3 motors out of 7 in this section are loaded below 50% on kW, which needs to be improved through phased downsizing the standard motors with EE motors, as and when feasible. This is advised in the ENCON section of this report. • Belt slip analysis was performed on the 5 major CTC motors (R V + 4 Cuts in each line), revealing decent scope for improvement in 4 motors. • One groove in the pulley of Cut 3 motor was missing a belt. This is mentioned in the report, and the need to stick with designed guidelines is recommended.

No	Section	Remarks
4	Drier Section	• The loading of the motors in this section (except for the HAF) is on the lower gamut - less than 50% on kW - which needs to be addressed. • Belt slippage computed for the Tray Conveyor motor is on the higher side, which makes it an ideal candidate for replacement with Energy Efficient Cogged V - Belt.
5	Sorting Section	• The loading pattern of all the 6 motors in this section is below 50%, of which in 5 motors it is less than 30%. This necessitates the need to enhance it considerably. • Suitable recommendations have been made in Chapter 10
6	Thermography - Electrical Safety & Motors	• Altogether, abnormality existed only in 5 out of all locations that were surveyed for possible discrepancy in electrical connection tightness, of which 2 are of “Critical” severity classification, requiring immediate attention; the electrical maintenance team however deserve due credit for limiting the abnormality incidences. • The surface temperature profiles of the motors revealed the absence of any abnormality.

11.3 SUM - UP

- As a whole, the motors operating in the Drier and Sorting section are found to be loaded sub - optimally, indicating the existence of reasonable potential to fine - tune in terms of enhancing the loading performance, through suitably downsizing them with Energy Efficient Motors
- Once the underperforming motors are done away with, the benchmarking performance is bound to improve
- The economics of carrying out remedial actions is quite reasonable as can be seen in the section of “ **Cost Conservation Proposals** ”, and “ **Energy Conservation Proposals** ”, with an overall payback of < 7 months, which is very encouraging
- Further, the performance of the utilities can be ranked at 6 in a scale of 10 and effort shall be made to upgrade it further.

12 THERMAL IMAGING STUDY : OUTCOME

12.1 INTRODUCTION

- Thermography is an extremely influential method of practically monitoring, sensing, and recording the temperature, a reflection of heat. It further assists in effectively troubleshooting any electrical, mechanical, electronics and structural system.
- Infrared Thermal Imaging offers accurate data related to the problems that remain undetected using standard visual inspection and diagnostic techniques. It offers solutions to the problems that cannot be seen with the naked eye being clearly visible with thermal imaging. The assessment of electrical safety has been done using thermal imaging camera.
- Thermal scanning was carried out on electrical systems including Panel Boards, Cables, Transformer Yard, BusBars, CTC section Motors, Drier section Motors, etc.,
- In all, thermo mapping was carried out at 29 locations, excluding locations where no discrepancies were observed w.r.t electrical connections.
- Based on the observations made, it is suggested that the electrical system issues are sorted out at the earliest as they impact the safety.
- The thermal images captured are expected to bring in safety in electrical systems operations, savings in terms of energy (though not significant) as well as reduction in maintenance cost to the management.
- The International Electrical Testing Association [I E T A] provides the guidelines [shownbelow in the Table] that aid in determining the degree of severity of a problem typically associated with electrical power transmission.
- The severity is categorized into 4 categories, namely,

  1) Mild 2) Moderate 3) Serious 4) Critical

  based on the magnitude of the temperature encountered.
- The following protocol depicted in Table 12.1 shall be followed while addressing the issues related safety as well as energy loss.

Table 12.1 : Severity Prediction : Remedial Action Suggested

Problem Classification	Temperature Range °C	Comments
Mild	30 - 40	Repair during regular maintenance schedule: Limited probability of physical damage
Moderate	41 - 60	Repair soon (2 - 4 weeks). Watch Load and change accordingly. Inspect for physical damage.
Serious	61 - 70	Repair within 1 or 2 days. Replace component and inspect the surrounding components for probable damage.
Critical	Above 70	Repair immediately. Replace component, inspect surrounding components for damage

- The following Table 12.2 can also be referred to assess the severity of the abnormalities and to address them accordingly

Table 12.2 : Severity Assessment : Recommended Action

Priority	ΔT between similar components under similar load	ΔT over ambient air temperature	Recommended Action
4	1 to 3 °C	1 to 10 °C	Possible deficiency; warrants investigation
3	4 to 15 °C	11 to 20 °C	Indicates probable deficiency; repair as time permits
2	-	21 to 40 °C	Monitor until corrective measures can be accomplished
1	> 15 °C	> 40 °C	Major discrepancy repair immediately

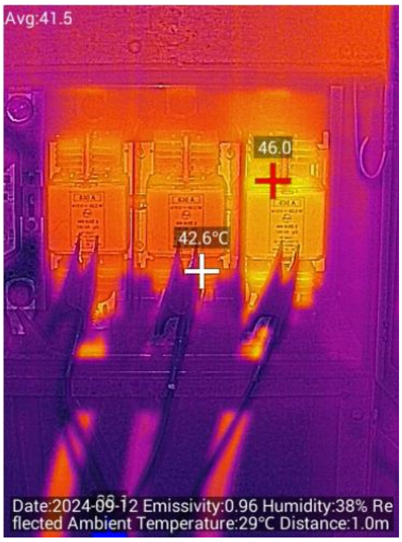
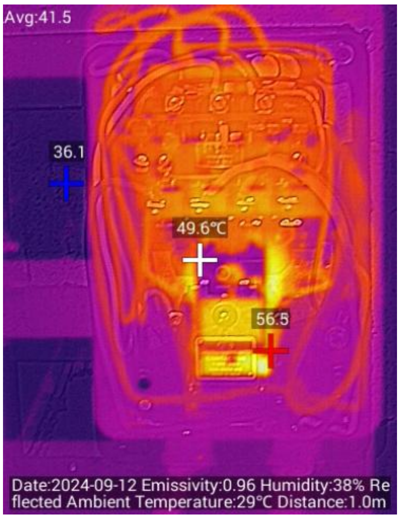
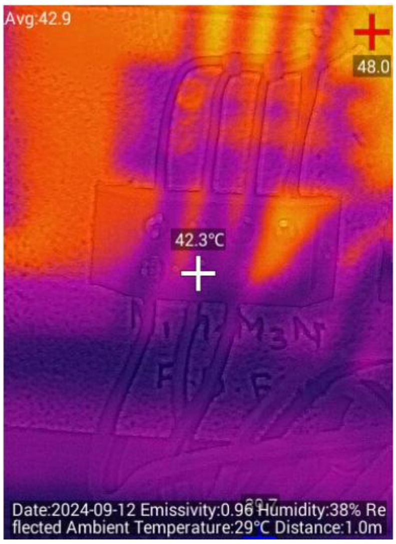
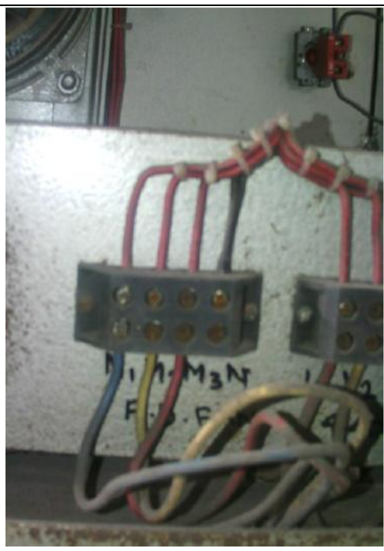
12.2 ABNORMALITIES NOTICED: 5 LOCATIONS: OVERALL

- The outcome is presented in this section as per the categorization made.
- Abnormalities have been noticed at only 5 locations of all the locations surveyed based on the Thermal Imaging Study conducted. The maintenance team deserves due credit for this.

No	Nature	No of Locations
1	Moderate	3
2	Critical	2

12.2.1 Category : Mild : No of Locations : NIL : Temp: 30 - 40 °C

12.2.2 Category : Moderate : No of Locations : 3 : Temp: 41 - 60 °C

No	Location	Thermal Image	Normal Image	Temp °C
1	Main Incoming			40°C + in all the 3 Phases
2	ID Fan Incoming			45°C noted at many locations within
3	FD Fan Incoming			48°C around the pointer location

12.2.3 Category : Serious : No of Locations : NIL : Temp: 61 - 70 °C

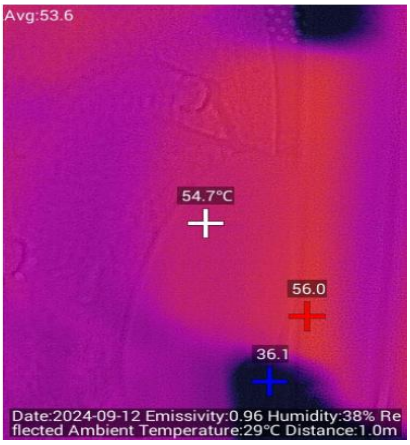
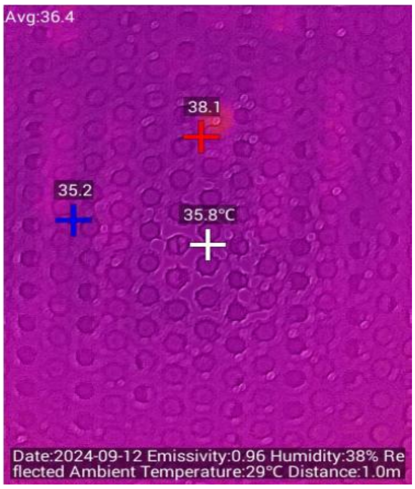
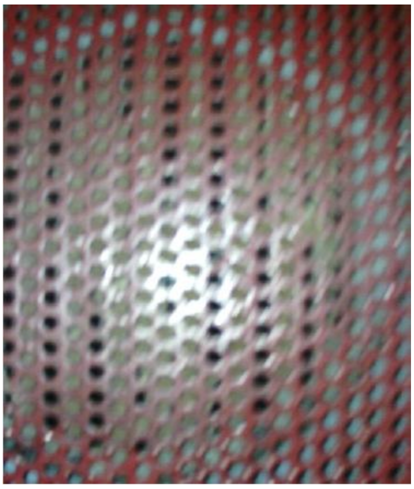
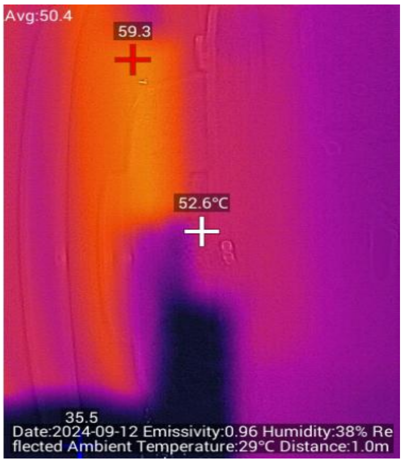
12.2.4 Category : Critical : No of Locations : 2 : Temp: above 70 °C

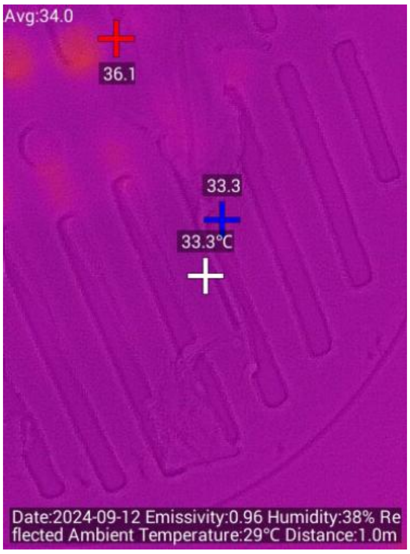
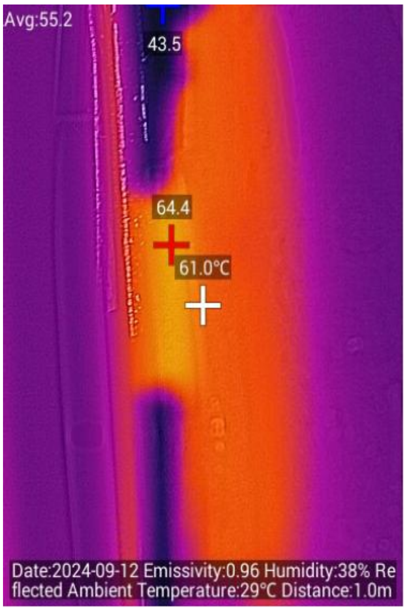
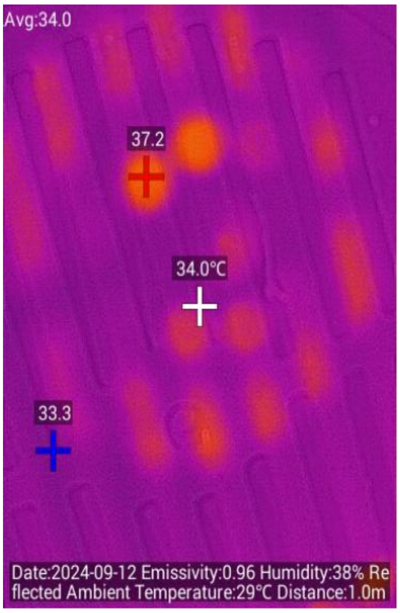
<table>
<tr><th>No</th><th>Location</th><th>Thermal Image</th><th>Normal Image</th><th>Temp °C</th></tr>
<tr><td>1</td><td>CTC Main Incoming - 1</td><td>
</td><td></td><td>141.9 °C on B Phase and a similar temp. on Y Phase as well</td></tr>
<tr><td>2</td><td>CTC Main Incoming - 2</td><td>
</td><td></td><td>76.2 °C on R Phase and a similar one on Y Phase</td></tr>
</table>

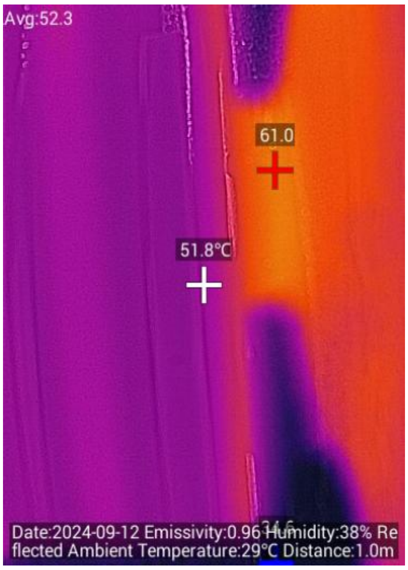
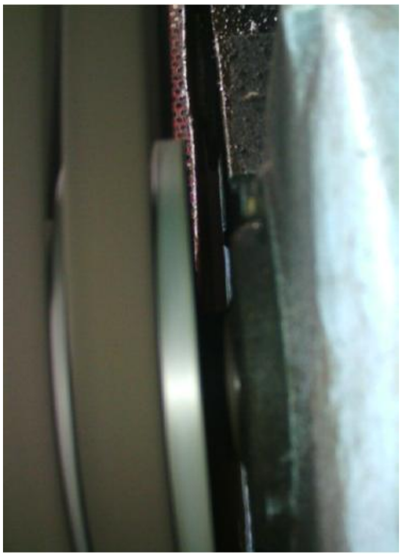
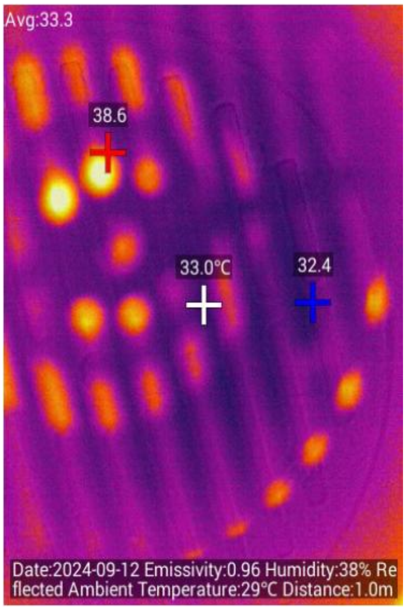
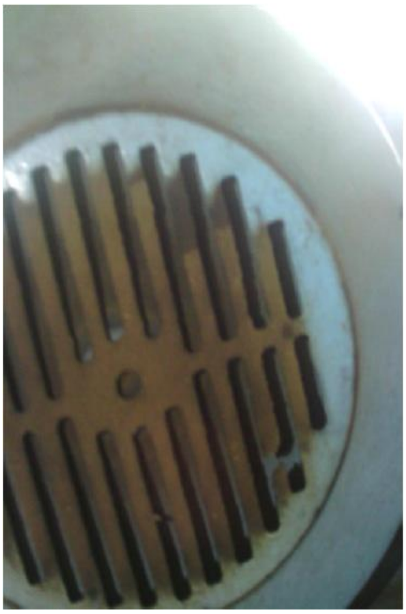
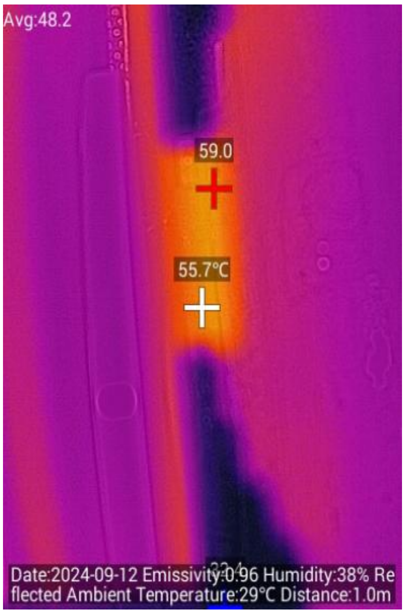
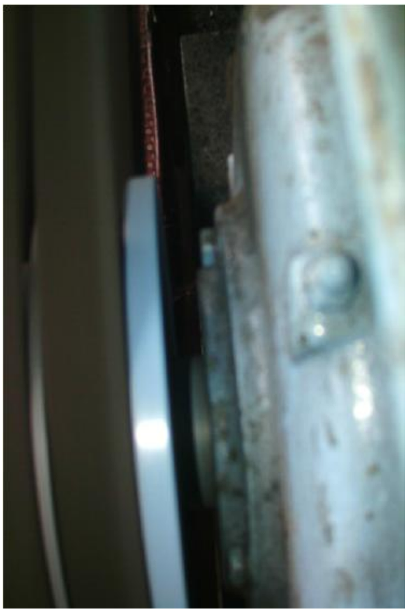
- **Three abnormalities** identified belong to the "**Moderate**" severity category, while the **remaining two** identify themselves with the "**Critical**" severity category, requiring immediate attention.
- The occurrence of faults can be attributed to:
  - I. Loose connections.
  - II. Deterioration of distribution lines (Cables)
- The possible remedies are:
  - ➢ Checking & Re doing / Re terminating the cables / busbars etc. as per observations made.
  - ➢ Providing adequate cooling.
  - ➢ Providing new & properly sized (Current carrying capacity) cables
- These abnormalities shall be attended to at the earliest opportunity

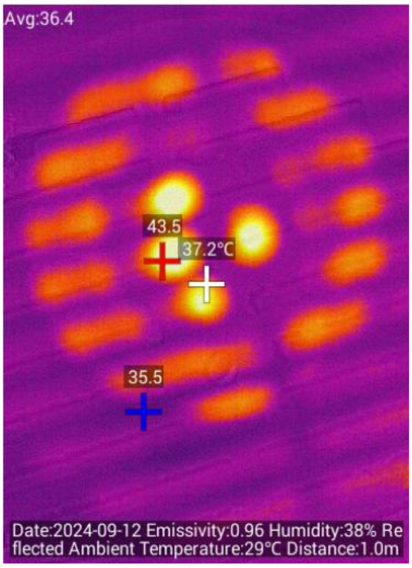
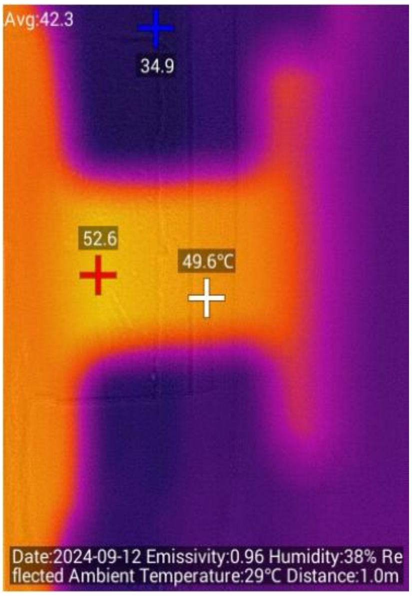
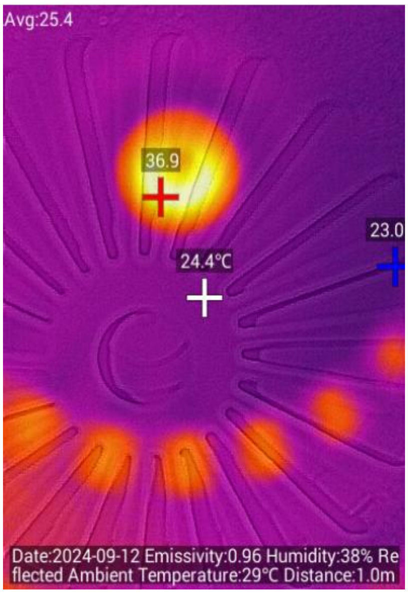
12.3 NIL ABNORMALITIES RECORDED: 14 LOCATIONS : MOTORS

- Thermal Imaging Study conducted for the motors to assess the presence / absence of abnormalities with reference to surface temperature profiles are presented below.
- It can be said with confidence that the comprehensive assessment carried out on all major motors in the factory revealed no abnormalities.
- The factory maintenance personnel deserve due credit for this.

1	**Rotor Vane Driving End**		
2	**Rotor Vane Non-Driving End**		
3	**CTC 1 Driving End**		

4	CTC 1 Non-Driving End		
5	CTC 2 Driving End		
6	CTC 2 Non-Driving End		

7	CTC 3 Driving End		
8	CTC 3 Non-Driving End		
9	CTC 4 Driving End		

10	CTC 4 Non-Driving End		
11	ID Fan Driving End		
12	ID Fan Non-Driving End		

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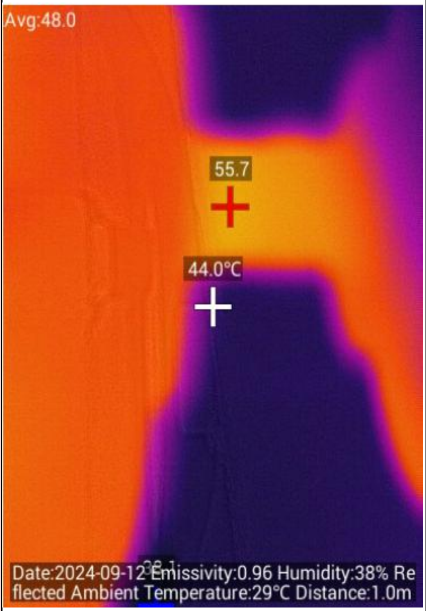
<td>13</td>
<td>FD Fan Driving End</td>
<td>
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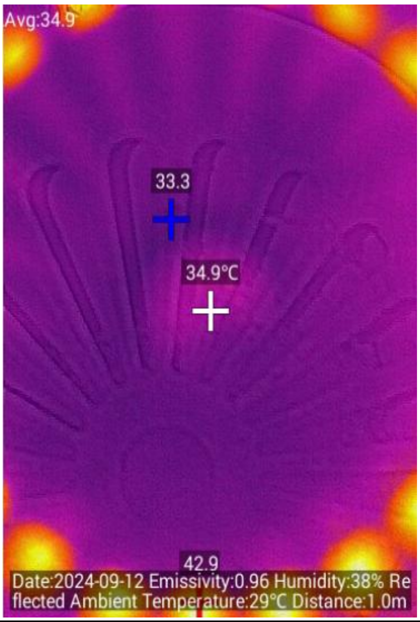
<tr>
<td>14</td>
<td>FD Fan Non-Driving End</td>
<td>
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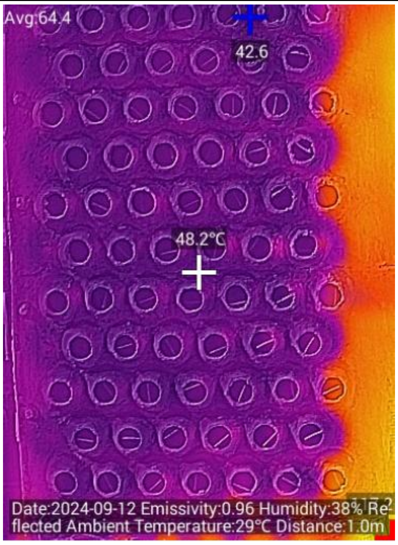
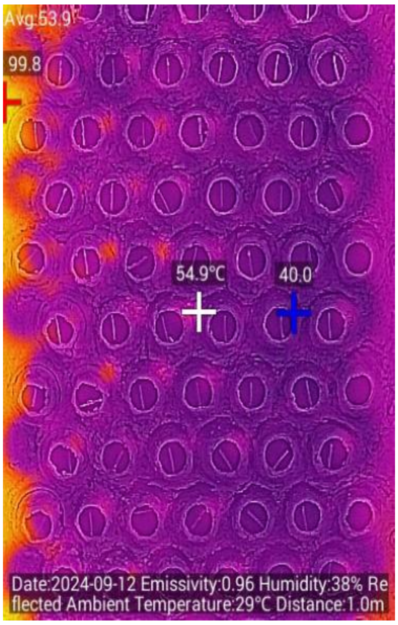
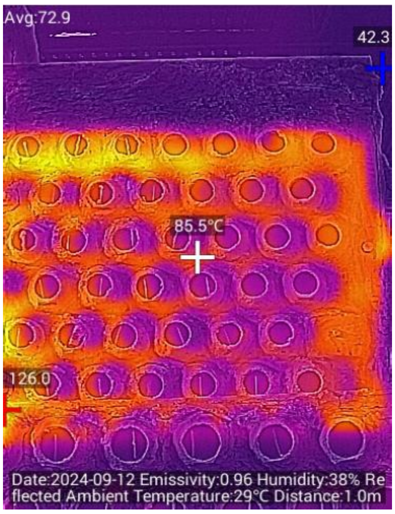
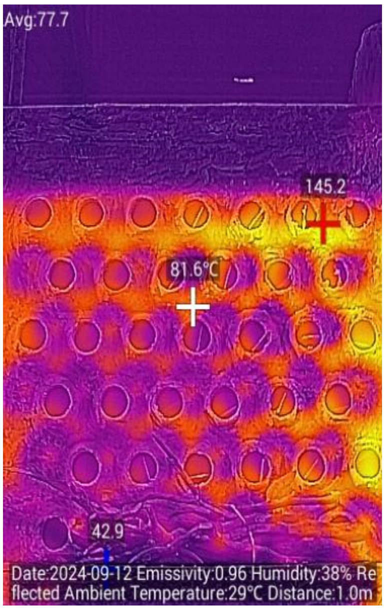
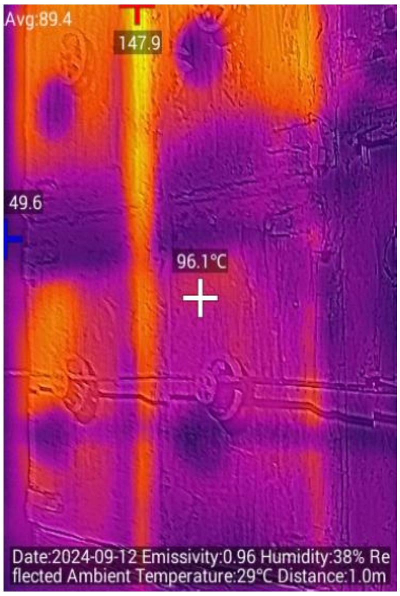
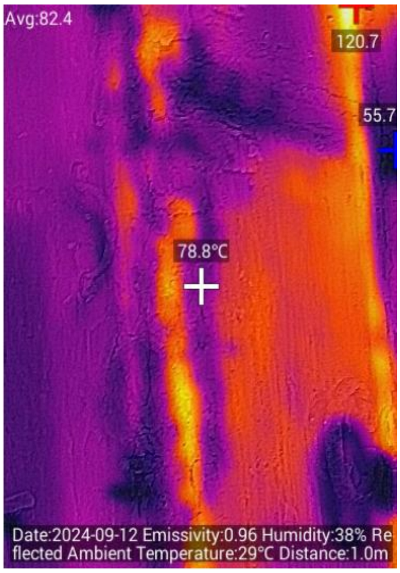
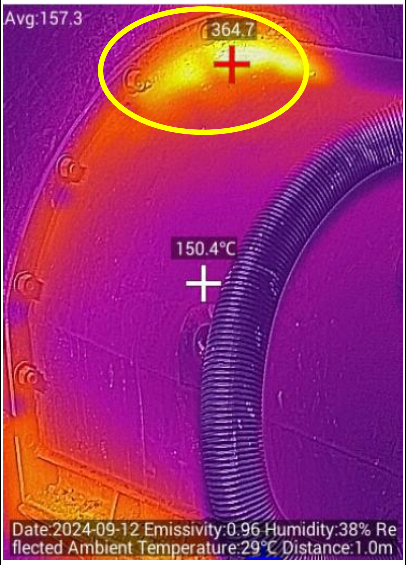
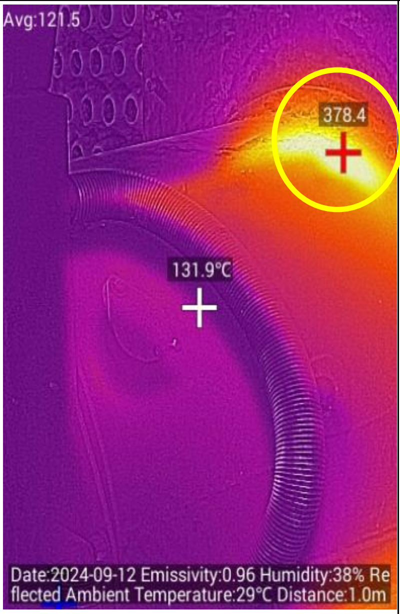
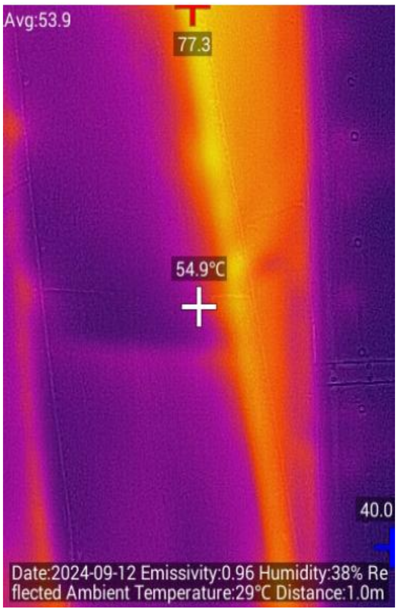
</table>

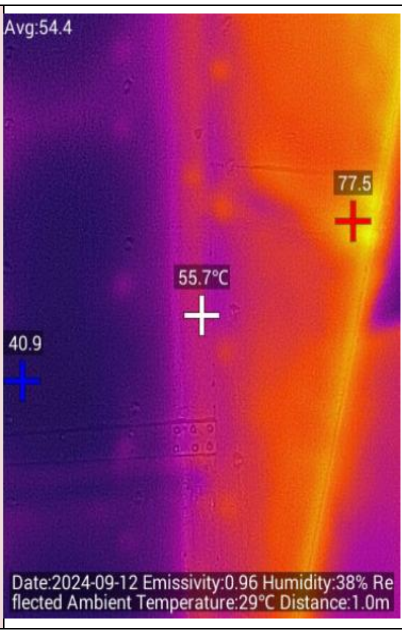
12.4 NIL ABNORMALITIES RECORDED : 11 LOCATIONS : DRIER

- Thermal Imaging Study conducted on the drier - to check for possible thermal insulation related improvements - has revealed the absence of any major discrepancies / locations with significant heat energy drain / loss. However, there is some scope for improvement in the quality of thermal insulation around the Furnace area, more from a thermal safety perspective, that shall be looked into.
- This comprehensive assessment of the drier surface temperature profile has uncovered **no major abnormalities**, and the factory management is appreciated for being aware of possible wasteful heat losses that result from inadequate thermal insulation, and for taking the required precautionary steps.

1	**Air Intake Zone: Picture captured from the Front, of the RHS of the Drier**		
2	**Air Intake Zone: Picture captured from the Front, of the LHS of the Drier**		
3	**Air Intake Zone: Picture captured from the Front of the Top LHS of the Drier**		

4	**Air Intake Zone: Picture captured from the Front of the Top RHS of the Drier**		
5	**Gas-Air Heat Exchanger Zone; Picture captured from the RHS of the Drier**		
6	**Gas-Air Heat Exchanger Zone; Picture captured from the LHS of the Drier**		

7	Picture captured of the RHS of the Furnace, adjacent to the air intake		
8	Picture captured of the LHS of the Furnace, adjacent to the air intake		
9	Picture captured of the back side of the Drier, from the RHS		

10	**Picture captured of the back side of the Drier, from the LHS**		

12.5 SUM UP

- Altogether, abnormality existed in only 5 out of all locations surveyed for possible discrepancy in electrical connection tightness; only a meager fraction of the surveyed lot for which the electrical maintenance team deserves appreciation.
- out of the 5 discrepancies identified 3 assume “Critical” severity status, and shall be attended to immediately in order to avert production disruption due to electrical fault. The remaining 3 abnormalities belong to the “Medium” severity status and shall be set right at the earliest possible opportunity.
- The cost needed for setting these faults correct shall be meagre only and hence can be taken up for rectification at the earliest.
- The motor surface temperature at the driving / non - driving end seemed fine. The bandwidth considered for scrutiny here is higher, as it is with reference to the temperature at which the winding film will begin to melt.
- The surface temperature profiling for the Drier has revealed that despite the presence of few cases / locations with higher surface temperature, it can be said that there is no significant impact / considerable heat loss arising from such situations, hence considered quite normal.
- The thermal insulation quality around the furnace shall be improved whenever feasible, more from the thermal safety perspective. It is bound to show some savings in coal consumption, though it may not be a significant / tangible quantity.

13 SAFETY CONSIDERATIONS AND UPKEEP

13.1 OBSERVATIONS AND COMMENTS

- In Switch Boards and MCCs, all the wires should be identified with reference to the circuits / loads to which it is connected. Also mark near the motor on the source of power supply. This will enable easy tagging of the load with its source of power, such that it becomes convenient even for personnel who do not get their hands on them on a regular basis to be able to handle with ease in times of need, thus reducing reliance on just the experienced crew. Hence, this suggestion.
- Record Maintenance found wanting in respect of the Transformer, Higher Capacity Motors, DG Sets, etc., It is mandatory to maintain the records for the sake of attending to the Preventive Maintenance of these production related critical Utilities.
- The Earth Resistance and Relays are not tested. Hence testing is recommended.
- There is no fire extinguisher near the panel in power house. Fix the DCP type portable fire extinguisher.
- 7 locations have been identified that demand adherence to safety aspects / protocol
- The electrical safety related issues will have to be resolved in the identified 3 locations while the rest 4 locations call for mechanical related safety protocol / upkeep
- The detailing is as below

13.2 SAFETY ISSUES AND UPKEEP : ELECTRICAL

No	Location	Image	Comment
1	Transformer Yard		Approach to the Transformer shall be made tidier to enable easier access

2	Transformer Yard		Temporary taping shall be removed and replaced with permanent insulation in the next maintenance schedule
3			Bare, exposed / taped cable lugs; shall be properly insulated in the next maintenance schedule to minimize risk

13.3 SAFETY ISSUES AND UPKEEP : MECHANICAL

No	Location	Image	Comment
4	Hot Air Fan		One groove is missing a belt

No	Location	Image	Comment
5	Sorter Machine		Poor belt condition
6	CTC Cut 3		One groove is missing a belt
7	Coal Dumping Yard		Open coal dumping / storage yard Covered storage shall be opted for to prevent moisture pickup from the ambient / due to rains

13.4 SUMMATION

- It is mandatory that the safety considerations are given due importance and priority and resolved at the earliest.
- It is felt that safety can at times result in energy saving by way of uninterrupted production.
- Hence this suggestion.

14 INSTRUMENTS USED

14.1 ELECTRICAL PARAMETERS – 2 INSTRUMENTS

1) 3 Power ϕ Quality Analyzer

2) Clamp - on Power Analyzer

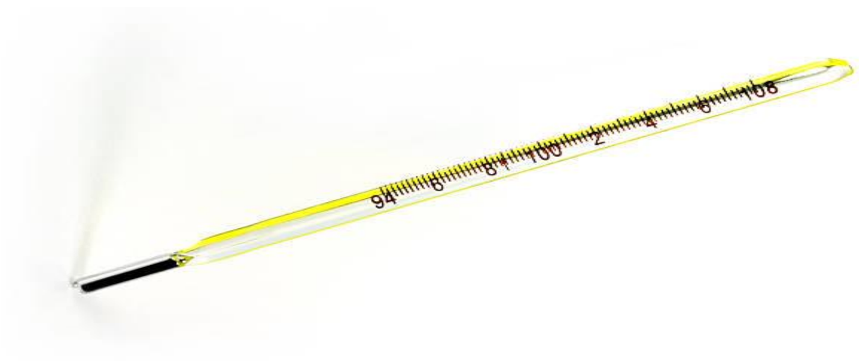
14.2 THERMAL PARAMETERS – 5 INSTRUMENTS

1) Thermal Imager

2) Thermo Hygrometer

3) Digital Thermometer

4) Sling Psychrometer



5) Mercury in Glass Thermometer

14.3 FLOW PARAMETERS – 1 INSTRUMENT

1) Vane Type Anemometer

END

CAG
Citizen consumer and civic Action Group

No.103 (First Floor), Eldams Road, Teynampet,
Chennai 600 018
T: +91(44) 2435 4458 | 2435 0387

www.cag.org.in

@CAGChennai