Detailed ENERGY AUDIT REPORT

Leelagarh Tea Factory

CAG
Citizen consumer and civic Action Group

Detailed Energy Audit Report on Leelagarh Tea Factory

Leelagarh Tea Estate Workers Co - operative Society Ltd,

P.O. Bijoy Nagar, Sabroom, Tripura (South)

October 2024

CAG
Citizen consumer and civic Action Group

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About CAG

Citizen consumer and civic Action Group (CAG) is a 39 - 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. Ratan Kumar Hazari, Manager, Leelagarh Tea Estate Workers Co - operative Society Ltd, Bijoy Nagar, Sabroom Dt** who rendered all necessary technical and manpower support towards the execution of this assignment.

The unstinted cooperation and encouragement offered by **Mr.Pradeep Majumdar, Factory In - charge** is very much acknowledged as he was instrumental in the flawless execution of field work by one and all concerned.

Further, **Mr. Ranjit Debnath,** Electrician, **Mr.Prasanjit Dhar,** Fitter and **Siba Prasad Nath** deserve 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*** **Leelagarh 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 savings 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, Twist, 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 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 Leelagarh Tea Factory is owned and operated by the Tea Estate Workers Co - operative Society and has kick started the production in the year **2002**.
- Located in in the southern part of Tripura in Bijoy Nagar, Sabroom Dt, the factory has a total built up area of **10 000 sq. ft** and manufactures CTC (Crush, Twist & curl) tea for which it uses both electrical and thermal energy.
- The factory has its own tea estate covering an area of 137.4 acres that cater 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 during the period **Sep 23 to Aug 24** is **1.42 lakh kWh**. Since tea manufacturing is a continuous process, 2 Diesel Generators are put into service to supply power whenever the FEDCO (Feedback Distribution Company, DISCOM of Tripura) supply fails. However, the DG sets are sparingly used (in terms of diesel consumed / units generated) and its 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 electricity drawn through is FEDCO **₹ 9.62 / 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 recommendations is **₹ 7.73 / kWh** (accounting only for the kWh charges as a realistic estimate).
- The fuel used for producing thermal energy is Coal which is sourced from the state of Meghalaya. The 2 year average quantity of coal consumed is **320 tons / y** costing close to **₹ 52 lakhs.**

SPECIFIC ENERGY CONSUMPTION

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

- The study revealed the following figures for this factory.
  - Electrical = **0.61 kWh / kg** of Made Tea
  - Thermal = **32.5 MJ / kg** of Made Tea (equivalent to 1.38 kg coal / kg of Made Tea with a coal GCV of 5 645 kcal / kg or 23 600 kJ / kg)
- As the basic raw material is green leaves, the specific energy consumption has been computed w.r.t green leaves also and presented below :
  - Electrical = **0.127 kWh / kg** of green leaves
  - Thermal = **6.84 MJ/kg** of green leaves (equivalent to **0.29 kg** of coal / kg of green leaves)
- 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 (13 & 14) by the Energy Audit Team.
- The study details out the Cost & Energy saving opportunities identified in various sections of the tea production and indicate the economic viability of each.
- The cost conservation proposals can be taken up for implementation at the earliest as the investment needed is either nil or meagre.
- The cost saving proposals made are quite simple to understand, easy to implement and are capable of saving cost right earnestly upon implementation.
- Hence these recommendations.

Table 1: Cost Conservation Proposals [C C Ps] Identified : 3 Nos

CCP No	Cost Conservation Proposals	Cost Savings ₹ / y	Invest ₹	Payback Period Months
1	Switching over to Chipped Wood from the Coal as the source of Thermal Energy for combustion in the furnace to cut down on the cost of coal paid towards the drying operation	1695 497	400 000	3

2	Rationalization [Reduction] of Contracted Demand of the H T 2 Service Connection with a view to optimize the demand charges payable to TSECL	50 400	Nil	Immediate
3	Installation and commissioning of 85 kW_p On - Grid Solar Roof Top PV Power Plant adopting "RESCO" model towards attaining self - sufficiency in energy requirement in a sustained fashion as well going Green	400 000	Nil	Immediate
Total		2145 897	400000	< 3

Table 2: Energy Conservation Proposals (E C Ps) Identified : 8 Nos

ECP 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	**16 250**	**Meager**	Immediate
2	Downsize and Usage of Energy Efficient Motors in the Rotor Vane of C T C Section aiming for reduced energy consumption and improved P F and thereby cost savings	**11 595**	**40 000**	**42**
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	**1 04 650**	**100 000**	**12**
4	Usage of Variable Speed Drive or Dual Speed Motor for the operation of the ID Fan of the coal furnace towards flue gas exit in order to achieve efficient combustion of coal in the furnace (by way of optimizing the excess air level requirement in combustion) and save on coal consumption.	**1 04 650**	**75 000**	**9**
5	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	**13 920**	**35 000**	**30**
6	Downsize and Usage of Energy Efficient Motors in the Drier/ Sorting Section aiming for reduced energy consumption and improved P F and thereby cost savings	**16 233**	**60 000**	**44**

ECP 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 saving in electricity	69 570	75 000	13
8	Replacement of existing 75 W Conventional Ceiling Fans with Energy Efficient 30 W "**BLDC**" Fans for the sake of energy / cost conservation	2 230	5 000	27
Total		3 39 098	390 000	14

HIGHLIGHTS

- **The specific energy consumption on electricity front appears 15 - 20 % 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 1.38 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 ₹ 21 lacs / y which is about 30 % 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, 8 Energy Conservation Proposals [ECPs] have been identified that are capable of dishing out a cost saving of ₹ 3.4 lakhs / y with an one - time investment of ₹ 3.9 lakhs only. The Return on Investment [RoI] works out to only 14 months.**

CONSOLIDATION

No of Conservation Proposals		Electricity Savings kWh / y	Cost Savings ₹ / y	Invest ₹	P P Months
Cost CCPs	Energy ECPs				
3	**8**	**16 800**	**24 84 995**	**7 90 000**	**4**

Overall Reduction

1) Electrical Energy : **11.8 %**
2) Electrical Energy Cost : **9.2 %**
3) Thermal Energy Cost. : **40.6 %**
4) Overall Cost Savings : **40.8 %**

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

1 INTRODUCTION

1.0 PREAMBLE

- Leelagarh Tea Factory is run by Tea Estate Workers Co-operative Society that had started its operation [tea production] in the year 2002
- The factory has its own tea estate covering an area of 137.4 Hectares.
- The total built up area of the factory is 10 000 sq ft.

2.0 GREEN LEAVES PROCUREMENT & TEA PRODUCTION

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

1) Leaf Grade

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

2) Dust Grade

i.	Pekoe Dust	(P D)
ii.	Dust	(D)
iii.	Fine Dust	(F D)

- The factory typically operates for 260 to 280 days in a year - leaving out the lean season period - with 12 working hours in a day [6 am to 6 pm].
- The average annual operating period has been computed as 3 000 hours on the conservative side.
- The factory provides direct employment to 20 workers and indirectly, to more than 100.
- The green leaves processing capacity is **3 500 to 4 000 kg / day** resulting in a Made Tea production of **800 to 900 kg / day.**
- Thus, the annual production of Made Tea works out to **2 50 000 kg**
- The quality of tea leaves obtained from the tea garden is good and hence the tea produced is also equally good and fetches a reasonably high rate in tea auction

Fig 1.1 : Leelagarh Tea Factory Premises | 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 two High Tension Service Connections.
- Additionally, the factory has 2 Diesel Generator (DG) 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 typically made to operate 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 carrying out the 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 also been collected from the factory personnel during the audit.
- 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.
- 11 Cost and Energy Conservation Proposals have been identified and elaborated in the ensuing Chapters 9 & 10 respectively.
- An overall cost reduction of 40.8% is anticipated that will demand a one - time investment of ₹ 8 lacs and fetch an annual return of ₹ 24.8 lakhs perennially.
- The RoI is 4 months and the Carbon Foot Print reduction shall be 100 tons of CO_2 / y if solar power drawl is also resorted to.

Fig 1.2 : Start - Up Meeting with the Plant Manager | CAG

5.0 SALIENT FEATURES

- The salient features gathered in respect of this tea factory are summed up below :

Table 1.1 : Salient Features : Leelagarh Tea Factory

Name / Address of the Factory	:	Leelagarh Tea Estate Workers Co-operative Society Ltd, P.O. Bijoy Nagar, Sabroom, Tripura
Key Officials	:	1) Ratan Kumar Hazari - Manager 2) Pradeep Majumdar - Factory In charge 3) Ranjit Debnath - Electrician 4) Prasenjit Dhar - Fitter 5) Siba Prasad Nath - Staff
Year of Establishment	:	2002
Total Factory Area	:	10 000 sq ft
Total Estate Area	:	137.40 hectares
Type and Grades of Tea Manufactured	:	CTC tea a) **Leaf Grades**: BOP (L), BOP (S), BOP, BP, BP (S), Orange Fannings b) **Dust Grades:** P D, D, FD
Number of Full Time Workers	:	20
Factory Operating Period	:	260 to 280 days in a year (Jan, Feb and March: Nil production)
Operating Time	:	12 h / d [6 am to 6 pm] and 3 000 h / y
Green Leaf Processing Capacity	:	3500 to 4000 kg / d
Made Tea Production Capacity	:	2.5 lakh kg / y
Thermal Energy Source	:	Coal procured from Meghalaya Mines
Electrical Energy Sources	:	• 2 H T SCs from FEDCO (A private DISCOM in Tripura) for factory & 1 SC for irrigation in the tea garden • Diesel Generator Sets during power outages

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 leaves into small, uniform 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: Green Tea 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.
- Leelagarh Tea Factory produces only CTC 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 demands both thermal and electrical energy.
- There are 8 major operations involved in the production of CTC tea and 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 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:

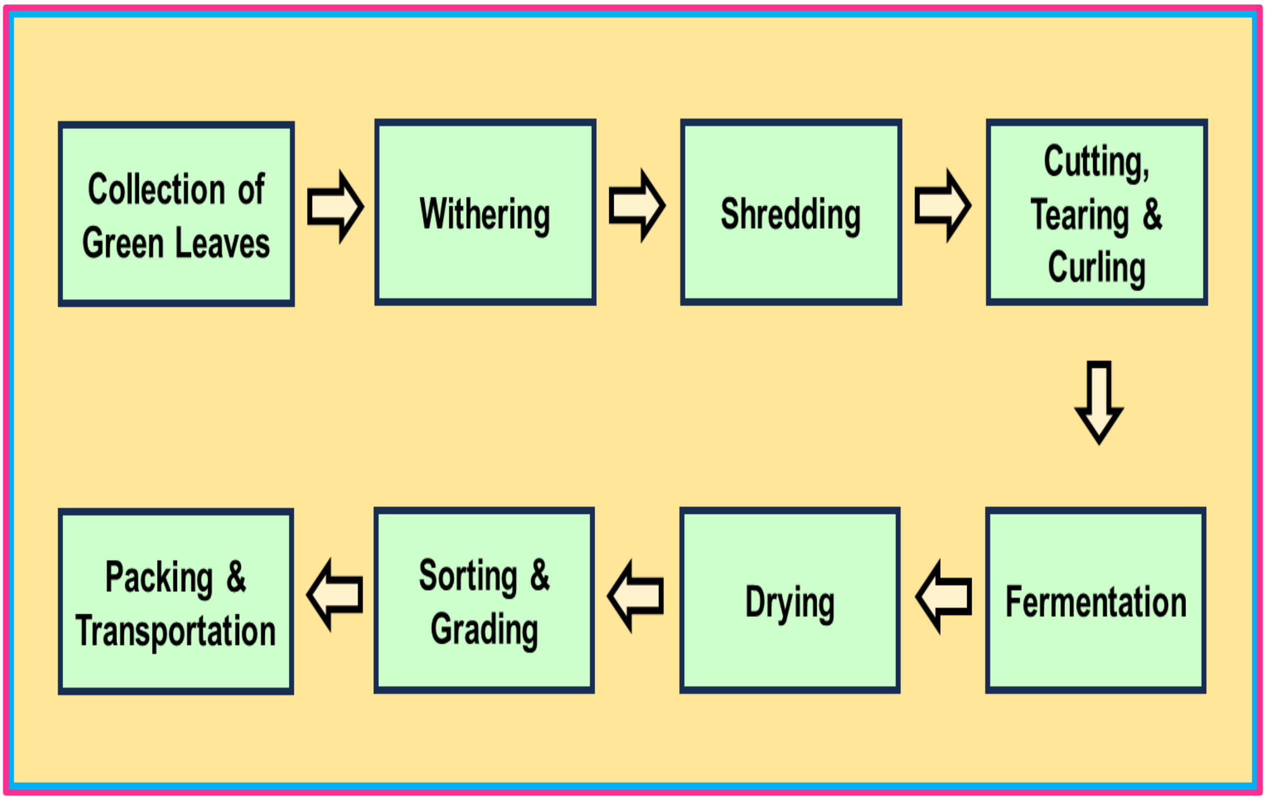


Fig 2.1 : Tea Production Process : Typical Flow Chart | CAG

- Of these 8 processes involved, chemical changes occur primarily In Withering, Fermentation & 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 137.40 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 the demand, their primary focus remains on processing their homegrown leaves. Plucking of green leaves is primarily done by hand.

Fig 2.2 :Tea Leaves getting Unloaded From Truck | 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 6 to 8 hours for withering depending on the season. There are 3 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 the factors like 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 (two blowers per trough) to ensure effective air supply and thereby moisture removal. Thus, there are 6 Withering Fans installed for 3 troughs.
- The fans have a power rating of 5 hp each with an air flow rate of 35 000 cfm.
- The pictorial presentation of Withering Troughs is depicted below:

Fig 2.3 : Withering Troughs Employed | CAG

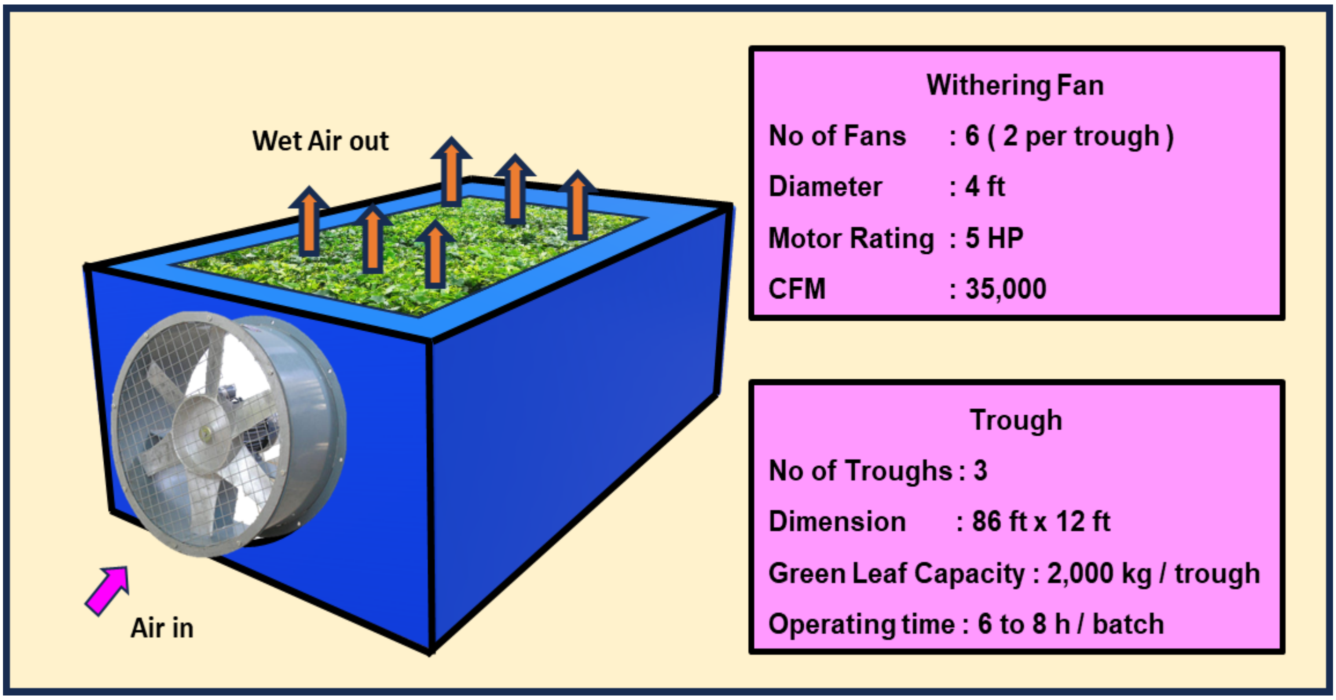


Fig 2.4 : Withering Troughs : Layout and Technical Specifications | CAG

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 machine - employing 4 roller machines (4 cuts) are used.
- 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 Rotary Vane, 3 Nos of CTC roller motors have power rating 20 hp. The 1st cut has a motor with a power rating of 25 hp. The Blower and Ghoogy Motors have power ratings 1 hp & 1.5 hp respectively.
- The CTC Line has a green leaf handling capacity of 600 kg / h.
- The typical lay out and a pictorial view of CTC Line are shown in Fig 2.5 & 2.6 respectively.

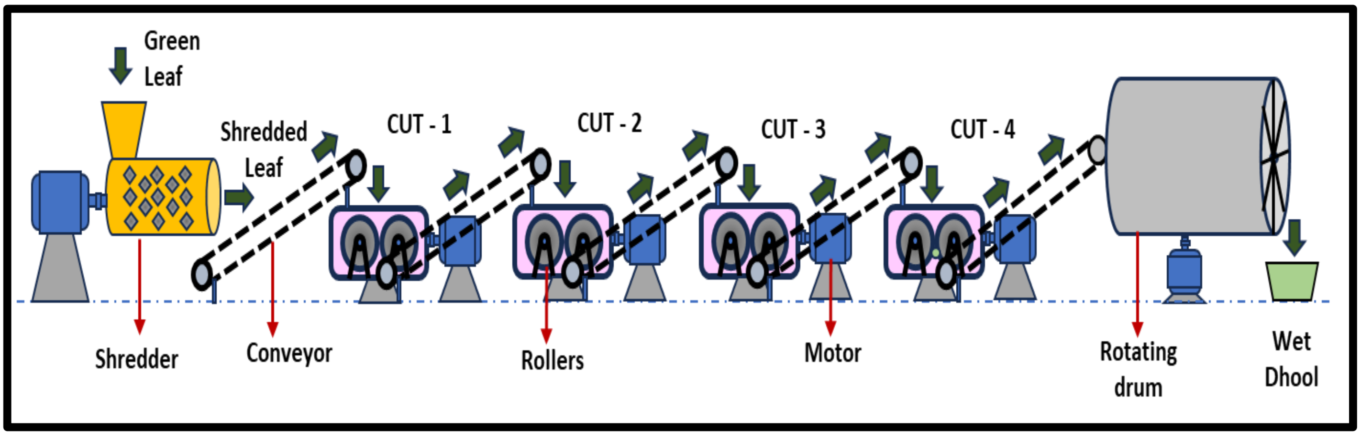


Fig 2.5 : CTC Machines : Typical Layout | CAG

Fig 2.6: CTC Machine: A Pictorial View | CAG

CTC machine

Capacity : 600 kg / h (Green Leaf)

No of cut : 4 cut

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 : 1 hp

Ghooghy : 1.5 hp

Fig 2.7 : CTC Machine : 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.
- In this factory, natural floor fermentation is resorted to, in which the rolled leaves are spread over the floor and humidifier fans (9 numbers each with a power rating 0.5 hp) are operated to maintain the humidity of the rolled leaves.

Fig 2.8 : Adoption of Natural Floor Fermentation | CAG

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 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 120°C.
- The quality of tea produced strongly depends on the drying technique practiced and the final moisture content of the product.
- 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.
- Normally, the fermented dhool entering the drier has a moisture content of 70 % and the final product coming out of drier i.e., drier mouth tea contains 3 % to 4 % moisture.
- 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 power rating of 15 hp and a tray carrying Conveyor Motor of 5 hp.
- Further, 2 fans (one FD Fan and one ID Fan) are used in coal combustion in the furnace that have a power rating of 2 hp and 7.5 hp respectively.
- On the thermal side, coal is burned for generating hot air for tea drying. The specific coal consumption is around 1.2 to 1.4 kg of coal 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.

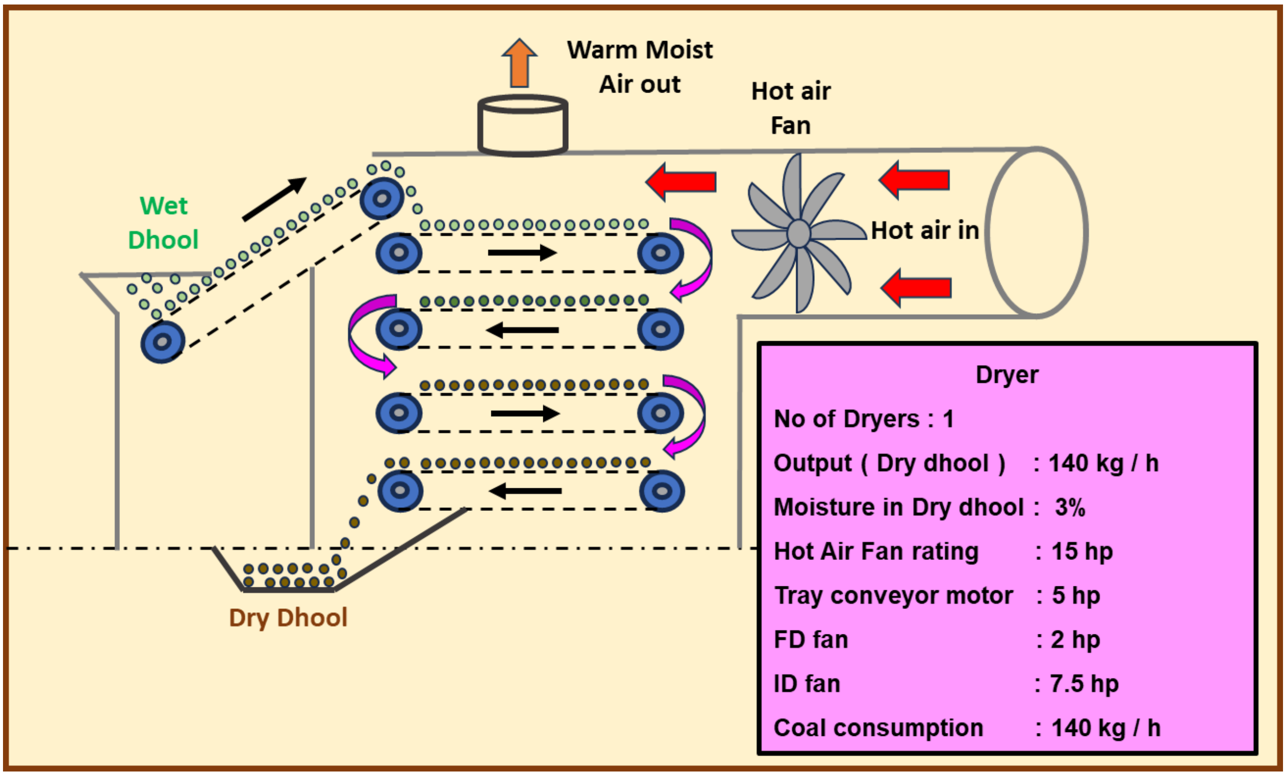


Fig 2.9 : Tea Drier : Layout and Technical Details | CAG

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

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

Fig 2.12 : Smoke Emanating from the Chimney of the Furnace | 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 various sized meshes.
- Different grades of tea are obtained by passing the DMT through these meshes in a sequential fashion.
- Sorting machines require several small motors to power the vibration of the meshes and as well the movement of conveyors.
- In this factory 5 to 6 motors of each rating 2 hp are employed in the sorting machine

Sorting machine

No of motors : 7

Motor rating : 2 hp x 5 no's

1 hp x 2 no's

- 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 2.13 : Sorting Section : A Pictorial View | 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
	BPS	Broken Pekoe Souchong	18 to 20
	PEKOE	Pekoe	20 to 22
	BOP - L	Broken Orange Pekoe (Large)	22 to 23
	BOP	Broken Orange Pekoe	23 to 25
	BOP - S	Broken Orange Pekoe (Small)	24 or 26
	BP	Broken Pekoe	24 or 26
	BP - 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 2.14 : Different Grades of Tea: A Pictorial Representation | CAG

2. 7 PACKING & TRANSPORTATION

∉ Made Tea, the final product ,thus produced is packed (based on their grades) in food grade quality bags and transported for auction / sale.

Fig 2.15 : Packing Section | CAG

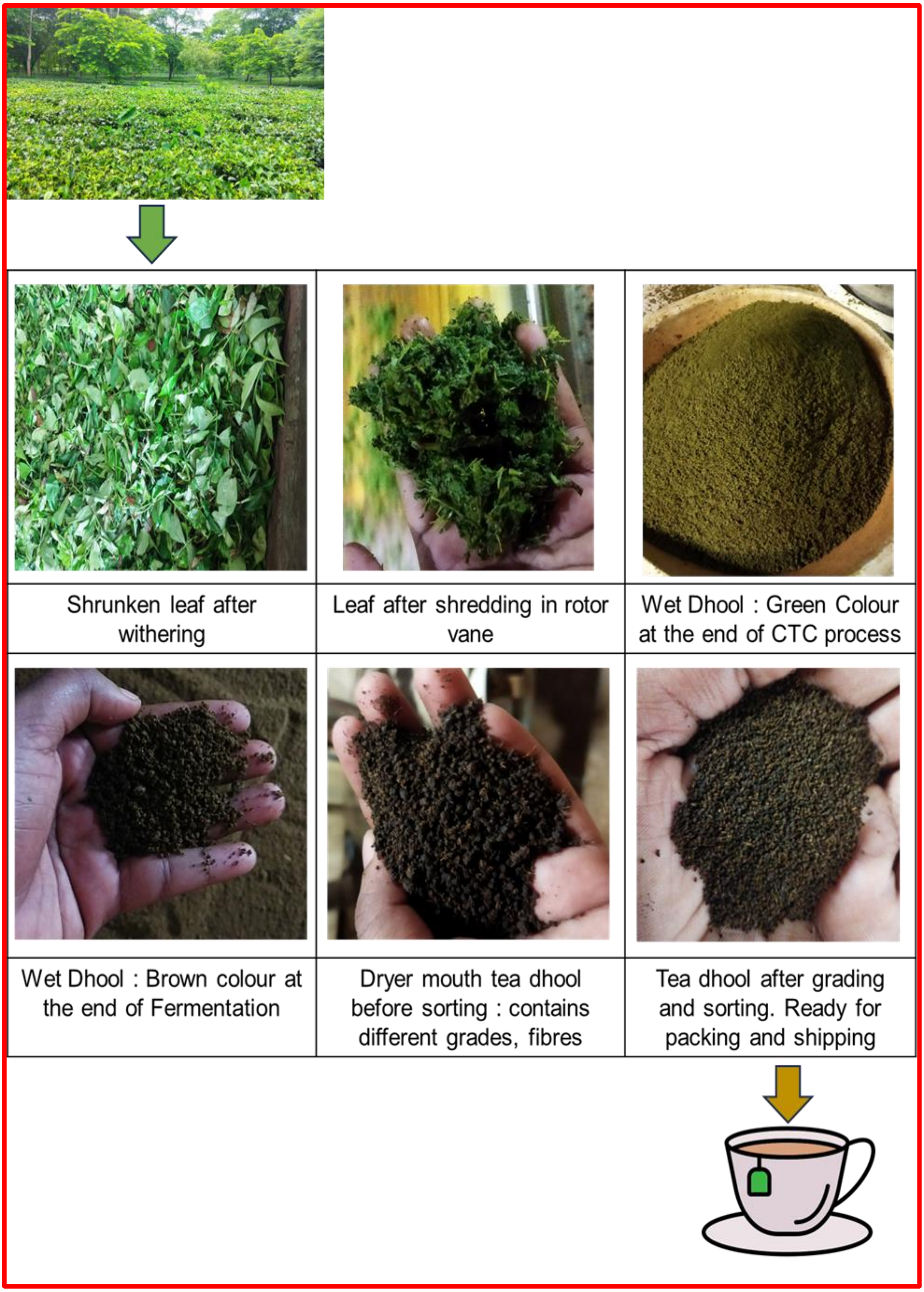


Fig 2.16 : From Garden to Cup : Tea Leaf Transformation Process | CAG

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 : 6 [2 per trough] Motor Rating : 5 hp each Diameter : 4 ft Air Delivery : 75 000 cfm	6 [30]
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 : 1 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 Ghooghy : 1.5 hp 7 Motors : cumulative power rating of 107.5 hp	7 [107.5]
3	Fermentation - Humidifier Fans	No of Humidifier Fans : 6 Power Rating : 1.5 hp each	6 [9]

No	Process Equipment	Specifications	No of Motors / [Total Rated hp]
4	Dryer	Dryer 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 : 5 hp ID fan for Coal Furnace : 7.5 hp FD fan for Coal Furnace : 2 hp Coal Consumption : 190 kg / h	4 [29.5]
5	Sorter	Number of Motors : 7 Rating : 5 Nos x 2 hp each 2 Nos x 1 hp each	7 [12]
6	Water Pump	Submersible Pump : 1 No Power Rating : 1 hp	1 [1]
Total			31 [189]

- Thus, it can be seen that there are 5 major sections / equipment involved directly in tea processing.

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 FD 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 (DG) 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 2 HT Service Connections [S C] for carrying out the tea production operation. The details are as below:

Table 3.1: Service Connection Details

<table>
<tr><th>No</th><th>Service Connection</th><th>Consumer No</th><th>Old A/c No.</th><th>C D kW</th><th>Energy Charges ₹ / kWh</th><th>Demand Charges ₹ / kW / m</th></tr>
<tr><td>1</td><td>H T 1</td><td>1068030480258900392</td><td>000220000101</td><td>40</td><td rowspan="2">7.73</td><td rowspan="2">105</td></tr>
<tr><td>2</td><td>H T 2</td><td>1068030480259005857</td><td>000220000102</td><td>118.4</td></tr>
</table>

- The electrical distribution system of the factory is schematically shown in Fig 3.1

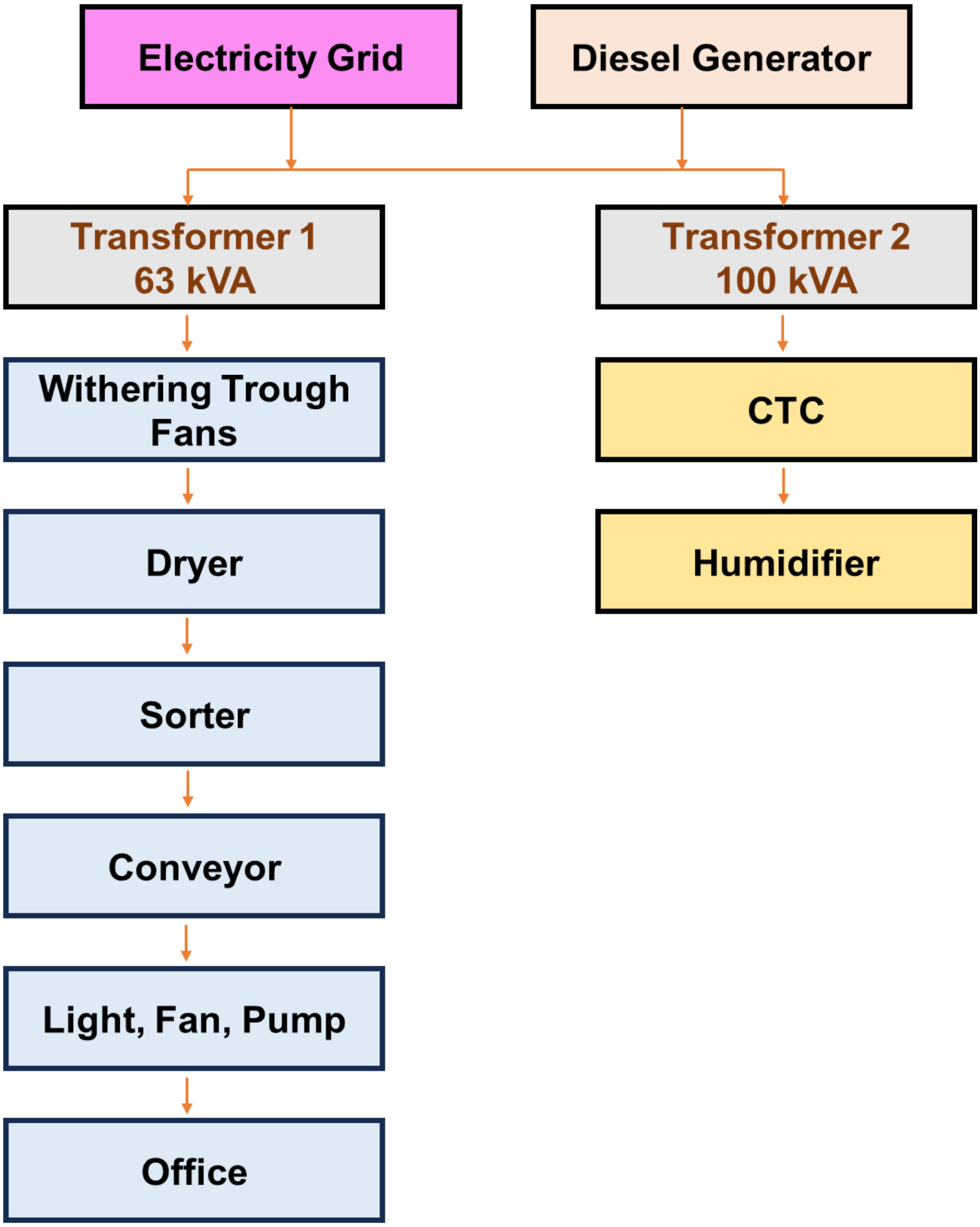


Fig 3.1 : Electrical Distribution System : An Overview | CAG

- 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.

Table 3.2 : Electricity Consumption (Sep '22 – Aug '23)

No	Month	Energy Consumption kWh	
		H T 1	H T 2
1	Sep 22	7 463	8 607
2	Oct	9 176	4 547
3	Nov	6 744	14 133
4	Dec 22	4 220	3 449
5	Jan 23	575.	7 377
6	Feb	318	7 377
7	Mar	1 055	833
8	Apr	3 537	3 171
9	May	2 976	2 347
10	Jun	7 661	5 242
11	Jul	10 527	7 855
12	Aug 23	7 989	8 165
Total		**65 497**	**73 098**

Electricity Consumption (Sep '22 to Aug '23) = 1 38 595 kWh

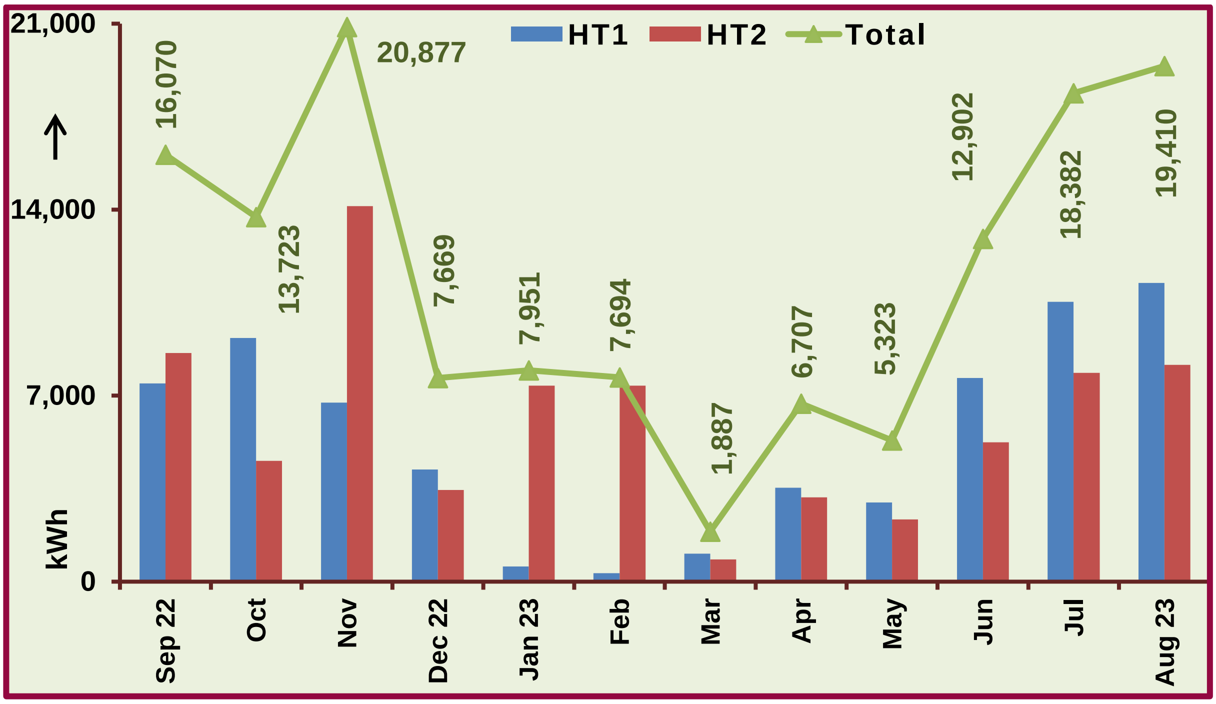


Fig 3.2: Electricity Consumption - Month wise (Sep '22 – Aug '23) | CAG

Table 3.3 : Electricity Consumption (Sep '23 – Aug '24)

No	Month	Energy Consumption kWh	
		HT1	HT2
1	Sep 23	8 113	7 613
2	Oct	8 359	6 666
3	Nov	4 515	7 022
4	Dec 23	2 749	4 532
5	Jan 24	5 208	6 073
6	Feb	837	98
7	Mar	3 383	3 493
8	Apr	3 498	4 368
9	May	4 736	9 937
10	Jun	8 442	5 504
11	Jul	10 557	10 811
12	Aug 24	14 381	1 336
Total		**74 778**	**67 450**

Electricity Consumption (Sep '23 to Aug '24) = 1 42 228 kWh

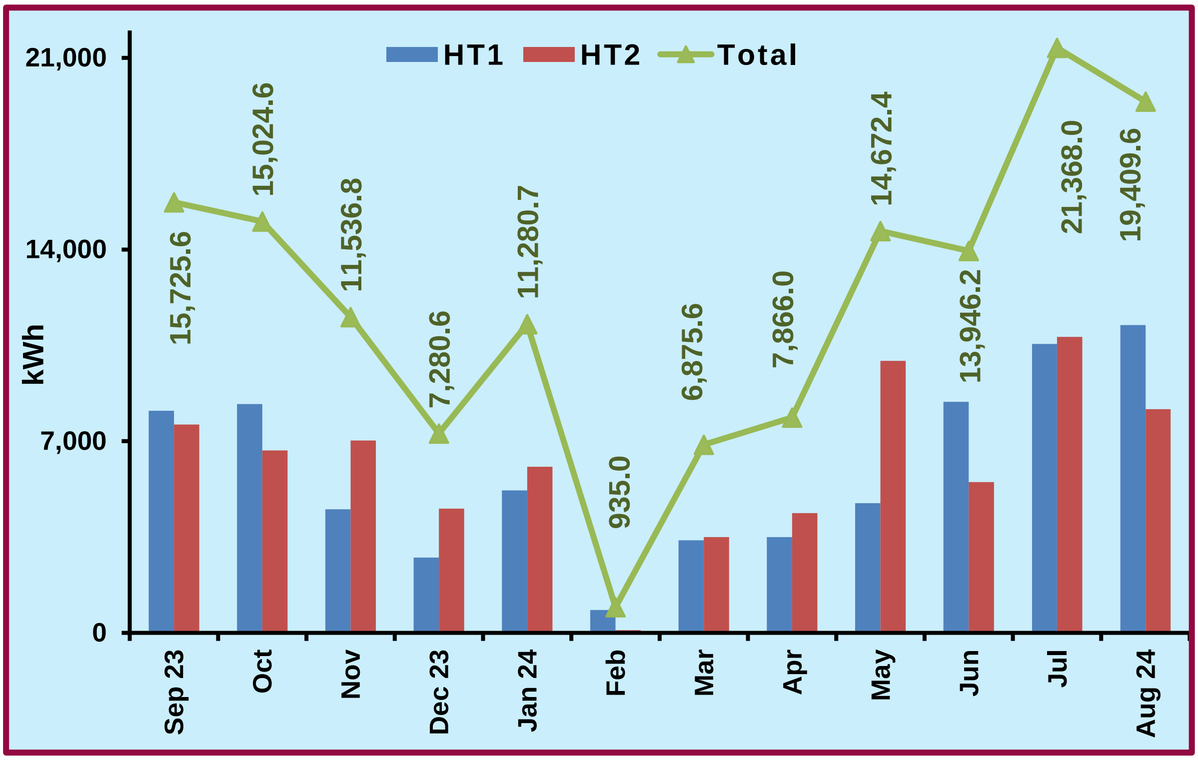


Fig 3.3: Electricity Consumption - Month wise (Sep '23 – Aug '24) | CAG

- 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. The electricity generated, operating hours and the corresponding diesel consumption details obtained on monthly basis are presented below.(Table 3.4 & 3.5)

Table 3.4 : Electricity Generation: DG Set (Sep '22 – Aug '23)

No	Month	Diesel Consumption litres	Operating Period h	Energy Delivered kWh
1	Sep 22	587	34.4	34.7
2	Oct	192	13.4	13.7
3	Nov	171	12.1	12.1
4	Dec 22	159	15.4	15.6
5	Jan 23	-	-	-
6	Feb	-	-	-
7	Mar	55	3.5	3.8
8	Apr	229	15.4	15.6
9	May	223	17.1	17.0
10	Jun	374	27.4	27.6
11	Jul	315	18.3	18.5
12	Aug 23	435	25.3	25.5
Total		**2 740**	**182**	**184**

Table 3.5 : Electricity Generation: DG Set (Sep '23 – Aug'24)

No	Month	Diesel Consumption litres	Operating Period h	Energy Delivered kWh
1	Sep 23	513	34.6	34.1
2	Oct	254	15.5	15.5
3	Nov	340	20.0	20.2
4	Dec 23	310	18.0	18.2
5	Jan 24	-	-	-
6	Feb	-	-	-
7	Mar	302	79.6	80.2
8	Apr	230	17.4	17.5
9	May	642	44.8	45.2
10	Jun	708	44.2	44.6
11	Jul	627	37.6	37.9
12	Aug 24	877	52.9	53.4
Total		**4 803**	**365**	**367**

- Further, based on our interaction with the factory manager, it was considered justifiable to account for about 45 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 3.6 : Electricity Cost Incurred (Sep '22 - Aug '23)

No	Month	Cost Incurred ₹	
		HT1	HT2
1	Sep 22	62 103.6	79 743.1
2	Oct	75 362.2	47 961.8
3	Nov	56 538.6	1 22 159.0
4	Dec 22	37 003.0	39 462.0
5	Jan 23	8 790.0	69 860.8
6	Feb	7 161.3	69 860.8
7	Mar	12 505.7	21 360.0
8	Apr	31 676.4	37 266.9
9	May	27 374.0	30 930.7
10	Jun	63 636.0	53 335.0
11	Jul	85 819.0	73 562.6
12	Aug 23	91 376.3	75 962.0
Total		**5 59 346**	**7 21 465**

Electricity Cost (Sep '22 to Aug '23) : ₹ 12 80 811

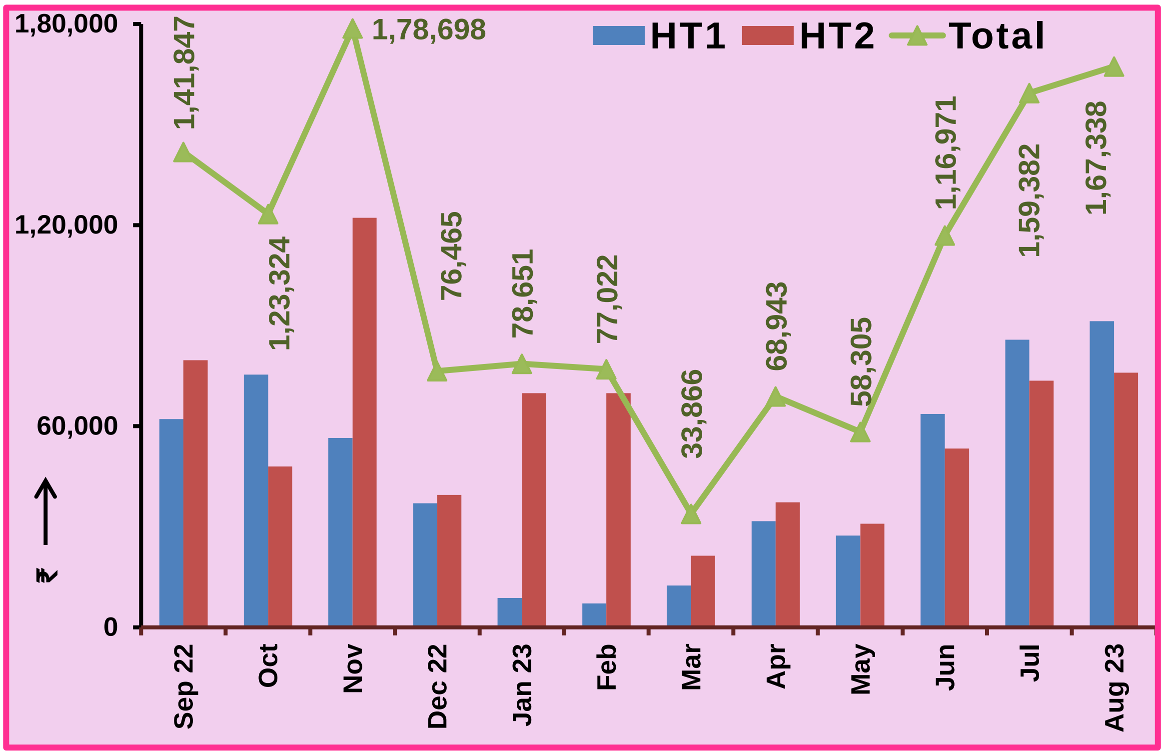


Fig 3.4 : Electricity Cost - Month wise (Sep '22 - Aug '23) | CAG

Table 3.7 : Electricity Cost Incurred (Sep '23 – Aug '24)

No	Month	Cost Incurred ₹	
		HT1	HT2
1	Sep 23	67 134.6	71 689.5
2	Oct	74 016.2	68 793.9
3	Nov	42 073.5	71 753.0
4	Dec 23	26 947.0	49 724.4
5	Jan 24	47 829.4	63 869.5
6	Feb	10 778.6	13 486.5
7	Mar	32 666.9	42 427.0
8	Apr	33 622.5	50 491.6
9	May	43 909.9	95 973.4
10	Jun	74 705.9	59 142.9
11	Jul	92 281.0	1 03 241.1
12	Aug 24	91 376.3	75 962.0
Total		**6 37 342**	**7 66 555**

Electricity Cost (Sep '23 to Aug '24) : ₹ 14 03 897

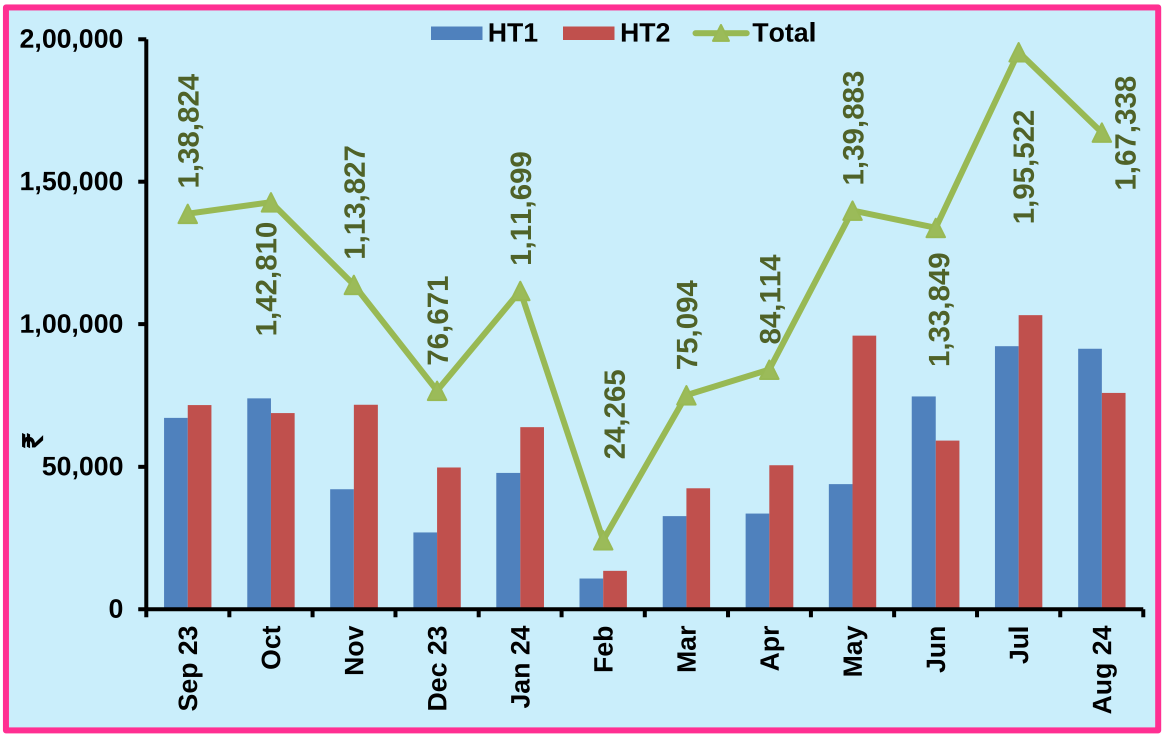


Fig 3.5 : Electricity Cost - Month wise (Sep '23 - Aug '24) | CAG

3.1.3 Cumulation

- The unit cost of electricity has been computed for 2 years considered in our analysis and depicted in Figs 3.6 & 3.7

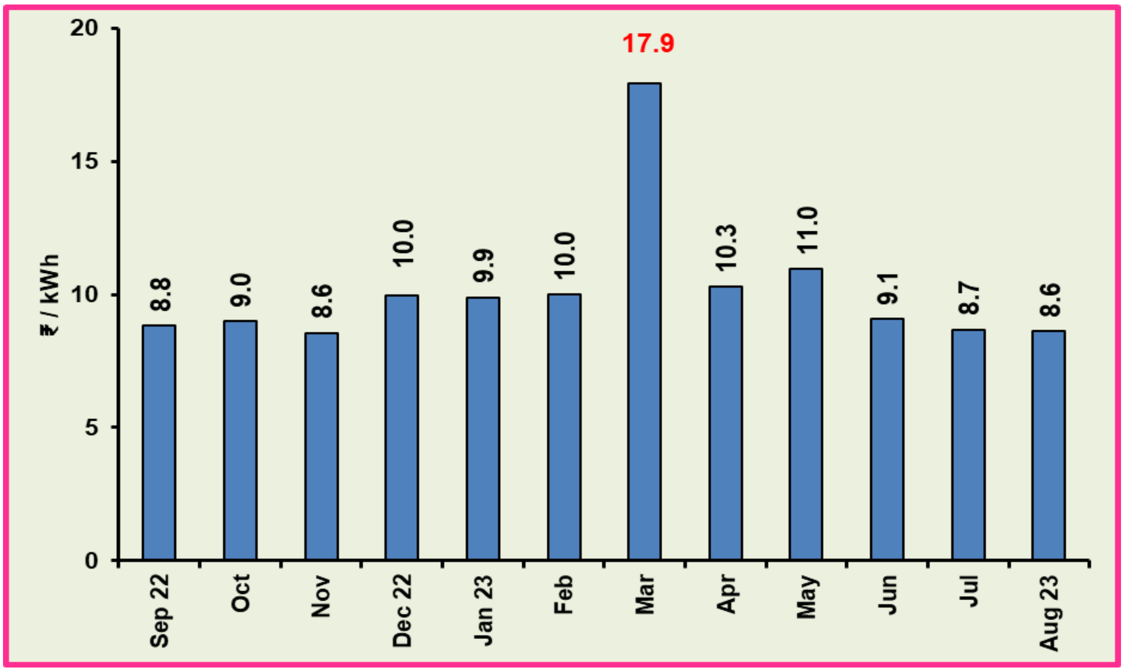


Fig 3.6 : Unit Cost of Electricity: Month wise (Sep '22 - Aug '23) | CAG

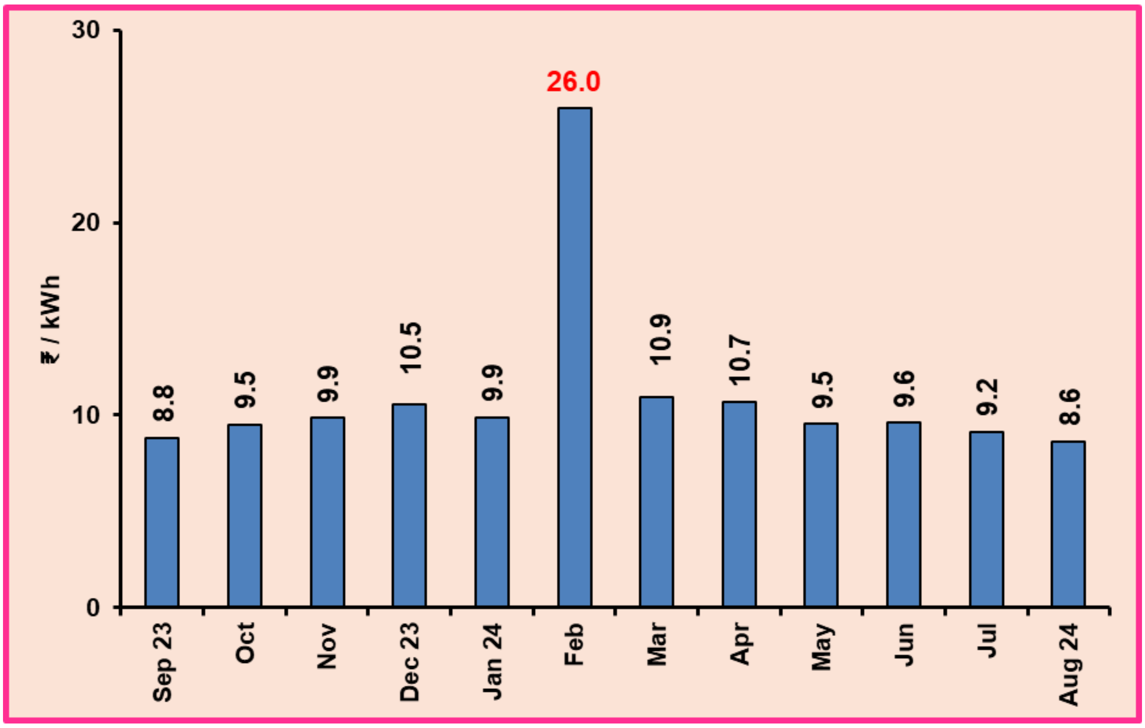


Fig 3.7 : Unit Cost of Electricity: Month wise (Sep '23 - Aug '24) | CAG

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 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 (inclusive of all)	
Service Connection	**Sep '22 – Aug '23**	**Sep '23 – Aug '24**
H T	**9.24**	**9.62**

3.2 THERMAL ENERGY

3.2.1 Coal Consumption

- Coal - procured from Meghalaya - is used for tea drying application in the dryers.
- The consumption details of the coal are depicted month wise in Table 3.8 and presented figuratively in Figs 3.8 & 3.9

Table 3.8 : Coal Consumption : 2 year Period

No	Month	Coal Consumption kg	
		2022 - 23	2023 - 24
1	Sep (22 / 23)	38 953	37 587
2	Oct	39 058	30 449
3	Nov	52 026	32 125
4	Dec	39 990	22 923
5	Jan (23 / 24)	-	-
6	Feb	-	3 396
7	Mar	5 930	14 670
8	Apr	18 905	23 105
9	May	17 420	24 890
10	Jun	34 265	42 400
11	Jul	40 287	38 670
12	Aug (23 / 24)	45 150	37 610
Total		**3 31 984**	**3 07 825**

Coal Consumption : (Sep '22 to Aug '23) : 3 31 984 kg

: (Sep '23 to Aug '24) : 3 07 825 kg

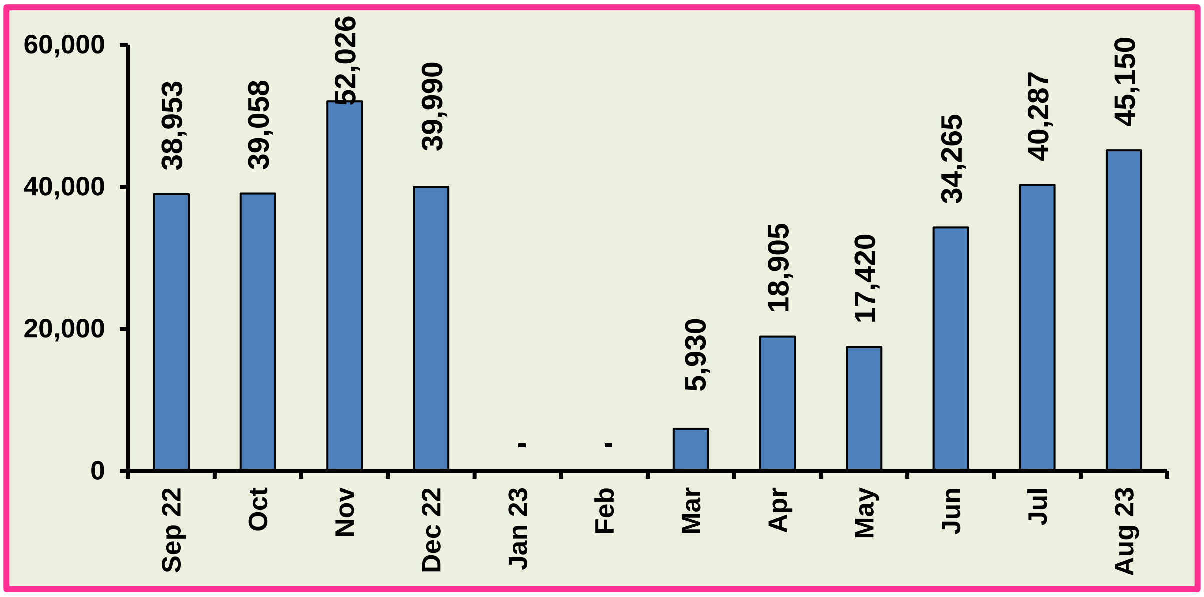


Fig 3.8 : Coal Consumption - Month wise (Sep '22 - Aug '23) | CAG

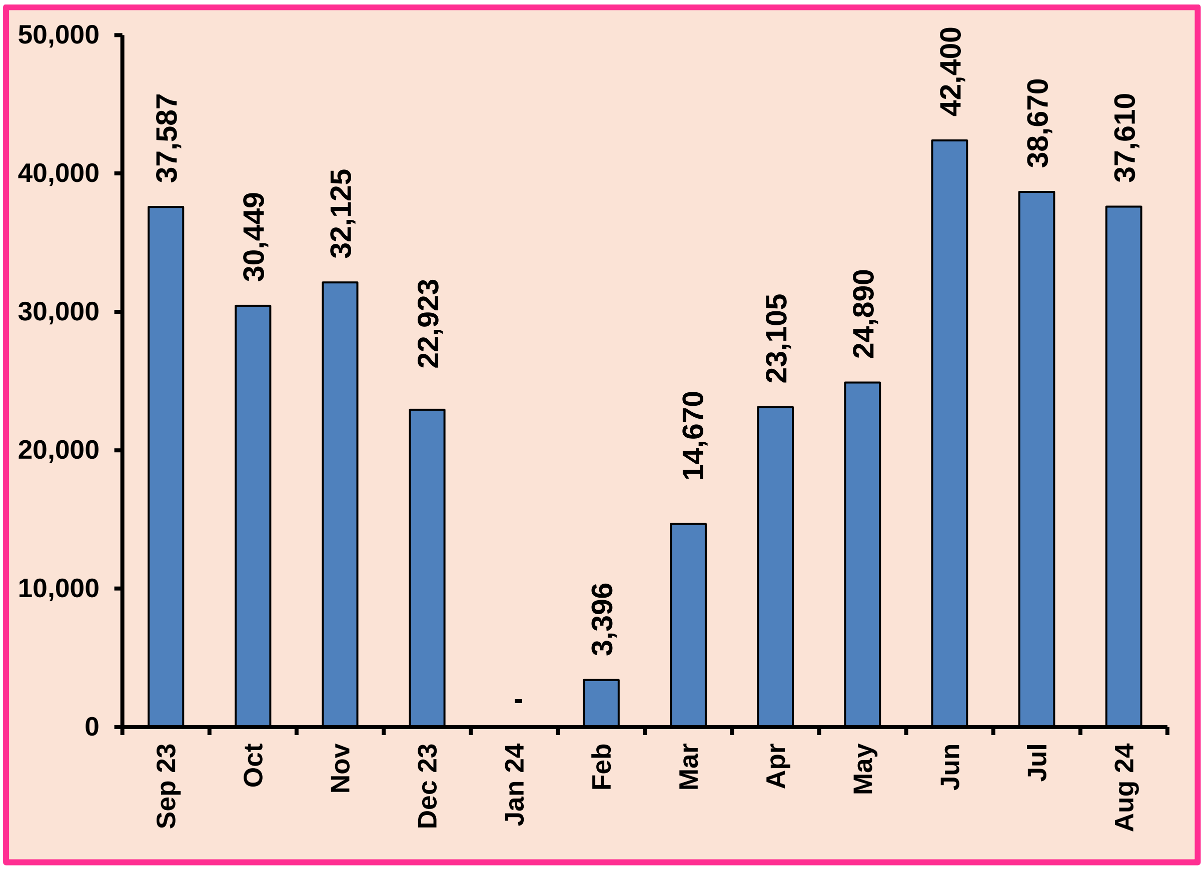


Fig 3.9 : Coal Consumption - Month wise (Sep '23 - Aug '24) | CAG

3.2.2 Cost of Coal 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 **₹ 15 000 / ton** to **₹ 18 000 / 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 3.9 : Coal Cost Incurred : 2 year Period

No	Month	Coal Cost ₹	
		2022 - 23	2023 - 24
1	Sep (22 / 23)	6 50 515	6 65 290
2	Oct	6 17 116	5 38 947
3	Nov	8 22 011	5 68 613
4	Dec	6 31 842	4 05 737

No	Month	Coal Cost ₹	
		2022 - 23	2023 - 24
5	Jan (23 / 24)	-	-
6	Feb	-	45 506
7	Mar	1 07 926	1 96 578
8	Apr	3 44 071	3 09 607
9	May	3 17 044	3 33 526
10	Jun	6 06 491	5 68 160
11	Jul	7 13 080	5 37 513
12	Aug (23 / 24)	7 99 155	5 22 779
Total		56 09 251	46 92 256

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

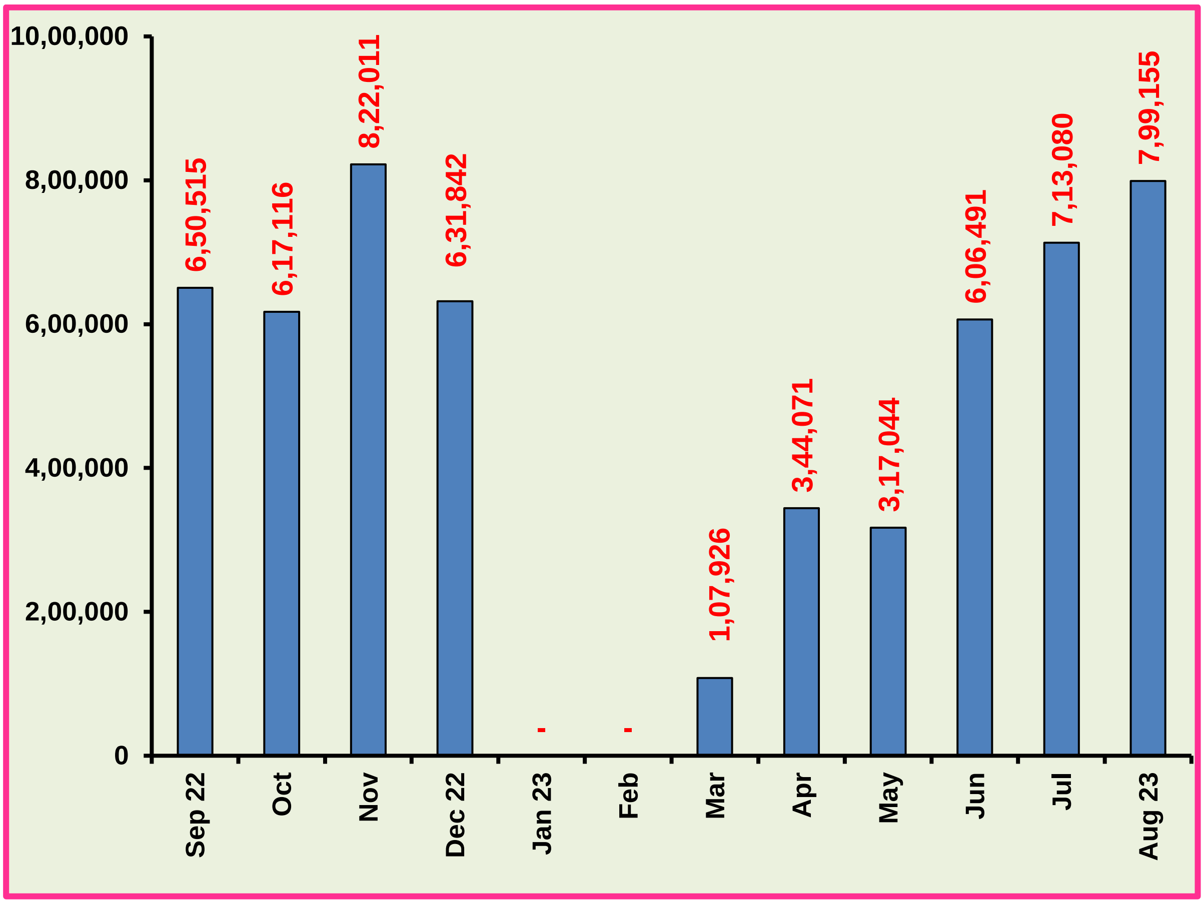


Fig 3.10 : Coal Cost incurred: Month wise (Sep '22 - Aug '23) | CAG

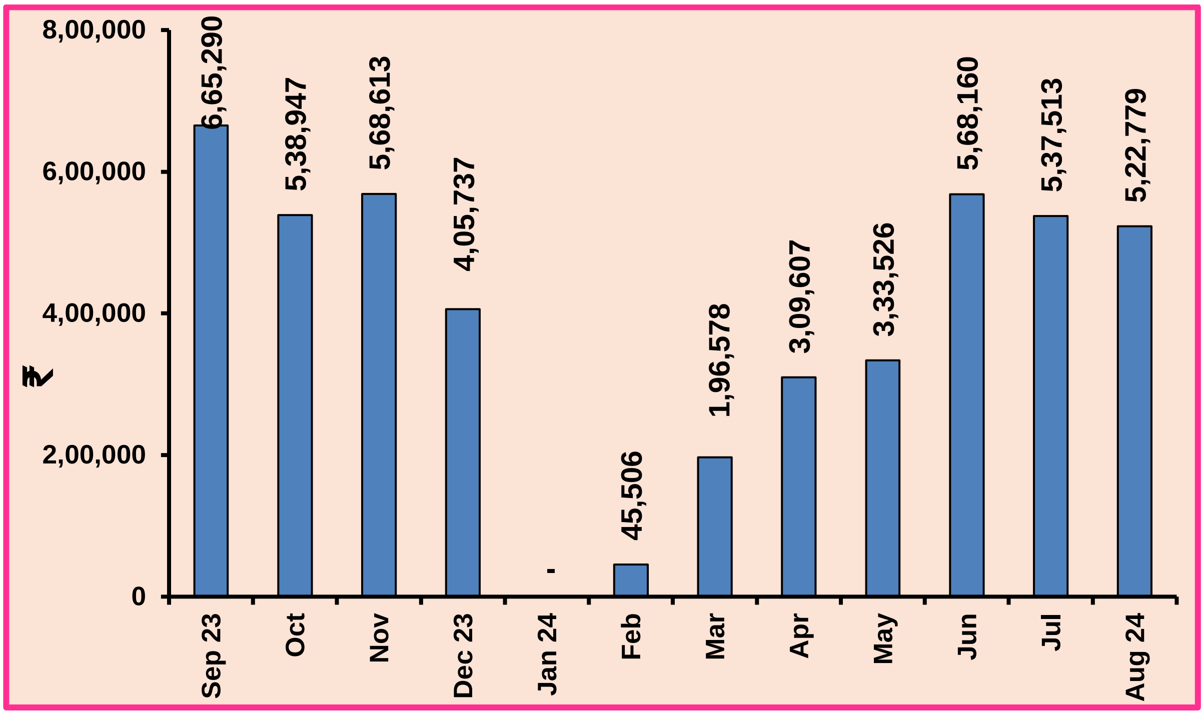


Fig 3.11 : Coal Cost incurred: Month wise (Sep '23 - Aug '24) | CAG

Coal Cost : (Sep '22 to Aug '23) : ₹ 56 09 251

: (Sep '23 to Aug '24) : ₹ 46 92 256

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 3.12 & 3.13

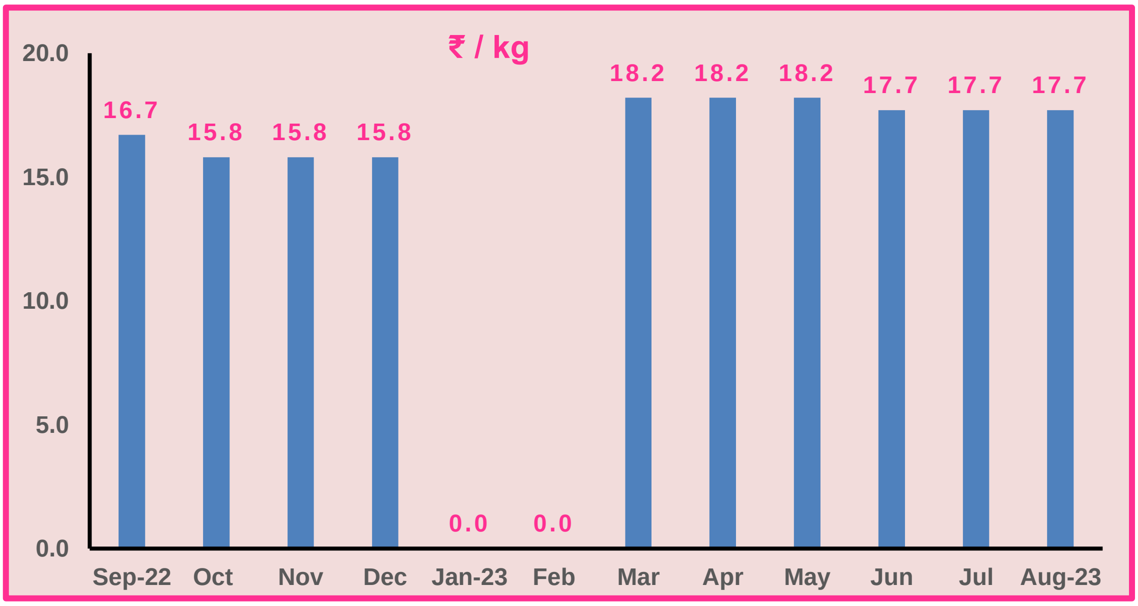


Fig 3.12 : Unit Cost of Coal : Month wise (Sep '22 - Aug '23) | CAG

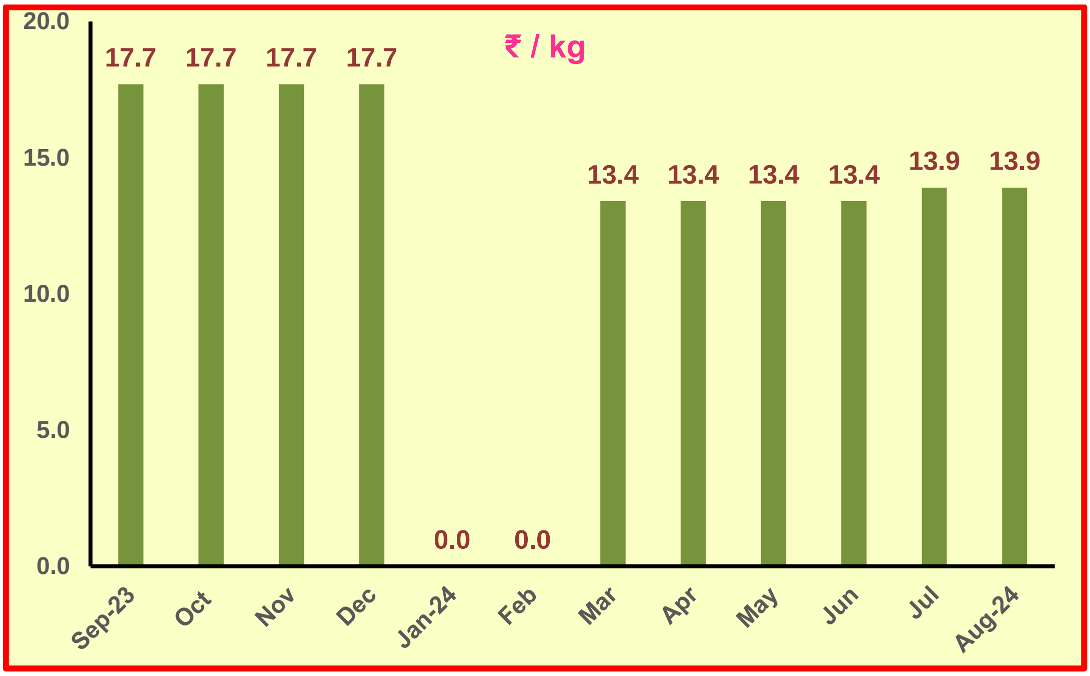


Fig 3.13 : Unit Cost of Coal: Month wise (Sep '23 - Aug '24) | CAG

Average Unit Cost of Coal paid :

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 3.10.

Table 3.10:Energy & Cost Share: Computed :Overall:Avg

No	Type of Energy	Energy		Cost Spent	
		MJ / y	%	₹ / y	%
1	Electricity: FEDCO / TSECL	5 04 753	6.3	13 42 354	20.7
2	Coal from Meghalaya	75 48 510	93.7	51 50 754	79.3
Total		80 53 263	100.0	64 93 108	100.0

- The thermal energy share is as high as 93.7 % of the total while that of the electricity is only 6.3 %. However, the cost spent on thermal energy procurement is 79.3 % and the corresponding cost of electricity is 20.7 %. This information is presented in Fig 3.14.

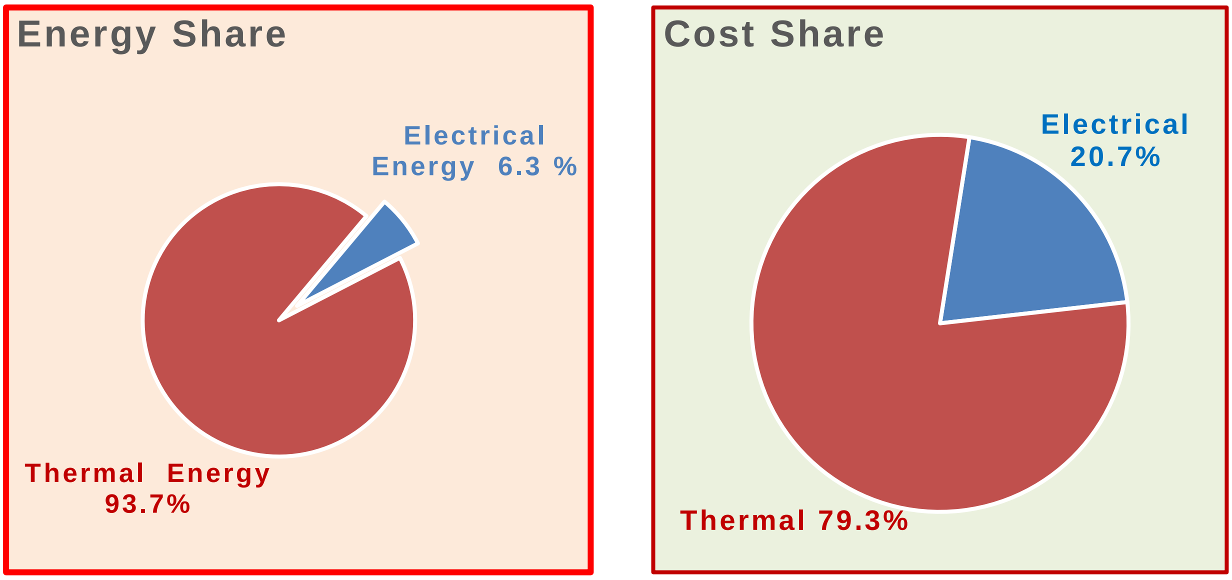


Fig 3.14: Energy & Cost Share: Manufacturing of Tea | CAG

3.4 SUMMATION

- The annual average cost spent on energy procurement (Electricity + Coal) is estimated as **₹ 65 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 a most appropriate one at this point of time .

It is inferred that the factory spends a substantial amount towards procurement of energy, close to **₹ 65 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 = **10 27 254 kg (Sep '22 - Aug '23)**

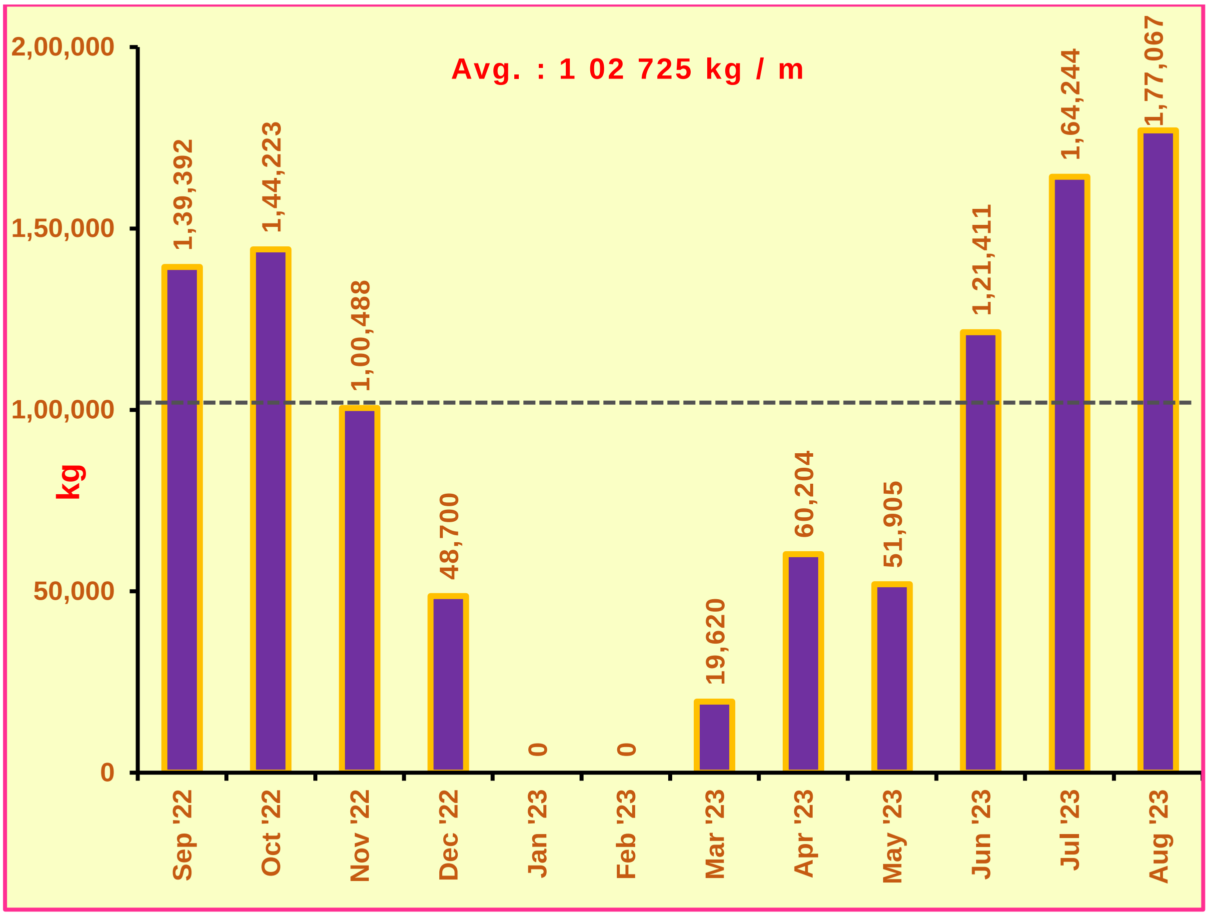


Fig 4.1: Green Leaves Processed: Month wise (Sep '22 - Aug '23) **| CAG**

∉ Green leaves processed = **11 78 544 kg (Sep '23 - Aug '24)**

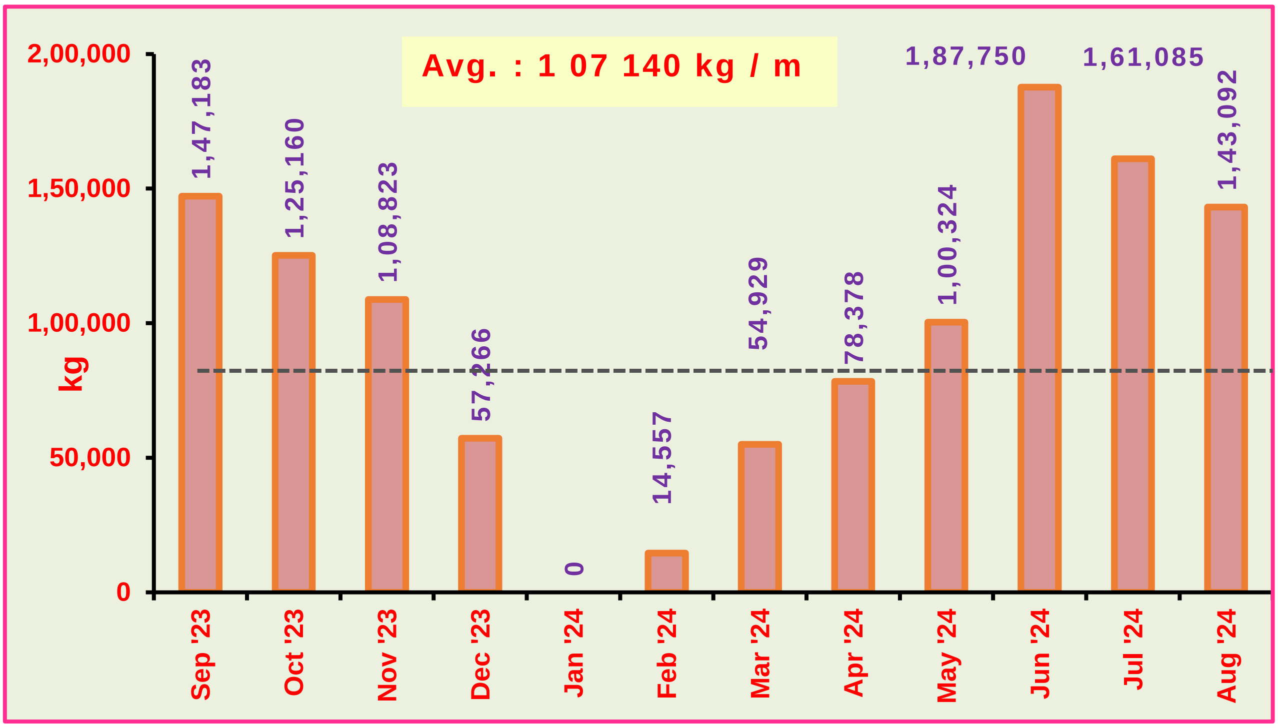


Fig 4.2: Green Leaves Processed: Month wise (Sep '23 – Aug '24) | CAG

- 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 Jun to Oct process the maximum quantity of leaves exceeding 120 tons / m.
- Likewise, the months of Dec - Mar experience minimal arrival of leaves (< 60 tons / m)

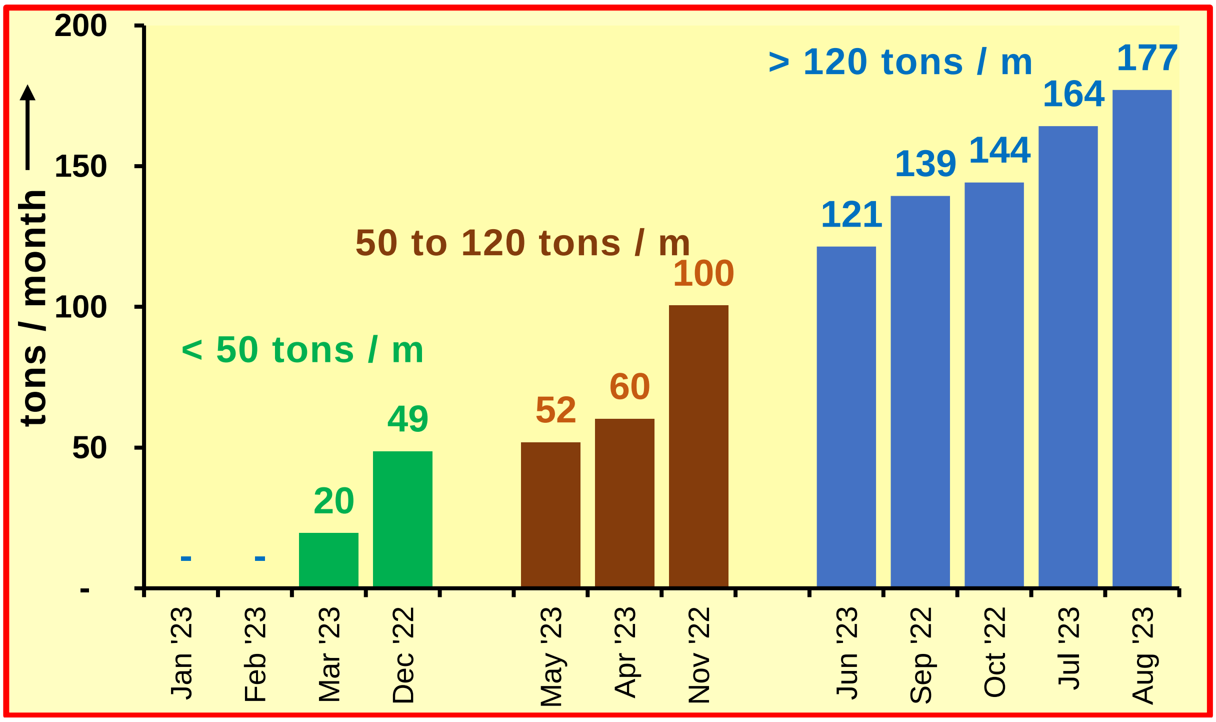


Fig 4.3:Green Leaves Processed :Quantity wise (Sep '22 - Aug '23) | CAG

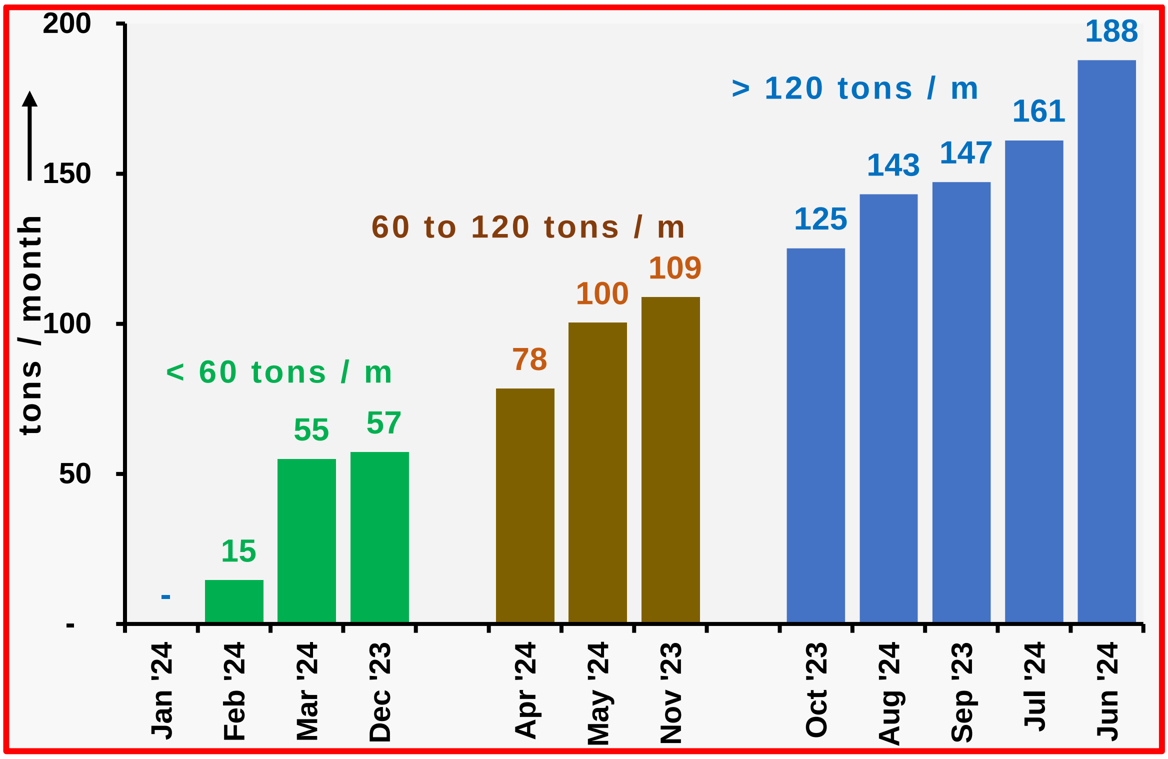


Fig 4.4: Green Leaves Processed: Quantity wise (Sep '23 - Aug '24) | CAG

4.1.2 Made Tea Produced

- Made Tea produced

  (i) 2 17 253 kg (Sep '22 - Aug '23) and (ii) 2 47 164 kg (Sep '23 - Aug '24)

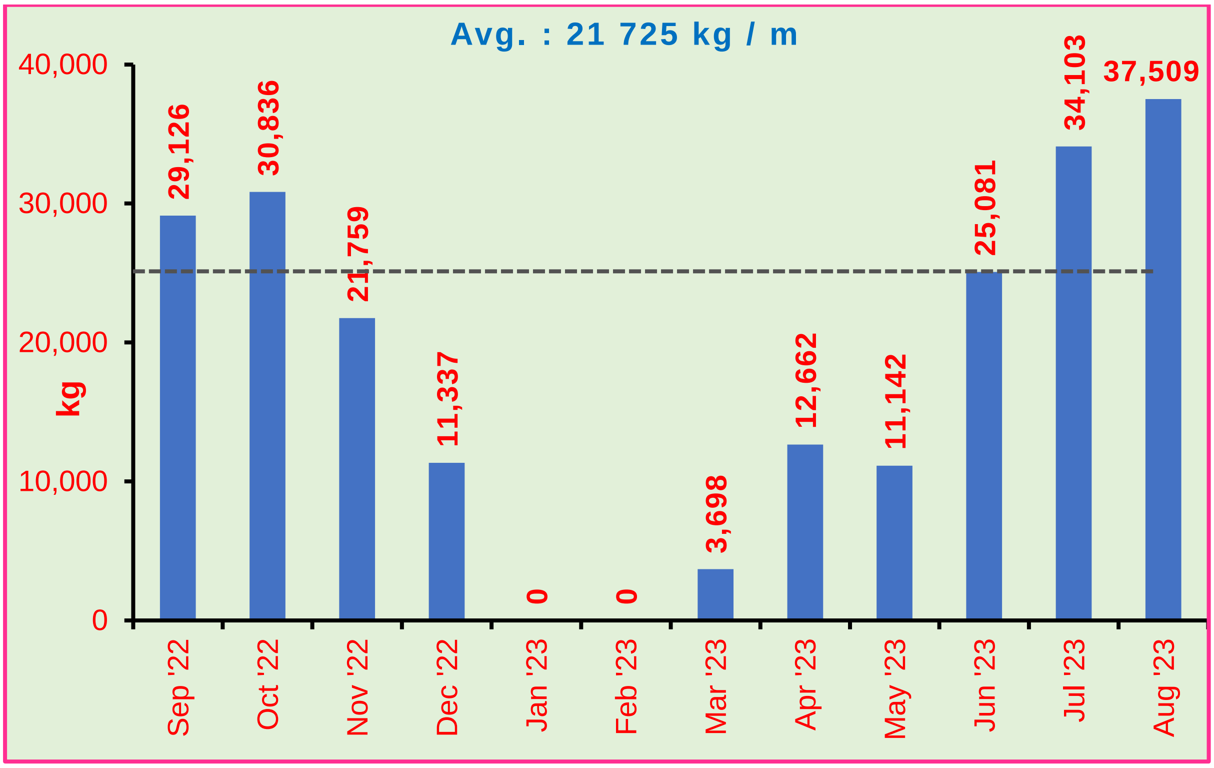


Fig 4.5 : Made Tea Produced : Month wise (Sep '22 - Aug '23) | CAG

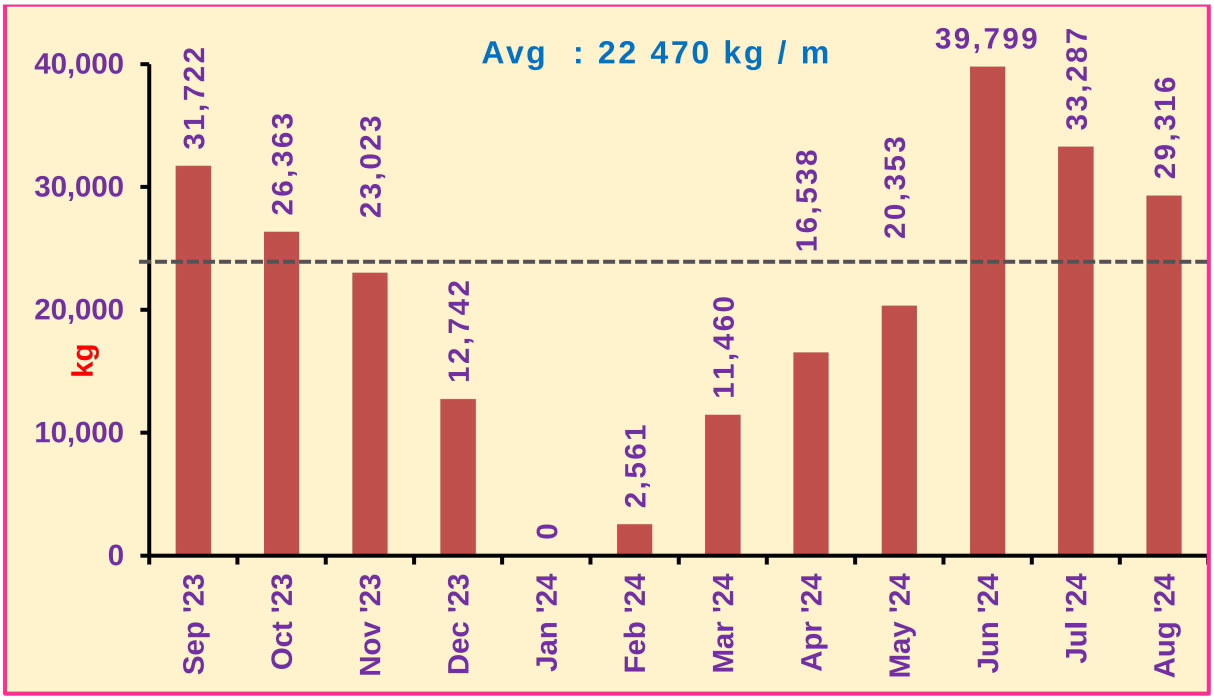


Fig 4.6 : Made Tea Produced : Month wise (Sep '23 - Aug '24) | CAG

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

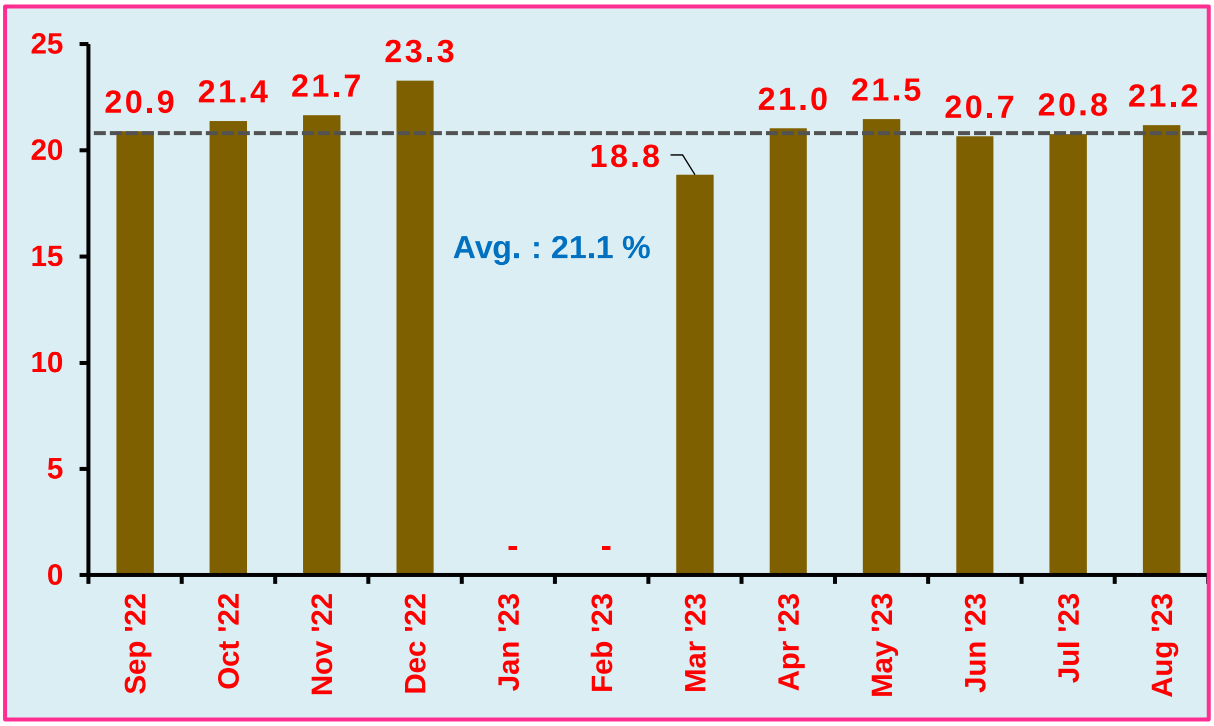


Fig 4.7 : Outturn Established - Month wise (Sep '22 - Aug '23) | CAG

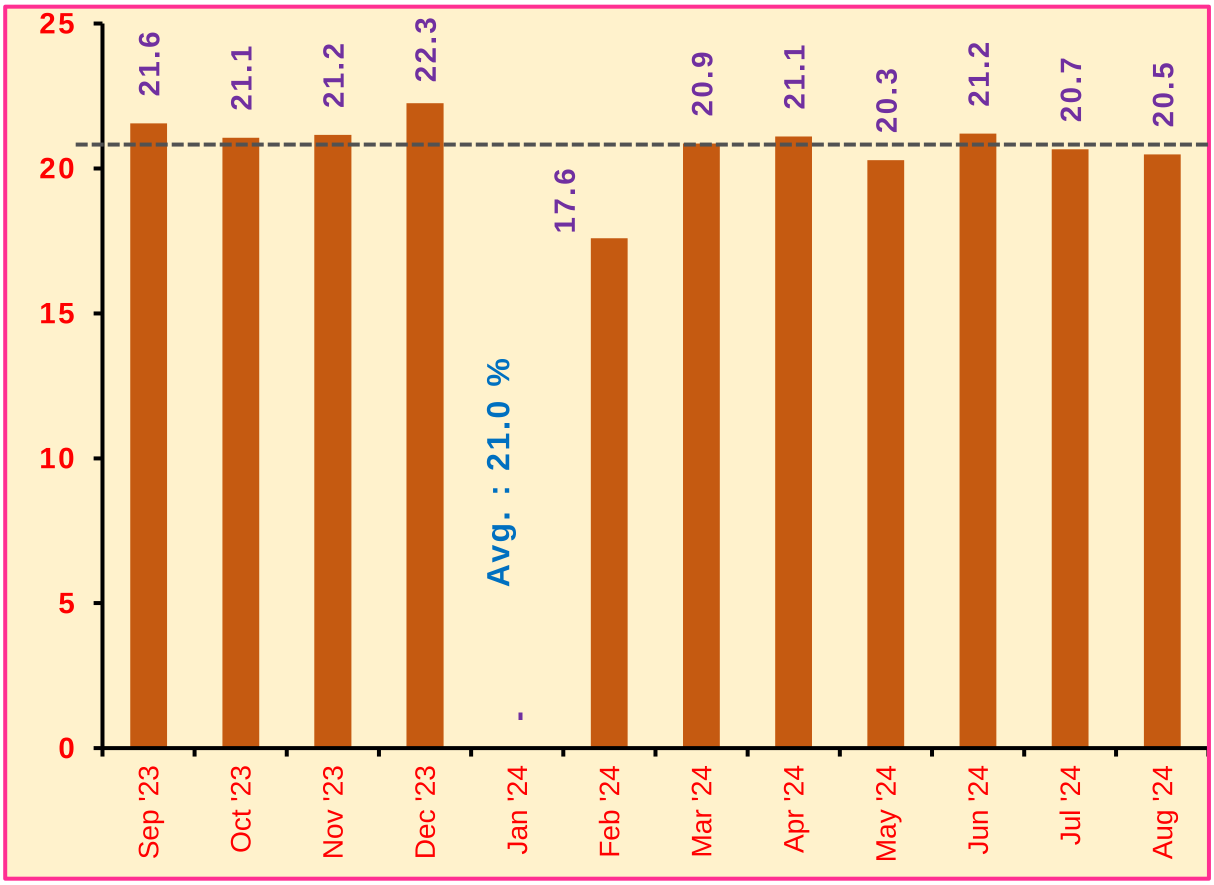


Fig 4.8 : Outturn Established - Month wise (Sep '23- Aug '24) | CAG

Average outturn in the period Sep '22 – Aug '24 = 21.1 %

4.2 CONSOLIDATION

- The consolidated production 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	10 27 254	2 17 253	21.1
Sep '23 - Aug '24	11 78 544	2 47 164	21.0
Total	22 05 798	4 64 417	21 1

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 24 - month period had hardly shown any variation. This is to say that the productivity of the factory remained unaltered in the past 2 years.
- Outturn is maintained at around **21.1 %** which is quite reasonable and acceptable.

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 usage pattern is 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 and 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 0.11 kWh / kg GL.
- During off - season the SEEC goes to as high as 0.21 kWh / kg GL as can be seen from Figs 5.1 & 5.2. This is as expected
- The overall SEEC has been established as **0.127 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	10 27 254	1 38 595	**0.135**
2	Sep '23 - Aug '24	11 78 547	1 42 228	**0.121**
Total		22 05 801	2 80 823	**0.127**

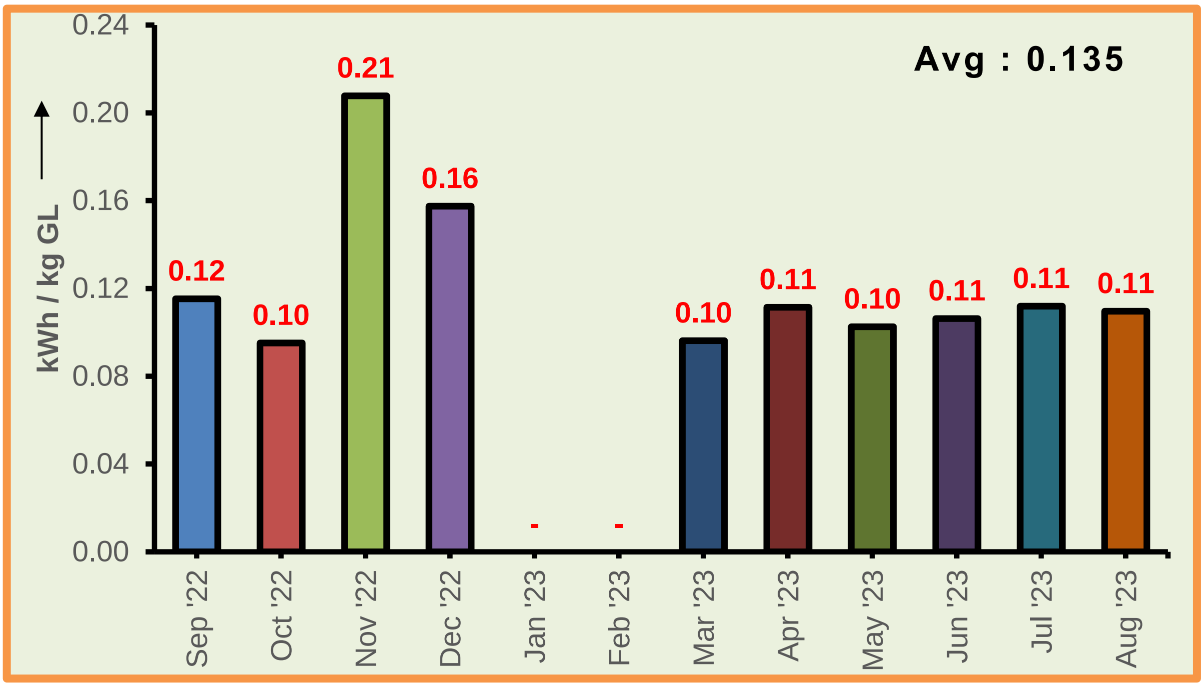


Fig 5.1 : SEEC Computed : Green Leaves Basis - Sep '22 to Aug '23 | CAG

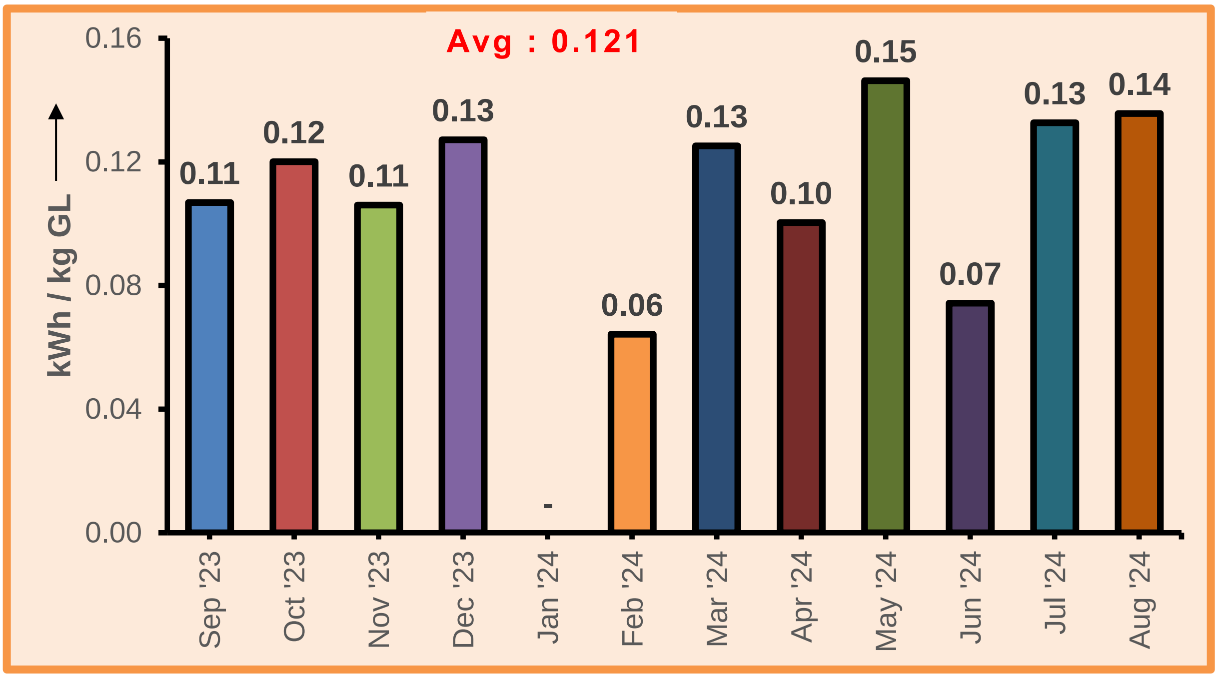


Fig 5.2 : SEEC Computed : Green Leaves Basis - Sep '23 to Aug '24 | CAG

5.2.2 : SEEC : Made Tea Basis

- The SEEC has been established on month wise basis for 24 - month period 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.

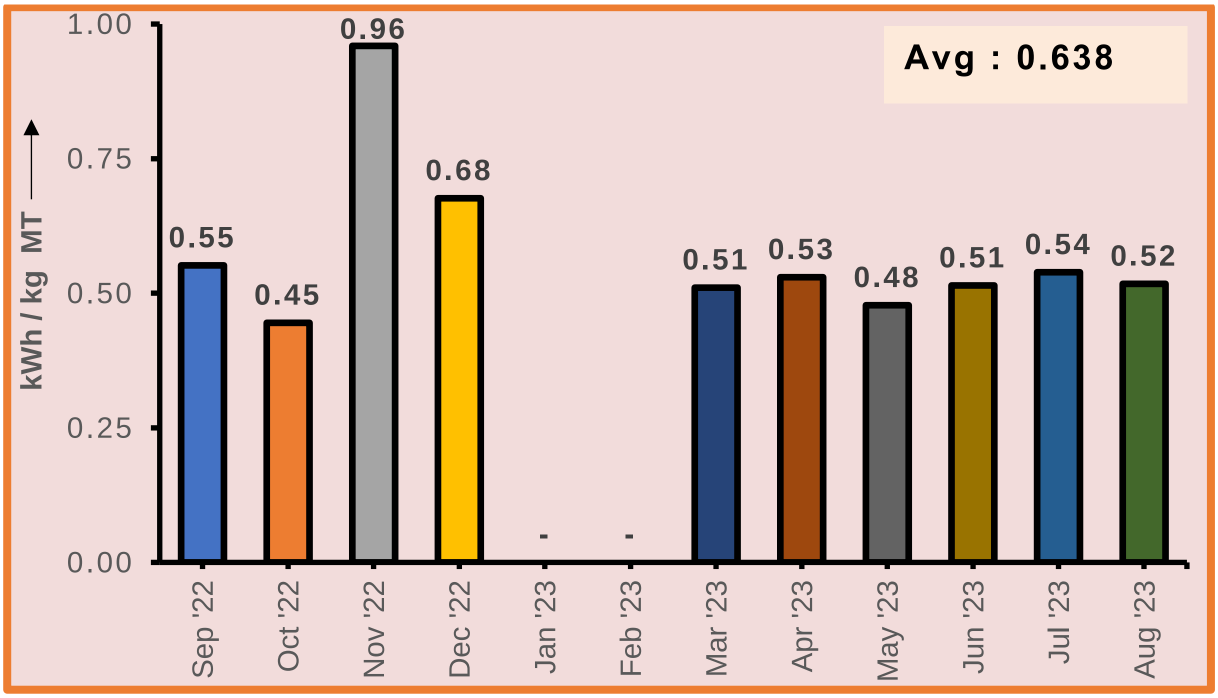


Fig 5.3 : SEEC Computed : Made Tea Basis - Sep '22 to Aug '23 | CAG

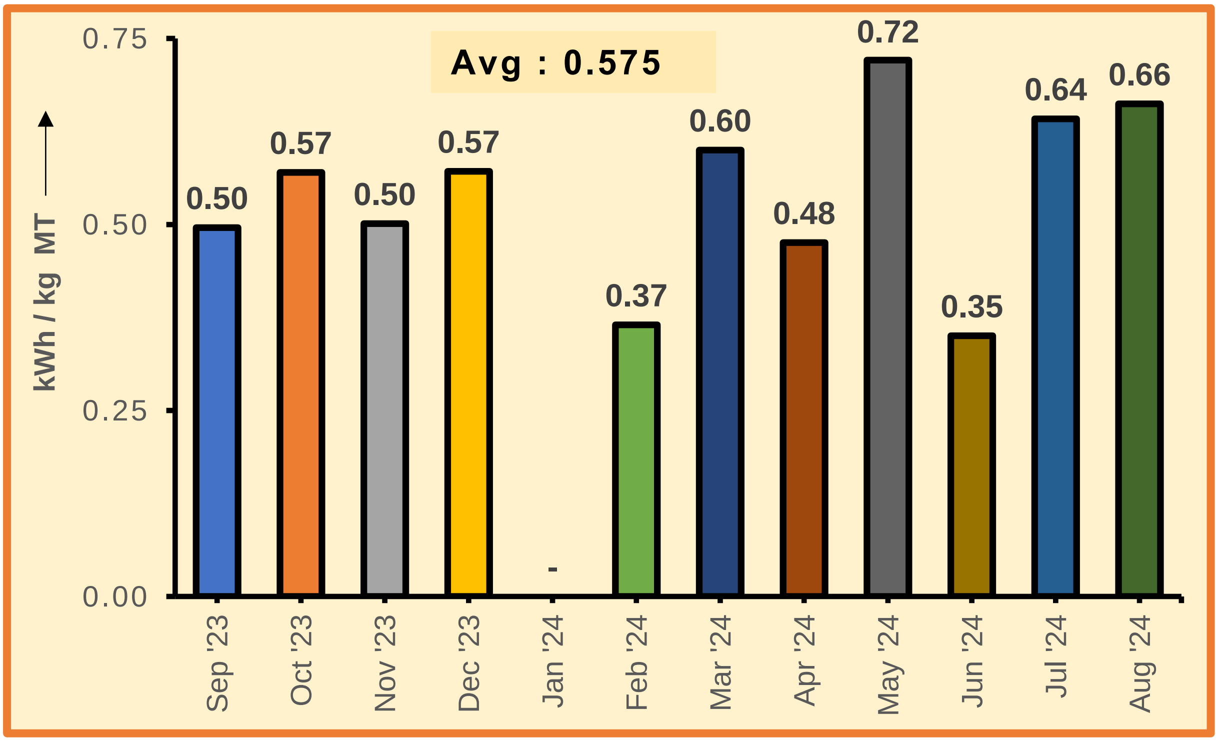


Fig 5.4 : SEEC Computed : Made Tea Basis - Sep '23 to Aug '24 | CAG

- As anticipated, S E E C goes lower during the season period [Jun to Sep] when the leaf arrival / Tea Production is higher. The SEEC value hovers around **0.54 kWh / kg Made Tea** during this period. During off - season the SEEC goes to as high as **0.96 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	2 17 253	1 38 595	**0.638**
2	Sep '23 - Aug '24	2 47 164	1 42 228	**0.575**
Total		**4 64 417**	**2 80 823**	**0.605**

- The average SEEC has been established as **0.605 kWh / kg Made Tea** which is reasonable if not optimum.

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 the 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.
- During season period, the S F C was **0.25 to 0.30 kg coal / kg GL** and is about **0.50 kg coal / kg GL** during low leaf arrival period. (off - season)

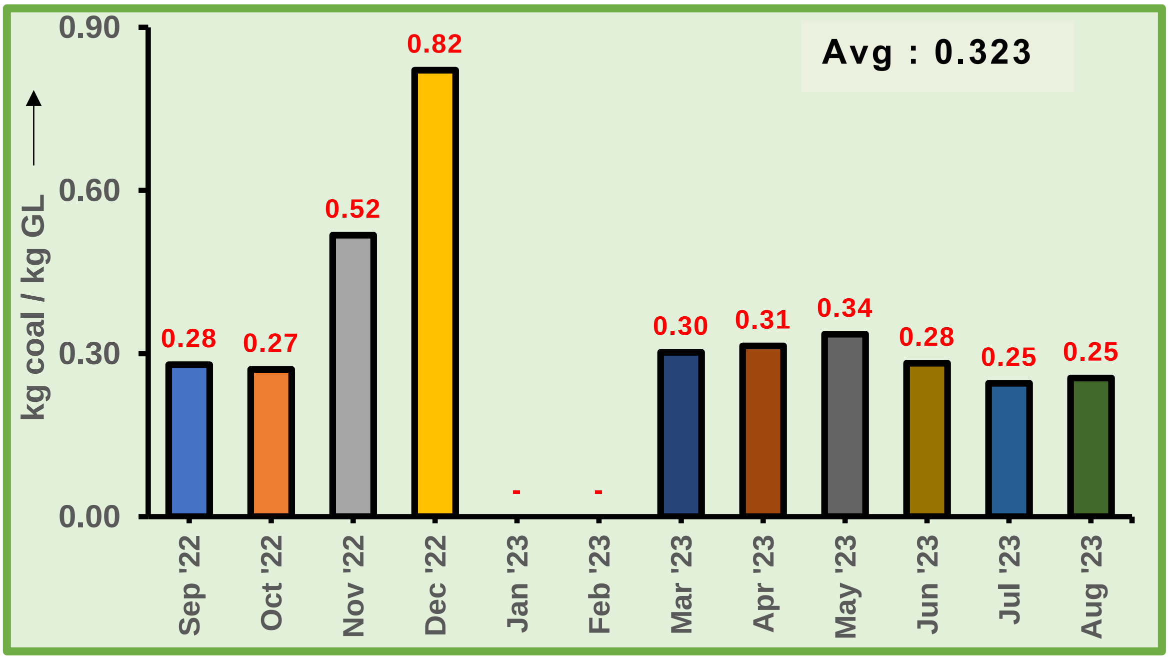


Fig 5.5 : SFC Computed : Green Leaves Basis : Sep '22 to Aug '23 | CAG

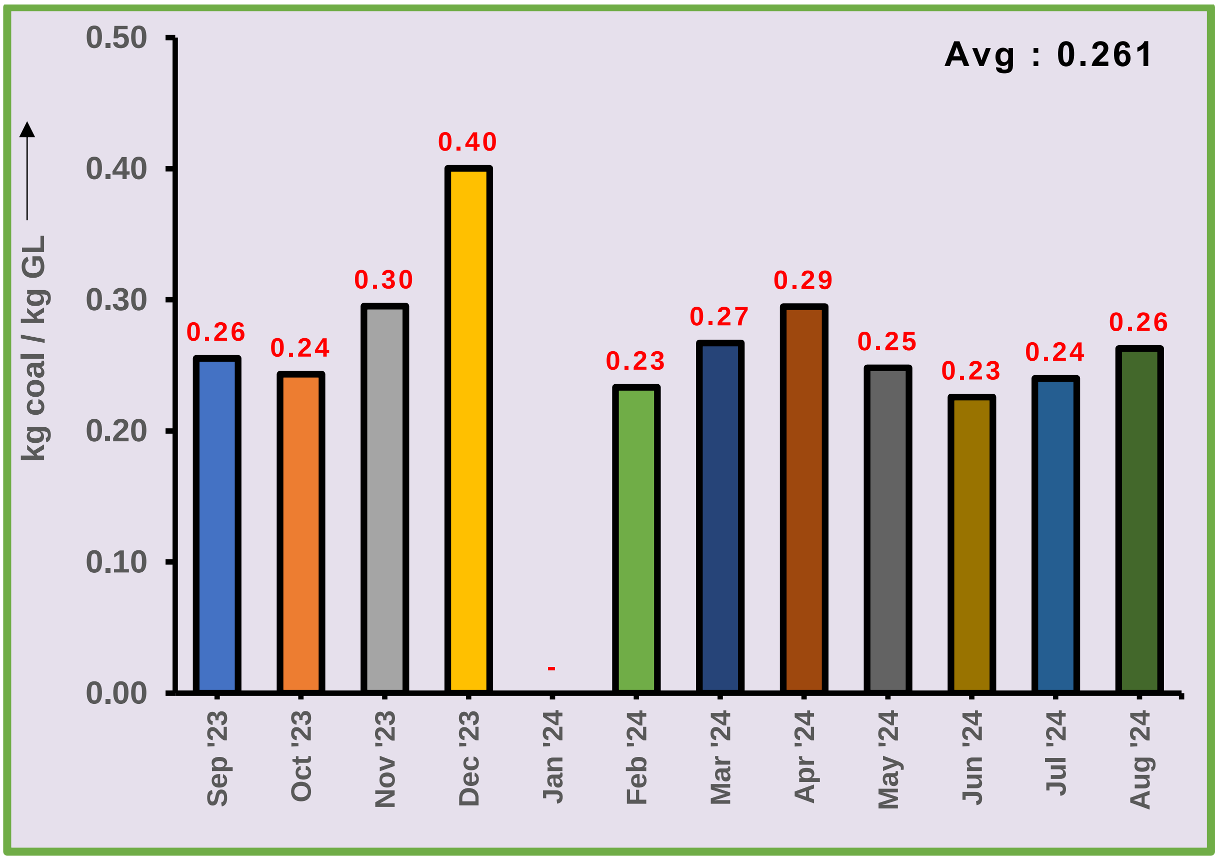


Fig 5.6 : SFC Computed : Green Leaves Basis : Sep '23 to Aug '24 | CAG

- The annualized values for 2 years are tabulated in Table 5.3 as well as the 2 - year average value.

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	10 27 254	3 31 984	**0.323**
2	Sep '23 - Aug '24	11 78 547	3 07 825	**0.261**
Total		22 05 801	**6 39 809**	**0.290**

- The SFC with respect to Green Leaves processed has been computed as **0.290 kg of coal / kg of GL** which is a 2 - year average value.

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.

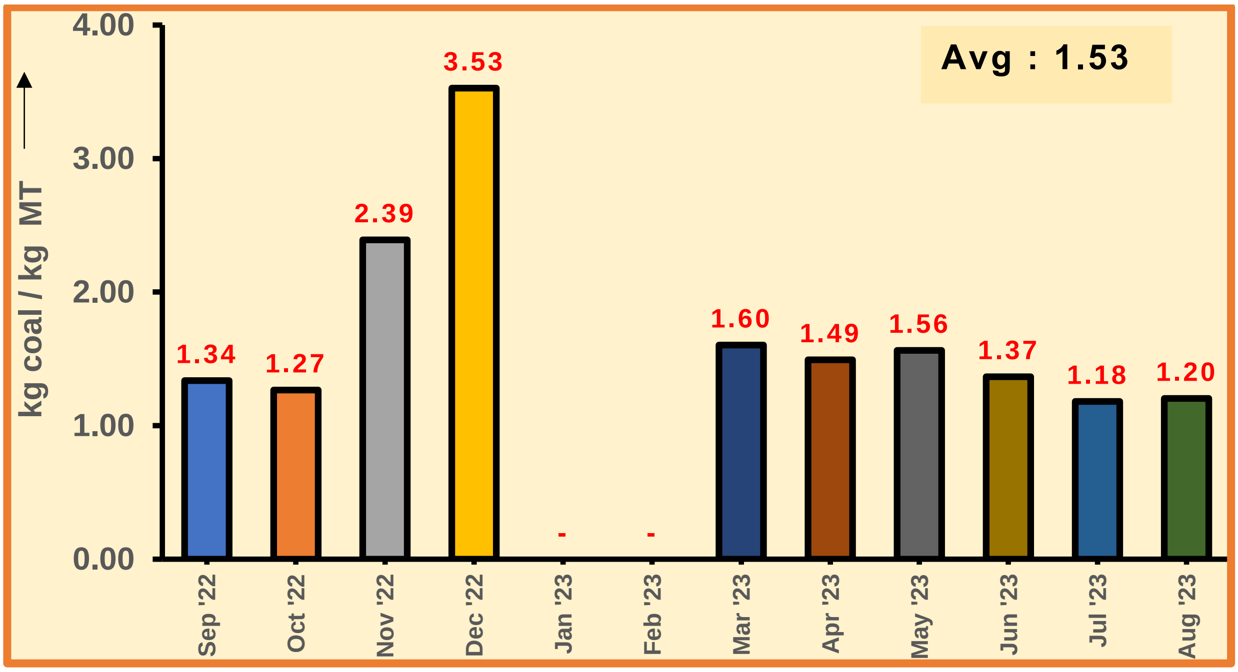


Fig 5.7 : SFC Computed : Made Tea Basis : Sep '22 - Aug '23 | CAG

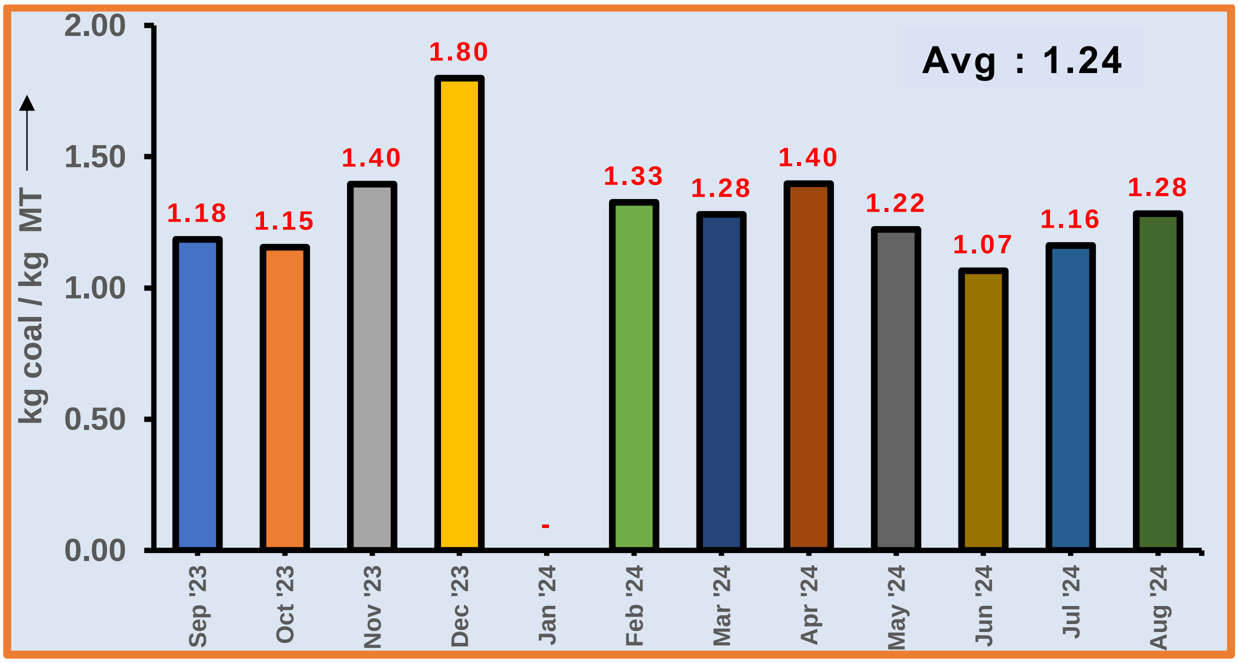


Fig 5.8 : SFC Computed : Made Tea Basis : Sep '23 - Aug '24 | CAG

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 GL
1	Sep '22 - Aug '23	2 17 253	3 31 984	**1.53**
2	Sep '23 - Aug '24	2 47 164	3 07 825	**1.24**
Total		**4 64 417**	**6 39 809**	**1.38**

- The SFC has been computed as **1.38 kg of coal / kg Made Tea** which is a 2 - year average value. This value appears reasonable.

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.

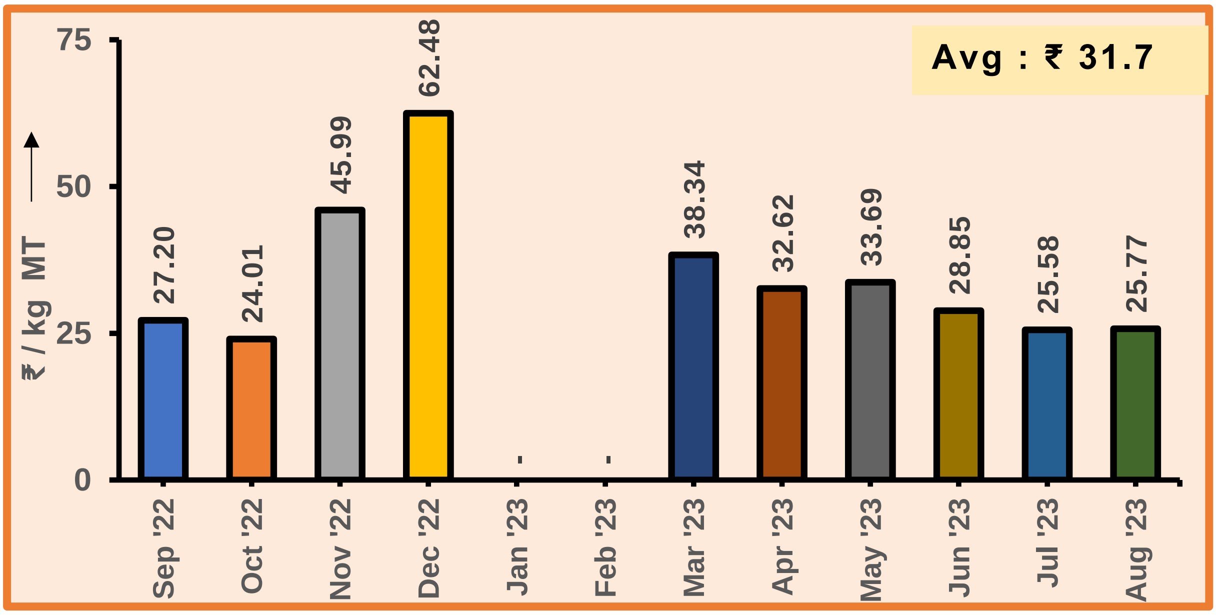


Fig 5.9 : Overall Energy Cost : Month wise : Sep '22 to Aug '23 | CAG

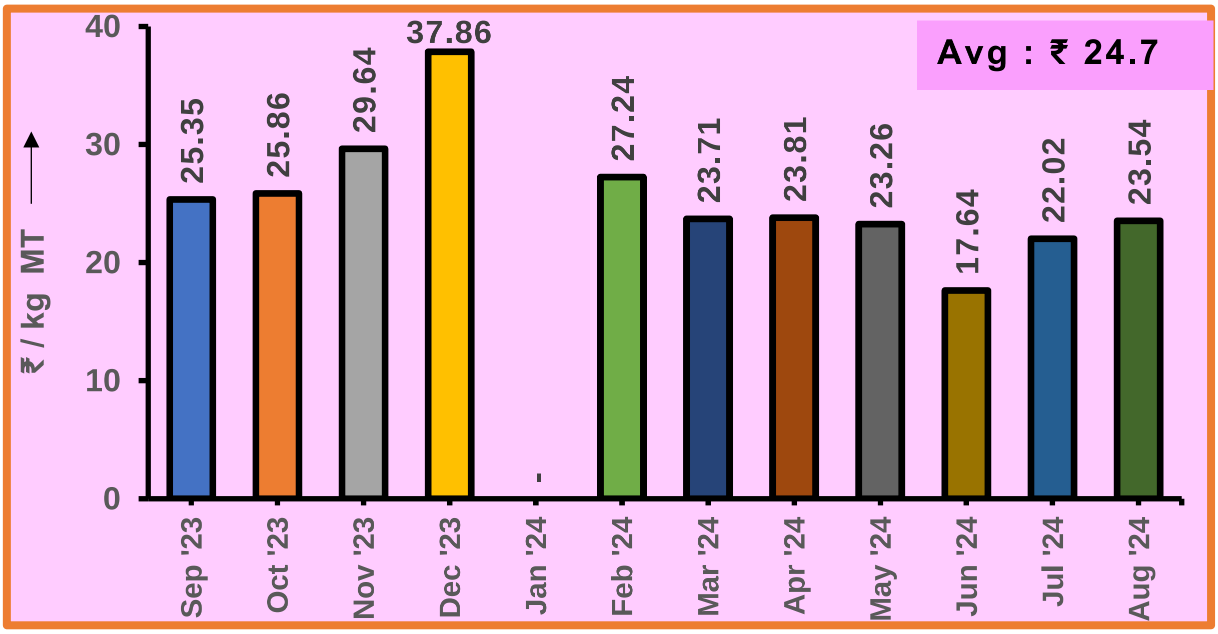


Fig 5.10 : Overall Energy Cost : Month wise : Sep '23 to Aug '24 | CAG

- 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	2 17 253	1280811	18.6	56 09 251	81.4	68 90 062	**31.7**
2	Sep'23 - Aug'24	2 47 164	1403897	23.0	46 92 256	77.0	60 96 153	**24.7**
Total		**4 64 417**	2684708	20.7	10301507	79.3	12986215	**28.0**

- The energy cost of tea production has been estimated as **₹ 28.0 / kg Made Tea**
- About 20.7 % of the energy cost is due to electricity and the rest 79.3 % 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

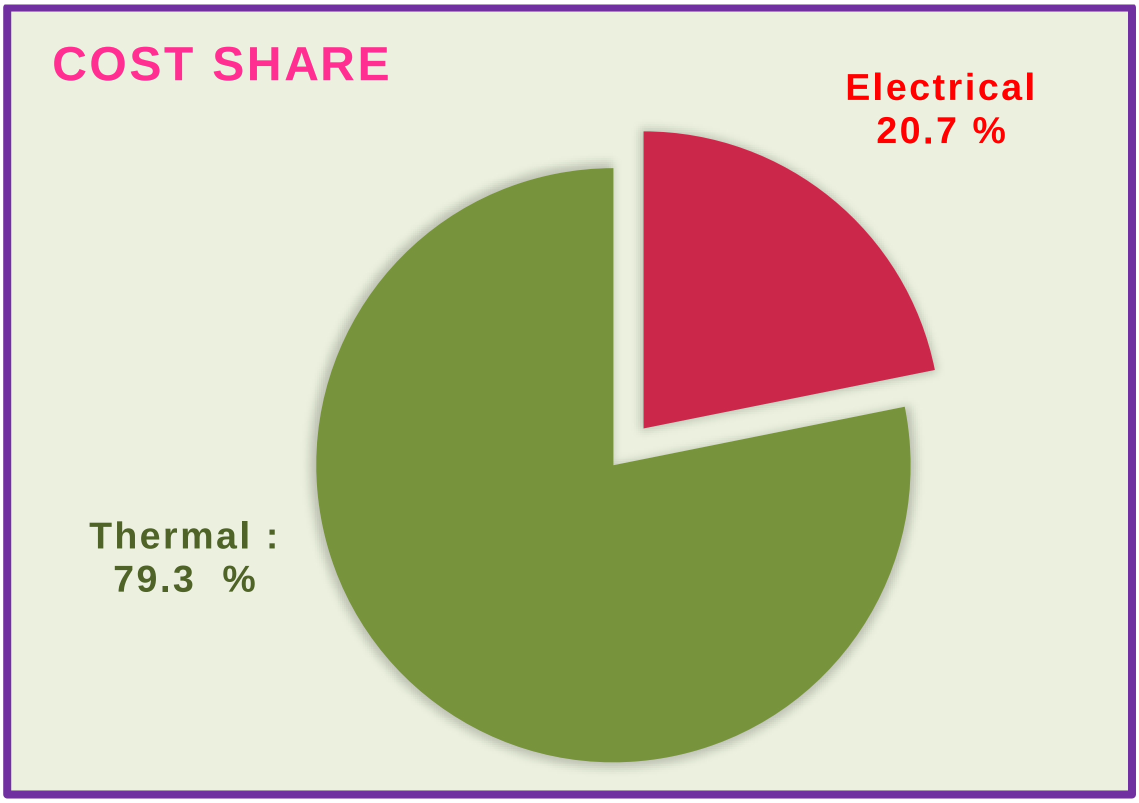


Fig 5.11 : Energy Cost Computed: per kg of Made Tea: 2 - year Avg | CAG

- In conclusion, it can be said - that on an average - ₹ 28 is the total energy cost for the production of 1 kg of made tea that comprises both electrical and coal 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	=	**0.127 kWh / kg GL**
	=	**0.290 kg coal / kg GL**
w.r.t Made Tea	=	**0.605 kWh / kg MT**
	=	**1.38 kg coal / kg MT**
Specific Energy Cost	=	**₹ 28.0 / 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 0.60]**
- However, on the Thermal Energy Front, the Specific Coal Consumption is higher by 35 % which is certainly on the higher side. **[1.38 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 **₹ 10 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 a 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 30 motors belonging to these.
- The outcome is presented in the ensuing sections

6.1 WITHERING SECTION

- The withering section has 3 troughs powered by 6 fans each having a motor power rating of 3.7 kW.
- The power measurements recorded & computed on these 6 motors / fans are tabulated below:

Table 6.1 : Motor Loading Details : Withering Section

No	Motor ID		Rated			Measured			% Loading	
			kW	Amps	η %	kW	Amp	PF	kW	Amps
1	Withering Trough Fan Motor	1 A	3.70	8.00	85	2.4	4.4	0.83	55.9	55.0
2		1 B	3.70	8.00	85	2.6	4.5	0.89	60.5	55.8
3		2 A	3.70	8.00	85	3.0	5.6	0.81	68.9	70.4
4		2 B	3.70	8.00	85	2.6	4.5	0.89	59.7	56.7
5		3 A	3.70	8.00	85	3.0	5.1	0.91	69.7	63.8
6		3 B	3.70	8.00	85	3.1	5.6	0.84	71.2	69.6
Total			**22.2**			**16.8**				

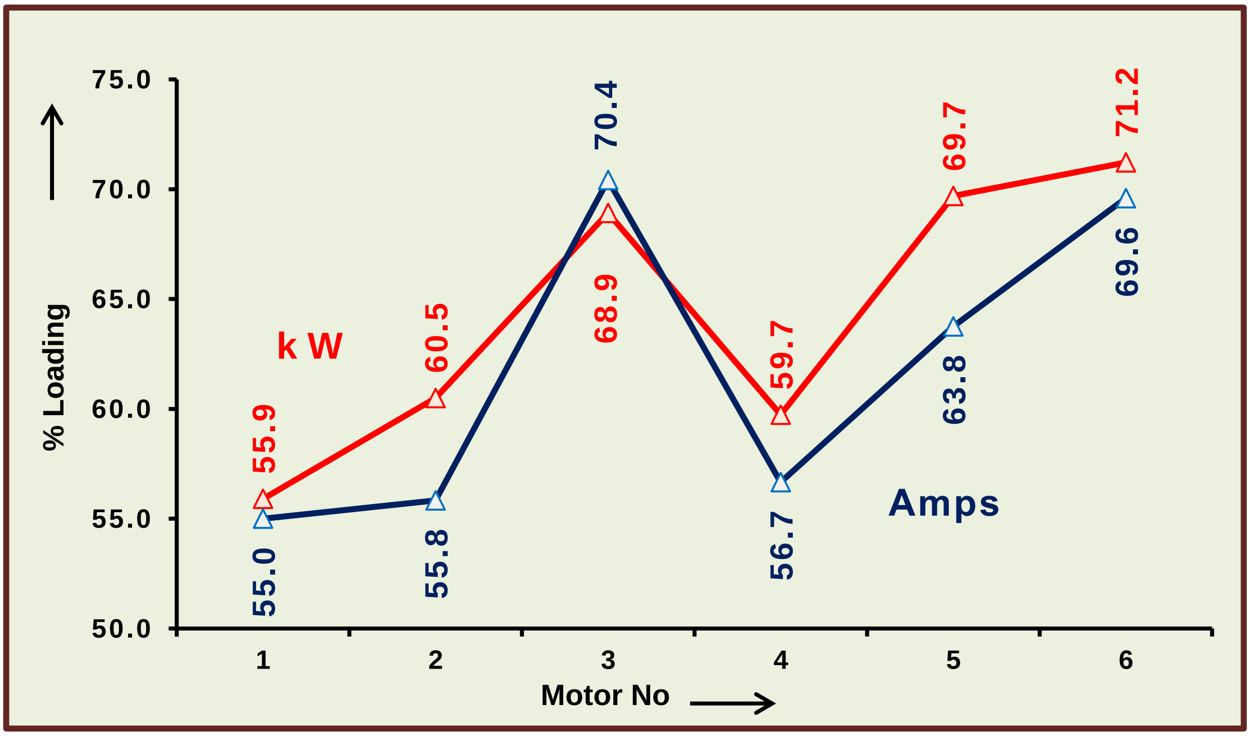


Fig 6.1: Motor Loading Details : Withering Section | CAG

Observations

- All the **6** withering trough fan motors are loaded at / beyond **55%** on both kW and Ampere front which indicates the optimal loading of the motors.
- The power factors recorded exceeded 0.80 for all the motors which are also quite optimum ones and therefore acceptable.

- The ampere loading is below that of kW in 5 motors, which is not a common occurrence. 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 also 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 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 **1.1 kW** to **18.5 kW.**
- The name plate details of the Blower Motor was not available and hence the kW and the current loading could not be computed for it.
- The loading pattern - established for the remaining 6 motors - is tabulated below, along with the measured parameters for the Blower Motor:

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	7.4	12.1	0.70	44.7	44.7
2	Cut 1	18.5	34.0	91.2	14.4	23.6	0.91	71.1	69.3
3	Cut 2	15.0	28.0	89.0	10.5	17.2	0.94	62.5	61.5
4	Cut 3	15.0	28.0	89.0	12.5	19.4	0.99	74.4	69.3
5	Cut 4	15.0	28.0	89.0	9.9	15.7	0.95	58.8	56.1
6	Ghoogy	1.1	3.0	78.0	0.6	1.6	0.52	40.2	52.2
7	Blower	-	-	-	0.2	0.6	0.41	-	-
		79.6			**55.6**				

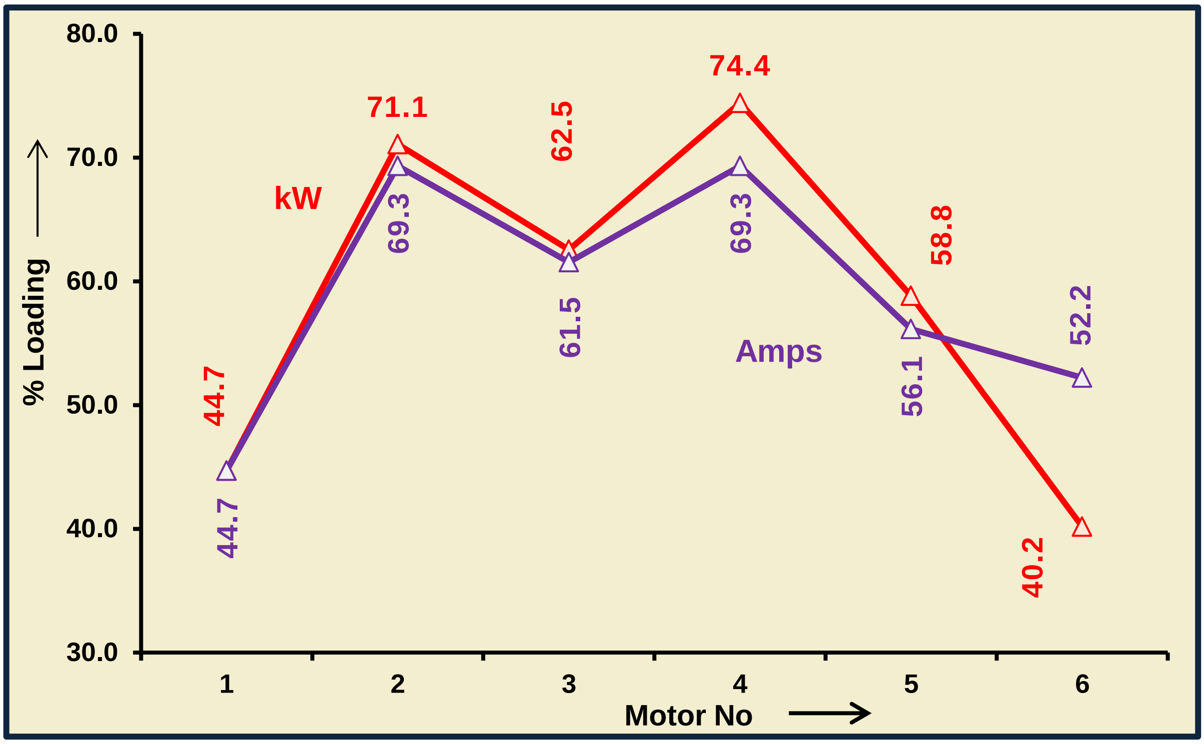


Fig 6.2: Motor Loading Details : CTC Section | CAG

Observations

- In effect, there are **6** motors for which the loading pattern has been established and **2** out of these **6** are loaded below **50%** on the kW front.
- The Rotor Vane and the Ghoogy motors are lowly loaded and hence exhibited relatively lower Power Factor of **0.7** and less, which is understandable. The effect of poor motor loading on Power Factor is much pronounced in Motor No. 6 (Ghoogy) that has a P F of only 0.52
- It also appears that the Blower Motor is lowly loaded considering the low PF recorded [**0.41 only].**
- The power factor is above **0.9** in all the four CTC motors (Cut 1 to 4), which is an indication that these motors are loaded adequately.
- To conclude, the loading appears to be optimum in the CTC section but for Rotor Vane, Cut 4 and Googhey Motor. This needs to be looked into.

6.3 FERMENTATION SECTION

- This section has **6** lower rated Humidifier Motors whose power ratings are unknown. Hence, the loading pattern of these motors could not be established.
- However, electrical measurements recorded are tabulated below :

Table 6.3: Motor Loading Details : Fermentation Section

No	Motor ID		Measured kW	Measured Amps	Measured PF
1	Humidifier Motor	1	0.30	0.50	0.88
2		2	0.25	0.47	0.76
3		3	0.22	0.47	0.75
4		4	0.22	0.47	0.77
5		5	0.26	0.47	0.85
6		6	0.25	0.43	0.86
Total			**1.50**		

Observations

- The total power drawl n this section is only a meagre **1.5 kW**.
- The power factors recorded belong to the upper spectrum (> 0.75) in all the Humidifier Motors, which could mean that these motors are possibly loaded well on kW.

6.4 DRIER SECTION

- This section has **4** motors and out of which the name plate details of Hot Air Fan Motor are not available
- The loading pattern established for the remaining 3 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	F D Fan	1.5	3.8	76.0	0.67	1.57	0.71	33.8	41.2
2	I D Fan	5.5	11.0	87.7	1.80	4.33	0.93	28.7	39.4
3	Tray Conveyor	3.7	8.2	84.0	2.03	4.00	0.85	46.2	48.8
4	Hot Air Fan	-	-	-	6.50	14.3	0.68	-	-
Total		**21.7**			**10.96**				

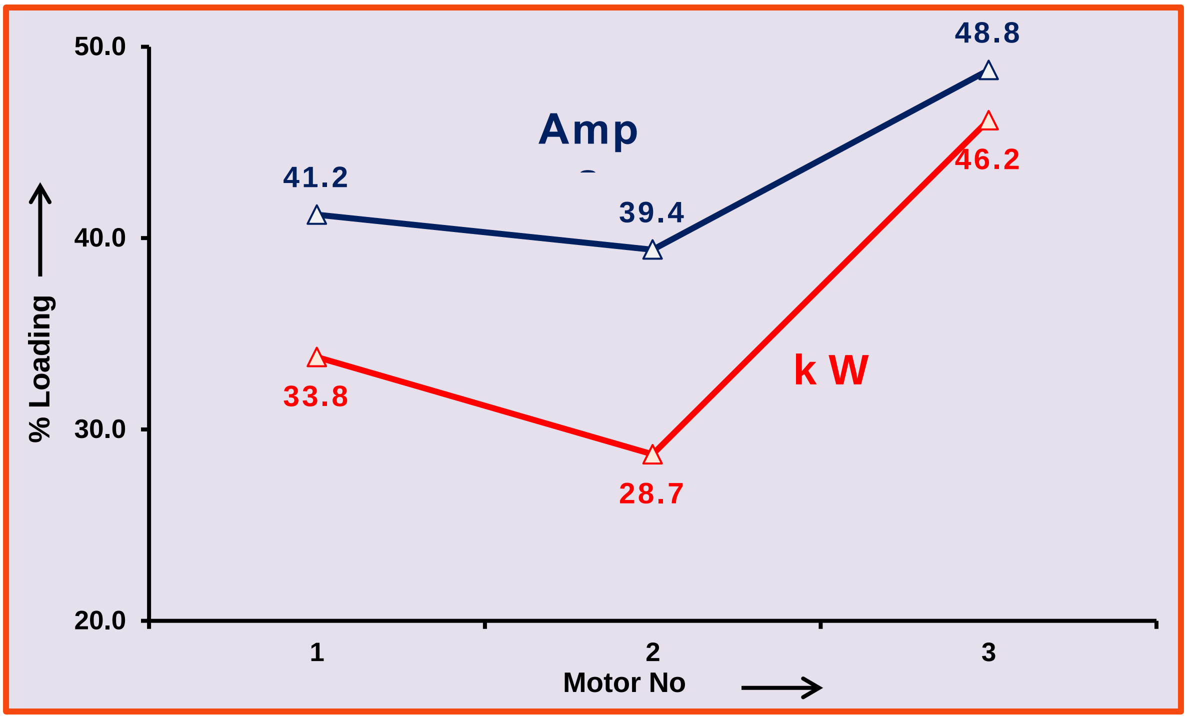


Fig 6.3: Motor Loading Details : Drier Section | CAG

Observations

- The loading of the 3 motors in this section is quite low, i.e., less than **50%** on both kW and Ampere front.
- Surprisingly, the Power Factors recorded are reasonably high for the ID Fan and the Tray Conveyor, despite the low kW loading. Also, the Power Factor has exceeded 0.65 in the remaining 2 motors, which is not bad.
- 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, the loading of the motors in the Drier section is on the lower gamut. This needs to be noted and taken care of from the viewpoint of enhancing their efficiency level of operation.

6.5 SORTING SECTION

- This section - as expected - has motors of very low power rating.
- There are 7 motors in operation in this section of which 5 motors are of **1.5 kW** power rating and the **2** motors are of **0.75 kW** rating
- The loading pattern established for all the 7 motors is tabulated 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	Loading Conveyor		0.75	1.96	74.5	0.20	0.60	0.48	19.6	30.6
2	Mother	Sorter	1.50	3.40	77.0	0.30	0.80	0.58	15.2	23.5
3	Top	Sorter	1.50	3.40	77.0	0.35	0.80	0.64	17.9	23.5
4	Dust	Sorter	1.50	3.40	77.0	0.30	0.90	0.50	15.3	26.5
5	Broken	Sorter	1.50	3.30	78.5	0.31	1.00	0.49	16.5	30.3
6	Fanning	Sorter	1.50	3.40	77.0	0.38	1.00	0.57	19.7	29.4
7	Conveyor Motor 2		0.75	1.96	74.5	0.17	0.50	0.48	16.5	25.5
	Total		**9.00**			**2.00**				

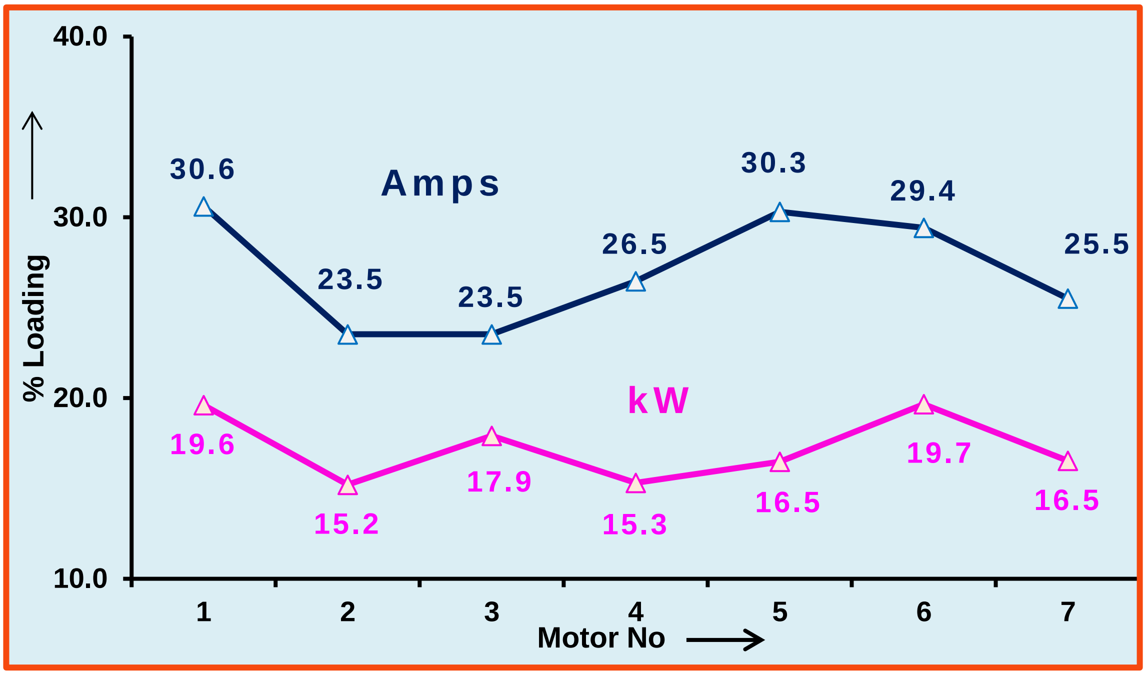


Fig 6.4: Motor Loading Details : Sorting Section | CAG

Observations

- The loading experienced on kW of all the **7** motors is below **20%**, necessitating the need for considerable improvement.
- The Power Factors recorded for all the motors are also in the lower gamut, i.e. below 0.65, with majority of the motors having P F of **0.50 or less**. This is quite understandable from the low kW loading experienced by the motors.

- The unfavourable effects of loading motors far below 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 the energy efficiency perspective.

6.6 SUMMATION

- The consolidated details of kW recorded for all the motors of the **5** sections are tabulated below and shown through a pie chart.

Table 6.6 : kW Loading : Section wise

No	Section	Power Recorded	
		kW	%
1	Withering	16.8	19.3
2	CTC	55.6	64.0
3	Fermentation	1.5	1.7
4	Drier	11.0	12.6
5	Sorting	2.0	2.3
Total		**86.9**	**100**

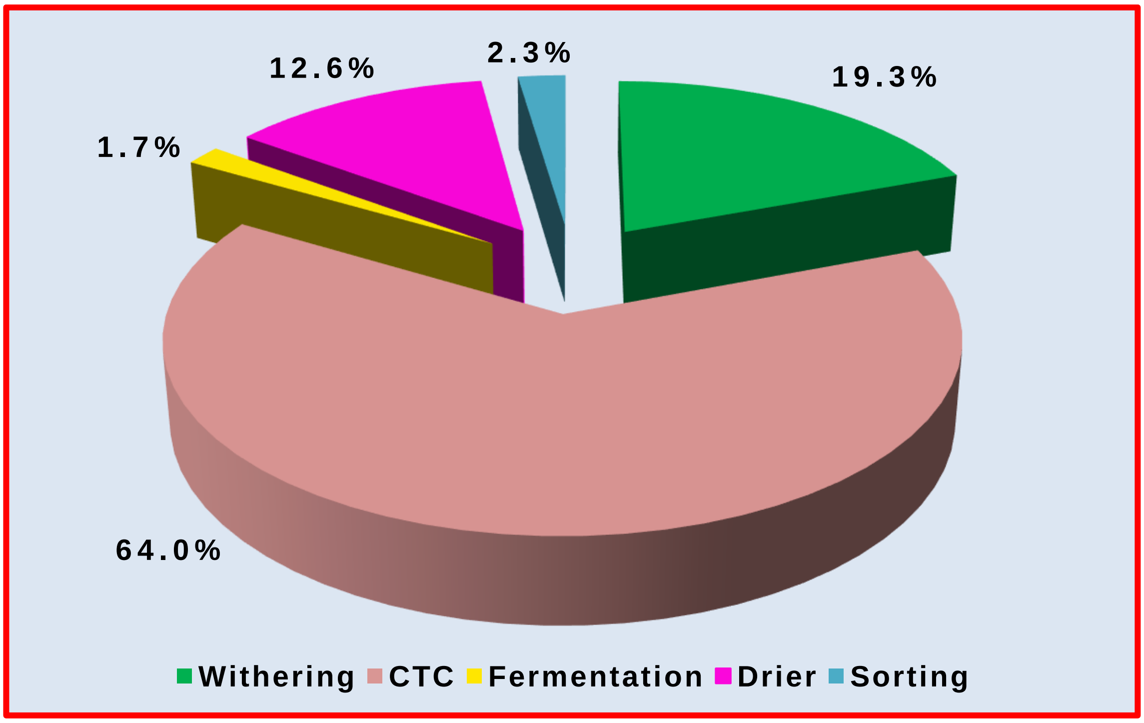


Fig 6.5: kW Loading : % : Section wise | CAG

- 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 or electricity loading of the individual sections is not being attempted here.
- As expected, the highest power drawl is by the CTC section & the lowest is in Fermentation section.
- The order (from highest to lowest power drawl) is as below:

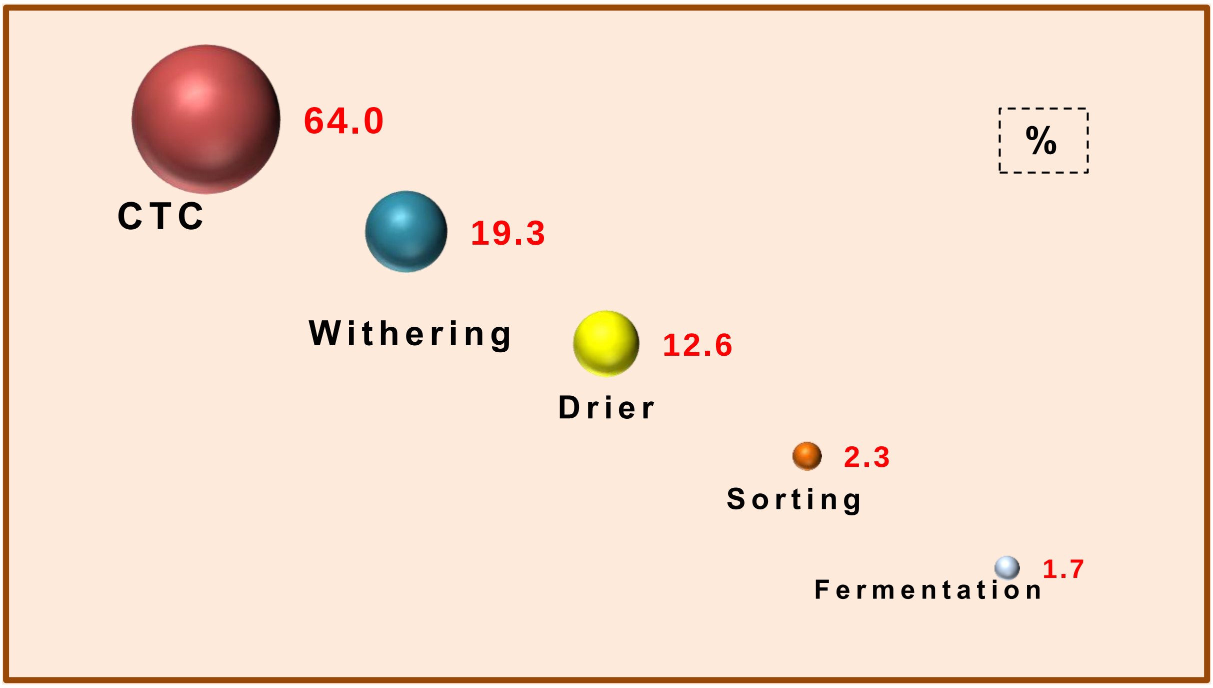


Fig 6.6: kW Loading : % Contribution : Section wise | CAG

- The power drawl / energy consumption in the CTC section of this factory is close to 65 % of the total.
- 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.

7 PERFORMANCE STUDY ON ELECTRICAL UTILITIES

7.0 INTRODUCTION

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

7.1 TRANSFORMERS

- The factory has two transformers installed in its premises and the ratings are 63 kVA and 100 kVA. The manufacturer of the 63 kVA transformer is **Eastern Trafo (P) Ltd, Kolkata** and that of the 100 kVA transformer is **Andrew Yule & Co Ltd, Kolkata.**
- The loading pattern was recorded for both these transformers 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 for the 63 kVA transformer have been obtained from the standard manual, as test certificates could not be made available to the energy audit team. However, the name plate of the 100 kVA transformer contained the details of transformer losses.
- The designed details of the transformers are as below:

Table 7.1: Name Plate Details : Transformers

No	Parameters	Unit	T R – 1	T R - 2
1	Make	-	Eastern Trafo (P) Ltd.,	Andrew Yule & Co. Ltd.,
2	Rating	kVA	63	100
3	H V	V / A	11 000 / 3.31	11 000 / 5.25
4	L V	V / A	433 / 84	433 / 133.34

No	Parameters	Unit	T R – 1	T R - 2
5	No Load Loss	kW	0.073	0.185
6	Full Load Loss	kW	1.067	1.020
7	Year of Mfg.	-	2014	2017

- Following provides the measurements made & the corresponding computed values:

Table 7.2: Operating Efficiency Prediction : Transformers

No	Parameter	Unit	T R 1	T R 2
1	Voltage	V	380	395
2	Current	Amps	40.8	88.6
3	Load	kVA	27.2	60.0
4	Power Factor	-	0.97	0.96
5	Load	kW	26.4	59.1
6	No Load Loss	kW	0.073	0.185
7	Full Load Loss	kW	1.067	1.020
8	Total Loss	kW	0.27	0.55
9	Loading	%	43.2	60.0
10	Operating Efficiency	%	99.0	99.1

- The loading pattern recorded of the two transformers is provided hereunder:

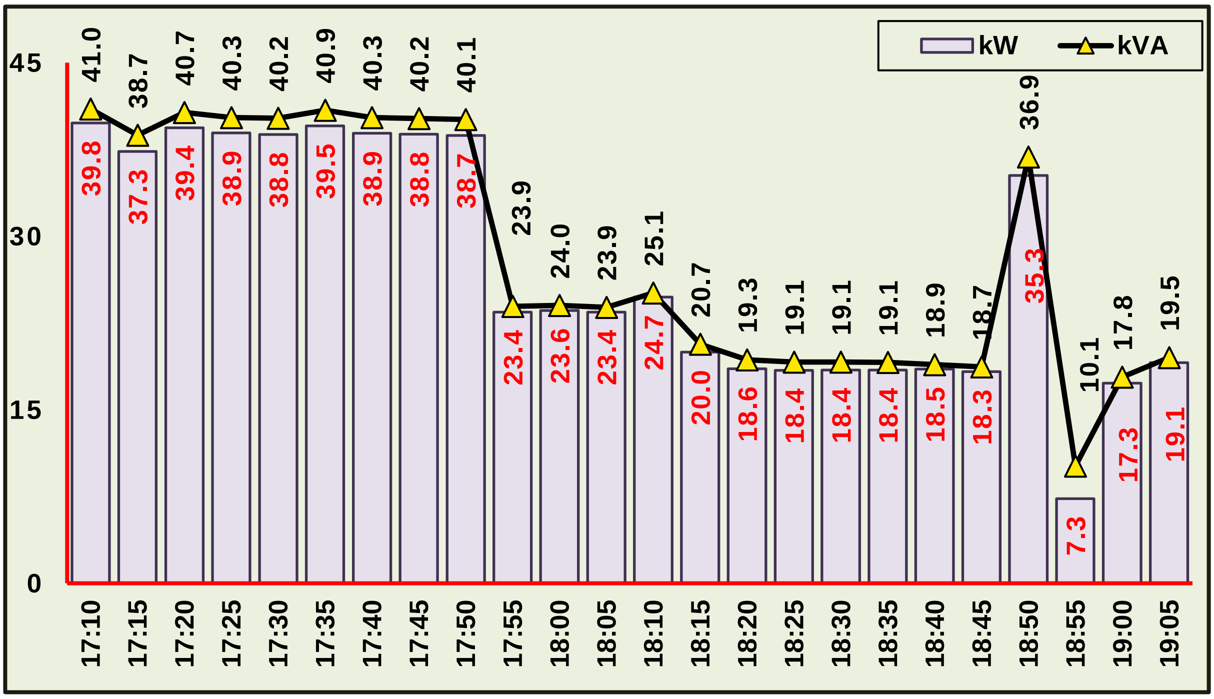


Fig 7.1: Active Power & Apparent Power Trend : Tr 1 : 63 kVA | CAG

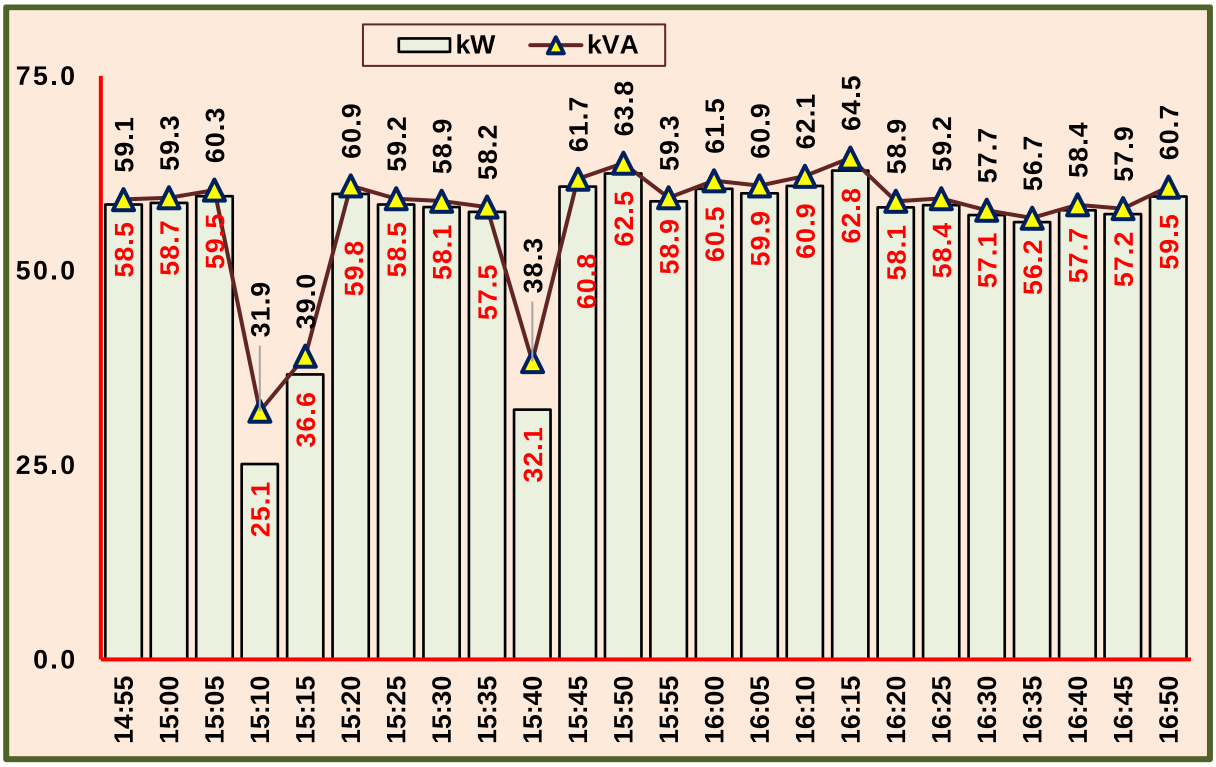


Fig 7.2: Active Power & Apparent Power Trend : Transformer 2 | CAG

- As evident from the plots above, the closeness between the kW and kVA profiles in the 2 Transformers (i.e., the smaller width of the gap between the two trends) is a reflection of the attainment of high power factor, close to unity.
- The total loss in transformer 1 is estimated as **0.27 kW**, and that in transformer 2 is computed at **0.55 kW**
- A loading of **43.2 % & 60 %** were observed in transformer 1 and 2 respectively.
- The efficiency of transformer 1 is computed at 99.0 % and that of transformer 2 at 99.1 %, and both seem quite optimum.

7.2 WITHERING FANS

- This section has 6 Withering Fans supplying air in 3 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 Table 7.3

Table 7.3: Withering Trough Fans - Performance Assessment

No	Motor ID		Fan Power kW		Air Delivered	Specific Air Flow
			Rated	Measured	cfm	cfm / kW
1	Withering Trough Fan Motor	1 A	3.70	2.4	21 788	8 954
2		1 B	3.70	2.6	20 923	7 945
3		2 A	3.70	3.0	18 667	6 222
4		2 B	3.70	2.6	19 934	7 667
5		3 A	3.70	3.0	22 654	7 468
6		3 B	3.70	3.1	32 420	10 458

- Fan No 6 delivers a little more than 32 000 cfm of air, which is acceptable for the fan rating of **3.7 kW.**
- The cfm delivered by Fans 1 to 5 ranges from 18 000 to 23 000 which is just satisfactory considering that they have the same fan motor rating of **3.7 kW** as that of Fan No 6

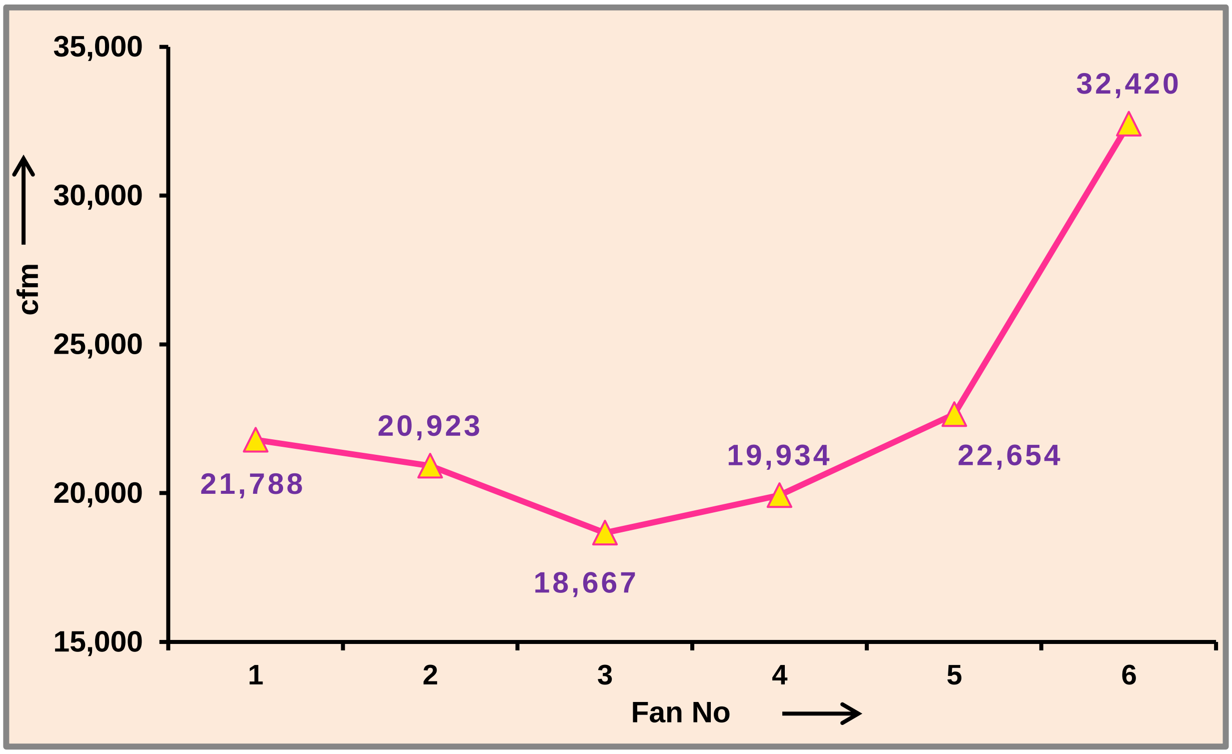


Fig 7.3: Air Flow Rate - Withering Trough Fans | CAG

- 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 :

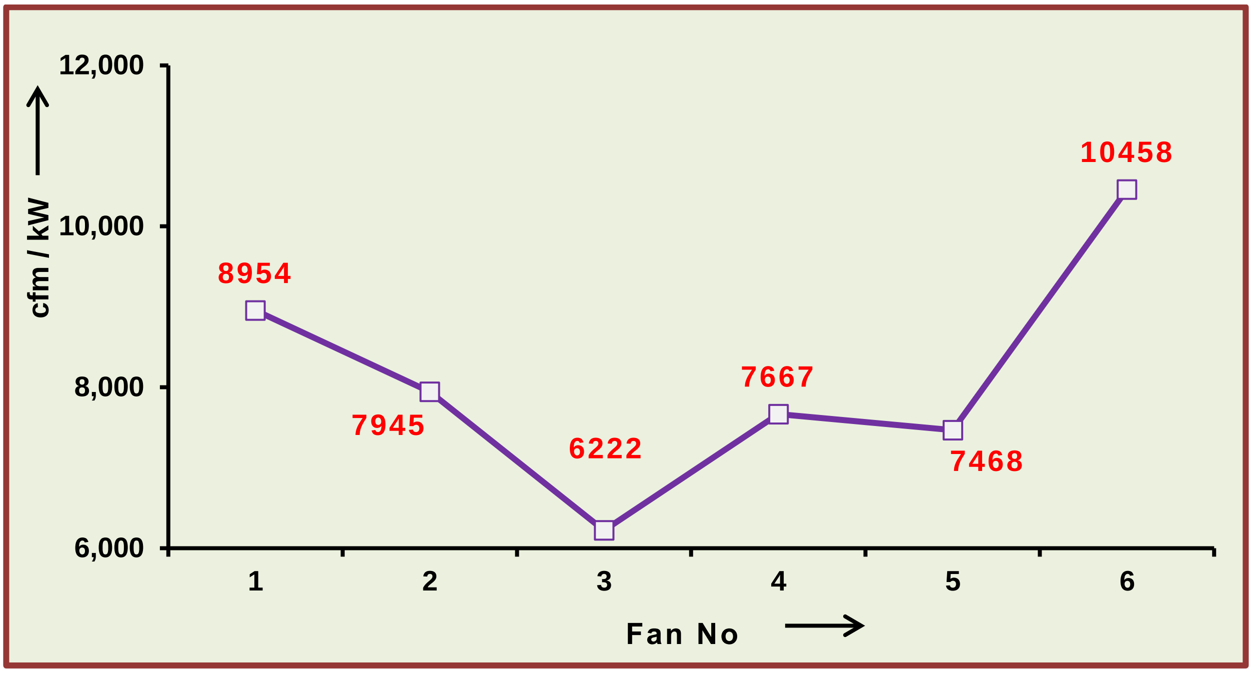


Fig 7.4: Specific Air Flow – Withering Trough Fans | CAG

- The fan No 6 delivers the highest cfm / kW and the fan No 3, the least cfm / kW
- The further breakup is as below:

Table 7.4: Withering Trough Fans - Performance Assessment

No	Specific Air Flow Rate cfm / kW	No of Fans
1	6 000 - 8 000	4
2	> 8 000	2

- It appears that the performance of 4 fans, namely Fan Nos. 2 - 5, is a few notches below the mark, more so with Fan No. 3
- The specific air flow computed for the Fans 1 & 6 is on the higher side when compared to the remainder
- To be more specific, the fans belonging to the Withering Troughs 1 and 3 (4 fans) have outperformed the fans in Trough 2 in terms of their specific output
- It is therefore advised to preferentially **load the troughs 1 and 3 more** considering that this would improve the quality of withering, hence the tea produced

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.

- 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	1494.2	584.6	597.7	2.2	5	5
2	Cut 1	180	350	1473.9	711.5	758.0	6.1	4	3
3	Cut 2	180	350	1479.5	707.8	760.9	7.0	4	3
4	Cut 3	180	350	1486.9	705.3	764.7	7.8	4	3
5	Cut 4	180	350	1472.4	710.3	757.2	6.2	4	3
6	Tray Conveyor	80	180	996.1	343.4	442.7	22.4	2	2

- The following are the notable observations made:
  1) Some of the grooves were missing a belt (i.e., in 4 out of the 5 cases), and these motors, namely Cut 1 - 4, exhibited considerable belt slippage. It is advised to stay in line with the designed installation procedure always.
  2) The measured slip with the Tray Conveyor Motor, despite staying in line with the designed operational characteristic - in terms of the number of grooves and belts - was about 3 times the slip measured for the Cut 1 - Cut 4 motors.
  3) These 5 motors exhibiting sizeable slippage have been chosen as target candidates for performance improvement in terms of enhancing the transmission efficiency, to optimize the 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 can be quite significant.
- This is discussed in detail in the “Energy Conservation Measures” section of this report, with a comprehensive cost to benefit analysis.

7.4 DRIER SECTION FANS

- The following three fans are connected to the Drier Section :
    1) Hot Air Fan (Induced Draft) : Power rating : 11 kW
    2) Supply Air Fan / F D Fan (Forced Draft) : 1.5 kW
    3) Exhaust Fan / I D Fan (Induced Draft) : 5.5 kW

Fig 7.5 : Drier Section Fans | CAG

- Coal is burned in the furnace, the FD Fan supplies the air required for combustion 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 and 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	6.46	4 330	670
2	F D Fan	1.5	0.67	1 330	1 995

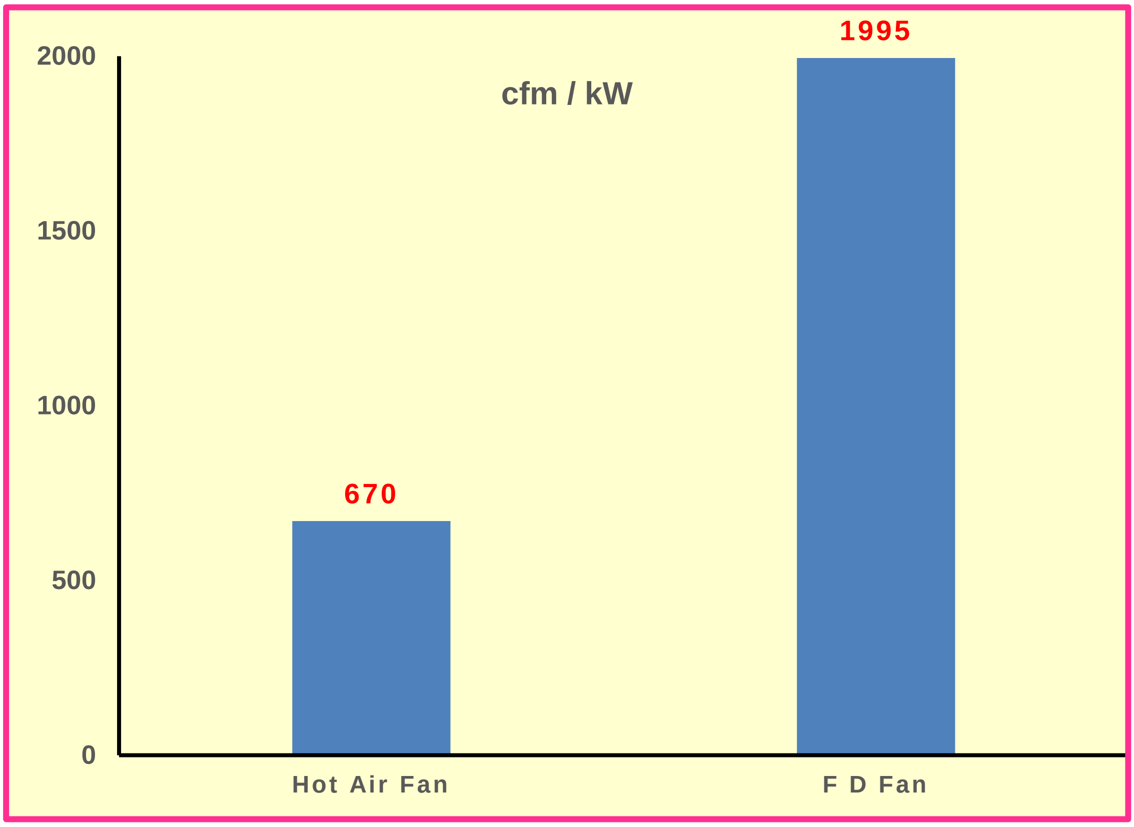


Fig 7.6 : Specific Air Flow Rates Established : Drier Section Fans | CAG

- 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 both the transformers is optimum and thus it is concluded that both of them perform well on energy front
- The performance of Withering Trough Fans is acceptable
- As far as CTC motors drive / driven mechanism are concerned, enormous slippage has been encountered and that needs to be set right at the earliest.
- The fans of the Drier section are performing sub optimally and a detailed performance study is therefore recommended.

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 14th of Sep 2024.
- The moisture content of DMT and Wet Dhool was affirmed through lab measurements at **3 %** and **74.05 %** 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 **5 645 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 **3 07 825 kg** for this period.

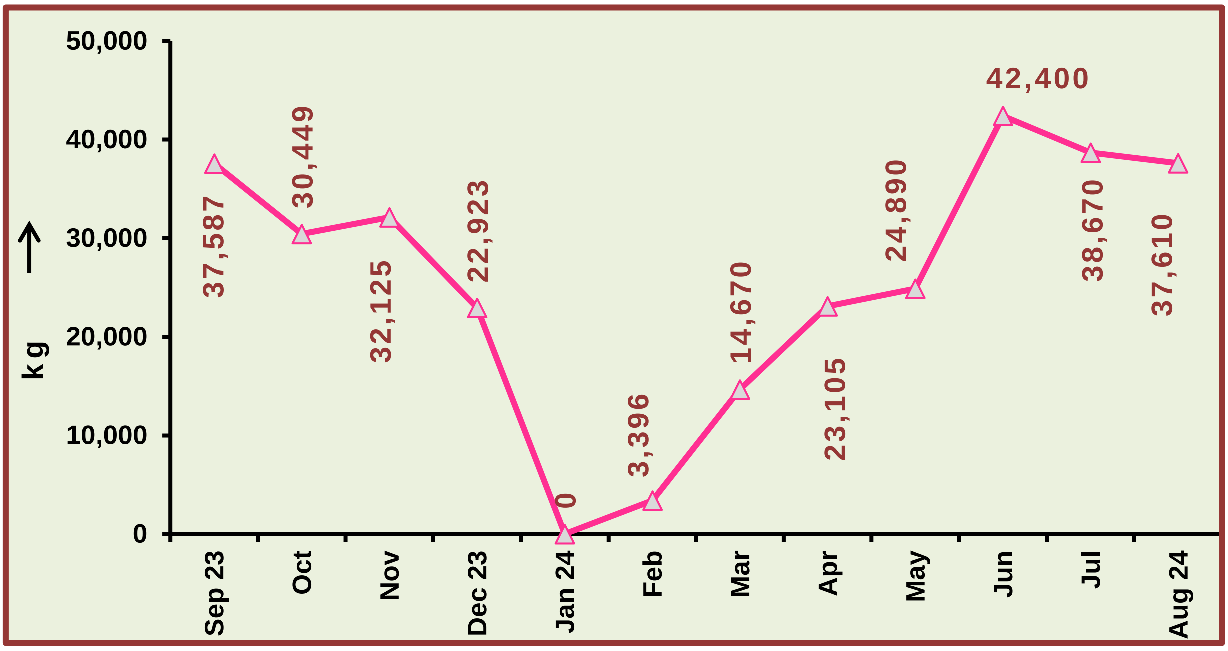


Fig 8.1: Coal Consumption – Month wise (Sep '23 – Aug '24) | CAG

- 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.

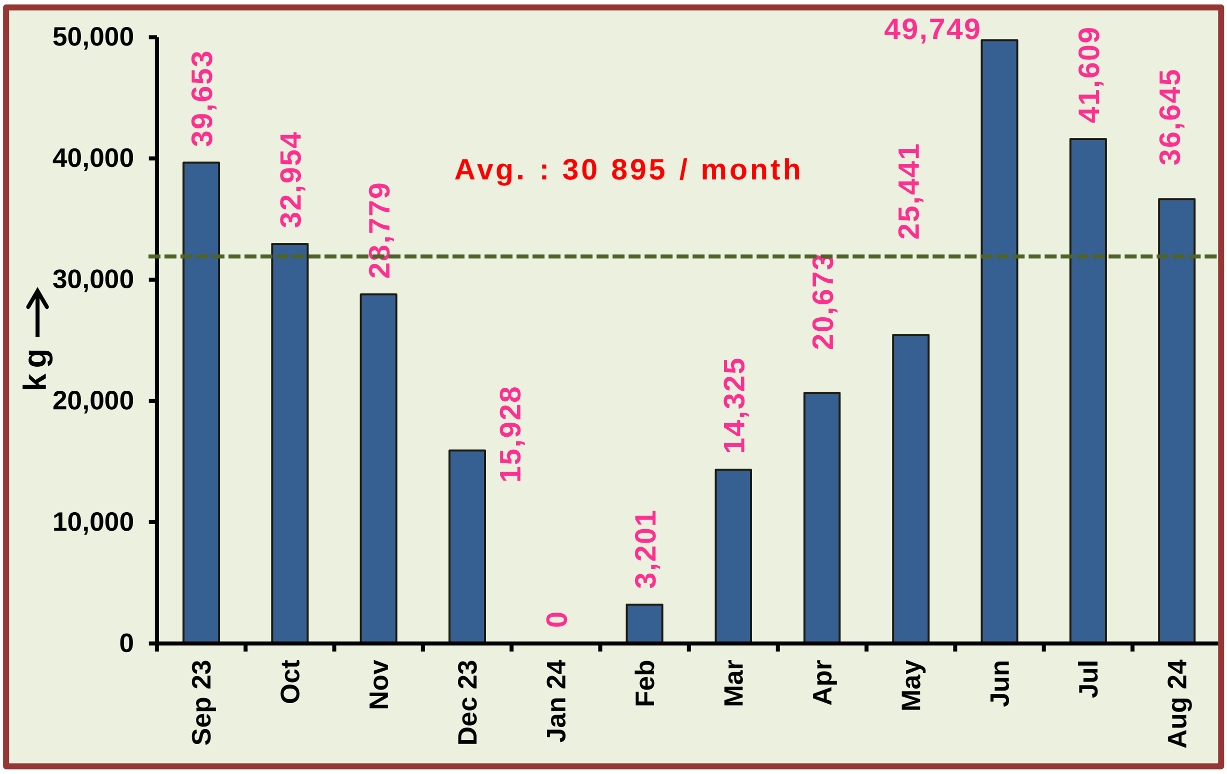


Fig 8.2: Drier Mouth Tea Output – Month wise (Sep '23 – Aug '24) | CAG

- The Drier Mouth Tea Output for the period Sep '23 to Aug '24 is **3 08 955 kg**
- 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 (**74.05%**) 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			Moisture %
		Quantity	Moisture	Solids (Tea)	
1	Wet Dhool	11 54 859	8 55 173	2 99 686	74.05
2	Drier Mouth Tea	3 08 955	9 269	2 99 686	3.0
Moisture Evaporated			8 45 904		

- The annualised quantity of moisture evaporated in the Drier is computed at **845 904 kg**.
- The theoretical amount of heat required to evaporate this amount of moisture would be **516 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 burned during this period is **3 07 825 kg**.
- The thermal energy input - from Coal - utilized for the process of drying is quantified as **1737.7 million kcal** considering the Gross Calorific Value (**GCV**) of Coal as **5645 kcal/kg.**
- The above assessment reveals that the Drier system operates at a thermal efficiency of **29.7%**.
- The results are summarized hereunder:

Moisture Removal kg	Theoretical Heat Requirement	Fuel Energy Input	Overall Thermal Efficiency %
	Million kcal		
8 45 904	**516**	**1 737.7**	**29.7**

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 **10:27 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 **6:49 pm**, and the aggregated coal consumption in this timeframe was computed as **1078 kg** in a span of **8 hrs and 22 min**.
- Thus, the coal firing rate was computed as **128.8 kg / h**.

b) Wet Dhool

- Similarly, the quantity of Wet Dhool loaded onto the Drier for moisture removal from **10:42 am** until **7:14 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 32 min** was **3 261.47 kg**, which would fix the Wet Dhool loading rate at **382.2 kg / h**.

c) Drier Mouth Tea Out

- 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 the same as that for Wet Dhool @ **10:42 am**, and the last bit of Wet Dhool added to the Drier came out as processed / dried tea at **7:39 pm**.
- The Drier Mouth Tea Output for the timeframe - **8 hrs and 57 min** - considered is **794.74 kg**, which establishes DMT production rate at **88.8 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 = 382.2 kg / h
  - **b.** Quantity of Dry Dhool collected at the Drier Mouth. = 88.8 kg / h
  - **c.** Hence, quantity of moisture evaporated = [382.2 - 88.8] = 293.4 kg / h
  - **d.** Heat Required for drying =
    [(88.8 x 0.97 x0.5 x 50) + (293.4 x 610) + (88.8 x 0.03 x 1 x 50)] = 1 81 261 kcal / h
  - **e.** Coal firing Rate = 128. 8 kg / h
  - **f.** Coal G C V = 5645 kcal / kg
  - **g.** Heat supplied by coal burning = (128. 8 x 5645) = 7 27 076 kcal / h
  - **h.** Hence, Overall Thermal Efficiency of the Drier = (1 81 261 / 7 27 076) = 25 %
- The overall thermal efficiency of the drier system is established as **25 %**.
- The thermal losses that formed around **75 %** of the heat input that comprises the following:
  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.

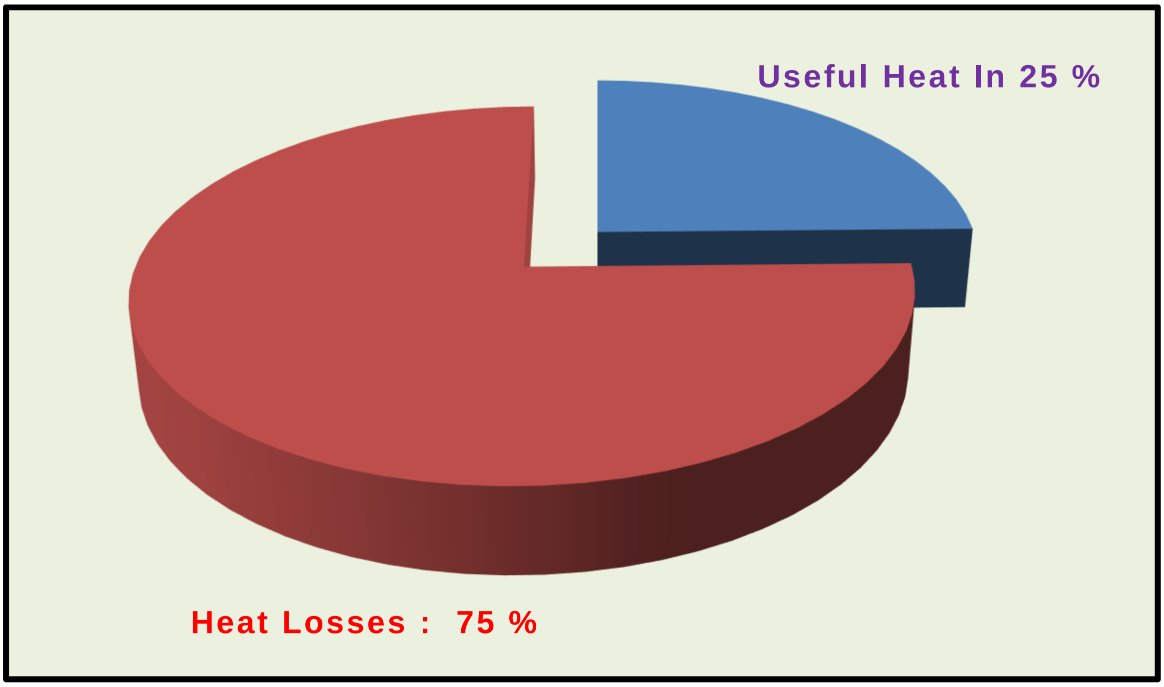


Fig 8.3: Overall Thermal Performance of the Drier | CAG

8.2 SUM-UP

- The overall thermal efficiency of the drier system established - through experiment during the time of audit - at **25 %** which is the typical value obtained in the coal fired furnace - cum - Drying system.
- The efficiency computed based on the historic data is **29.7 %.** This is determined considering parameters viz. GCV of Coal, Moisture Content in Wet Dhool and Drier Mouth Tea that were measured for the samples collected during the time of the audit. 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.
- The thermal energy [Coal] cost works out to **₹ 22.2 / kg** of Made Tea, which constitutes about **79.3%** of the total energy cost of tea production. This is in comparison to the electricity cost share of only **20.7 %**

- 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 **₹ 16 100 / 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 THE COAL AS THE SOURCE OF THERMAL ENERGY FOR COMBUSTION IN THE FURNACE TO CUT DOWN ON THE COST OF COAL PAID TOWARDS THE DRYING OPERATION

Cost Savings ₹/ y	Investment ₹	Payback Period Months
16 95 497	4 00 000	3

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 **5 645 kcal / kg as its Gross Calorific Value.**
- **The average landed cost of coal at the factory premises is ₹ 16 100 / ton**
- **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)
- The coal consumption pattern for the period Sep ‘23 - Aug ‘24 is depicted below :

Table 9.1: Coal Consumption & Cost Incurred

No	Period	Coal		Unit Cost
		Consumption kg	Cost ₹	₹ / kg
1	Sep 22 – Aug 23	3 31 984	56 09 251	16.9
2	Sep 23 – Aug 24	3 07 825	46 92 256	15.2
Total		6 39 809	1 03 01 507	16.1

- The aggregated coal consumption is estimated as **6 39 809 kg** and the factory had paid **₹ 1 03 01 507** towards the usage of Coal during the period of Sep ‘22 - Aug ‘24.
- The coal cost works out to **₹ 22.2 / kg** of Made Tea, which constitutes about **79.3 %** of the total energy cost of tea production
- It is felt that the cost spent on coal 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 Wooden 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) It was noted that the factory had installed a gasifier in its premises a couple of years back and not in use currently.[Refer the picture below]. Salvaging the parts of this abandoned system to build a wood chipper machine can be thought of as an option to save money.

Fig 9.1: Abandoned Gasifier : near the Factory Premises | CAG

ECONOMICS

- Calorific value of Coal = 5 645 kcal / kg
- Calorific value of Wood = 3 200 kcal / kg
- Therefore , 1 kg of Coal is equivalent to 1.8 kg of Wood on energy front.
- Coal Consumption = 3 19 905 kg / y
- Hence, expected wood consumption = (3 19 905 x 1.8) = 5 75 829 kg / y
- Landed cost Coal = ₹ 16.10 / kg
- Landed cost Wood (likely) = ₹ 6.0 / kg
- Cost Savings Possible = [(3 19 905 x 16.10) - (5 75 829 x 6.00)] = **₹ 16 95 497 / y**
- Investment Required = **₹ 4 00 000**
- Simple Payback Period = **3 months**

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

Cost Savings ₹/ y	Investment ₹	Payback Period Months
50 400	Nil	Immediate

OBSERVATIONS

- The factory has availed 2 HT SCs for powering the operations of various utilities involved in the manufacturing of tea.
- The demand contracted are 40 kW (HT SC 1) and 118.4 k W (HT SC 2) 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 Maximum Demand [M D] 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.
- Hence, it was decided to record the loading pattern of both the HT SCs 1 & 2 .

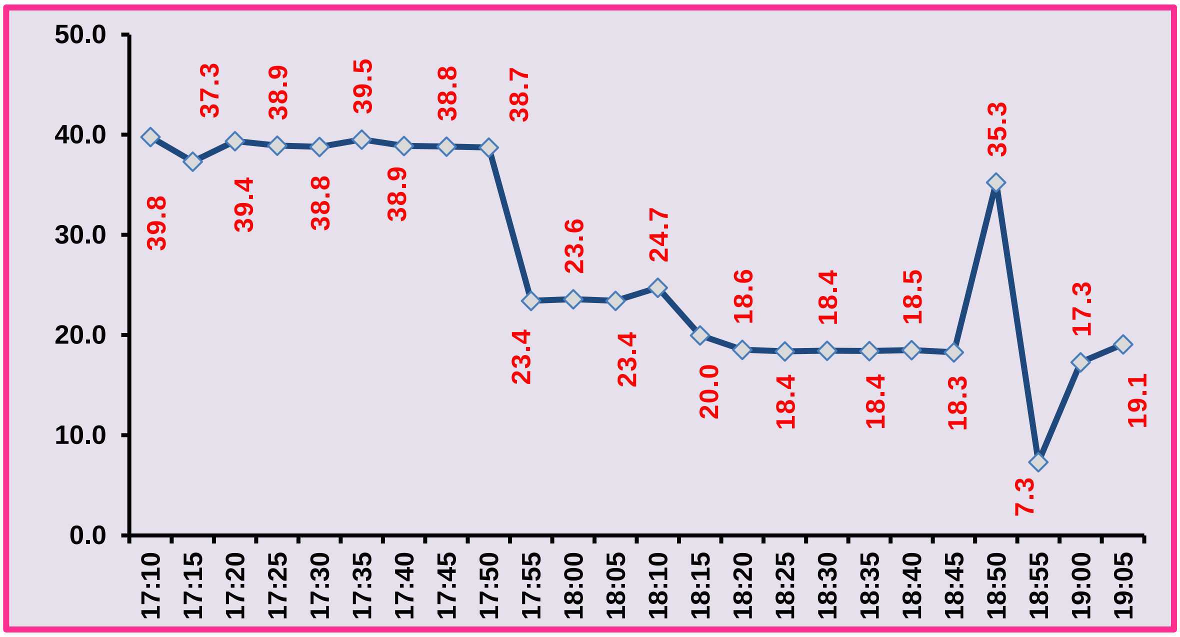


Fig 9.2 : Loading Pattern Recorded : HT1 SC: 2 h of Operating Period | CAG

COMMENT

- The loading pattern established for a period of 2 hours on the HT 1 transformer is shown in Fig 9.2 where the maximum load recorded was **39.5 kW**. The demand contracted for this SC is 40 kW
- This indicates that the contracted demand closely matches with the actual demand recorded leaving no scope for trimming further.
- However, the situation is different as far as HT SC 2 is concerned where the actual demand recorded is lesser than the contracted demand by a large margin.
- The loading pattern recorded in Transformer 2 for 2 hr period is shown in Fig 9.3

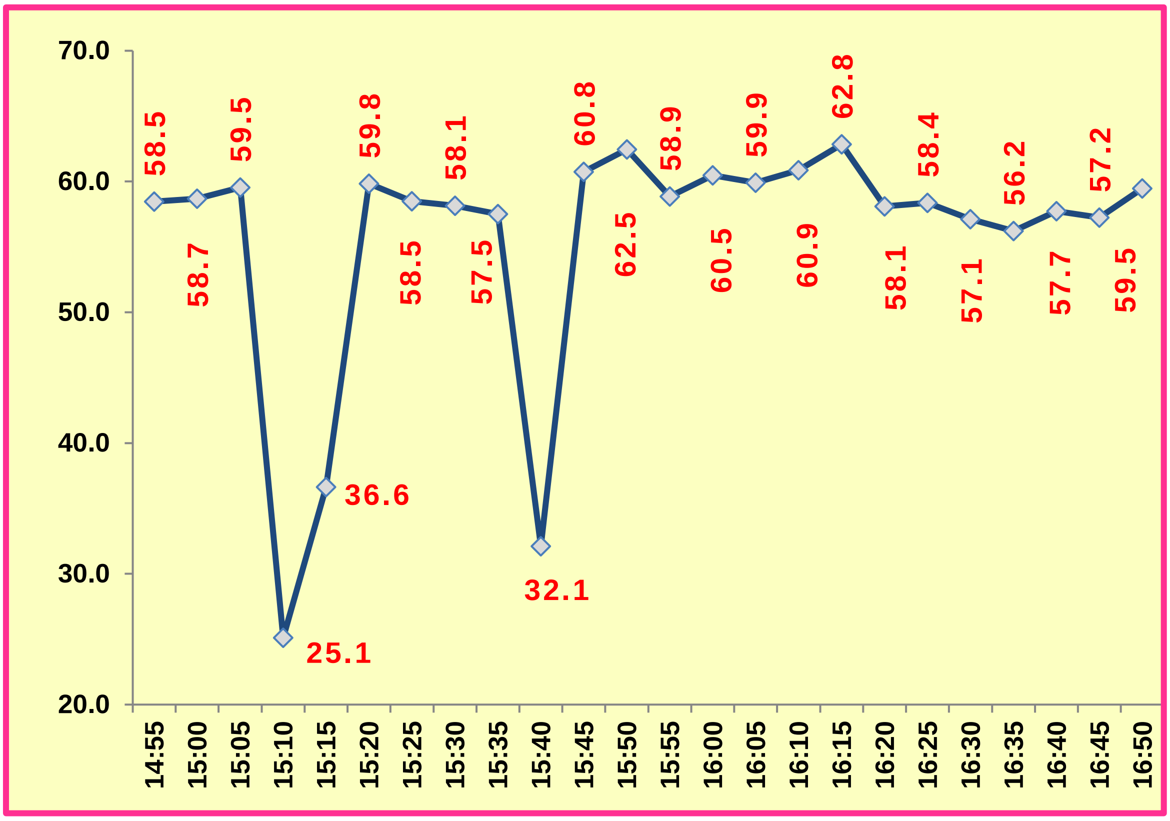


Fig 9.3: Loading Pattern Recorded : HT 2 SC: 2 h of Operating Period | CAG

- From the above, it is inferred that the maximum demand recorded was only **62.8 kW**. It is anticipated that the maximum load on this transformer will not exceed **70 kW**, considering the process loads linked to this SC that are the CTC and Humidifier Motors, a fairly constant load.
- In other words, the contracted demand is 118.4 kW whereas the MD reached can be around 70 kW only and this gives us a bandwidth of **40 kW** that can be trimmed on the HT2 SC.

RECOMMENDATION

- We therefore recommend trimming down the Contracted Demand of the **HT2** Service Connection from **118.4 kW to 78.4 kW**.
- It is also suggested to fix a Maximum Demand [M D] Controller in order to avoid exceeding the Contracted Demand

ECONOMICS

- Contracted Demand planned to clip = (118.4 – 78.4) = 40 kW
- Demand Charges levied. = ₹ 105 / kW / month
- Cost Savings thro' trimming C D = (40 kW x ₹ 105 / kW / m x 12 m / y)
  = **₹ 50 400 / y**
- Investment: = **Nil**
- Payback Period = **Immediate**

C C P 3

INSTALLATION AND COMMISSIONING OF 85 kWp 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
4 00 000	Nil	Immediate

OBSERVATION

- Tea manufacturing is an energy intensive process consuming both electrical and thermal energy in substantial quantities.
- As far as this factory is concerned, the Specific Electricity Consumption is **0.575 kWh / kg Made Tea** for the year '23 - '24 which is reasonable enough.
- Currently 100 % of its electricity requirement is sourced from the TSCEL through two H T Service Connections.
- The electricity consumption is **1.4 lakh kWh / y (= 390 kWh / day)** and the energy bill amount is close to **₹ 14 lakhs / y**
- The average cost of electricity is estimated at **₹ 9.62 / kWh** [inclusive of all charges] and **₹ 7.73 / kWh** [only energy charges]
- 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 entire electricity 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 85 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 6 000 sq ft and the factory has this area.

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

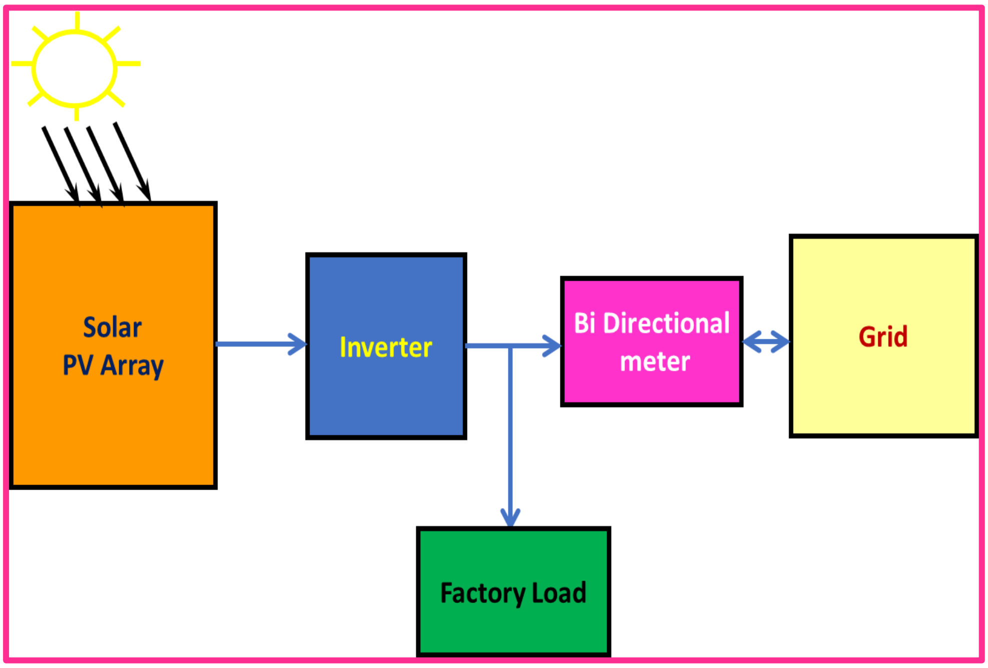


Fig 9.4 : Typical Solar ON -GRID System Configuration | CAG

ECONOMICS

- Capacity of On - Grid Solar Power Plant suggested = 85 kWe
- Electricity generation possible = 380 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 380 kWh / d x 350 d / y) = **₹ 4 00 000 / y**
- Investment required in RESCO model **= Insignificant**
- Simple payback period = **Immediate**

Fig 9.5 :Satellite Image of Leelagarh Tea Factory & Garden | CAG

- **Therefore, suitable action shall be initiated by the factory management in this regard**

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
16 250	Meagre	Immediate

OBSERVATIONS

- Electrical measurements have been recorded on both the transformers 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 & 10.2 respectively for the lower rated (63 kVA) and the higher rated (100 kVA) transformers.

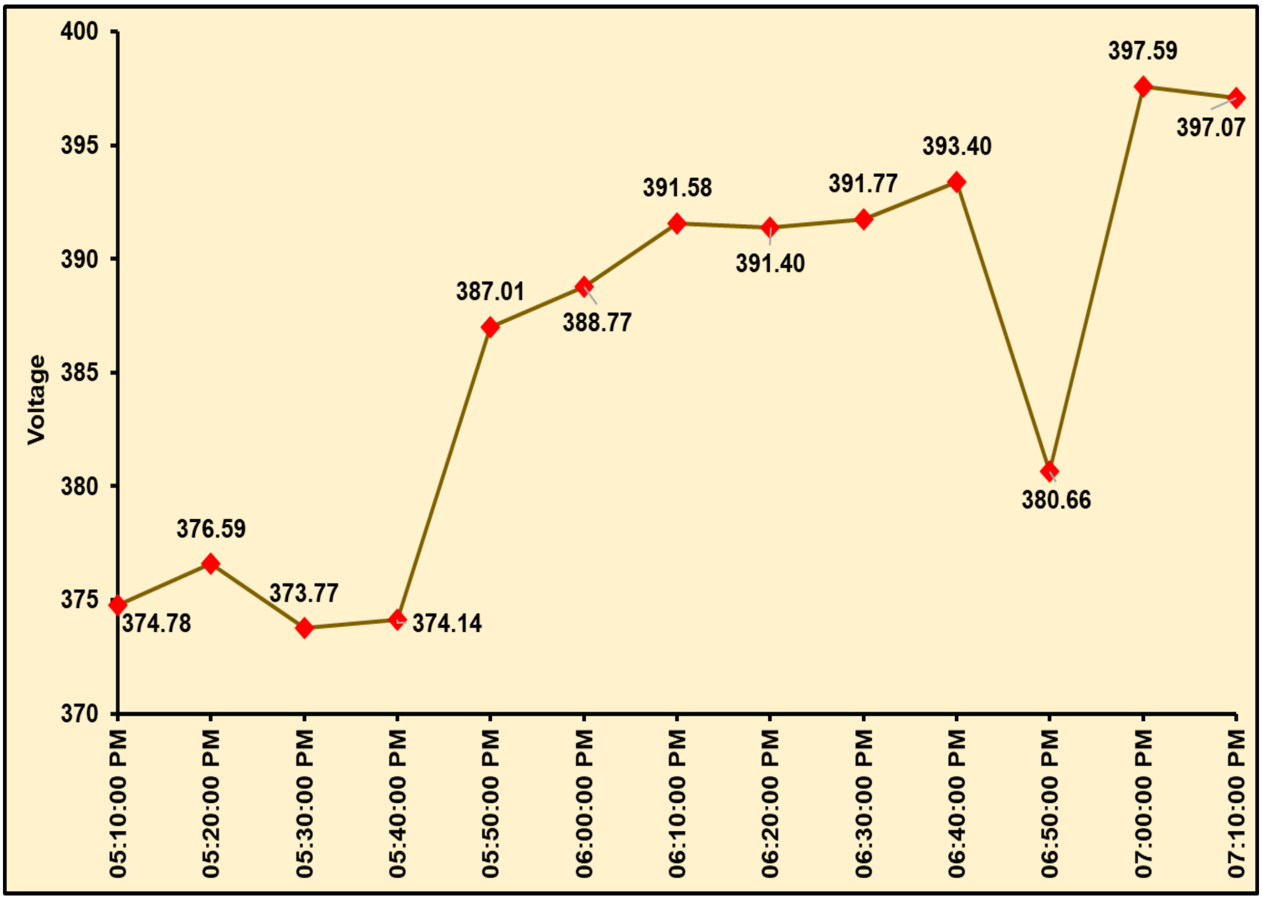


Fig 10.1: Voltage Variation Recorded:63 kVA Transformer | CAG

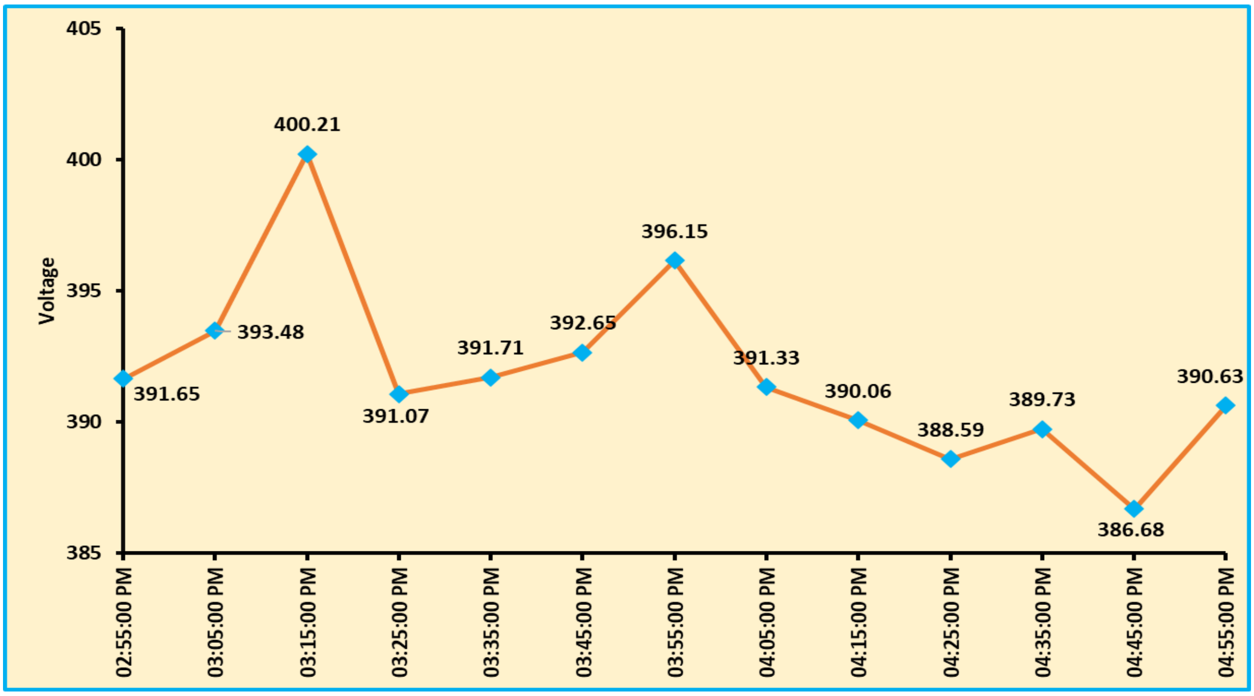


Fig 10.2: Voltage Variation Recorded : 100kVA Transformer | CAG

- The average operating voltage hovered around 380 in the 63 kVA transformer while it was 390 in the 100 kVA transformer
- The voltage range recorded was 374 to 397 (63 kVA Tr) and 387 to 400 (100 kVA Tr)
- The average operating voltage was found to hover around 380 for the lower rated transformer while it was 390 for the 100 kVA transformer.
- It was observed that majority of the process motors are supplied with power by the 63 kVA Transformer and motors of CTC Section only are attached to the 100 kVA Tr.
- 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

III 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.

c) Re working on the windings of T R 1 as it is noticed that T R 2 delivers the near required voltage for utilities operation [Fig 10.2]

ECONOMICS

- Energy consumed through Transformer 1 = [74778 + 65497] / 2 = 70 140 kWh / y
- Energy loss anticipated due to operation of motors at 385 V [7.5 % less] = 3 %

  = [70 140 kWh / y x 3 %] = 2100 kWh / y
- Energy Savings possible by setting correct the Voltage. = 2 100 kWh / y
- Cost Savings = (2 100 kWh / y x ₹ 7.73 / kWh) = **₹ 16 250 / y**
- Investment = **Meagre**

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

E C P 2

DOWNSIZE AND USAGE OF ENERGY EFFICIENT MOTOR IN THE ROTOR VANE OF C T C SECTION AIMING REDUCED ENERGY CONSUMPTION AND IMPROVED PF AND THEREBY COST SAVINGS

Cost Savings. ₹ / y	Investment ₹	Payback Period Months
11 595	40 000	42

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 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 Rotor Vane Motors is 15 kW (20 hp) and the electricity measurements carried out showed that this motor is lowly loaded on kW front.

Table 10.2 : Electrical Loading Pattern of Rotor Vane Motor

No	Motor ID	Rated			Measured			% Loading	
		kW	Amps	η %	kW	Amps	PF	kW	Amps
1	Rotor Vane	15	27.0	90.0	7.5	12.1	0.7	44.4	44.8

COMMENTS

- **It is quite clear from the above table that the Rotor Vane Motor is lowly loaded.**
- **As a consequential effect of this, the PF recorded was also lower at 0.70**
- **It appears that this motor is 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 Rotor Vane Motor - 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 hp (11 kW) enabling it to get loaded close to 70 %.
- The P F recorded for this motor was observed to be quite low and this is bound to improve as well through appropriate sizing of motor.

ECONOMICS

- Power drawn by the Rotor Vane Motor : present = 7.5 kW
- Power drawl anticipated – post replacement: = 7.0 kW
- Power Savings = 0.5 kW
- Energy Savings = (0.5 kW x 3 000 h / y) = 1 500 kWh / y
- Cost Savings = (1 500 kWh / y x ₹ 7.73 / kWh). = **₹ 11 595 / y**
- Investment towards installation of an E E Motor of 15 hp rating = **₹ 40 000**
- Simple payback Period = **42 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
1 04 650	1 00 000	12

OBSERVATIONS

- Coal is the fuel 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 10.3: Coal Fired Furnace in use for Hot Air Generation | CAG

- The average coal consumption is 320 tons / y and it is procured from Meghalaya mines.
- On an average, the landed cost of coal is **₹ 16 100 / 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 **25%**. The efficiency of the Heater alone is expected to be around **40%**.

- On an average 1.4 kg of coal is used to produce 1 kg of Made tea and that results in a lower operating efficiency of the Furnace.
- 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.
- 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.
- In short, 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] = 320 tons / y @ ₹ 16 100 / ton
- Coal savings anticipated by way of storage in an enclosure @ 2%

  = (320 tons / y x 2 %) = 6.5 tons / y
- Cost savings = (6.5 tons / y x ₹ 16 100 / ton) = **₹ 104 650 / y**
- Investment required for shed construction = **₹ 1 00 000**
- Simple payback period = **12 months**

E C P 4	USAGE OF VARIABLE SPEED DRIVE OR DUAL SPEED MOTOR FOR THE OPERATION OF THE ID FAN OF THE FURNACE TOWARDS FLUE GAS EXIT IN ORDER TO ACHIEVE EFFICIENT COMBUSTION OF COAL IN THE FURNACE [BY WAY OF OPTIMISING THE EXCESS AIR LEVEL REQUIREMENT IN COMBUSTION] AND SAVE ON COAL CONSUMPTION

Cost Savings ₹ / y	Investment ₹	Payback Period Months
1 04 650	75 000	9

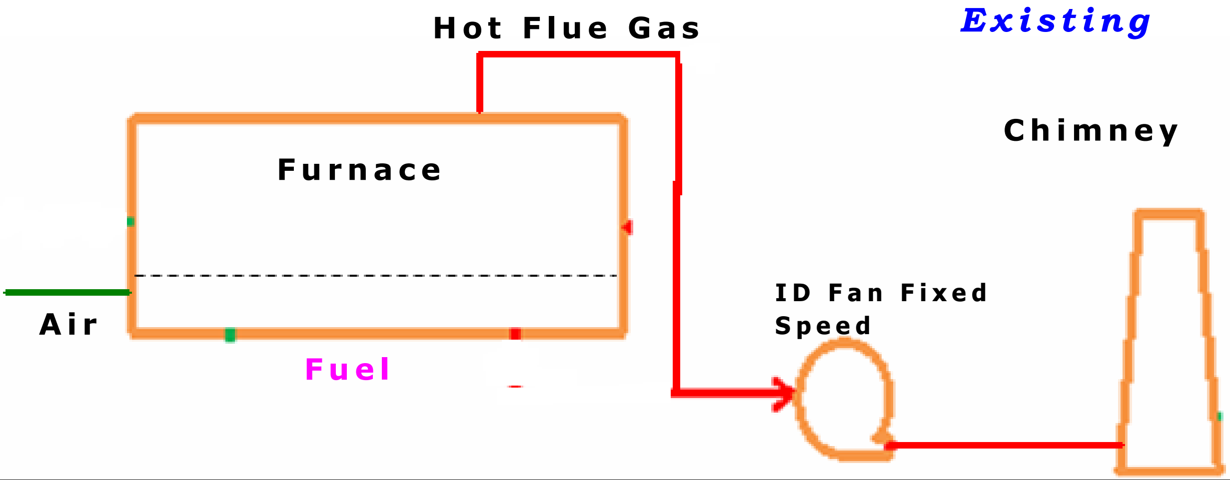
OBSERVATIONS

- It was our experience that ID fan ratings of hot air furnaces are not correctly sized in most of the factories.
- In the present case, the hot air furnace is fitted with an ID fan operated by a motor of 7.5 hp (5.5 kW). It was observed that the damper of the flue gas line is throttled to control the flue gas exit to the atmosphere.
- Further, as a norm, the fan operates at a single speed only independent of the fuel firing rate.
- This is to say that the quantity of flue gas let out has no direct relevance to the quantity of coal fired. In other words, there is no air modulation control on fuel firing.
- The power drawl of the ID Fan is recorded as 1.8 kW as against the rated power of 5.5 kW. The kW loading is less than 30 %.

Fig 10.4 : ID Fan for Flue Gas Exhaust and Chimney | CAG

COMMENT

- It is felt that ID fan could be a culprit in the HAG in bringing down the combustion efficiency partly due to the suction of uncontrolled quantum of flue gas.
- It is anticipated that the air supplied for combustion of coal will be much more than that demanded stoichiometrically which is 50 % or less for manually coal fired furnaces.
- In order to address this issue of higher excess air (higher flue gas heat loss) and to eliminate all the shortcomings noticed (ex: damper throttling, low kW loading and constant speed operation of the motor), it is suggested to install a variable speed / frequency drive to the ID fan that would control its operations (by varying in the speed) based on flue gas temperature / hot air temperature and make the air / flue gas flow always optimum.
- The present and the proposed scheme are shown in Fig 10. 5



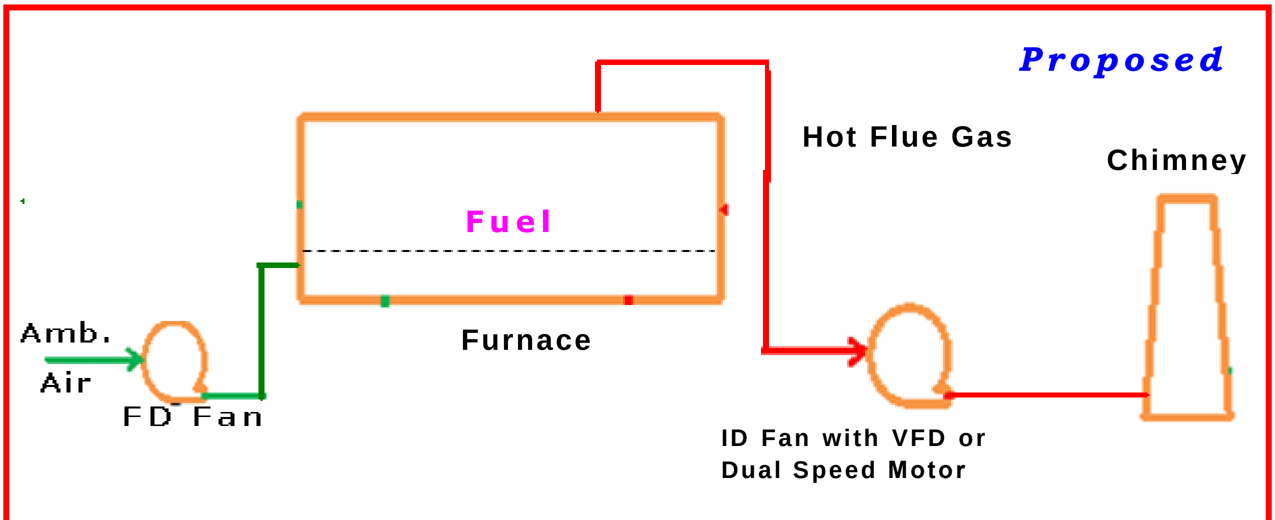


Fig 10.5 : ID Fan Motor Operation : VFD / Dual Speed Motor | CAG

- This arrangement would result in the operation of furnace in an optimal fashion enabling a reasonable saving in the coal.

RECOMMENDATION

- The suggestion made here is to provide
  a) **V**ariable **F**requency **D**rive (**VFD**) or
  b) **D**ual **S**peed **M**otor to the ID fan of the furnace
  in order to adjust the quantity of flue gas exiting by way of altering the speed of the motor based on coal firing rate.
- This arrangement will optimise the excess air drawl into the furnace and ultimately will enable the effective combustion of coal & thereby its saving.
- A number of the Estate & Bought Leaf Factories in South India have installed this ID fan controller & considerable cost saving has been achieved.

ECONOMICS

- Coal consumption = 320 tons / y
- Fuel savings expected @ 2 % = 6.5 tons / y
- Fuel cost (averaged) = ₹ 16 100 / ton
- Cost savings. = (6.5 tons / y x ₹ 16 100 / ton) = **₹ 1 04 650 / y**
- Investment = **₹ 75 000**
- Simple payback period = **9 months**

[Note: Dual - speed motors can be made to operate at 900 rpm as well as at 1440 rpm as per the need. It lose less power compared to speed control systems]

ECP 5

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
13 920	35 000	30

OBSERVATIONS

- The factory has installed a Drier and provided with a Hot Air Fan (Forced Draft w r t 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 a bit lowly loaded at 50 % 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	21.3	87.5	6.5	14.3	0.68	**51.7**	67.1

COMMENTS

- The lower kW loading indicates to the possible oversizing of the motor of this HAF.
- 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 as the kW loading is on the lower side needing correction at the earliest.
- 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 = 6.5 kW
- Power Savings Anticipated = 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). = **₹ 13 920 / y**
- Investment [Fitment of one VFD] = **₹ 35 000**
- Simple payback Period = **30 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
16 233	60 000	44

OBSERVATIONS

- The factory employs a total of 30 motors for carrying out its various process operations related to tea production.
- The loading pattern has been established for 23 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).
- The name plate details of 7 motors were not available to the audit team; hence their loading pattern could not be assessed.
- In addition, 6 motors of humidifier fans do not exhibit any name plate information and hence the loading pattern of these could not be established. In effect, the loading pattern has been established for only 17 motors.
- Out of the 17 motors that have been analysed, 11 motors have been found to be loaded to less than 50%.
- This is highlighted in Table 10.4 (motors with a power rating of 7.5 kW and less)

Table 10.4 : Loading Pattern of Motors: < 7.5 kW of Rated Power

No	Motor ID	Rated			Measured			% Loading	
		kW	Amps	η %	kW	Amps	PF	kW	Amps
1	Ghoogy	1.10	3.00	78.0	0.57	1.57	0.52	**40.2**	52.2
2	FD Fan	1.50	3.80	76.0	0.67	1.57	0.71	**33.8**	41.2
3	ID Fan	5.50	11.00	87.7	1.80	4.33	0.93	**28.7**	39.4
4	Tray Conveyor	3.70	8.20	84.0	2.03	4.00	0.85	**46.2**	48.8
5	Loading Conveyor	0.75	1.96	74.5	0.20	0.60	0.48	**19.6**	30.6

No	Motor ID		Rated			Measured			% Loading	
			kW	Amps	η %	kW	Amps	PF	kW	Amps
6	Mother	Sorter	1.50	3.40	77.0	0.30	0.80	0.58	15.2	23.5
7	Top		1.50	3.40	77.0	0.35	0.80	0.64	17.9	23.5
8	Dust		1.50	3.40	77.0	0.30	0.90	0.50	15.3	26.5
9	Broken		1.50	3.30	78.5	0.31	1.00	0.49	16.5	30.3
10	Fanning		1.50	3.40	77.0	0.38	1.00	0.57	19.7	29.4
11	Conveyor Motor 2		0.75	1.96	74.5	0.17	0.50	0.48	16.5	25.5
-	Humidifier	1	-	-	-	0.30	0.50	0.88	-	-
-		2	-	-	-	0.25	0.47	0.76	-	-
-		3	-	-	-	0.22	0.47	0.75	-	-
-		4	-	-	-	0.22	0.47	0.77	-	-
-		5	-	-	-	0.26	0.47	0.85	-	-
-		6	-	-	-	0.25	0.43	0.86	-	-
12	Withering Trough Fans	1 A	3.70	8.00	85.0	2.43	4.40	0.83	55.9	55.0
13		1 B	3.70	8.00	85.0	2.63	4.47	0.89	60.5	55.8
14		2 A	3.70	8.00	85.0	3.00	5.63	0.81	68.9	70.4
15		2 B	3.70	8.00	85.0	2.60	4.53	0.89	59.7	56.7
16		3 A	3.70	8.00	85.0	3.03	5.10	0.91	69.7	63.8
17		3 B	3.70	8.00	85.0	3.10	5.57	0.84	71.2	69.6

COMMENTS

- It can be deduced from above Table 10.4 that 11 motors (Sl No : 1 to11) have been found to be partly loaded with loading going below 30 % for majority of motors.
- Hence, it is appropriate that these 11 poorly 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 the 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	Measured	kW	%	kW Rating	O/p η	kW drawn	Load %
1	Ghoogy		78.0	1.10	0.57	40.2	67.9	0.75	82.5	0.47	51.3
2	F D Fan		76.0	1.50	0.67	33.8	66.1	0.75	82.5	0.53	58.8
3	I D Fan		87.7	5.50	1.80	28.7	80.7	2.20	86.7	1.68	66.0
4	Tray Conveyor		84.0	3.70	2.03	46.2	82.0	2.20	84.3	1.98	75.8
5	Loading Conveyor		74.5	0.75	0.20	19.6	61.1	0.20	71.1	0.20	60.3
6	Mother		77.0	1.50	0.30	64.7	64.7	0.37	51.8	0.25	51.8
7	Top		77.0	1.50	0.35	64.7	64.7	0.37	61.0	0.29	61.0
8	Dust	Sorter	77.0	1.50	0.30	64.7	64.7	0.37	52.1	0.25	52.1
9	Broken		78.5	1.50	0.31	65.9	65.9	0.37	56.1	0.27	56.1
10	Fenning		77.0	1.50	0.38	64.7	64.7	0.37	66.9	0.32	66.9
11	Conveyor Motor 2		74.5	0.75	0.17	16.5	61.1	0.20	71.1	0.15	50.8
	Total			**20.8**	**7.08**			**8.15**		**6.38**	

ECONOMICS

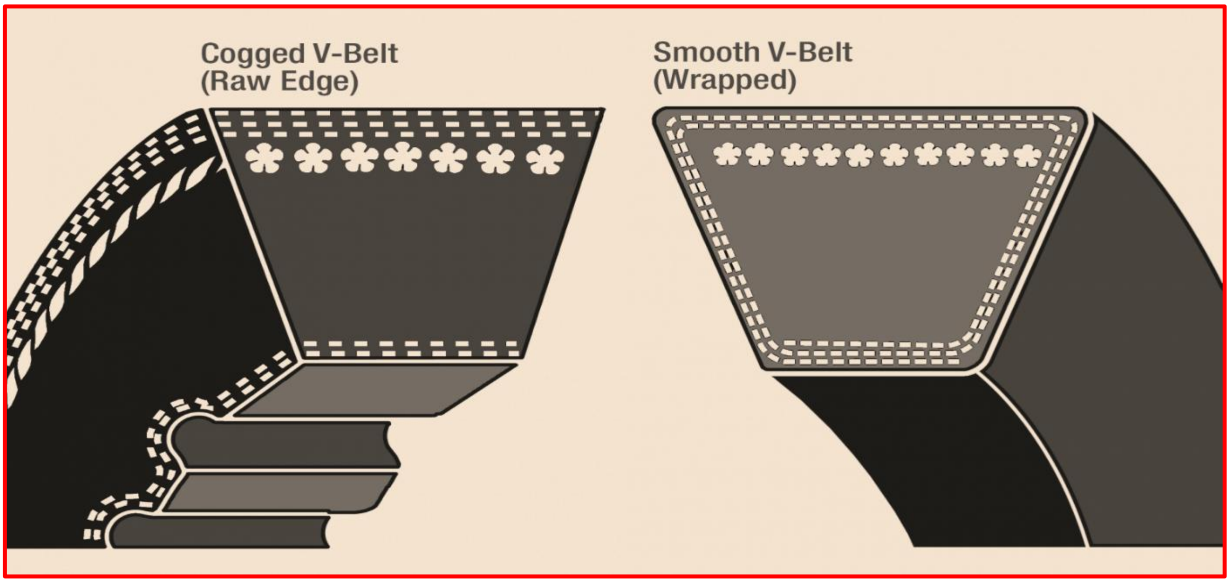
- Total Power Drawn presently by the identified 11 motors = 7.08 kW
- Anticipated Power Consumption – post replacement = 6.38 kW
- Power Savings = (7.08 – 6.38) = 0.7 kW
- Energy Savings = (0.7 kW x 3 000 h / y) = 2 100 kWh / y
- Cost Savings = (2 100 kWh / y x ₹ 7.73 / kWh). = **₹ 16 233 / y**
- Investment = **₹ 60 000**
- Simple payback period = **44 months**

E C P 7	REPLACEMENT OF CONVENTIONAL V-BELTS DRIVES WITH COGGED V-BELTS DRIVES IN THE IDENTIFIED MOTORS TO REDUCE BELT SLIP THEREBY ENHANCING THE TRANSMISSION EFIICIENCY AND SAVING ON ELECRICITY

Cost Savings ₹ / y	Investment ₹	Payback Period Months
69 570	75 000	13

PREAMBLE

- The speed of the CTC Roller / Rotor Vane shredder 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 will be more than 97 % for the cogged V - belt drives having a very meagre 'Slip'
- In addition, the transmission efficiency gets severely hampered by the usage of non - sufficient number of belts for transmission (ex : 3 belts instead of 4 and so on)



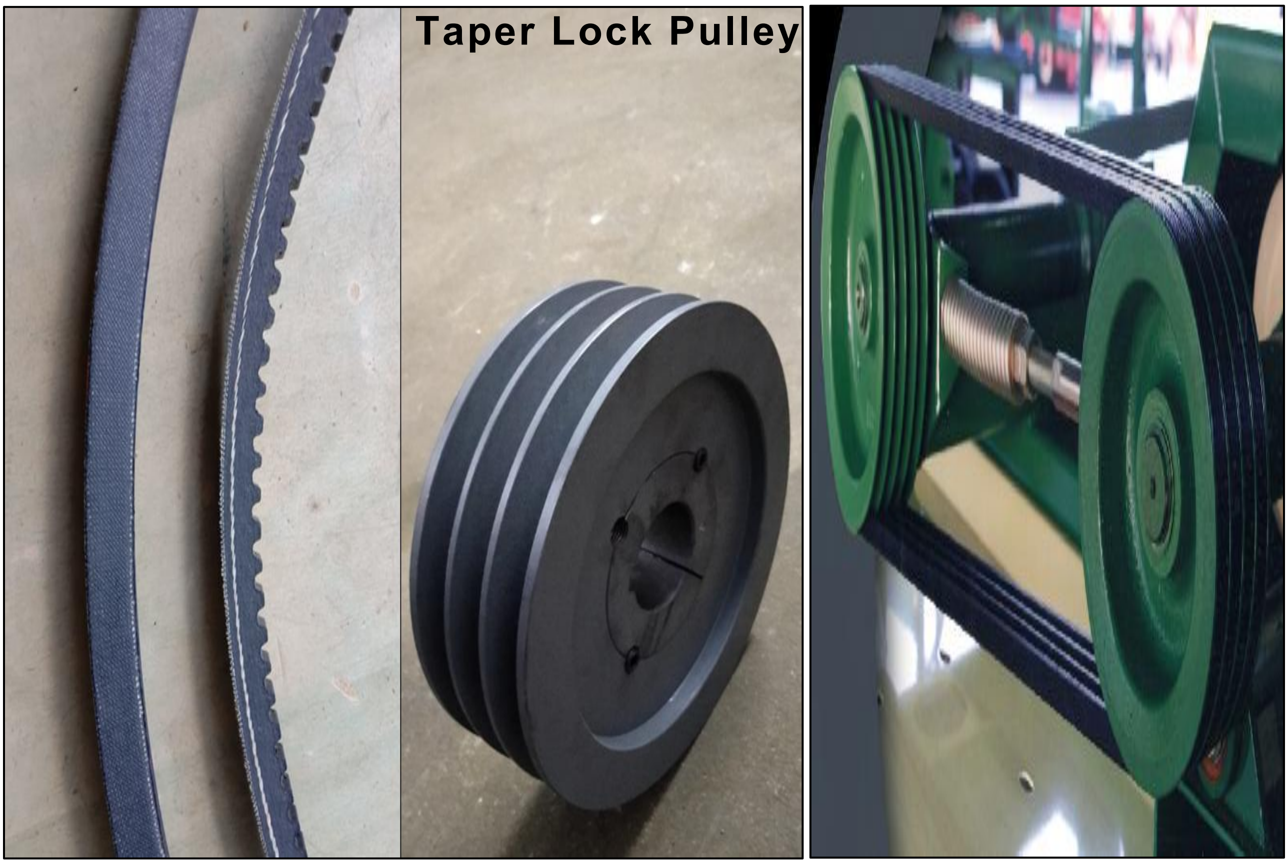


Fig 10.6 : Cogged V -Belt Drives : Proposed, Baart group | CAG

OBSERVATIONS

- The CTC line consists of 5 major motors, of which one drives the Rotor Vane, and the rest drive 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 the 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 is 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	**Rotor Vane**	120	300	1494.2	584.6	597.7	2.2	5	5
2	**Cut 1**	180	350	1473.9	711.5	758.0	**6.1**	4	3
3	**Cut 2**	180	350	1479.5	707.8	760.9	**7.0**	4	3
4	**Cut 3**	180	350	1486.9	705.3	764.7	**7.8**	4	3
5	**Cut 4**	180	350	1472.4	710.3	757.2	**6.2**	4	3
6	**Tray Conveyor**	80	180	996.1	343.4	442.7	**22.4**	2	2

COMMENTS

1) Four motors, namely the CTC Cut 1 - Cut 4 motors were 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.

2) The slip measured with the Tray Conveyor Motor was 22.4 % which is unacceptable. The Rotor Vane was the only exception where the slip recorded was only 2.2 % which is within permissible limits.

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 view point of reducing slippage and enhancing power transmission efficiency.

4) Cogged V-belts score over standard V - belts by at least 2 % 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 present V - belts on Cut 1 to 4 of the CTC section and the **Tray Conveyor** motor of the Drier Section with cogged V-belts, in a phased manner starting with the **Tray Conveyor,** in the descending order of slippage.

- Based on the success of this - effectiveness of which shall be established with power consumption measured before and after retrofit installation, as a way of validating the measure - this concept can be extended to the Rotor Vane 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	14.40	6.1	5	13.67
2		2	10.50	7.0	6	9.86
3		3	12.50	7.8	6	11.75
4		4	9.90	6.2	5	9.40
5	Tray Conveyor		2.03	22.4	18	1.65
Total			**49.33**			**46.33**

ECONOMICS

- Power Drawn - at present - by the identified 5 motors = 49.33 kW
- Anticipated Power Drawl - post retrofit = 46.33 kW
- Anticipated power savings with the incorporation of Cogged V-belts = 3 kW
- Energy Savings = (3 kW x 3 000 h / y) = 9 000 kWh / y
- Cost Savings = (9 000 kWh / y x ₹ 7.73 / kWh) = **₹ 69 570 / y**
- Investment = **₹ 75 000**
- Simple payback Period = **13 months**

E C P 8

REPLACEMENT OF EXISTING 75 W CONVENTIONAL CEILING FANS WITH ENERGY EFFICIENT 30 W "BLDC" FANS FOR THE SAKE OF ENERGY / COST CONSERVATION

Cost Savings ₹ / y	Investment ₹	Payback Period Months
2 230	5000	27

PREAMBLE

- Energy Efficient DC fan is a Brushless DC (BLDC) fan that has a permanent magnet for stator . This motor is modulated electronically.
- These fans are highly energy efficient ones and hence are rated with 5 star by BEE
- Motors of this fans have extremely low heat dissipation and therefore lesser associated power loss.

OBSERVATIONS & COMMENTS

- **2** Nos of Ceiling Fans are installed in the office premises of the factory.
- These fans will have a motor rating of 70 W and considering the age of these, it is anticipated that the energy consumption could be more than the rated value of 70 W
- These two old ceiling fans can be replaced with 5 star rated BLDC fans that are energy efficient ones
- This measure can be implemented as and when the replacement is due for these 2 ceiling fans

RECOMMENDATION

- The existing old inefficient ceiling fans can be replaced with BLDC - EE fans
- These E E fans demand a power drawl of only 30 W
- Hence, considerable energy savings can be anticipated
- However, these fans are costlier by 2 times of the conventional ones and hence economic viability has to be ensured prior to implementation

Economics

- No of Ceiling Fans targeted for replacement = 2
- Cumulative running period of these 2 Fans :

  = (2 fans x 12 h / d x 300 d / y) = 7 200 h / y
- Power Drawl: Present = 70 W / fan
- Power Drawl anticipated with BLDC Fans = 30 kW / fan
- Power Savings = (70 – 30) = 40 W / fan
- Energy Savings = (40 W x 7 200 h /y). = 288 kWh / y
- Cost Savings = (288 kWh / y x ₹ 7.73 / kWh). = ₹ 2 230 / y
- Investment towards procurement of 2 BLDC Fans = ₹ 5 500
- Salvage Value of 2 old Fans = ₹ 500
- Net Investment = **₹ 5 000**
- Simple Payback Period = **27 months**

11 CONSOLIDATION AND CONCLUSION

11.1 ENERGY CONSERVATION PROPOSALS: IDENTIFIED

- The Detailed Energy Assessment engagement at Leelagarh Tea Factory, Sabroom has revealed the availability of decent scope for improvement in 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 of less than 3 months). Two of these CCPs are NIL investment proposals, while the 3rd one brings in considerable savings in comparison with the investment to be incurred.
- At present, **3 Cost Conservation Proposals and 8 Energy Conservation Proposals** have been identified, the consolidated 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 the Coal as the source of Thermal Energy for combustion in the furnace to cut down on the cost of coal paid towards tea drying operation	**16 95 497**	**4 00 000**	**3**
2	Rationalization [Reduction] of Contracted Demand of the H T 2 Service Connection with a view to optimise the demand charges payable to TSECL	**50 400**	**Nil**	Immediate
3	Installation and commissioning of 85 kW_p On - Grid Solar Roof Top P V Power Plant adopting "RESCO" model towards attaining self-sufficiency in electricity demand in a sustained fashion and simultaneously going green	**4 00 000**	**Nil**	Immediate
	Total	**21 45 897**	**4 00 000**	**< 3**

Table 11.2: Energy Conservation Proposals: 8 Nos

No	Energy Conservation Proposals	Cost Savings ₹ / y	Investment ₹	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	**16 250**	**Meager**	**Immediate**
2	Downsize and Usage of Energy Efficient Motors in the Rotor Vane of C T C Section for reduced energy consumption and improved P F for the sake of cost savings	**11 595**	**40 000**	**42**
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	**1 04 650**	**1 00 000**	**12**
4	Usage of Variable Speed Drive or Dual Speed Motor for the operation of the ID Fan of the Furnace towards flue gas exit in order to achieve efficient combustion of coal in the furnace (by way of optimizing the excess air level requirement in combustion) and save on coal consumption	**1 04 650**	**75 000**	**9**
5	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 energy /cost saving	**13 920**	**35 000**	**30**
6	Downsize and Usage of Energy Efficient Motors in the Drier / Sorting Section for reduced energy consumption and improved P F for the sake of cost savings	**16 233**	**60 000**	**44**
7	Replacement of Conventional V - Belts with Cogged V-Belts In the identified motors to reduce belt slip thereby enhancing the transmission efficiency and saving on electricity	**69 570**	**75 000**	**13**

No	Energy Conservation Proposals	Cost Savings ₹ / y	Investment ₹	Payback Period Months
8	Replacement of existing 75 W Conventional Ceiling Fans with Energy Efficient 30 W "**BLDC**" Fans for the sake of energy / cost conservation	**2 230**	**5 000**	**27**
	Total	**3 39 098**	**3 90 000**	**14**

- The overall anticipated savings is computed at **₹ 24 84 995 / y** at an investment of **₹ 7 90 000** which shall be paid back in about **4** months.
- On the energy front, the overall savings is expected to be **16 790 kWh / y** on Electrical, equivalent to a cost saving of **₹ 1 29 800 / y**.
- Of the **8** 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 Leelagarh 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 **25%**. • The thermal energy cost works out to **₹ 22.2 / kg** of Made Tea, which constitutes about **79.3%** 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 coal feeding area - where there is a scope for improvement • Fuel switch from coal to cheaper, more affordable wood chips shall result in significantly lowering the fuel cost paid. [CCP 1] • Further, suggestion has been made to provide a Closed Storage Yard for coal in order to avoid the coal from picking up moisture which is detrimental to the performance of the drier. (It will pull down the combustion efficiency) that will ultimately result in higher

No	Section	Remarks
		coal consumption per kg of Made Tea production. At present, the specific coal consumption is 35 % above the benchmark value.
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	• 2 out of the 6 motors of this CTC 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 (RV + 4 Cuts in each line), revealing decent scope for improvement in 4 motors. • Some grooves were missing a belt. This is mentioned in the report, and the need to stick with designed guidelines is recommended.
4	Drier Section	• The loading of the motors in this section is on the lower gamut - less than 50% on kW - which needs to be addressed. • Belt slippage computed for the Tray Conveyor motor is considerably high at 22 %, which makes it an ideal candidate for replacement with Energy Efficient Cogged V - Belt.
5	Sorting Section	• The loading pattern of all the 11 motors of this section is uniformly less than 20%, necessitating the need to enhance it considerably. • Suitable recommendations have been made in Chapter 10.
6	Thermography - Electrical Safety & Motors	• Altogether, abnormality existed only in 2 out of 26 locations that were surveyed for possible discrepancy in electrical connection tightness; the electrical maintenance team deserve due credit for this. • The surface temperature profiles of the motors revealed the absence of any abnormality. • As such, the Thermography study has revealed NO abnormality either in electrical or thermal side. This is well appreciated

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 period is less than 3 months, which is very encouraging
- In short, the performance of the utilities can be ranked at 7 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.,
- 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.
- In all, thermo mapping was carried out at 26 locations, excluding locations where no discrepancies were observed.
- Based on the observations made, 2 locations were found to exhibit abnormality and hence suggested for attention at the earliest as they are likely to impact the safety.
- The International Electrical Testing Association [I E T A] provides the guidelines [Table 12.1] that aid in determining the degree of severity of a problem typically associated with electrical power transmission.
- The severity is grouped into 4 categories, namely,

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

  based on the magnitude of the temperature encountered
- The IETA 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: Limitedprobability of physical damage
Moderate	41 - 60	Repair soon (2 - 4 weeks). Watch Load and change accordingly. Inspect for physical damage.
Serious	61 - 80	Repair within 1 or 2 days. Replace component and inspect the surrounding components for probable damage
Critical	Above 80	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 to address them accordingly:

Table 12.2 : Severity Assessment : Recommended Action

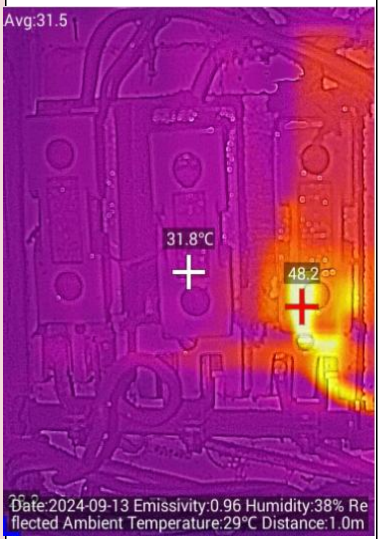
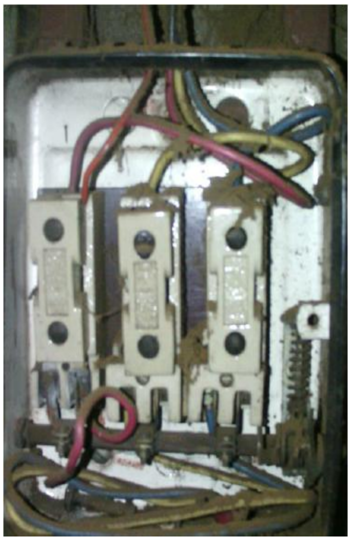
Priority	ΔT between similar Components under similar load	ΔT over ambient air temperature	Recommended Action
4	1 to 3 °C	1 to 10 °C	Possible deficiency; warrants investigation
3	4 to 15 °C	11 to 20 °C	Indicates probable deficiency; repair as time permits
2	– – –	21 to 40 °C	Monitor until corrective measures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

12.2 ABNORMALITIES NOTICED: 2 LOCATIONS: OVERALL

- Abnormalities have been noticed at only 2 locations of all the 26 locations surveyed through Thermal Imaging Study conducted. The maintenance team deserves due credit for restricting the abnormality to only 2 locations.
- Remedial action may be initiated to set right the abnormality.

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

12.2.2 Category : Moderate : No of Locations : 2 : Temp: 41 - 60 °C

No	Location	Thermal Image	Normal Image	Temp °C
1	**Mother Sorter Incoming**			48.2 °C in B Phase
2	**C T C INCOMER**			51.2 °C in R Phase, 46 °C in Y Phase & a similar temp. in B Phase as well

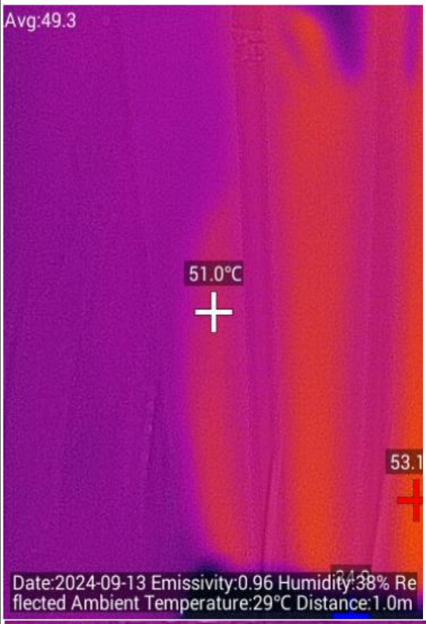
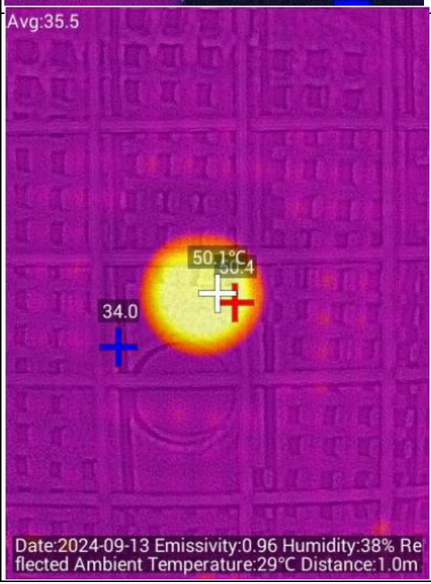
- The **two abnormalities** identified belong to the "**Moderate**" severity category
- The occurrence of faults can be attributed to
  - Loose connections.
  - Deterioration of distribution lines (Cables)
- The possible remedies are
  - Check & Re do / Re terminate the cables / busbars etc. as per the observations made.
  - Provide adequate cooling.
  - Provide new & properly sized (Current carrying capacity) cables
- These abnormalities shall be attended to at the earliest opportunity

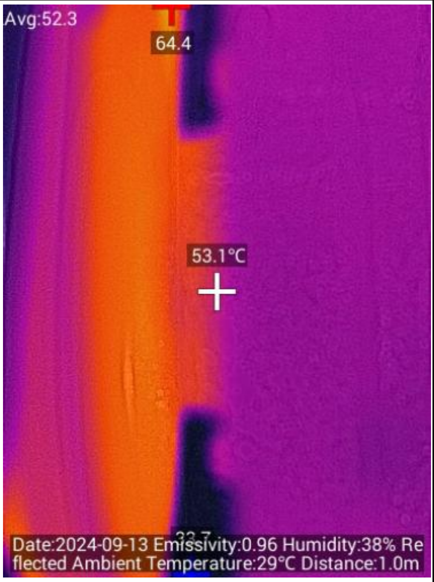
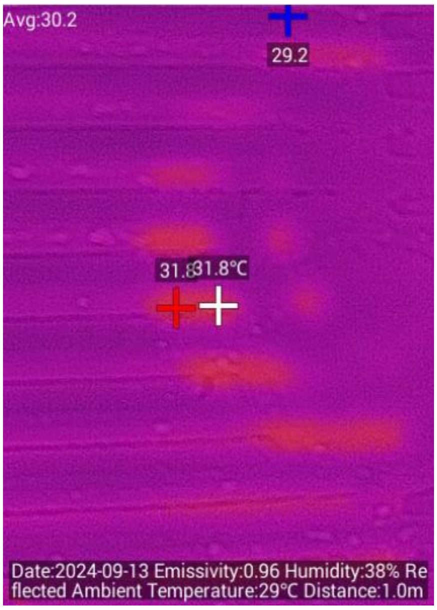
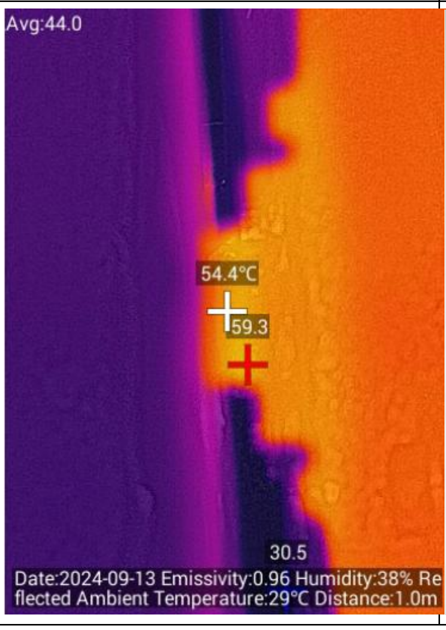
12.2.3 Category : Serious : No of Locations : NIL : Temp: 61 - 80 °C

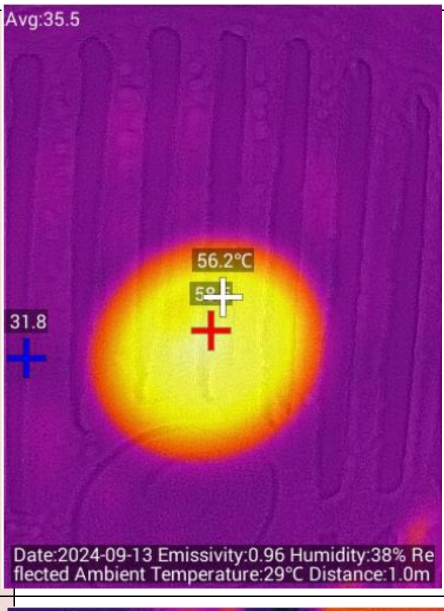
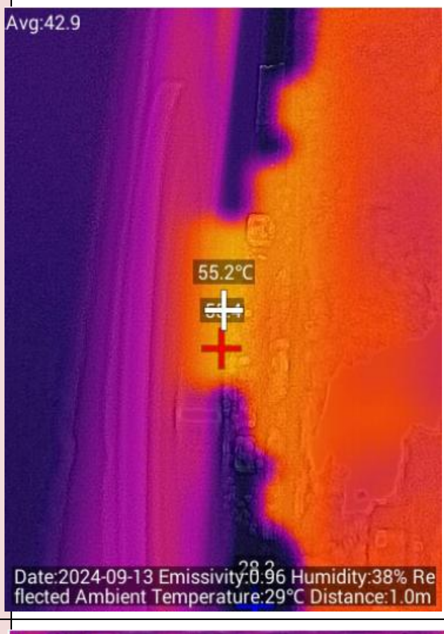
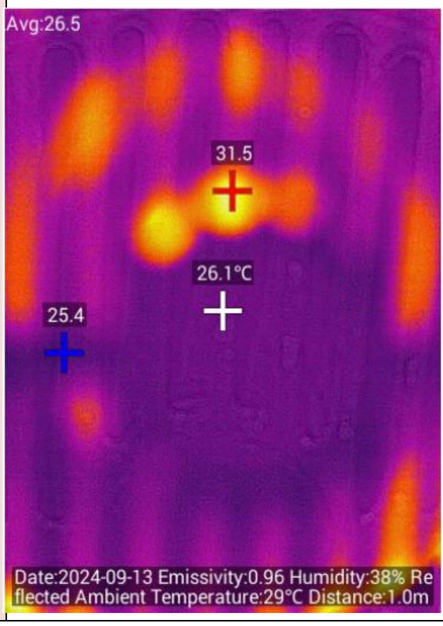
12.2.4 Category : Critical : No of Locations : NIL : Temp: above 80 °C

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 the same.

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		

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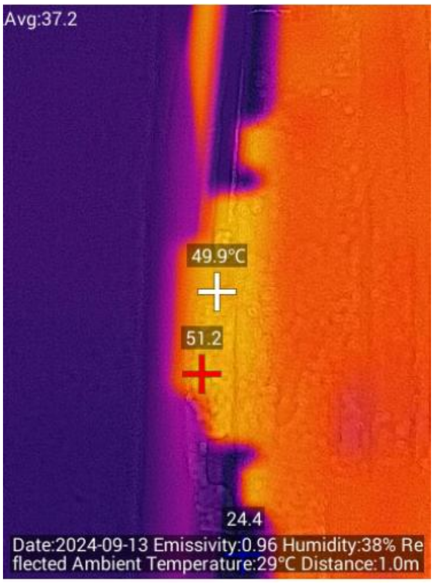
Driving End</td><td>
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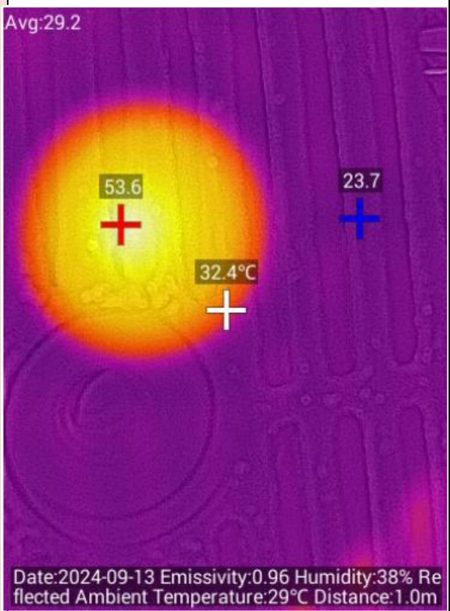
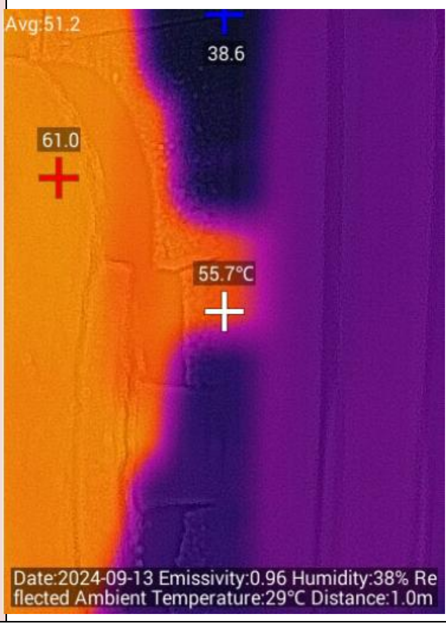
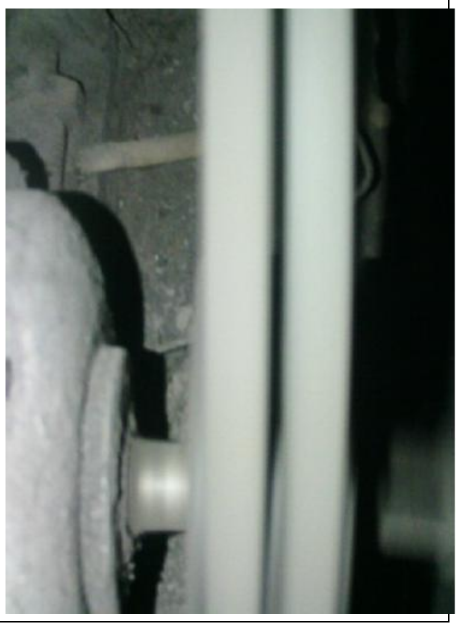
Non-Driving
End</td><td>
</td><td></td></tr>
<tr><td>11</td><td>ID Fan
Driving End</td><td>
</td><td></td></tr>
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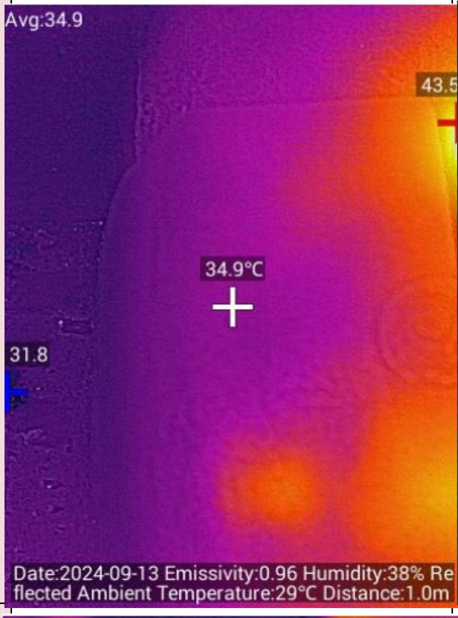
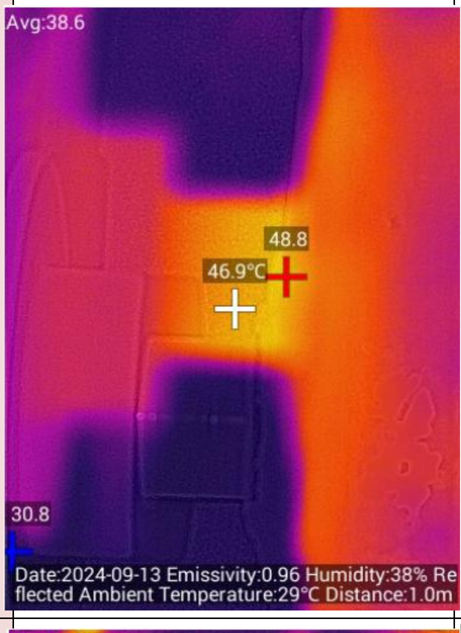
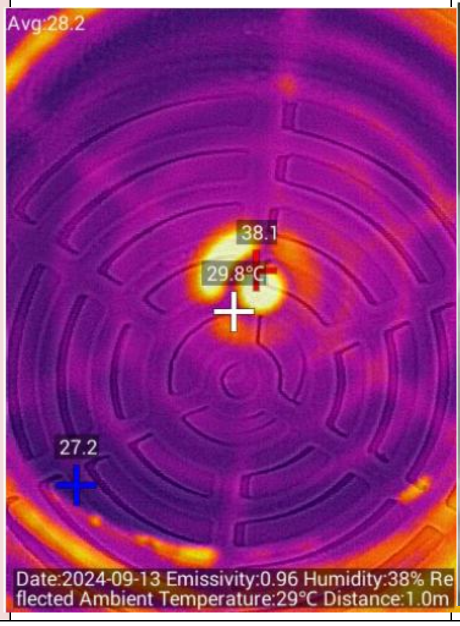
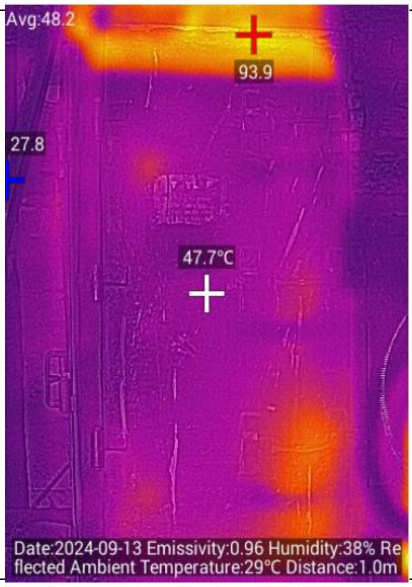
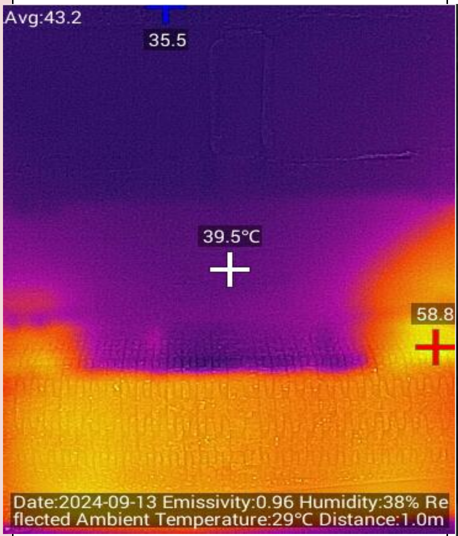
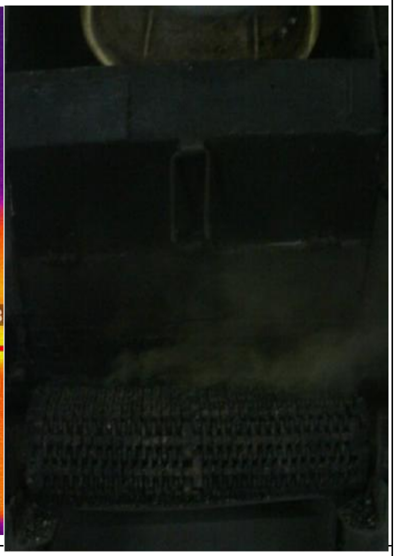
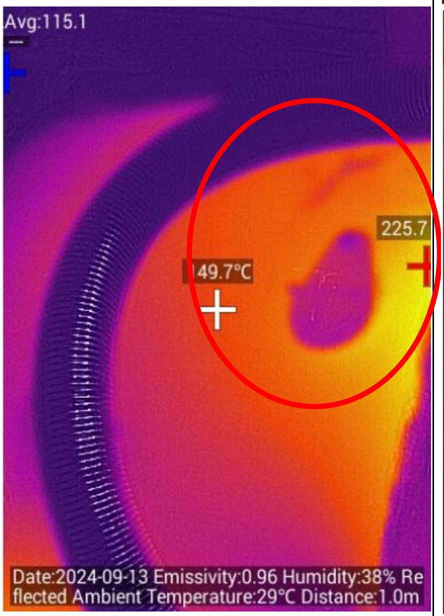
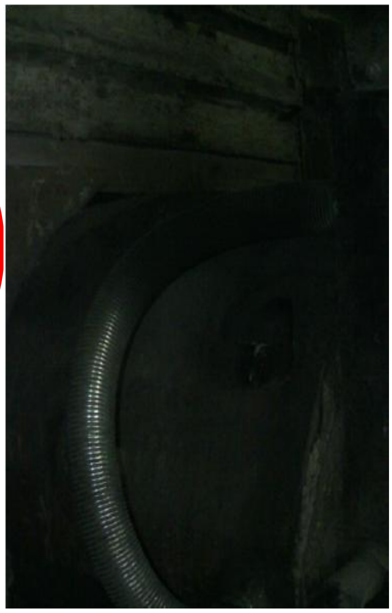
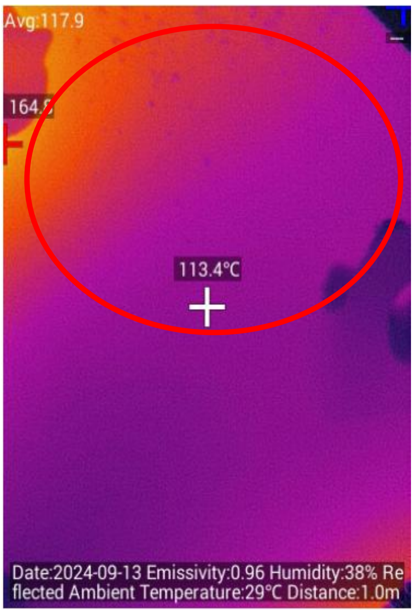
12	**ID Fan Non-Driving End**		
13	**FD Fan Driving End**		
14	**FD Fan Non-Driving End**		

12.4 NIL ABNORMALITIES RECORDED : 10 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 Coal Firing 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	**Near Coal Feeding Zone; Picture captured from the Front, of the RHS of the Drier**		
2	**Near Coal Feeding Zone; Picture captured from the Front, of the LHS of the Drier**		

3	Coal Feeding Zone; Picture captured from the Front		
4	Coal Firing Zone; Picture captured from the RHS of the Drier		
5	Coal Firing Zone; Picture captured from the LHS of the Drier		

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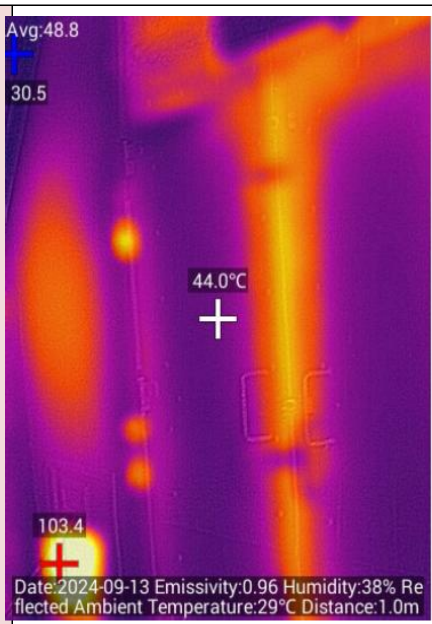
<tr><td>6</td><td>Picture captured of the RHS of the Drier, below the HAF air intake</td><td>
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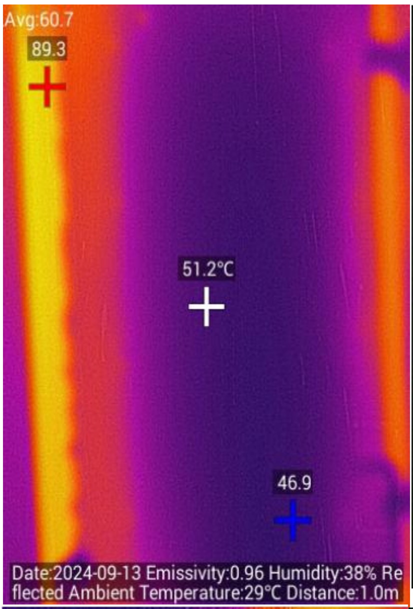
<tr><td>7</td><td>Picture captured of the LHS of the Drier, below the HAF air intake</td><td>
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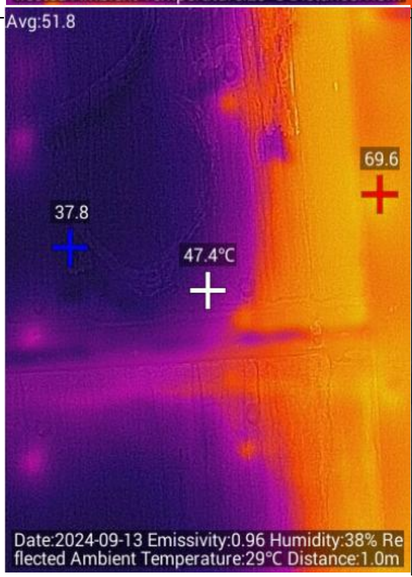
<tr><td>8</td><td>Picture captured of the back side of the Drier, from the LHS</td><td>
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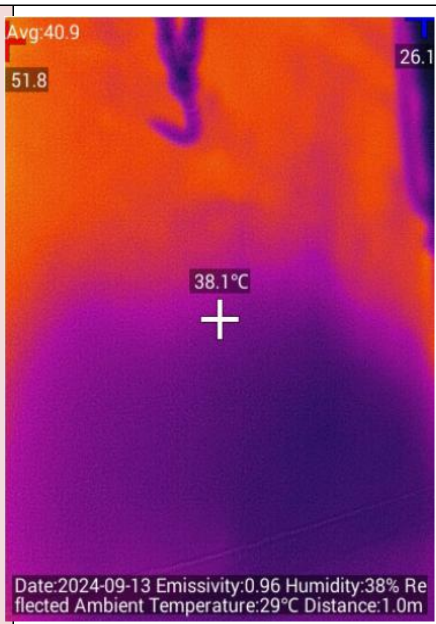
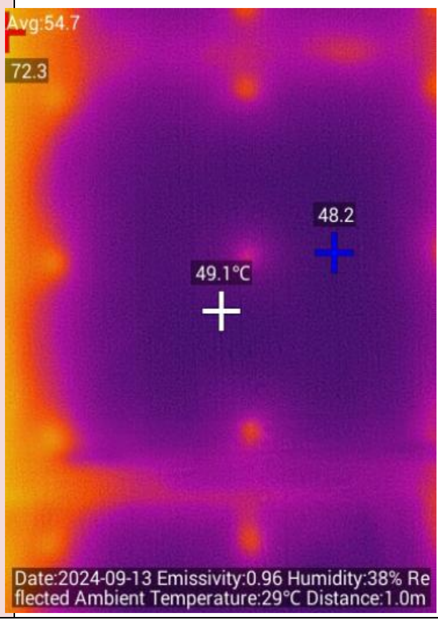
9	**Picture captured of the front portion of the back side of the Drier**		
10	**Picture captured of the back side of the Drier, from the RHS**		

12.5 SUM UP

- Altogether, abnormality existed in only 2 out of 26 locations surveyed for possible discrepancy in electrical connection tightness. It is only a meager fraction of the surveyed lot and the electrical maintenance team deserves appreciation.
- The 2 discrepancies highlighted in this section - even though they assume only “Moderate” severity status - shall be set right at the earliest in order to avert production disruption due to electrical fault.
- The cost needed for setting these faults correct shall be absolutely meagre and hence can be taken up for rectification at the earliest.

- The surface temperatures of motors 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 shall 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 coal firing zone 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 amount.

13 SAFETY CONSIDERATIONS AND UPKEEP

13.1 OBSERVATIONS

- 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.
- Maintenance of Records was found wanting in respect of Transformers, 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 the power house. Fix the DCP type portable fire extinguisher.
- The following 3 locations have been identified that call for mechanical related safety protocol.

No	Location	Image	Comment
1	CTC Cut 1		• Poor belt condition • Groove missing a belt

2	CTC Cut 3		• Poor belt condition
3			• Groove missing a belt

- Similar to the above, one groove out of the 4 grooves in the pulley corresponding to the Cut 2 and Cut 4 motors of the CTC Line were running empty too, i.e., they were one belt short of operating in the requisite manner.
- This shall be corrected too, as it is advised to stay in line with the designed principles from safety as well as from an energy efficiency viewpoint. It shall be noted that these 4 CTC motors, namely Cut 1 – Cut 4 exhibited significant belt slippage, and one of the reasons for the same would be this off - design characteristic.

13.2 SUMMATION

- It is felt that safety shall be given due consideration it deserves as 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

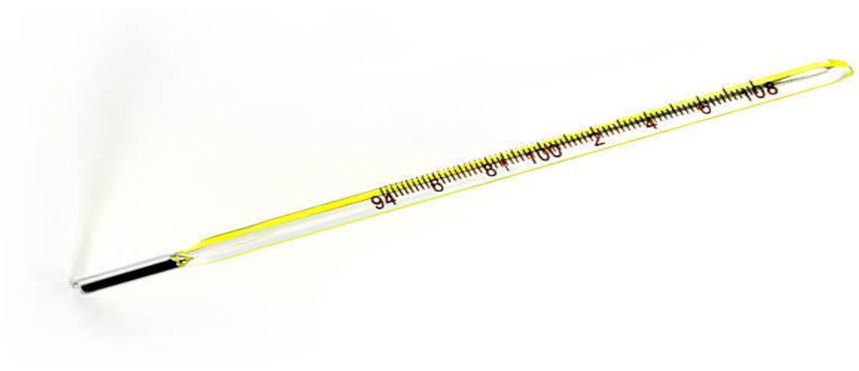
14.2 THERMAL PARAMETERS – 5 INSTRUMENTS

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

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