Detailed ENERGY AUDIT REPORT

Durgabari Tea Factory

CAG

Citizen consumer and civic Action Group

Detailed Energy Audit Report on Durgabari Tea Factory

Durgabari Tea Estate Workers Co-operative Society Ltd,

P.O. Tebaria, Tripura (W)

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CAG
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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 Workers Co - operative Society and aided partially by the Tripura State Government.

This work would not have been 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, FAO - Head, Tea Board, Agartala**

Our thanks are due to **Mr Asish Adhikari, Manager, Durgabari Tea Estate Workers Co - operative Society Ltd** who rendered all necessary technical and manpower support towards the execution of this assignment.

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The remarkable rapport, cooperation and clear understanding shown by the concerned supporting staff of the 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 Durgabari Tea Factory*** to the management of the Tea Factory. The Energy / Cost Conservation schemes identified and proposed in this report - when implemented - are expected to bring in lasting benefits (savings) in terms of energy as well as cost to the Tea factory.

We request the concerned authorities to take up the energy - cum - cost conservation suggestions for implementation on priority basis..

Any omission of names in the acknowledgement is purely unintentional and we ask that it be pardoned.

LIST OF ABBREVIATIONS

BEE	Bureau of Energy Efficiency
BLDC	Brushless Direct Current
BQ	Booked Quantity
CCP	Cost Conservation Proposals
CD	Contracted Demand
CFM	Cubic Feet per Minute
CNG	Compressed Natural Gas
CTC	Crush, Twist, Curl
DG	Diesel Generator
DISCOM	Distribution Company
DTF	Durgabari Tea Factory
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 Durgabari Tea Factory is owned and operated by the Tea Estate Workers Co - operative Society, with production starting in the year **2004**.Located in Agartala, the factory has a total built up area of **20 000 sq. ft** and manufactures CTC (Crush, Tear and curl) tea for which it uses both electrical and thermal energy.The factory has estates at 2 locations, one in Durgabari (**183 acres**) and the other in Simna (**420 acres**) that cater to its production requirements. The total area under tea plantation cultivation is **145** and **165** acres respectively.

ENERGY ASPECTS

- The electricity is sourced through Feedback Energy Distribution Company Limited (FEDCO) as per the agreement with Tripura State Electricity Corporation Limited (TSECL). The consumption of electricity for the period from **Sep 23 to Aug 24** is **3.14 lakh kWh**. Since the tea manufacturing is a continuous process, 2 Diesel Generator (DG) sets are put into service to supply power whenever FEDCO supply is not available. The usage of DG sets (in terms of diesel consumed / units generated) is not recorded as it was realised that it's usage is quite insignificant and hence was ignored in the computation of the Weighted Average Cost of Energy.
- The cost of FEDCO energy has been computed as **₹ 9.31 / kWh** (that includes all charges) for the period Sep 23 - Aug 24. However, the value considered in the commercial evaluation of the Energy and Cost Conservation recommendations is **₹ 7.73 / kWh** (considering only the energy charges as a conservative estimate).
- The fuel used for producing thermal energy is Compressed Natural Gas (CNG) which is sourced from Tripura Natural Gas Company Limited (TNGCL) . The total quantity of CNG used is **220 000** SCM in the one year period. (Sep'23 - Aug'24)

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 = **0.53 kWh / kg** of Made Tea
    - Thermal = **14.27 MJ / kg** of Made Tea (equivalent to **0.37 SCM** of CNG / kg of Made Tea with a CNG GCV of 9 210 kcal / SCM or 38 562 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 .12 kWh / kg** of green leaves
    - Thermal = **3.12 MJ / kg** of green leaves
    - (equivalent to **0.08 SCM** of CNG / 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 60 % 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 3 days in Sep 24 (9 , 10 & 11) 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 proposal.
- The cost conservation proposals can be taken up for implementation at the earliest as the investment needed are either nil or meagre. These cost saving proposals are quite simple to understand and are capable saving cost right immediately upon implementation. Hence this recommendation.

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

CCP No	Cost Conservation Proposals	Cost Savings ₹ / y	Invest ₹	Payback Period Months
1	Merging the LTSC With H T-1 S C combined with marginal reduction of the Contracted Demand enabling the optimized use of Contracted Demand as well ensuring reduced energy cost outflow	**84 754**	Meagre	Immediate

2	Rationalization [Reduction] of Contract Demand of the **HT SC 2** in order to optimize the Demand Charges payable to TSECL	**32 760**	Nil	Immediate
3	Rationalization [Reduction] of Contracted "Booked Quantity " of the C N G with TNGCL in order to optimize the charges payable towards its usage	**3 16 814**		
4	Recasting of the present Off - Grid SPV Power Plant into On - Grid System to cater to the energy needs of the Administration Office and to export the surplus energy to grid thereby reap the financial benefits perennially	**12 700**	**20 000**	**19**
5	Installation and commissioning of **200** $\mathbf{kw_p}$ On - Grid Solar P V Roof Top Power Plant through "**R E S C O**" model of Govt of India	**9 75 000**	Meagre	Immediate
Total		**14 22 028**	**20 000**	**< 1**

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

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	**32 540**	**Meagre**	Immediate
2	Prioritize the Withering of Fresh Green Leaves in Troughs with high specific air flow rate for enhanced energy efficiency and improved withering quality	**7 730**	**Nil**	
3	Downsize and Usage of Energy Efficient Motors and simultaneous improvement of PF in the Rotor Vanes of Lines 1 & 2 of C T C Section for the sake of Energy / Cost savings	**23 190**	**60000**	**31**

ECP No	Energy Conservation Proposals	Cost Savings ₹ / y	Invest ₹	Payback Period Months
4	Fitment of VFD to the Hot Air Forced Draft Fan - whose operation shall be controlled by the exiting moist flue gas temperature - enabling Energy Efficient operation of the fan resulting in cost savings	**23 190**	**75000**	**39**
5	Downsize and Usage of Energy Efficient Motors and simultaneous improvement of PF in the Sorting / Grading / Packing Sections for the sake of Energy / Cost savings	**11 595**	**45 000**	**47**
6	Replacement of conventional V - Belts drives with Cogged V – Belts drives in the identified motors to reduce Belt Slip thereby enhancing the transmission efficiency	**27 828**	**36 000**	**16**
7	Replacement of existing 75 W conventional Ceiling Fans with Energy Efficient 30 W "**BLDC**" Fans for the sake of Energy / Cost Conservation	**9 895**	**24 500**	**30**
Total		**1 35 968**	**2 40 500**	**21**

HIGHLIGHTS

- **The specific energy consumption on both Electricity and C N G front appears nearer to the benchmark values as we could evolve. Therefore, the scope for energy conservation thereupon subsequent cost conservation is limited.**
- **However, it was realized that the factory spends enormously on non-production related activities.**
- **Hence, the present study focused more on optimizing the expenditure on non-production activities and that offered a tremendous scope by way of identifying 5 CCMs [Cost Conservation Measures] that offered a potential saving of close to ₹ 14 lacs / y**
- **The factory may initiate action to implement the CCMs on priority basis and reap the benefits.**

CONSOLIDATION

No of Conservation Proposals		Electricity Savings kWh / y	Cost Savings ₹ / y	Invest ₹	P P Months
Cost **CCPs**	Energy **ECPs**				
5	**7**	**19 209**	**15 57 996**	**2 61 500**	**2**

Overall Reduction

1) Electrical Energy : **5.6%** (applies only to HT / factory power drawll)
2) Electrical Energy Cost : **5.1%** (on factory as well as colony / office, i.e. HT+LT)
3) Thermal Energy Cost. : **2.4 %**
4) Overall Cost Savings : **4.1%** (on factory as well as colony / office, i.e. HT+LT)

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

1 INTRODUCTION

1.0 PREAMBLE

- The Durgabari Tea Factory is run by the Tea Estate Workers Co - operative Society that had started tea production operation in the year 2004.
- The factory has its own tea estates at 2 locations, one in Durgabari (183 acres) and the other in Simna (420 acres) and the area under tea plantation is respectively 145 and 165 acres.
- The factory has a total build up area of 20 000 sq ft.

2.0 GREEN LEAVES PROCUREMENT & TEA PRODUCTION

- The factory manufactures the following 2 grades of **CTC**

  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)

- The factory typically operates for 250 days in a year - leaving out the lean season period - with 12 working hours in a day [6 am to 6 pm]. Thus, the average annual operating period works out to 3000 hours. This number is made use of in the economic evaluation of ENCON recommendations made in this report.
- The factory provides direct employment to 35 workers and indirect to more than 100.
- The Green Leaves processing capacity is **16 000 kg /day** and the made tea production is **3 500 kg / day** working out to an annual production close to **6 lakh 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 : Durgabari 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 **C**ompressed **N**atural **G**as [**CNG**]-purchased from **T**ripura **N**atural **G**as **C**ompany **L**td [**TNGCL**] - drawn through pipe lines in the burner.
- 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 two Diesel Generator (DG) sets that operate as and when required. These are pressed into service whenever the FEDCO power goes off. The DG Sets operated for about 3 hours in a week as a part of maintenance protocol.
- The state of Tripura is a power surplus one and hence the power outages are quite a rare occurrence.

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 in 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 for consumer's energy interests, etc.,

- As far as the state of Tripura is concerned - where the tea industries consume a significant quantum of energy - it was decided to perform Energy Audits in a couple of specimen tea factories 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 from 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 more vulnerable from operation perspective and 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 Workers' Cooperative Societies, viz., **1) *Durgabari Tea Factory 2) Ludhua Tea Factory and 3) Leelagarh 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 to determine the scope for energy conservation.
- In addition, further required data has also been collected from the factory personnel during the audit. The performance of utilities has been evaluated and presented in Chapters 7 & 8. This report is prepared based on the present energy consumption pattern and informs the scope for cost cum energy conservation in various processes / equipment.

- 12 Cost / Energy Conservation Proposals [**C / E C P**] have been identified and elaborated in Chapters 9 and 10.
- An overall cost reduction of **4 %** is anticipated that will demand a one - time investment of **₹ 2.4 lakhs** and fetch an annual return of **₹ 14.2 lakhs** perennially.
- The **RoI** is **2** months and the Carbon footprint reduction shall be **15 tons of CO_2 / y**

Fig 1.2 : Meeting with the Plant Manager | CAG

5.0 SALIENT FEATURES

- The salient features gathered are summed up below :

Table 1.1 : Salient Features Captured

Name / Address of the factory	:	Durgabari Tea Estate Workers Co-operative Society Ltd, P.O. Tebaria, Tripura (W) - 799 015
Key Officials	:	> Asish Adhikari - Manager

		> Prasanta Deb - Factory In charge > Pintu Debnath - Electrician > Paritosh Deb - Shyamali G H in - charge
Year of Establishment	:	2004
Total Factory Area	:	20 100 sq ft
Total Estate Area	:	603 acres Durgabari (183 acres) and Simna (420 acres)
Total Tea Area Plantation	:	Durgabari (145 acres), Simna (165 acres)
Type and Grades of Tea Manufactured	:	CTC tea **a) Leaf Grades**: BOP (L), BOP (S), BOP, BP, BP (S), Orange Fannings **b) Dust Grades :** PD, D
Number of Full Time Workers	:	35
Factory Operating Period	:	250 day 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	:	16 000 kg / d
Made Tea Production Capacity	:	6 lakh kg / y
Thermal Energy Source for Dryers	:	C N G obtained from Tripura Natural Gas Company Ltd, Agartala, Tripura
Electrical Energy Sources	:	• 2 HTSCs from FEDCO (A private DISCOM in Tripura) for factory & 1 LTSC for Admn Office & Residential Colony • 2 Diesel Generator Sets

2 PROCESS DESCRIPTION

2.0 PREAMBLE

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

> **CTC Tea :** The CTC Tea, comprising over 85% of the market, 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 pellet or 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.

- **D**urgabari **T**ea **F**actory **[DTF]** produces only CTC tea. The final product coming out from the process is termed as "**Made Tea**".
- Generally, 5 kg of green leaves are required to produce one kg of Made tea suggesting an outturn of 20 %.
- Tea production requires 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 the presence of oxygen)
6. Drying (moisture removal and stoppage of fermentation)
7. Sorting (fiber removal; grading based on size)
8. Packing & Transportation

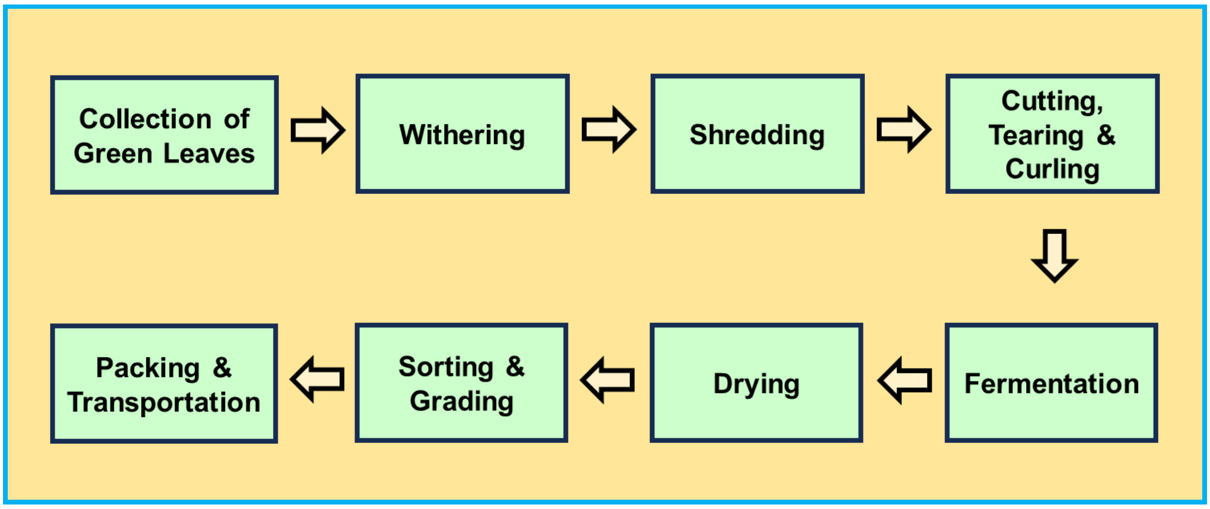


Fig 2.1 : Tea Production Process : A Flow Chart | CAG

- 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 located in Durgabari (183 acres) & Simna (420 acres). The green tea leaves are transported to the factory site through trucks. While DTF process leaves from external sources when their own gardens cannot meet demand, their primary focus remains on processing their homegrown leaves. Plucking of green leaves is primarily done by hand.

Fig 2.2 : Durgabari Tea Garden, Agartala, Tripura | CAG

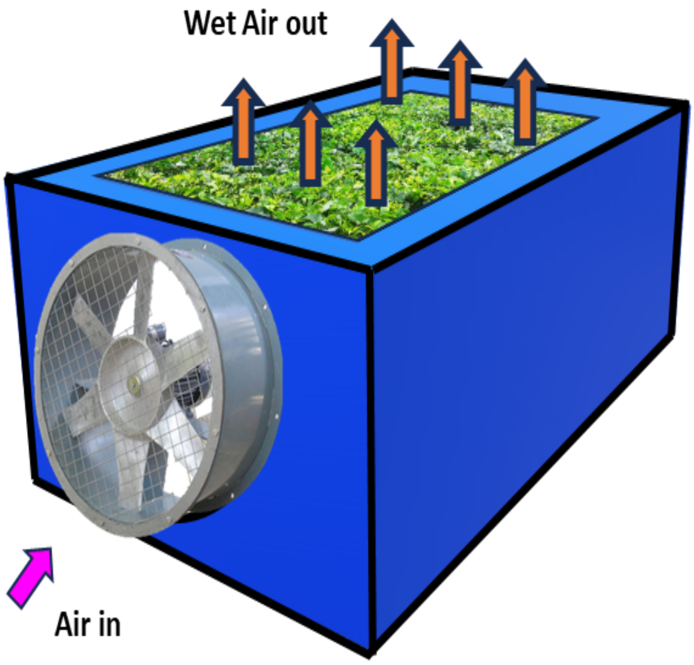
Fig 2.3 :Tea Leaves getting Unloaded From Truck & Manual Leaf Collection | CAG

2.2 WITHERING

- Withering is a crucial step in tea processing that prepares the freshly harvested green leaves for subsequent stages like Rolling and Fermentation.
- By carefully removing surface moisture while retaining some internal moisture, withering creates 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 typically placed in **Withering Troughs** for a period of 6 to 8 hours depending on the season. There are 6 Withering Troughs installed measuring 84' x 12' (2 Nos) and 80' x 12' (4 Nos) and each trough has a leaf holding capacity of 2000 kg.
- Air is circulated through the leaves spread on the troughs over a wire mesh for the removal 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 this stage.
- This withering process is influenced by factors like time and temperature and plays a vital role in determining the quality of the final tea produced.
- The goal 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 Air Flow Fans are used in Withering Troughs (two blowers per trough) to ensure efficient air circulation through the leaves and moisture removal. The fans have a power rating of 5 hp (4 fans) and 3 hp for the remaining 8 fans. Thus, there are 12 Withering Fans installed.
- The corresponding air flow rates for 3 hp and 5 hp fans are respectively 50,000 to 75,000 cfm (cubic feet per minute).
- The pictorial presentation of Withering Troughs is depicted in Fig 2.4

Fig 2.4 : Withering Troughs Employed in the Factory | CAG

Fig 2.5 : Shrunken Leaves in Withering Trough | CAG



Withering Fan

No of Fans : 12 (2 per trough)

Diameter : 5 ft

Motor Rating : 4 No's x 5 HP
8 No's x 3 HP

CFM : 50,000 to 75,000

Trough

No of Trough : 6 Troughs

Dimension : 2 No's : 84 ft x 12 ft
4 No's : 80 ft x 12 ft

Green Leaf Capacity : 2,000 kg / batch

Operating time : 8 h / batch

Fig 2.6 : Withering Trough : 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 fibre 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 it 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 moisture of the leaves to 55 %. Depending on the grade of tea,3 to 4 CTC cuts are used. In this factory, 2 lines of C T C Cuts, employing 4 roller machines each - 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 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 final product.
- In this factory, 7 motors are employed in each cut comprising a Rotor Vane (20 hp), Blower (2 hp), CTC Roller 1st cut (25 hp), CTC Roller 2nd, 3rd and 4th cut (each with 20 hp) and a Rotary Shifter / Ghooghy (3 hp).
- Each CTC Machine has a green leaf handling capacity 700 kg / h.

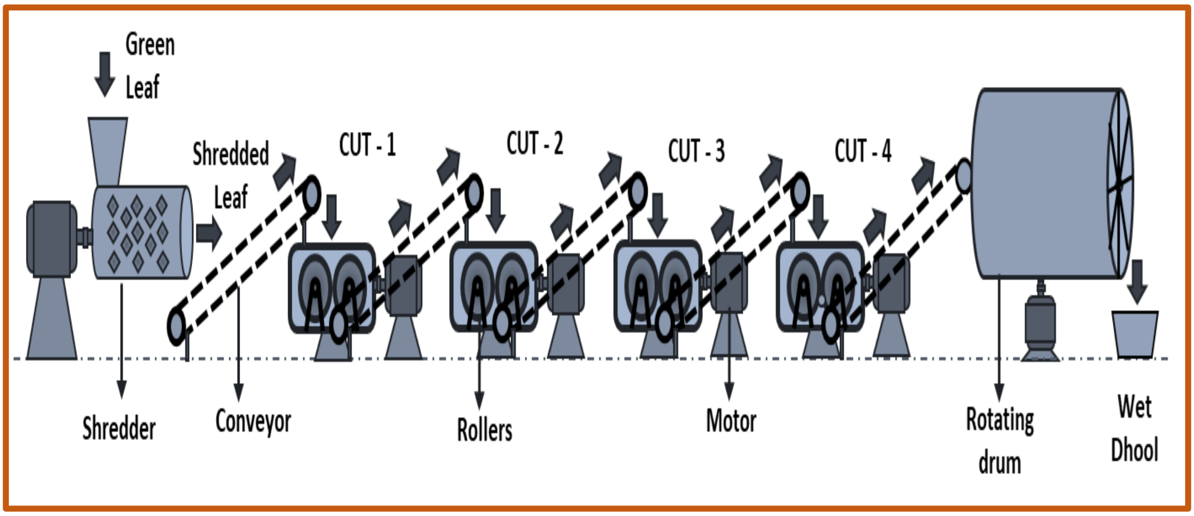


Fig 2.7 : CTC Lines : Typical Process Flow | CAG

CTC machine

Capacity	**: 700 kg / h (Green Leaf)**
No of cut	**: 4 cut**
Motors rating	**: Shredder : 20 HP**
	Blower : 2 HP
	CTC Roller 1st cut : 25 HP
	CTC Roller 2nd cut : 20 HP
	CTC Roller 3rd cut : 25 HP
	CTC Roller 4th cut : 20 HP
	Ghooghy : 3 HP

Fig 2.8 : CTC Machine : Technical Information

Fig 2.9: CTC Machine | CAG

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

- The factory has its own workshop accommodating a Lathe Machine, Milling Machine and a Grinding Machine for the sake of periodically machining the CTC roller surfaces.

Fig 2.10: Machineries for Maintaining C T C Rollers | CAG

- 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 or in a rotating drum. Fermentation of rolled tea leaves turns them to a brown color.
- Short or light fermentation gives more flavored and aroma rich tea, whereas long or deep fermentation provides rich color in tea brewing.
- The factors that influence good quality fermentation are time, temperature, humidity, aeration, spreading thickness, and cleanliness of the factory.
- In this factory, natural fermentation is resorted to, in which the rolled leaves are spread over the floor and humidifier fans (9 Nos each with a power rating 0.5 hp) are operated to maintain the humidity of the rolled CTC leaves (wet dhool).

Fig 2.11 : 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 hot air - produced by combustion of CNG in the burner - 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 colour of dhool from coppery red to black. This color change indicates the stoppage of the fermentation process in drying.
- Normally, the fermented dhool enters the drier at a moisture content of 70 % and the final product coming out of driers i.e., dryer mouth tea (dry dhool) contains 3 % to 4 % moisture.

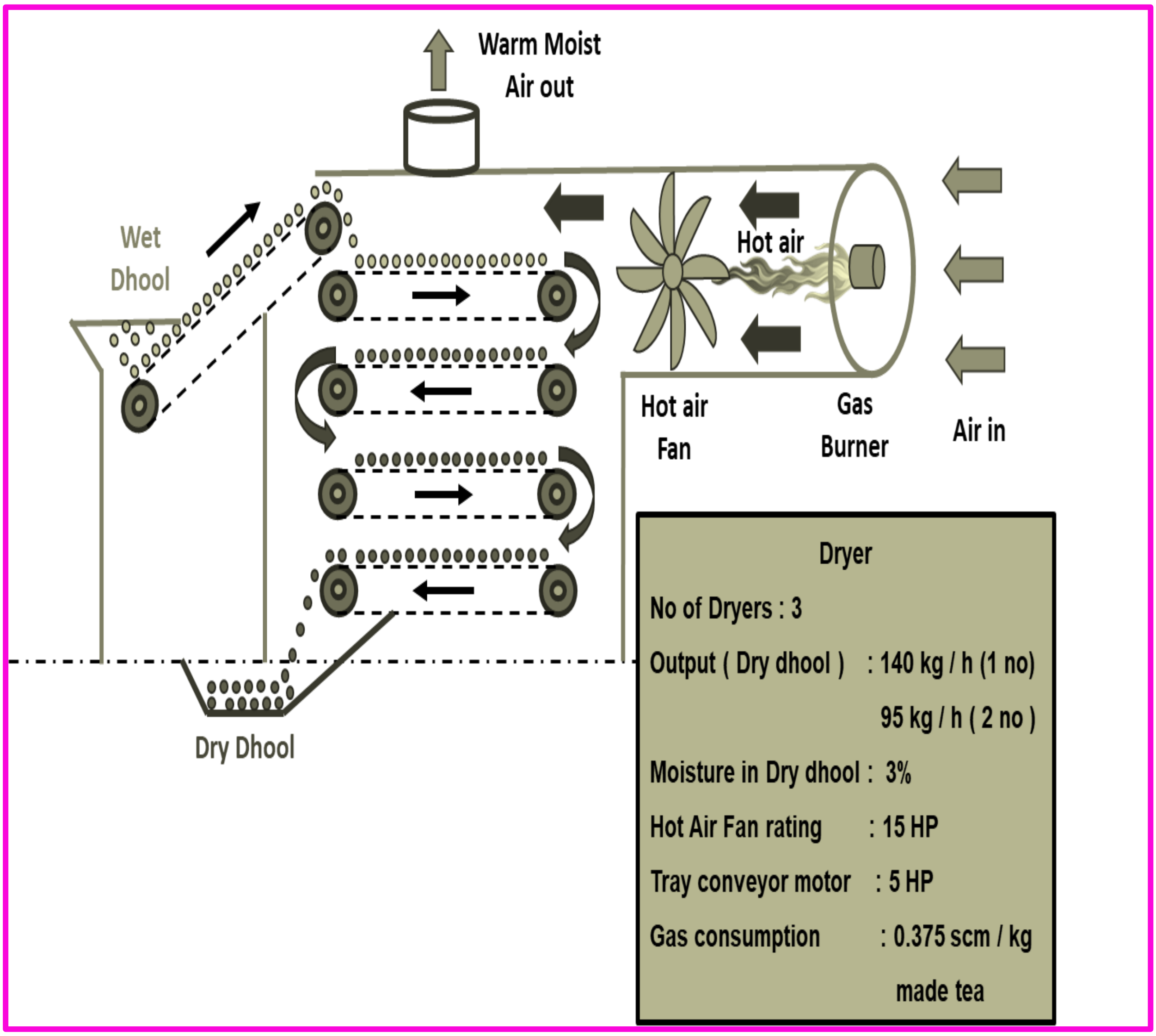


Fig 2.12: Tea Drier : Layout and Technical Details | CAG

- In DTF, 3 ECP dryers are in use. One Dryer has an output capacity of 140 kg / h (Dryer Mouth Tea) while the other two dryers have an output capacity of 95 kg / h of D M T.
- Drying operation is an energy intensive one requiring both thermal and electrical energy for its effective operation.
- The main equipment consuming electrical energy are (i) Hot Air Fan (which sucks the atmospheric air and delivers it into the dryer) that has a power rating of 15 hp and (ii) a tray carrying Conveyor Motor (5 hp).
- On the thermal side, CNG is burned for generating hot air for tea drying. The specific CNG consumption is **0.375 SCM per kg of Made Tea** produced as per the factory records.

Fig 2.13 : Tea Dryer : E C P Type : Front View and Back View | CAG

Fig 2.14 : C N G : Instrumentation & Metering Station | CAG

2.6 SORTING / GRADING

- Sorting is a crucial step in tea processing that separates bulk tea (dryer mouth tea) into different grades based on size. This process is achieved using a machine equipped with various sized meshes.
- Different grades of tea are obtained by passing the tea through these meshes.
- For example, BOP - Small (Broken Orange Pekoe Small) is typically sold at a higher price due to its superior taste and aroma, while fine dust is the least expensive grade.
- Sorting machines require several small motors to power the vibration of meshes and movement of conveyors.
- This factory employs

1. Fiber Extractor Machine (3 hp) : 1 No
2. C M Ho Complete Sorter Machine : 9 Nos

(Total = 9 Motors : 6 Nos x 2 hp rating, 3 Nos x 1 hp rating)

Sorting machine

Sorter Machine 1	:	2 HP motor x 1
Sorter Machine 2	:	2 HP motor x 1
C M Ho sorter 1	:	2 HP motor x 6 no's
C M Ho sorter 2	:	1 HP motor x 3 no's
Vibro screener	:	3 HP x 1

Fig 2.15 : Technical Information of Sorter Machine

Fig 2.16 : Sorting Section | CAG

- **Different grades of tea have varying sizes. This detail is presented in Table 2.1**

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
	BOPF	Broken Orange Pekoe Fannings	28 to 30
C T C Dust	PD	Pekoe Dust	28 to 35
	D	Dust	35
	CD	Churamaul Dust	37
	RD	Red Dust	30 to 35
	GD	Golden Pekoe	36
	SRD	Super Red Dust	36
	FD	Fine Dust	37
	SFD	Super Fine Dust [Small size Dhool]	38

Fig 2.17 : Different Grades of Tea | CAG

2. 7 PACKING & TRANSPORTATION

- The made tea produced is packed (based on their grades) in food grade quality bags and transported for auction / sale.
- A pictorial view of the Sorting Section is shown below.

Fig 2.18 : Packing Section | CAG

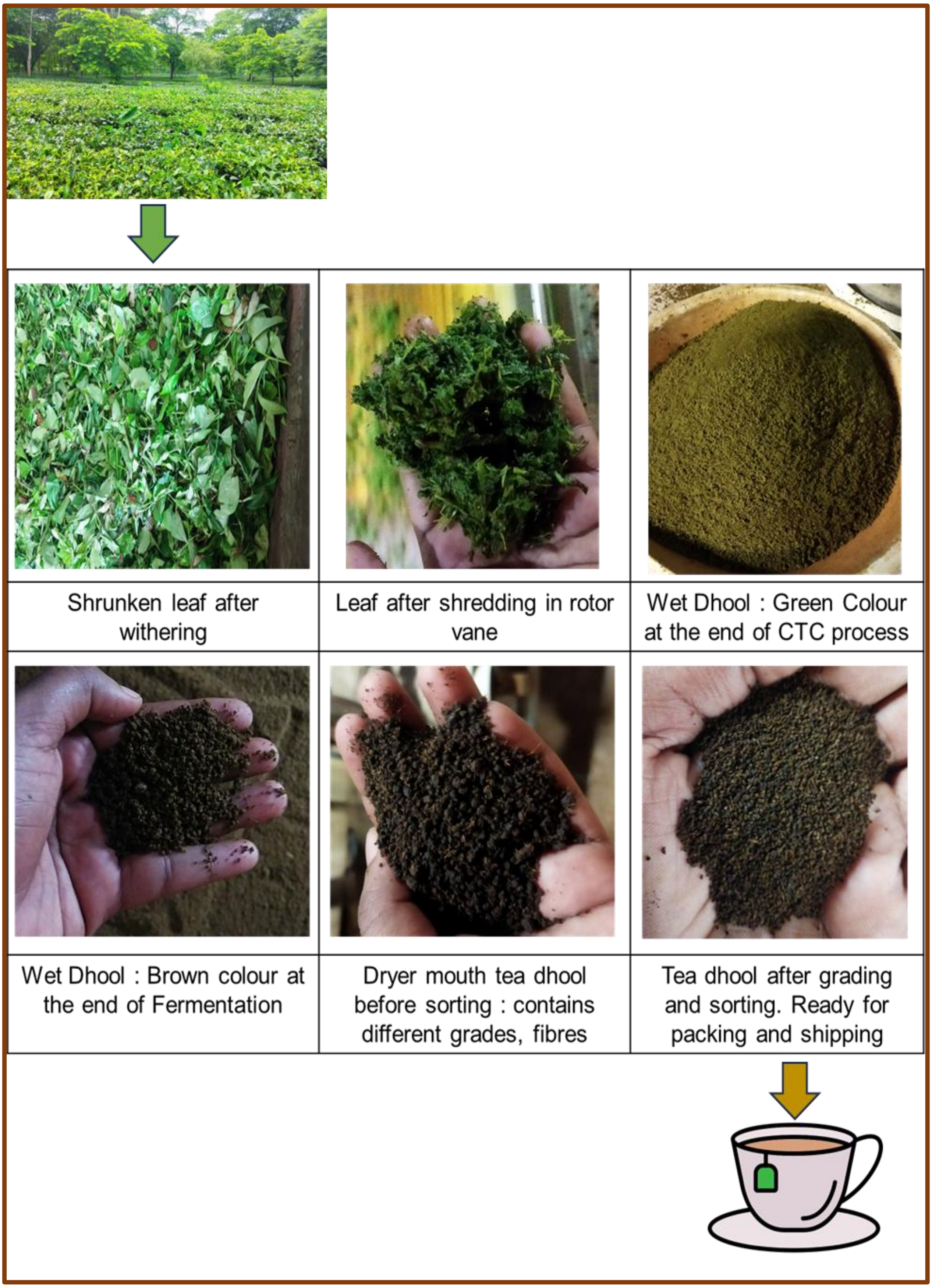


Fig 2.19 : From Garden To Cup : Tea Leaf Transformation Process | CAG

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 in the Factory

No	Process Equipment	Specifications	No of Motors / [Total Rated hp]
1	Withering Trough Fan	No of Fans : 12 [2 per trough] Motor Rating : 4 Nos x 5 hp + 8 Nos x 3 hp Blade Diameter : 5 ft Air Delivery : 50 000 to 75 000 cfm	12 [44]
2	CTC Machine	Capacity : 700 kg / h (Green Leaf) No of Lines : 2 No of Cuts. : 4 per line Motor Rating: Shredder : 20 hp Blower : 2 hp CTC Roller 1st cut : 25 hp 2nd , 3rd & 4th Cut : 20 hp each Ghooghy : 3 hp 7 Motors with a cumulative power rating of 110 hp (for one CTC Row)	14 [220]
3	Fermentation : Humidifier Fan	9 Nos x 0.5 hp	9 [4.5]
4	Dryer	Type : ECP No of Dryers : 3 Output :**140 kg / h** (1 No) & **95 kg / h** (2 Nos) Moisture in Wet Dhool : 70 -75 % Moisture in Dry Dhool : 3% Hot Air Fan : 15 h p Tray Conveyor Motor : 3 hp GNG Consumption : 0.375 scm / kg Made Tea	6 [5 4]
5	Sorter	Sorter Machine 1 : 1 No x 2 hp Sorter Machine 2 : 1 No x 2 hp C M Ho Sorter 1 : 6 Nos x 2 hp C M Ho Sorter 2 : 3 Nos x 1 hp Vibro Screener : 3 hp x 1	12 [22]

No	Process Equipment	Specifications	No of Motors / [Total Rated hp]
6	Workshop	Lathe : 1 No x 3 hp Milling Machine : 1 No x 2 hp Tool Grinder : 1 No x 0.5 hp Bench Grinder : 1 No x 0.5 hp	4 [6]
7	Conveyor Motor	2 Nos x 1 hp	2 [2]
8	Water Pump	Submersible Pump: 2 Nos x 1 hp each	2 [2]
9	Exhaust Fan	4 Nos x 1 hp	4 [4]
Total			**65 [358.5]**

- Thus, it can be seen that there are 5 major sections / equipment involved in the direct tea processing and the rest 4 support the process operation.

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 has 3 Driers each fitted with a C N G burner. The hot air required for drying is obtained by burning CNG along with required air. The hot air F D fans enable the circulation of hot air through driers.
- The electricity is supplied by the FEDCO and during the power outage period, electricity is generated through its own DG sets (2 Nos).
- The energy details for the past 24 months (Sep 22 to Aug 24) period have been gathered and summarized in the ensuing section.

3.1 ELECTRICAL ENERGY

3.1.1 Consumption

- The factory has availed 3 Service Connections [S C] to meet the tea production operation.
- Two HT Service Connections serve the process loads of the factory while one LT Service Connection meets electricity requirement of the admin office and the residential colony.

Table 3.1: Service Connection Details

No	Service Connection	Consumer No	Old A/c No.	C D kW	Demand Charge ₹ / kW / Month
1	HT 1	203604 267999214267	000210000719	160.0	105
2	HT 2	203604 0886249079908	000210000706	136.0	105
3	LT	203604 264590407877	000210000718	30.9	80

- The electricity bill does not furnish details regarding Maximum kW Demand (MD) attained in kW on a monthly basis. This makes it difficult to analyse the MD drawn pattern, to justify the optimality of the CL / CD agreed upon with FEDCO. Nevertheless, an attempt was made to capture the load pattern in this energy audit, which could reflect on such matters.

- The electricity consumption details (as gathered from the factory personnel) are given below.

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

No	Month	Electricity Consumption kWh		
		H T 1	H T 2	L T
1	Sep 22	12 768	21 958	9 234
2	Oct	6 870	23 276	9 521
3	Nov	10 058	17 155	12 940
4	Dec 22	4 250	8 099	10 565
5	Jan 23	341	1 554	10 565
6	Feb	243	1 622	10 565
7	Mar	4 161	5 992	10 565
8	Apr	7 344	12 552	10 565
9	May	9 719	15 842	10 565
10	Jun	14 826	24 124	10 565
11	Jul	16 245	26 852	10 565
12	Aug 23	18 474	30 878	10 565
Total		**1 05 299**	**1 89 904**	**1 26 780**

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

1) **Factory (HT1+HT2) =. 2 95 203 kWh**
2) **Office + Colony (LT) = 1 26 780 kWh**

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

No	Month	Electricity Consumption kWh		
		H T 1	H T 2	LT
1	Sep 23	17 870	28 269	10 565
2	Oct	15 318	22 942	10 565
3	Nov	13 718	15 056	10 565
4	Dec 23	4 470	8 687	10 565
5	Jan 24	734	1 992	10 565
6	Feb	195	1 057	10 565
7	Mar	5 298	6 688	10 565
8	Apr	1 332	2 122	10 565
9	May	9 879	24 684	10 565
10	Jun	17 808	32 664	10 565
11	Jul	12 324	21 900	10 565
12	Aug 24	18 474	30 878	10 565
Total		**1 17 420**	**1 96 939**	**1 26 780**

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

1) **Factory (HT1+HT2) : 3 14 359 kWh**
2) **Office + Colony (LT) : 1 26 780 kWh**

- It was noted that the LT meter stopped working from Dec 22 onwards and ever since that happened, the average electricity consumption of the previous three months (Sep 22 – Nov 22) has been considered as the billed consumption.
- Going forward, we shall account for the HT1 and HT2 service connections only, taking note of their direct relationship with tea production. The need to rectify the LT meter to reflect actual consumption is emphasized in the later sections of this report .

- The electricity consumption pattern across the year is depicted below.

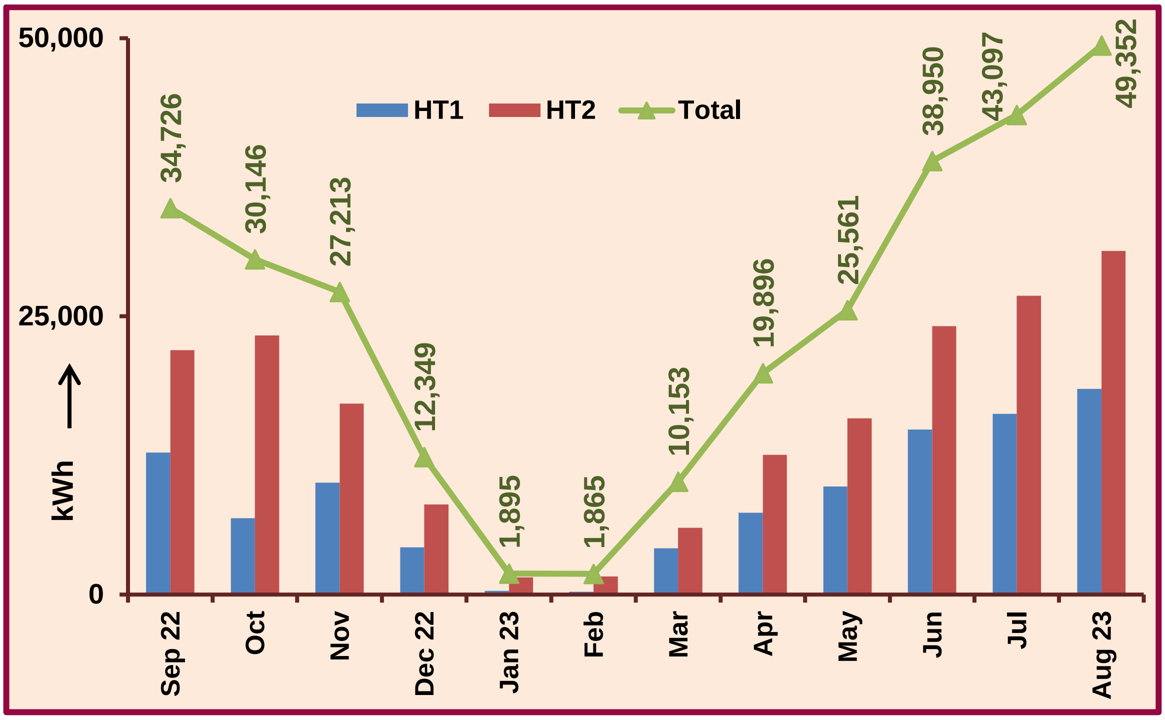


Fig 3.1: Electricity Consumption - Month wise (Sep '22 – Aug '23) | CAG

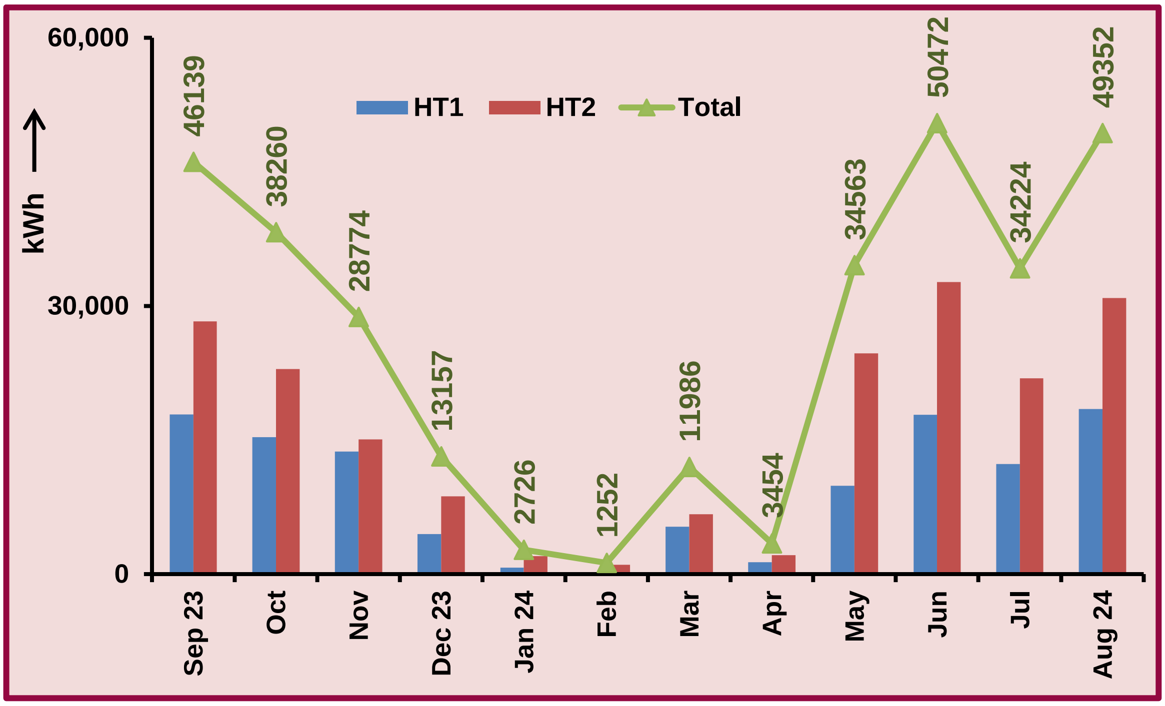


Fig 3.2: Electricity Consumption - Month wise (Sep '23 – Aug '24) | CAG

- Significant 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 this industry operation.

- Electricity is sourced from 2 DGs during power outage period. However, no log book is being maintained towards the electricity generation from DG sets, and the corresponding diesel consumption on a daily / monthly basis.
- Also, based on our interaction with the factory manager, it was considered justifiable to account for about 30 minutes per day of DG set operation ,an average that does not impact the weighted average cost of energy. DG electricity generation is therefore not considered in the evaluation of unit cost of energy and going further - in our analysis - we shall use FEDCO energy cost only.

3.1.2 Cost Details

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

Table 3.4: Electricity Cost Incurred (Sep ‘22 – Aug ‘23)

No	Month	Cost Incurred ₹		
		H T 1	H T2	LT
1	Sep 22	1 02 634	1 61 259	72 269
2	Oct	63 353	1 70 038	74 427
3	Nov	84 582	1 29 271	1 00 112
4	Dec 22	45 901	68 959	82 270
5	Jan 23	19 867	25 369	82 270
6	Feb	19 218	25 822	82 270
7	Mar	49 805	61 398	86 142
8	Apr	74 442	1 12 172	86 142
9	May	92 820	1 27 636	86 142
10	Jun	1 32 353	2 01 740	86 142
11	Jul	1 43 336	2 22 855	85 742
12	Aug 23	1 60 589	2 54 016	85 742
Total		**9 88 901**	**15 60 535**	**10 09 670**

Electricity Cost (Sep ‘22 – Aug ‘ 23):

1. **Factory (HT1+HT2) : ₹ 25 49 436**
2. **Office + Colony (LT) : ₹ 10 09 670**

Table 3.5 Electricity Cost Incurred (Sep '23 – Aug '24)

No	Month	Cost Incurred ₹		
		HT1	HT2	LT
1	Sep 23	1 36 610	2 03 291	85 742
2	Oct	1 45 749	2 06 393	91 700
3	Nov	1 32 601	1 41 107	91 700
4	Dec 23	53 799	86 403	91 700
5	Jan 24	23 704	29 994	91 700
6	Feb	20 080	24 534	91 700
7	Mar	56 567	64 797	91 700
8	Apr	34 162	38 718	91 700
9	May	90 641	1 94 707	91 700
10	Jun	1 91 408	3 16 941	91 700
11	Jul	1 20 869	1 97 735	91 700
12	Aug 24	1 60 589	2 54 016	91 700
Total		**11 66 779**	**17 58 636**	**10 94 442**

Electricity Cost (Sep '23 – Aug '24):

1) **Factory (HT1+HT2) : ₹ 29 25 415**

2) **Office + Colony (LT) : ₹ 10 94 442**

- The above data are presented figuratively in Fig 3.3 and fig 3.4

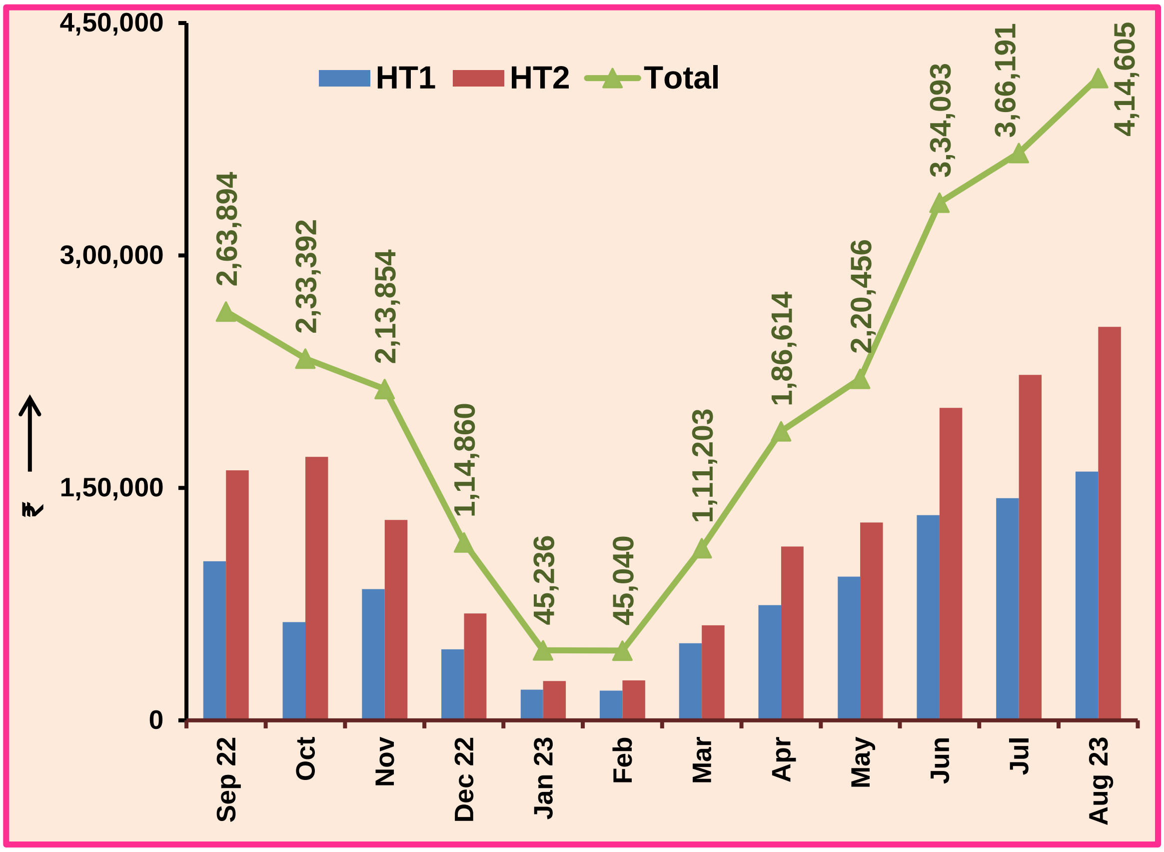


Fig 3.3 : Electricity Cost – Month wise (Sep '22 – Aug '23) | CAG

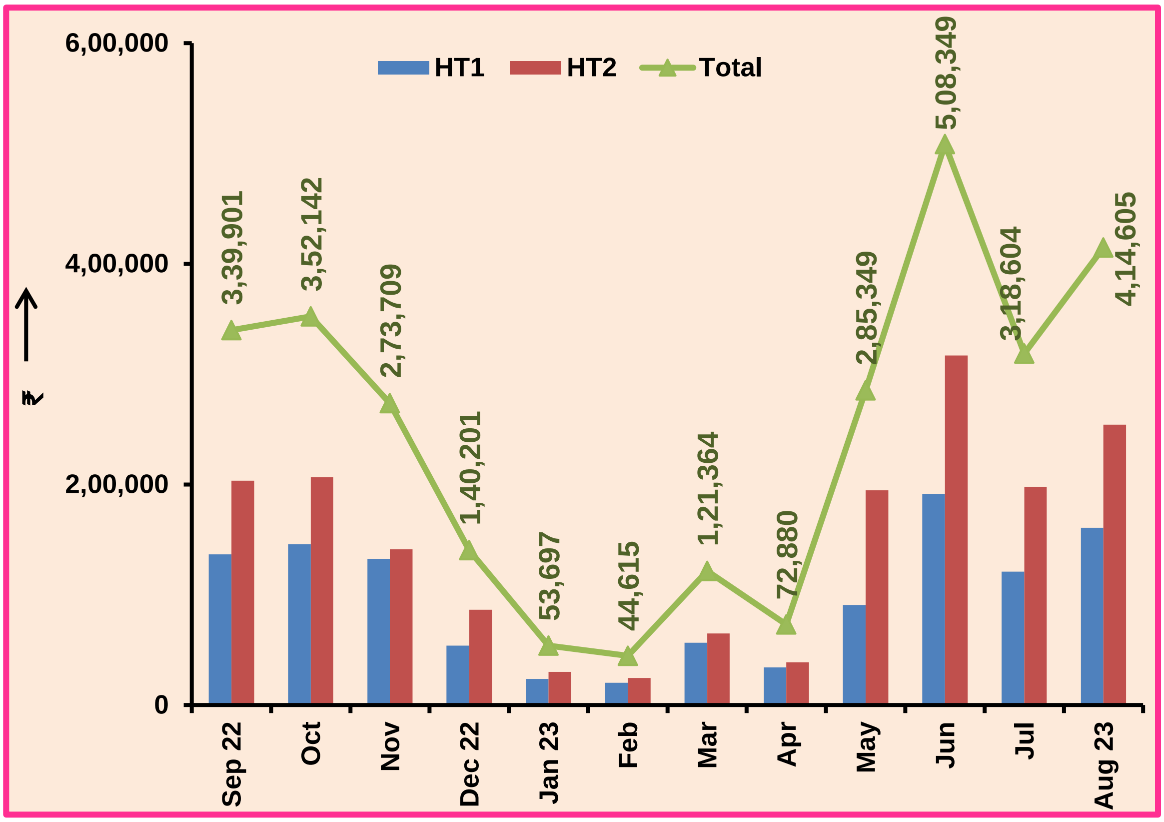


Fig 3.4 : Electricity Cost – Month wise (Sep '23 – Aug '24) | CAG

3.1.3 Cumulation

- The unit cost of energy has been computed for 2 years considered in our analysis and depicted below in Figs 3.5 & 3.6

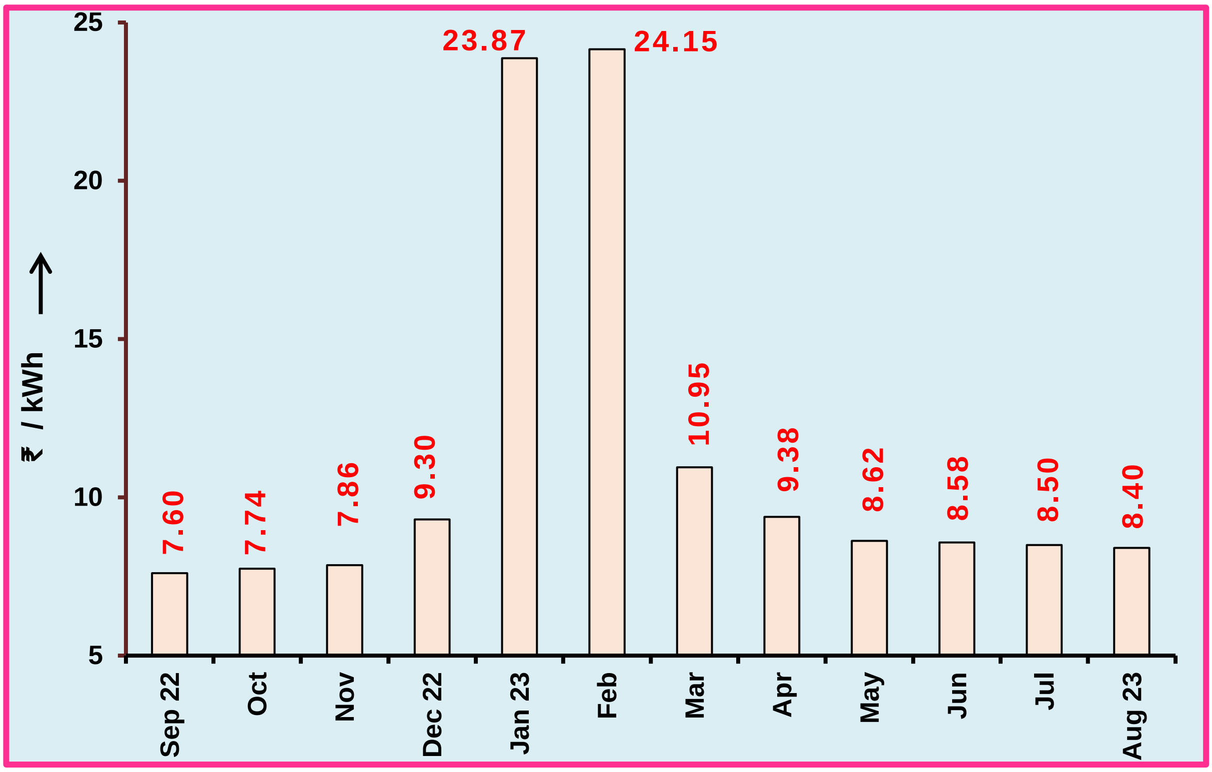


Fig 3.5 : Unit Cost of Electricity - HT – Month wise (Sep '22 – Aug '23) | CAG

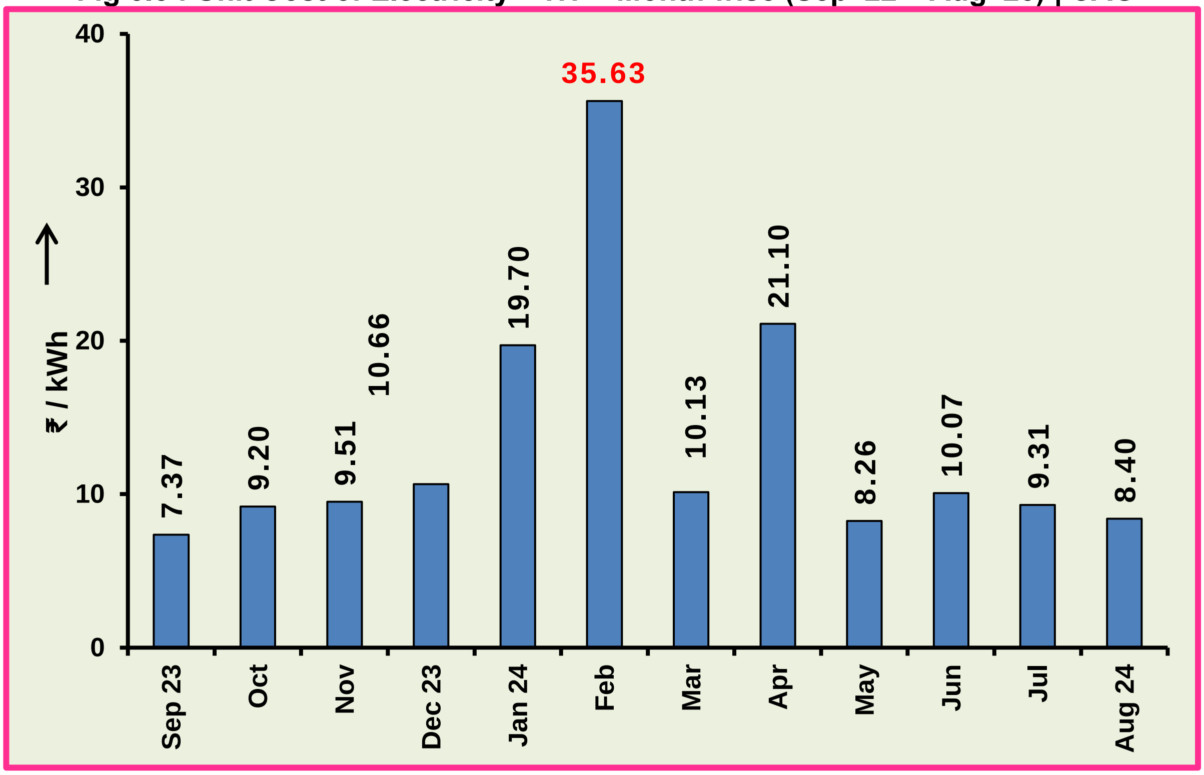


Fig 3.6 : Unit Cost of Electricity - H T – Month wise (Sep '23 – Aug '24) | CAG

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

	Unit Cost of Energy ₹ / kWh	
Service Connection	**Sep '22 – Aug '23**	**Sep '23 – Aug '24**
H T (Factory)	**8.64**	**9.31**
LT (Office + Colony)	**7.96**	**8.63**

3.2 THERMAL ENERGY : C N G

3.2.1 Consumption

- **As indicated earlier, CNG is used for tea drying operation in the driers.**

Table 3.6: C N G Consumption (2 year period)

No	Month	Consumption SCM	
		22 -23	**23 – 24**
1	Sep	20 672	27 452
2	Oct	15 256	25 145
3	Nov	18 672	28 265
4	Dec	8 496	10 510
5	Jan	0	0
6	Feb	0	0
7	Mar	4 524	0
8	Apr	13 954	12 943
9	May	12 940	12 703
10	Jun	23 253	30 887
11	Jul	15 299	31 516
12	Aug	27 370	40 474
Total		**1 60 436**	**2 19 895**

- **The consumption details of CNG are depicted month wise in Figs 3.7 & 3.8**
- **CNG Consumption :**

Sep 22 – Aug 23 : 1 60 436 scm & Sep 23 – Aug 24 : 2 19 895 scm

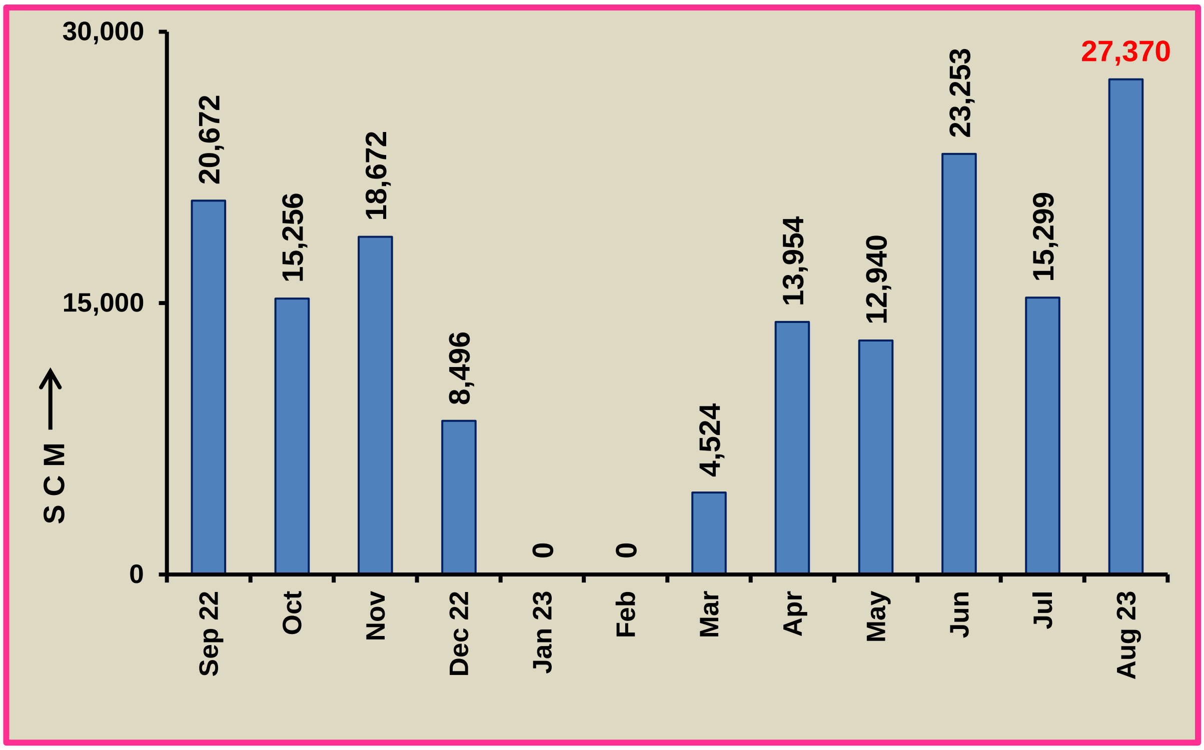


Fig 3.7: CNG Consumption – Month wise (Sep '22 – Aug '23) | CAG

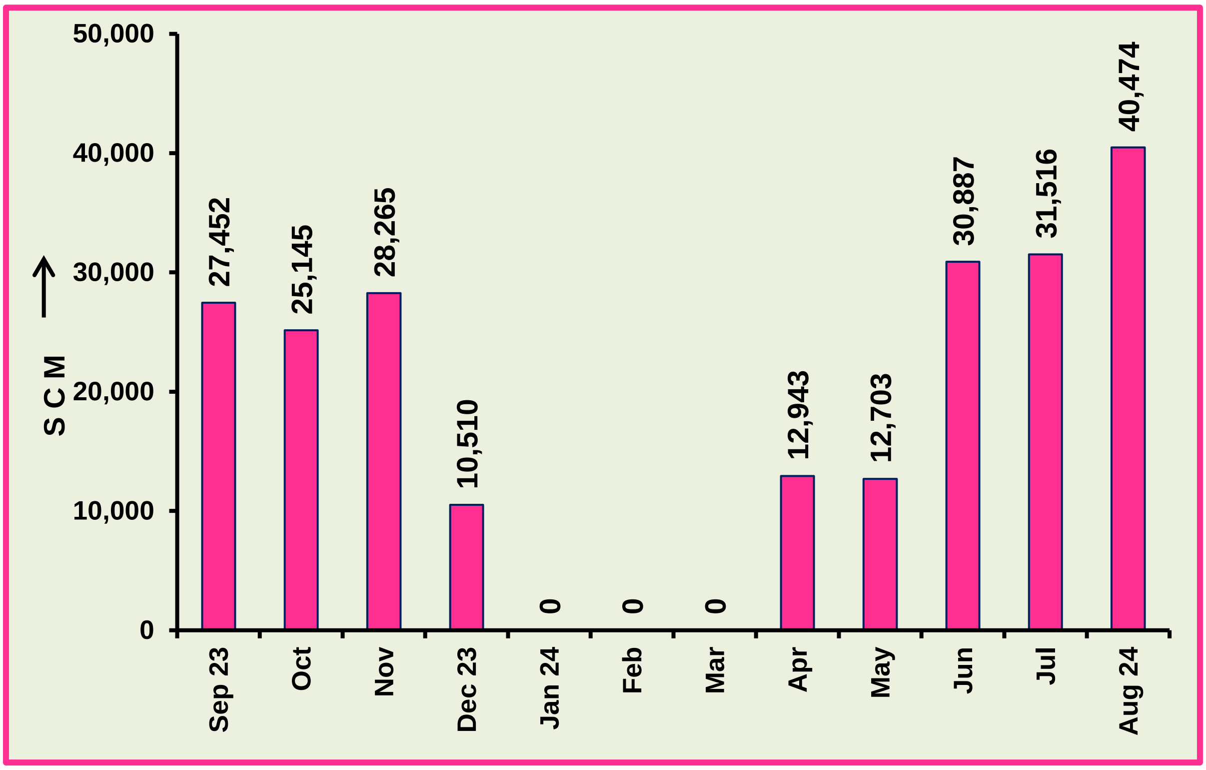


Fig 3.8 : CNG Consumption – Month wise (Sep '23 – Aug '24) | CAG

3.2.2 Cost Incurred

- The cost incurred towards the purchase of C N G for the 2 year period is depicted in Tables 3.7 and in Figs 3.9 & 3.10
- CNG Cost :

  Sep 22 - Aug 23 : ₹ **97 57 071** and Sep 23 - Aug 24 : ₹ **1 33 39 668**
- Average cost of CNG paid has been computed as below :

  a) Sep 22 - Aug 23 : ₹ **60.82 / SCM** b) Sep 23 - Aug 24 : ₹ **60.66 / SCM**
- The Gross Calorific Value of C N G considered : **9 210 kcal / SCM**

Table 3.7: C N G Cost Incurred (2 year period)

No	Month	Cost ₹	
		22 -23	23 - 24
1	Sep	9 65 254	14 51 640
2	Oct	7 73 807	13 14 841
3	Nov	9 81 681	14 98 367
4	Dec	6 07 508	5 86 631
5	Jan	6 07 508	5 86 631
6	Feb	5 49 265	5 48 784
7	Mar	6 08 115	5 86 631
8	Apr	6 58 291	6 19 913
9	May	6 03 672	6 08 418
10	Jun	12 10 304	16 49 066
11	Jul	7 48 944	16 86 163
12	Aug	14 42 722	2202 582
Total		**97 57 071**	**1 33 39 668**

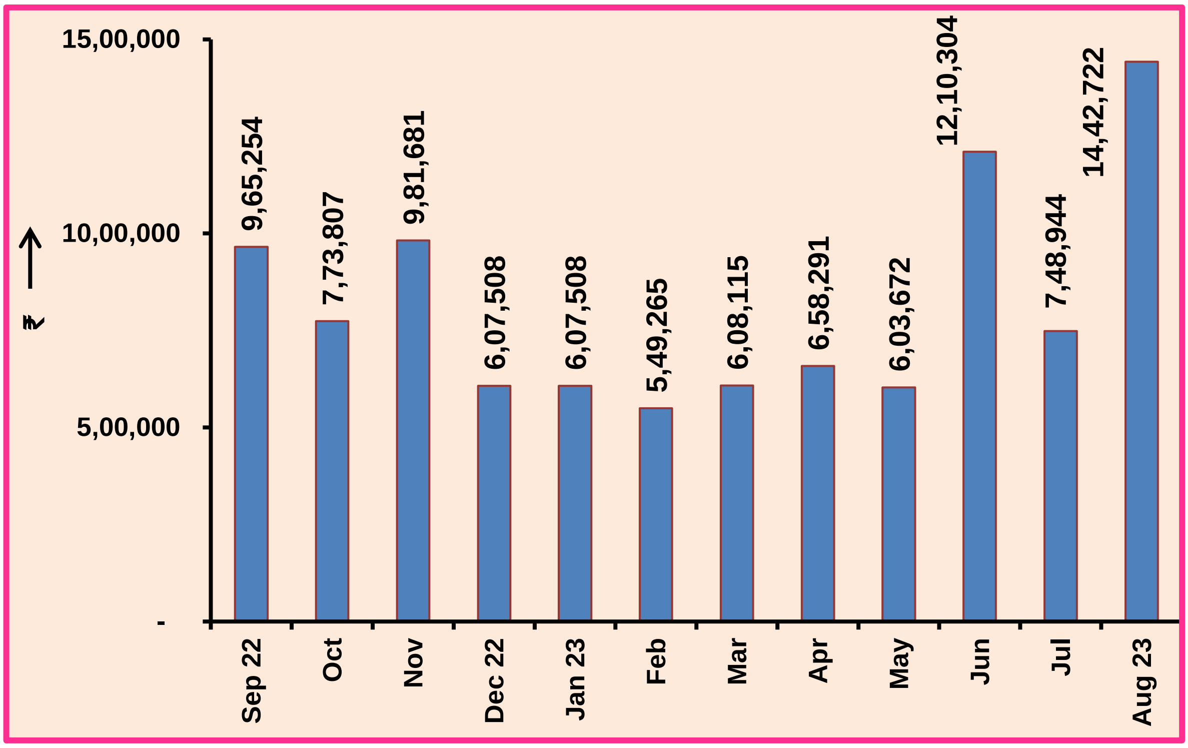


Fig 3.9 : CNG Cost – Month wise (Sep '22 – Aug '23) | CAG

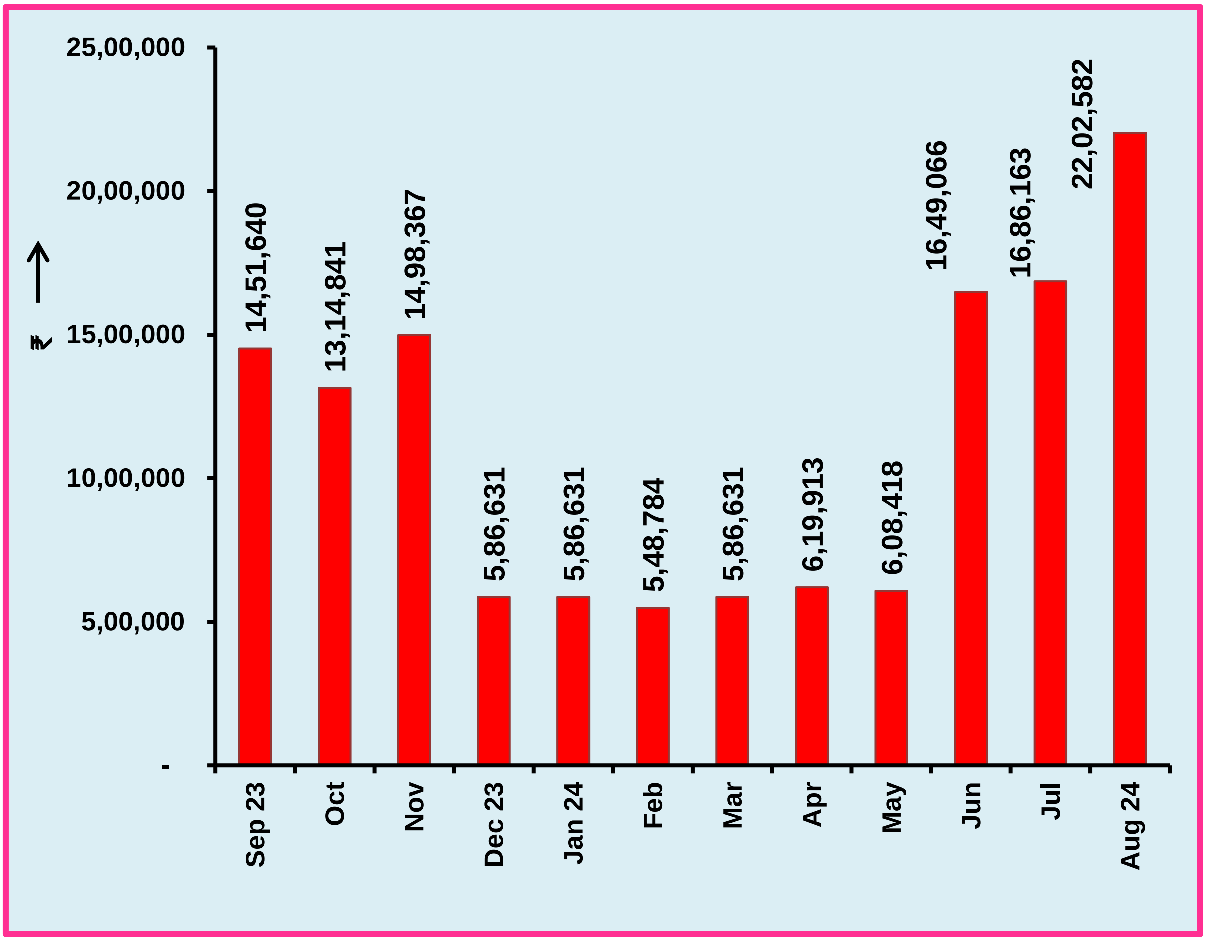


Fig 3.10: CNG Cost – Month wise (Sep '23 – Aug '24) | CAG

3.2.3 Inferences Drawn from CNG Bills

- The Monthly Minimum Guaranteed Off-take is 90 % of the Booked Quantity **(BQ)**, which is **439 SCM / day**. This implies that irrespective of whether or not CNG is consumed, the factory is obligated to pay for **90 %** of the BQ corresponding to the month at the normal unit price.
- As and when the CNG consumption exceeds the monthly BQ, the factory pays for the excess quantity at 120 % of the normal unit price. This has happened 13 times in the 2 year time frame considered.
- The graph shown below [Fig 3.11] indicates the relationship between the average cost of CNG and average daily CNG consumption - on a monthly basis - over a 2-year time frame. This has been drawn for the months when the CNG consumption had exceeded the BQ. [overdrawn months]
- In effect, the CNG consumption had exceeded the BQ on 16 out of 24 months.

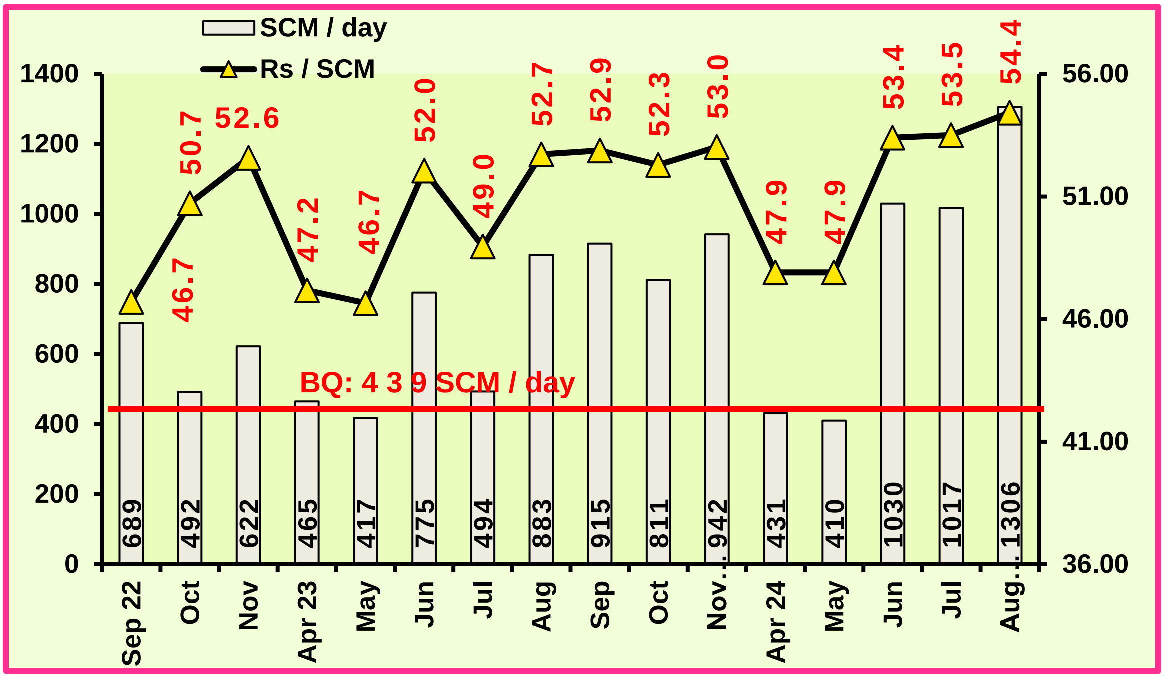


Fig 3.11: Cost of CNG vs CNG: Over drawn : (Sep '22 – Aug '24) | CAG

- The average unit cost of CNG stands at **₹ 52 / SCM** during this 16 months period.
- This unit cost of CNG is about **16.5 %** higher than the minimum / base price.
- On the flip side, monthly average consumption below the BQ leads to much higher average unit CNG cost, which shall be looked into in more detail - in terms of possibility for fine tuning - in the later sections of this report.

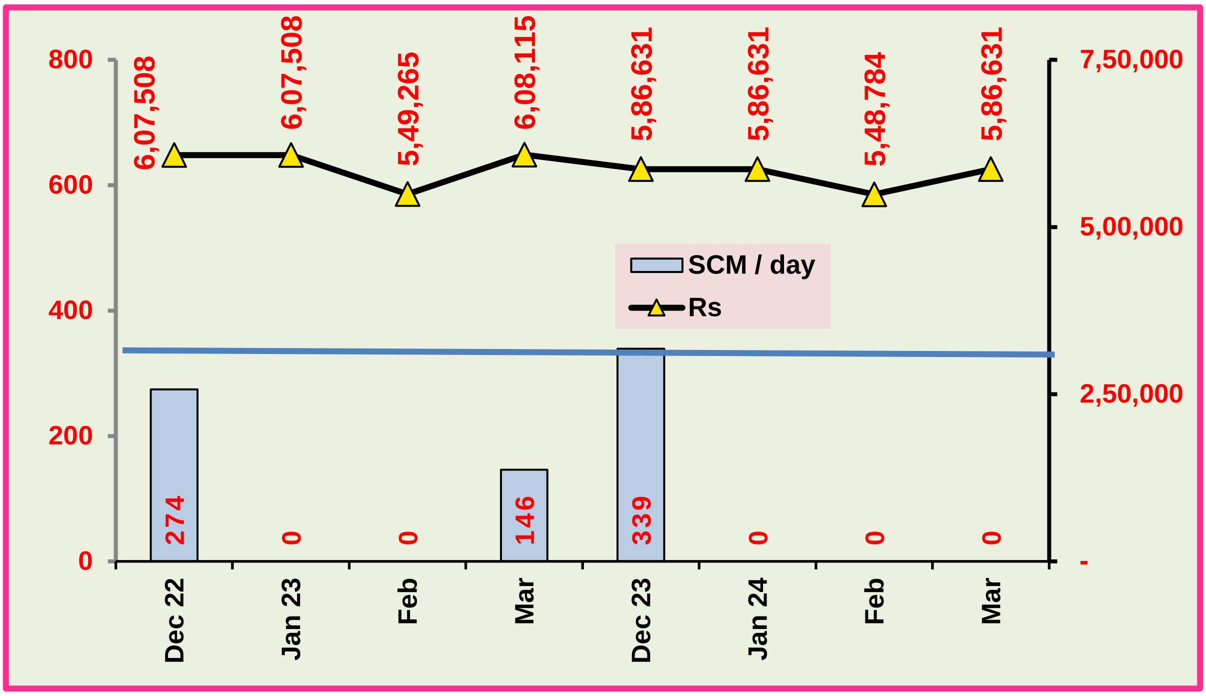


Fig 3.12: Cost of CNG vs CNG : Under drawl : (Sep '22 – Aug '24) | CAG

- The plot above shows how the factory needs to pay a minimum of about ₹ **5.5 Lakh** towards fuel irrespective of whether CNG is drawn from the pipeline or not.
- The average unit cost of CNG stood at **₹ 200 / SCM** during the 8 months of under drawl period which is about **4 times** the price compared to the normal / over drawl.

3.3 ENERGY & COST SHARE

- The energy and its corresponding cost share of the factory is depicted below:

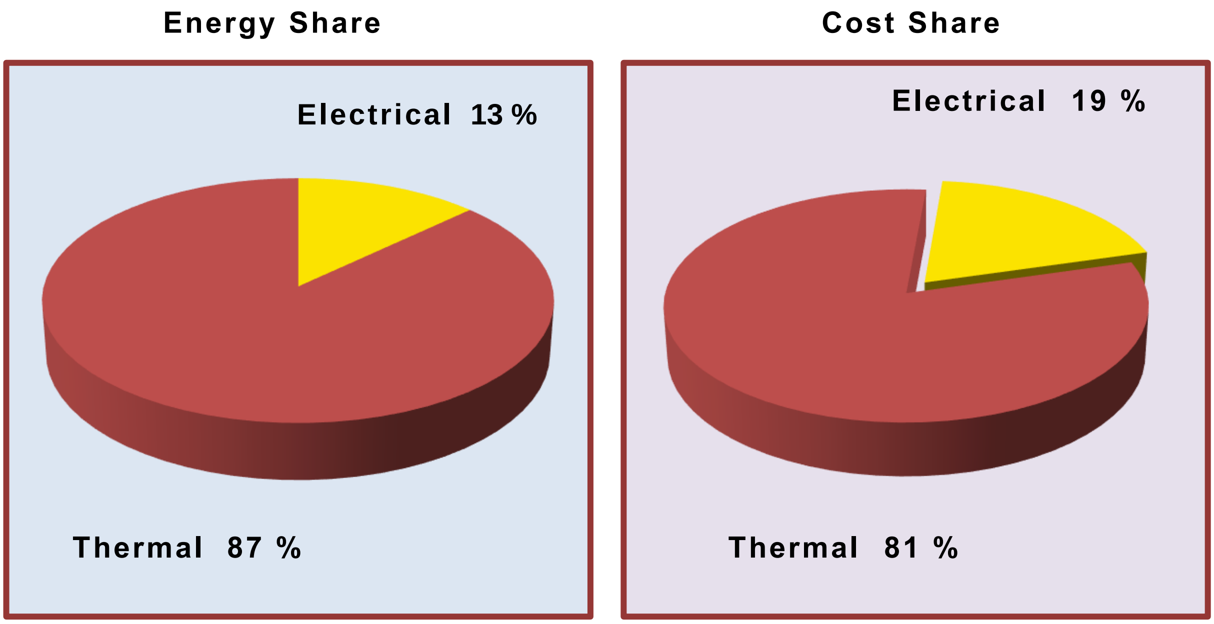


Fig 3.13: Energy & Cost Share of the Factory | CAG

- The Energy & Cost Share profiles of the factory are quite similar, which is majorly attributed to the choice of CNG as fuel for satisfying the thermal energy needs of tea production.
- The higher price that the factory has to pay for utilizing the clean, convenient and flexible fuel ie., CNG evens out the profits.
- The proposed energy study will focus on both Electrical and Thermal Energy Utilisation and look for avenues to reduce the cost paid for their procurement.
- The energy cost - at present - works out to **₹ 11.9 Lakhs / month** amounting to **₹ 1.43 crores per annum.**

Thus, it is inferred that the factory spends a substantial amount on energy, close to **₹ 1.43 crores / 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 ensuing section
- The period considered is **24 months (Sep '22 - Aug '24)**

4.1.1 Green Leaves Processed

- Green Leaves processed = **21 28 147 kg (Sep '22 - Aug '23)**

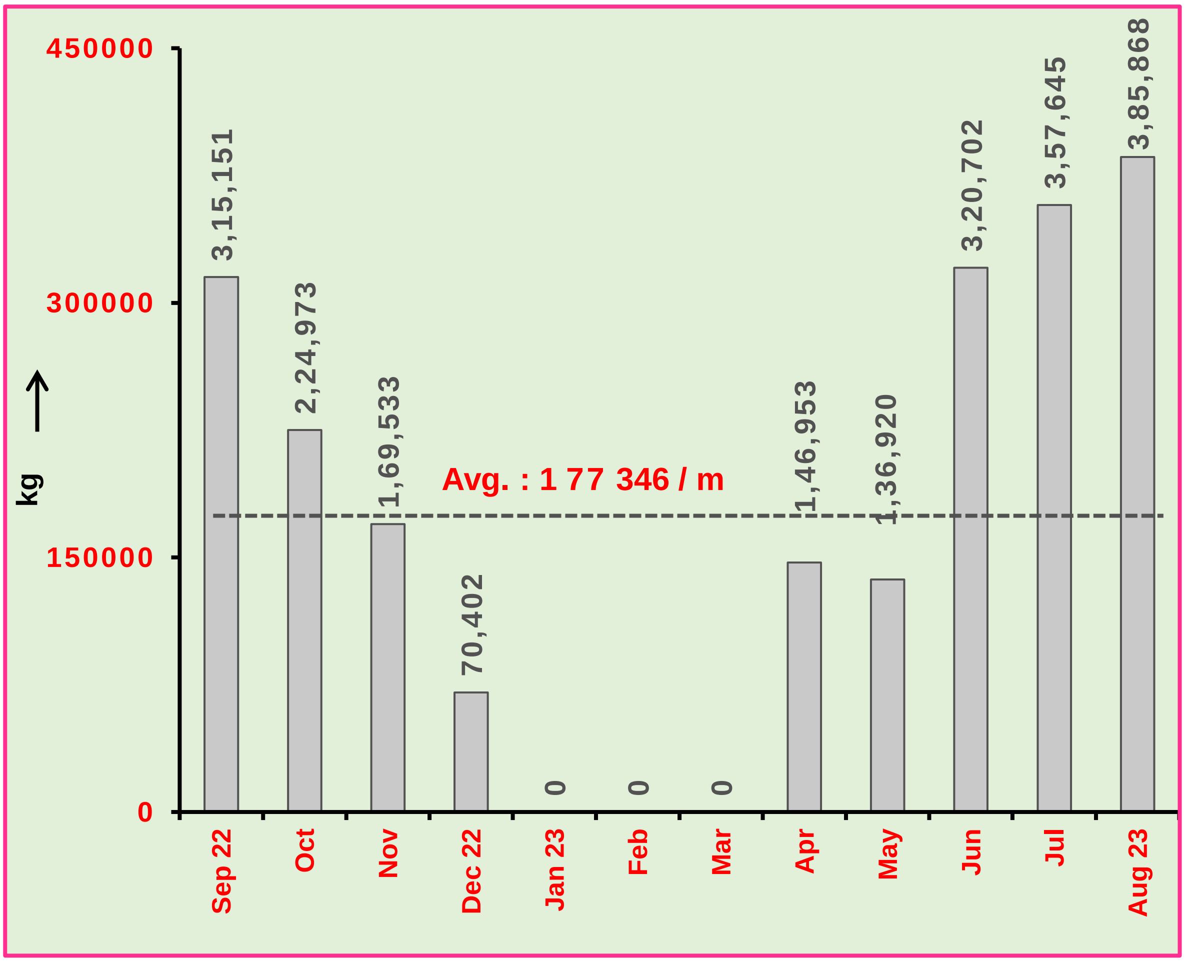


Fig 4.1: Green Leaves Processed - Month wise (Sep '22 – Aug '23) | CAG

- Green Leaves processed = **= 27 00 003 kg (Sep '23 - Aug '24)**

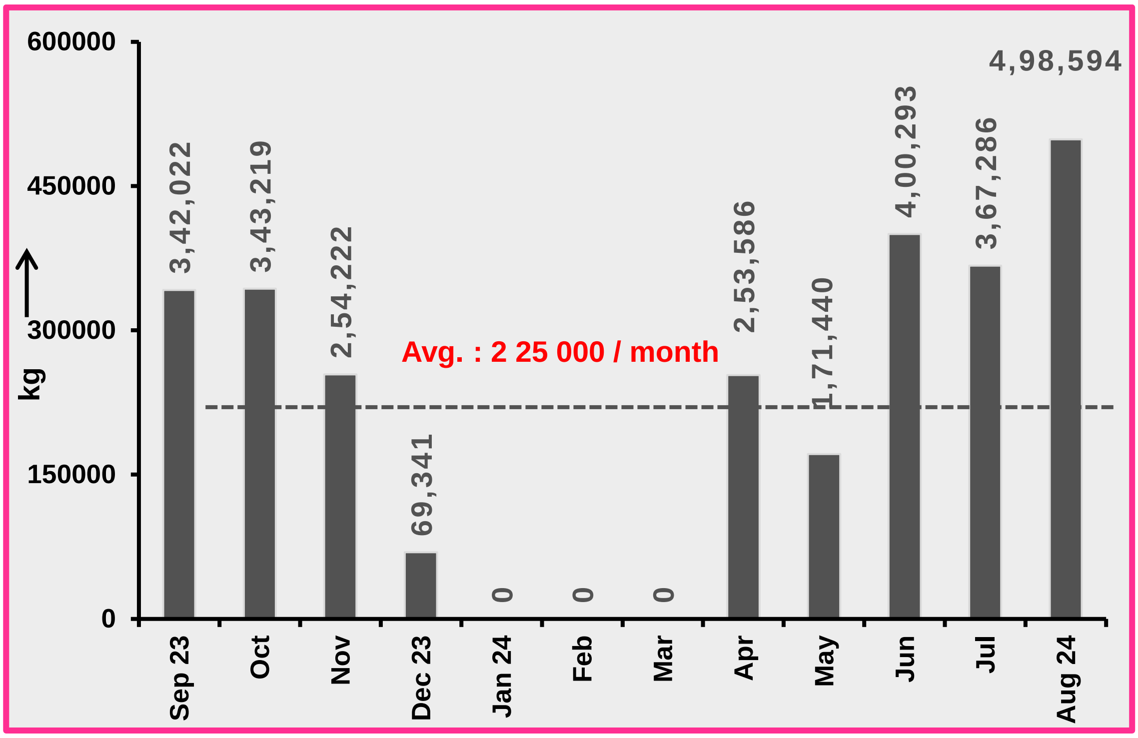


Fig 4.2 : Green Leaves Processed – Month wise (Sep '23 – Aug '24) | CAG

- 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.

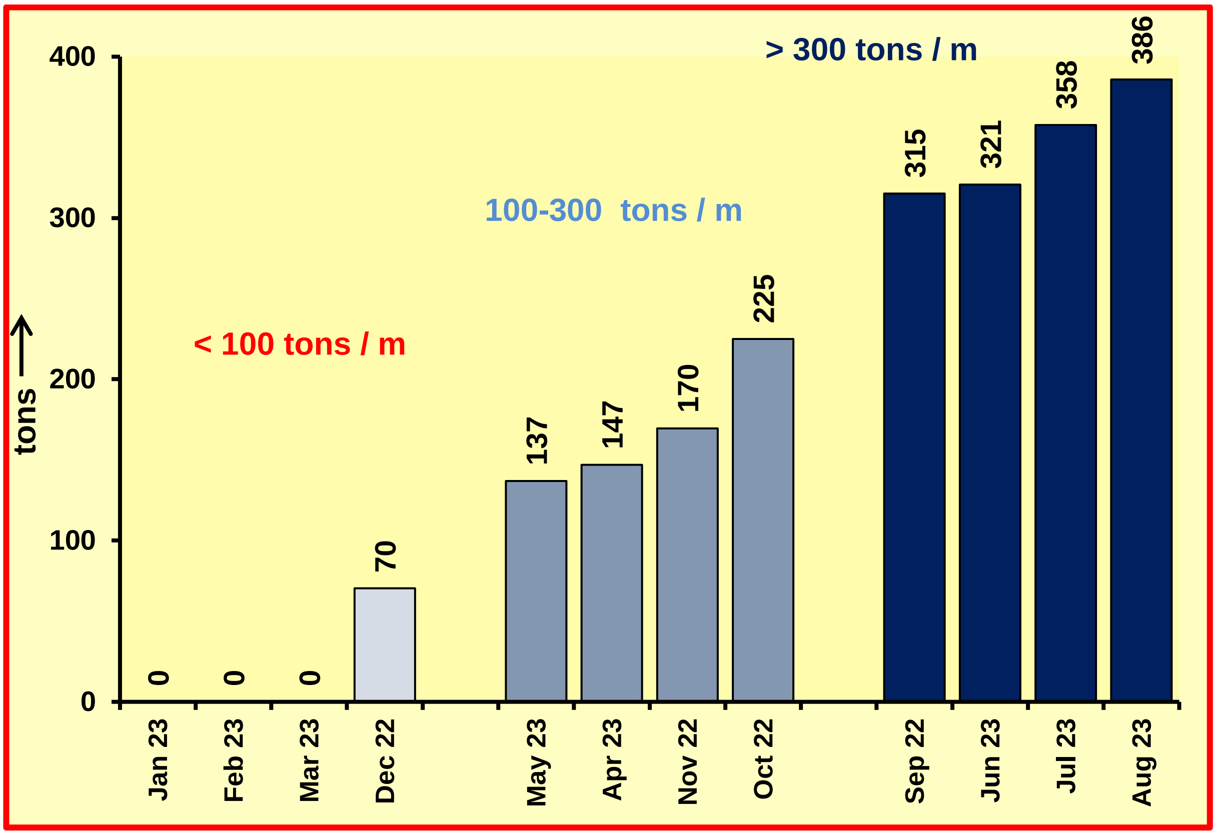


Fig 4.3 : Green Leaves Processed: Quantity wise (Sep '22 - Aug '23) | CAG

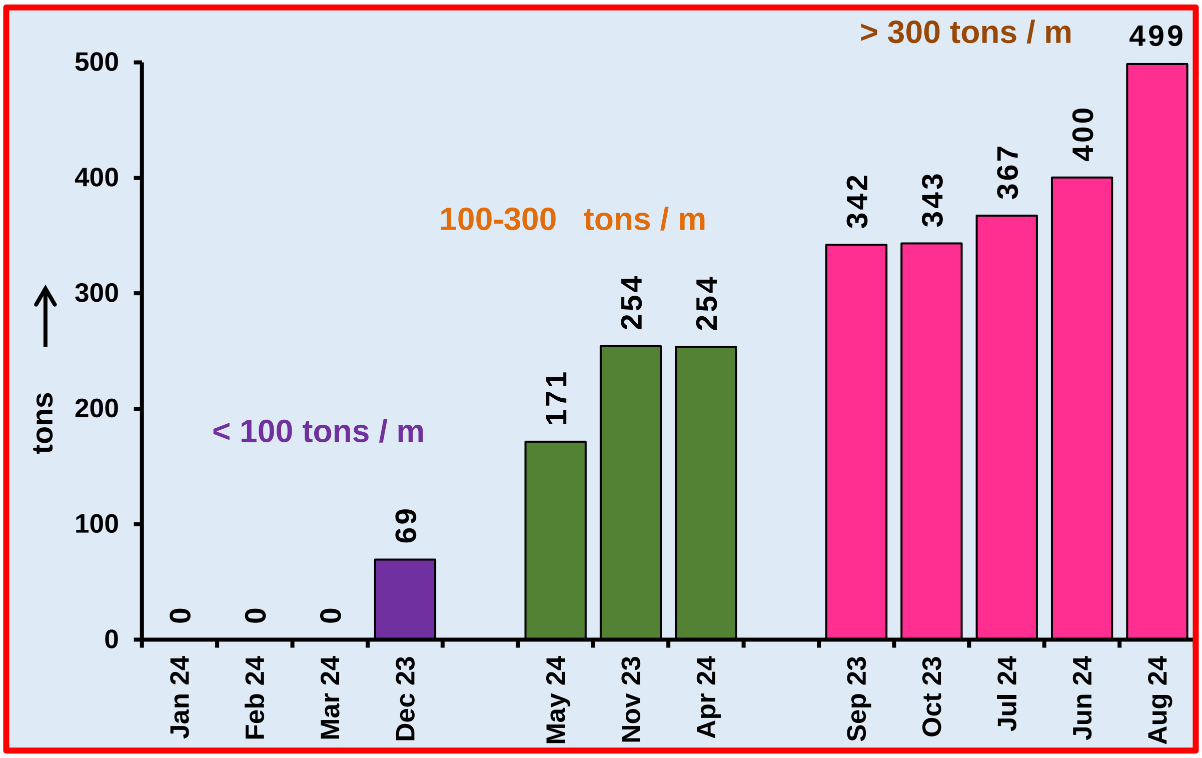


Fig 4.4 : Green Leaves Processed : Quantity wise (Sep '23 - Aug '24) | CAG

- On an average about **2 lakh kg** of green leaves are processed per month.

4.1.2 Made Tea Produced

- Made Tea produced = **4 62 040 kg (Sep '22 - Aug '23)**

  = **5 93 020 kg (Sep '23 - Aug '24)**

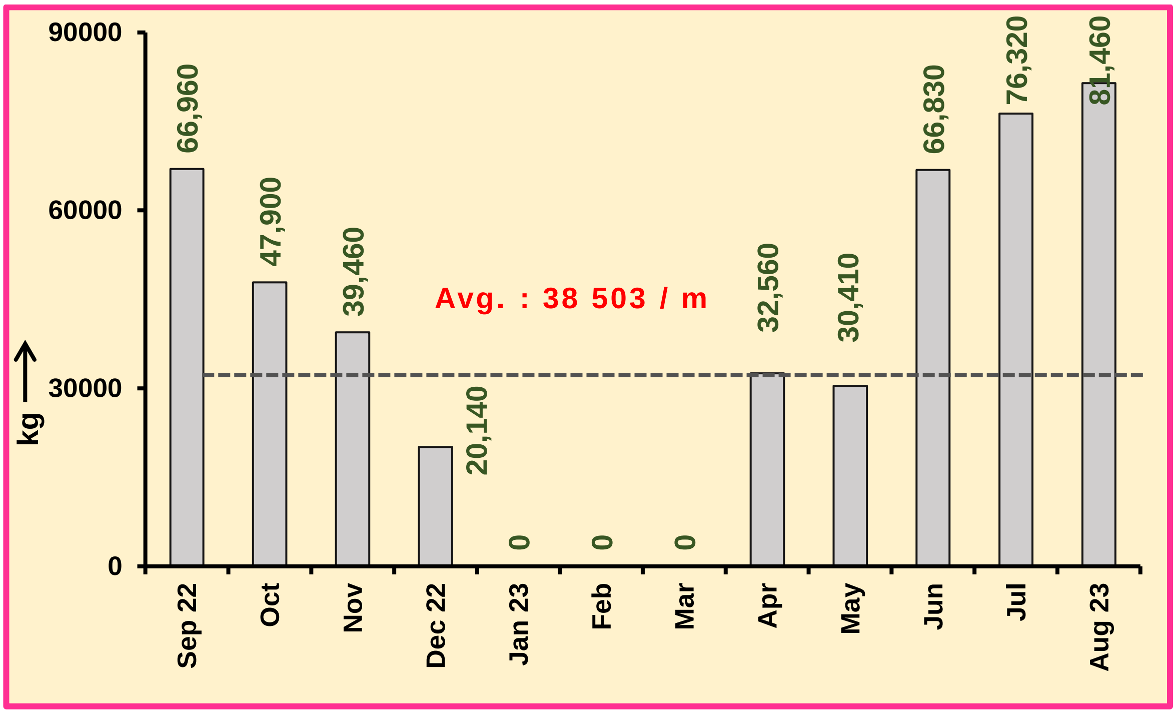


Fig 4.5 : Made Tea Produced – Month wise (Sep '22 – Aug '23) | CAG

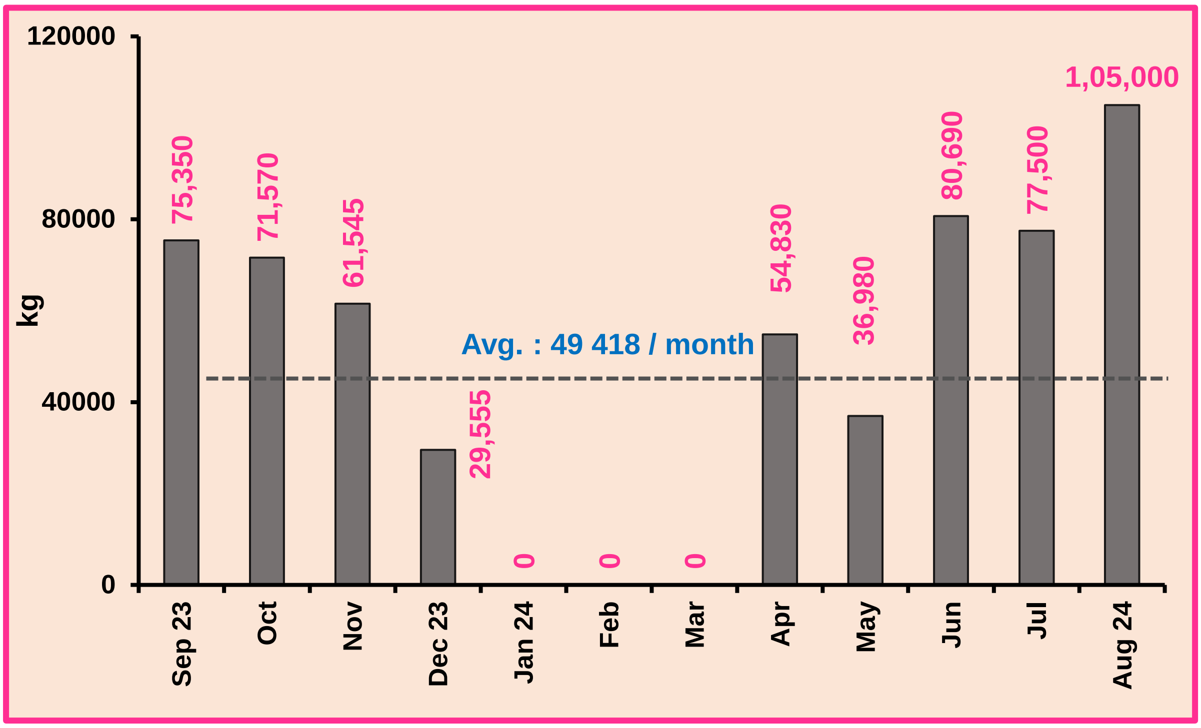


Fig 4.6 : Made Tea Produced – Month wise (Sep '23 – Aug '24) | CAG

4.1.3 Out Turn Recorded

- This parameter - Outturn - 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 - on - month and presented in Figs 4.7 & 4.8 for 2 year period.

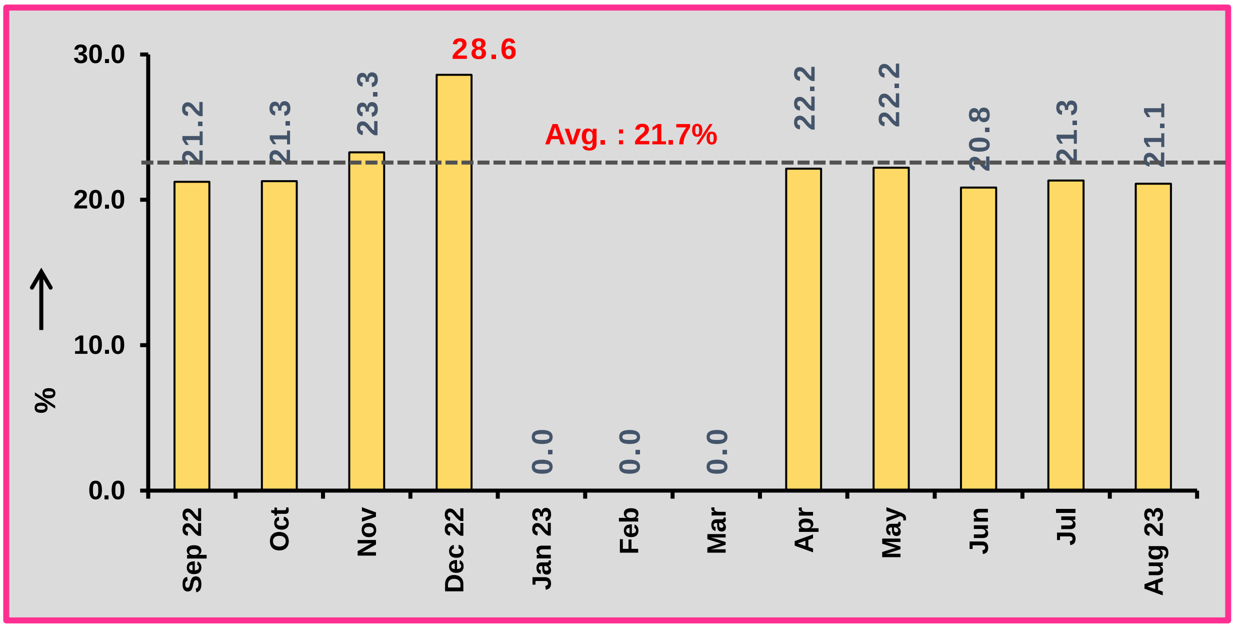


Fig 4.7 : Outturn Established – Month wise (Sep '22 – Aug '23) | CAG

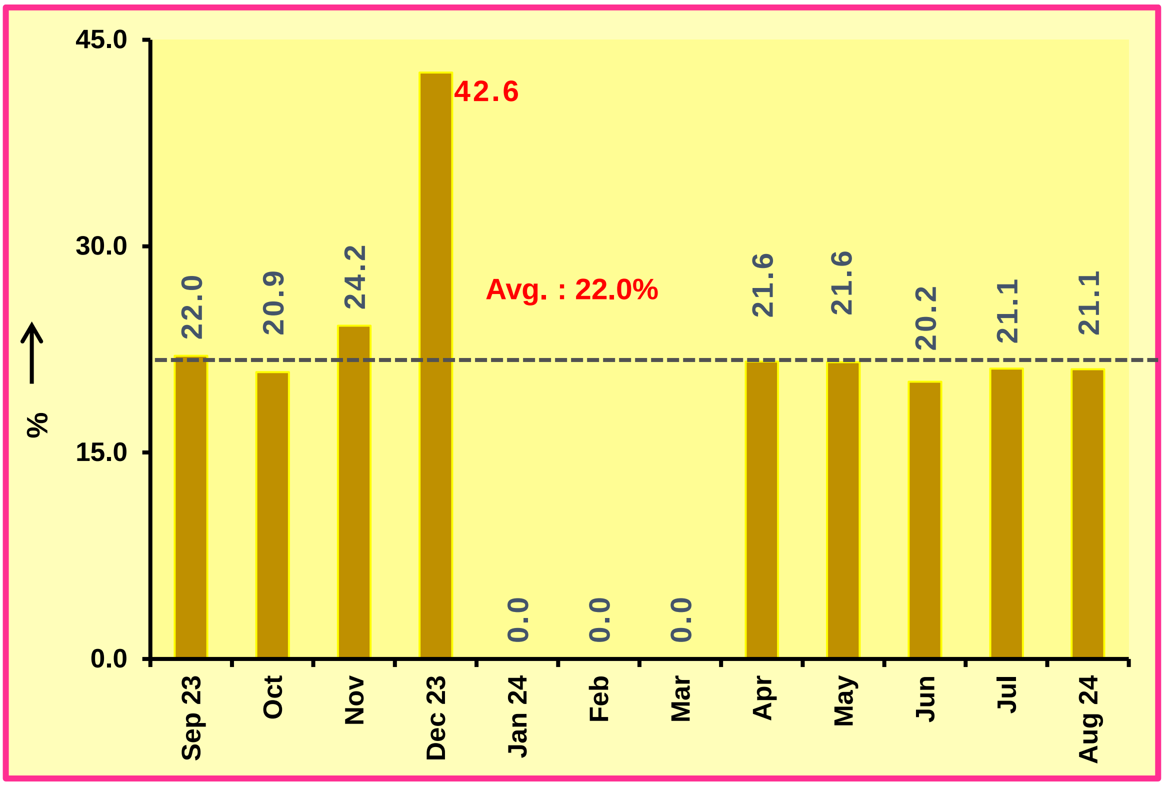


Fig 4.8: Outturn Established – Month wise (Sep '23 – Aug '24) | CAG

Average outturn in the period Sep '22 – Aug '24 = 21.9 %

4.2 CONSOLIDATION

- The consolidated production details are provided below:

Table 4.1 : Production related Information : 2 year : Consolidated

Period	Green Leaves Processed kg	Made Tea Produced kg	Outturn %
Sep '22 - Aug '23	21 28 147	4 62 040	21.7
Sep '23 - Aug '24	27 00 003	5 93 020	22.0

4.3 SUMMATION

- The seasonal dependence of tea production is quite clear - exhibiting consistent behaviour 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 abnormally 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 Sep 23 - Aug 24 is about **27- 28%** higher than that in the preceding 12 month timeframe (Sep 22 – Aug 23).
- Outturn is maintained at around. **22%.**

5 SPECIFIC ENERGY CONSUMPTION – A COMPUTATION

5.1 INTRODUCTION

- 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. 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.
- Both electrical energy and thermal energy are required in substantial quantities in the manufacturing of tea from the virgin green tea leaves.
  1) Electrical Energy : C T C, Withering Fans, Dryer Fans, Sorting Machines, etc.
  2) Thermal Energy : Tea drying through C N G combustion
- 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 S E E C : 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 0.20 kWh / kg GL as can be seen from Figs 5.1 & 5.2 **.** This is as expected
- The overall SEEC has been established as **0.126 kWh / kg Green Leaves** processed based on the annual data of 2 consecutive years [years 22 - 23 & 23 - 24]
- This detail is tabulated in Table 5.1

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

No	Period	Green Leaves kg	Electricity Consumption kWh	S E E C kWh / kg GL
1	Sep ‘22 - Aug’23	21 28 147	2 95 203	**0.139**
2	Sep’23 - Aug’24	27 00 003	3 14 359	**0.116**
Total		48 28 150	6 09 562	**0.126**

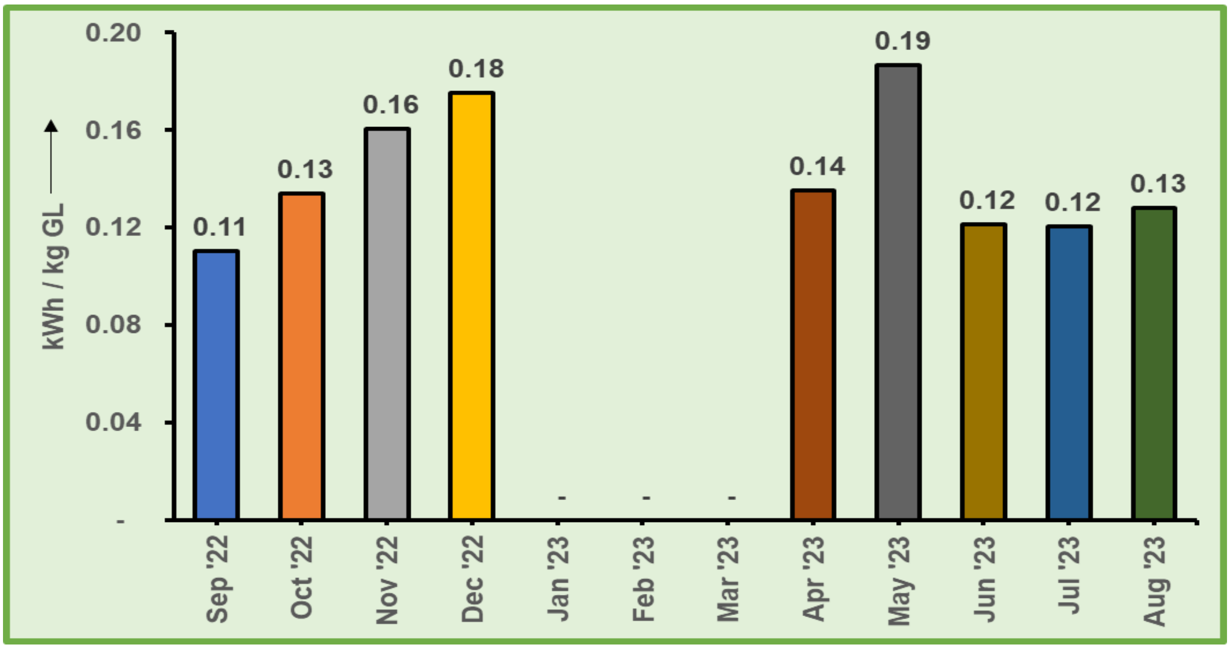


Fig 5.1 : S E E C Computed : Green Leaves Basis - Sep ‘22 to Aug ’23 | CAG

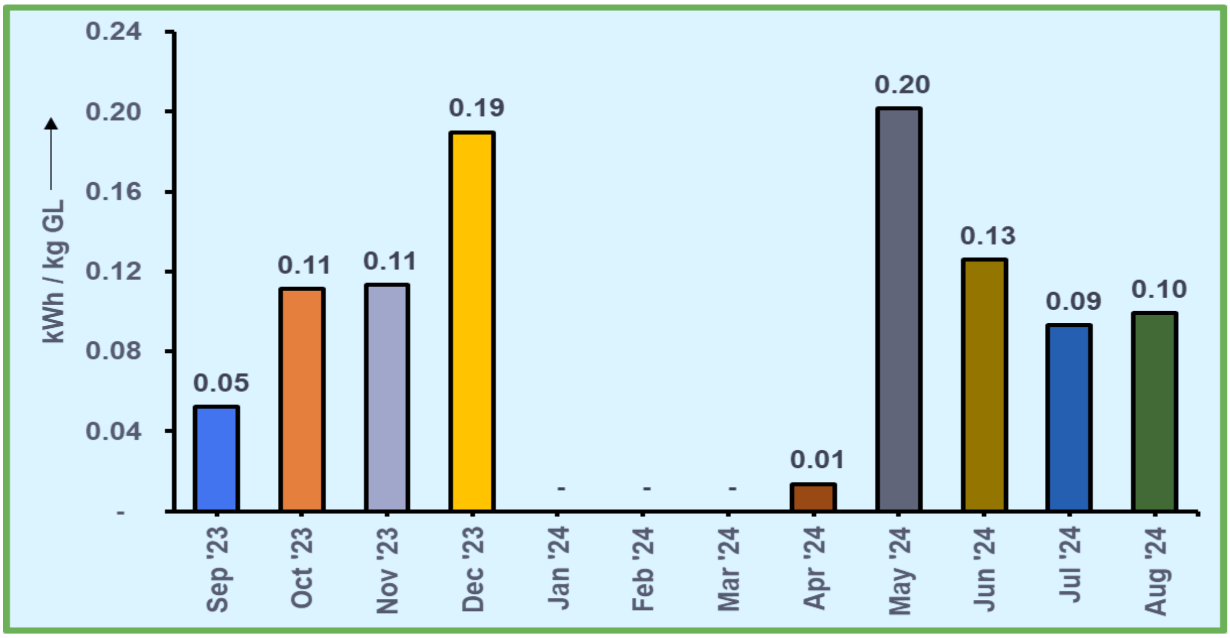


Fig 5.2 : S E E C Computed : Green Leaves Basis - Sep ‘23 to Aug ’24 | CAG

5.2.2 : S E E C : Made Tea Basis

- The SEEC has been established on month wise basis for 24 - month period and presented in Figs 5.3 & 5.4 respectively. This is carried out w r t the Made Tea produced in the factory.
- 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.

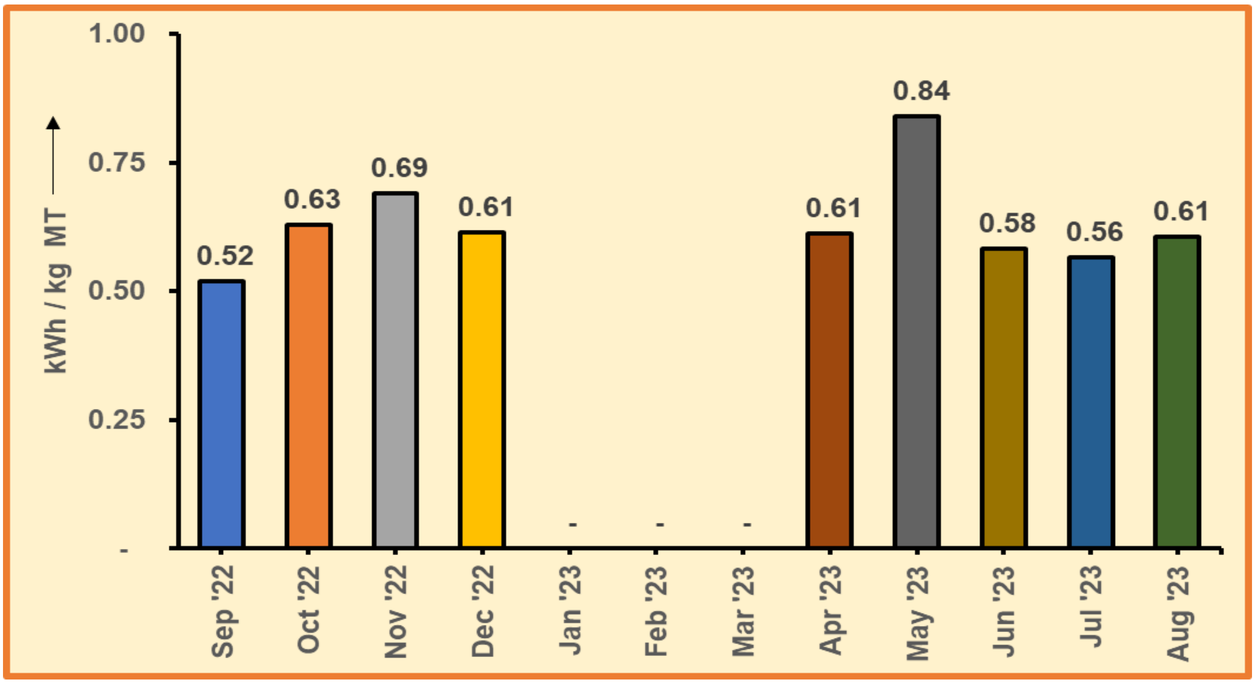


Fig 5.3 : S E E C Computed : Made Tea Basis - Sep '22 - Aug '23 | CAG

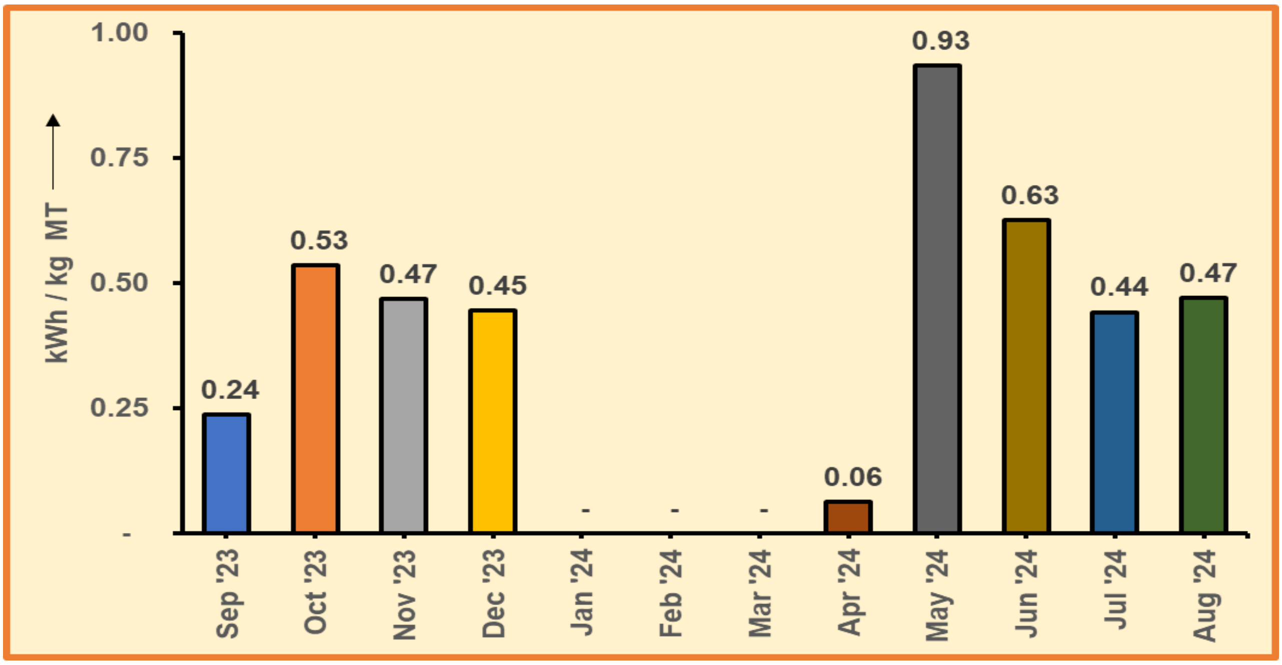


Fig 5.4 : S E E C Computed : Made Tea Basis - Sep '23 - Aug '24 | CAG

- 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 0.57 kWh / kg Made Tea during this period.
- During off - season the SEEC goes to as high as 0.80 which is a rare occurrence.
- The annualized data on SEEC w r t Made Tea is presented in Table 5.2.
- The SEEC has been established as **0.578 kWh / kg Made Tea** which is quite reasonable.

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	**4 62 040**	**2 95 203**	**0.639**
2	Sep’23 - Aug’24	**5 93 020**	**3 14 359**	**0.530**
Total		**10 55 060**	**6 09 562**	**0.578**

5.3 SPECIFIC FUEL CONSUMPTION (S F C)

5.3.1 S F C : Green Leaf Basis

- **The factory employs** ECP Dryers to remove the moisture in the Wet Dhool to produce Tea.
- The hot air / gas is produced by burning the CNG in the burner and making it to flow through the drier. Since CNG is a clean fuel, the hot gas produced by burning it is directly used for drying which results in obtaining a higher thermal efficiency in the drier.
- The moisture laden wet air exits the drier from the top and let out to the atmosphere.
- The Specific Fuel Consumption [S F C] has been established on a month wise basis for 24 - month period and presented in Figs 5.5 & Fig 5.6 respectively.
- During season period, the SFC was **0.09 scm / kg GL** and is about **0.12 scm / kg GL** during low leaf arrival period. (off – season)

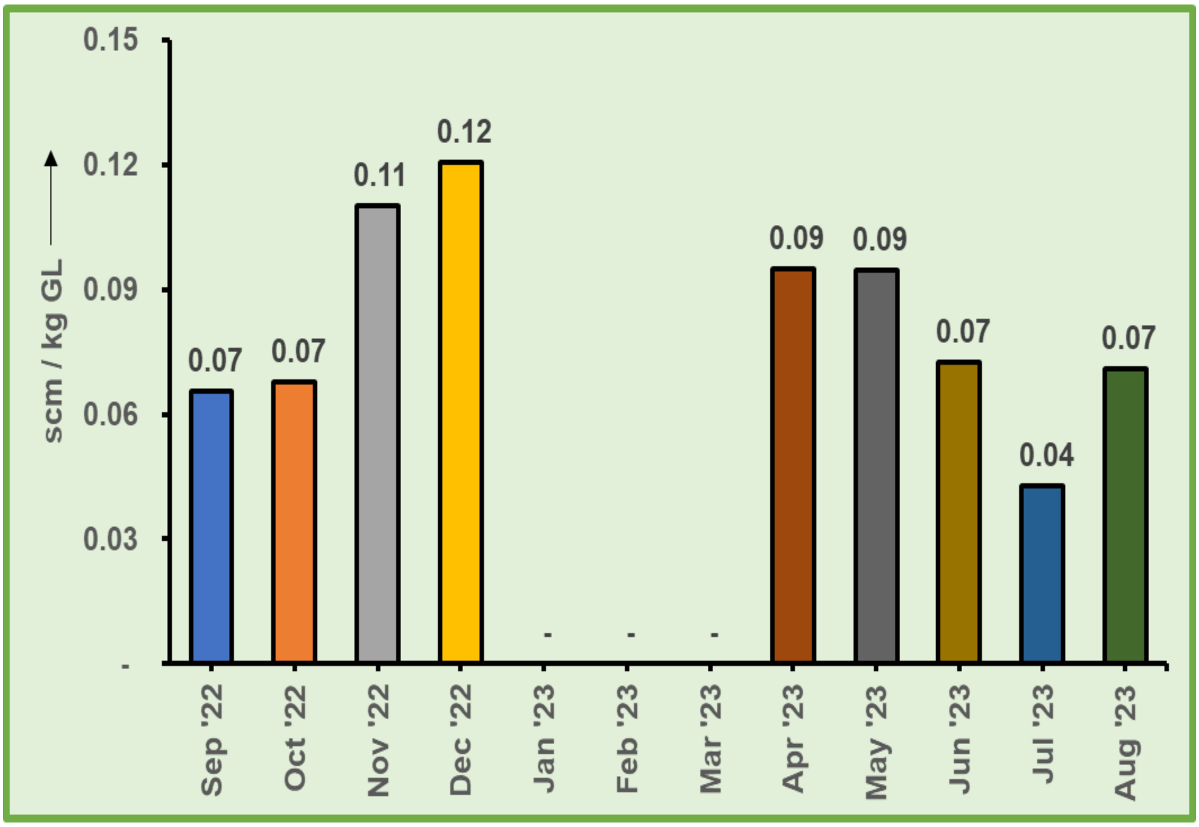


Fig 5.5 : S F C Computed :Green Leaves Basis: Sep '22 to Aug '23 | CAG

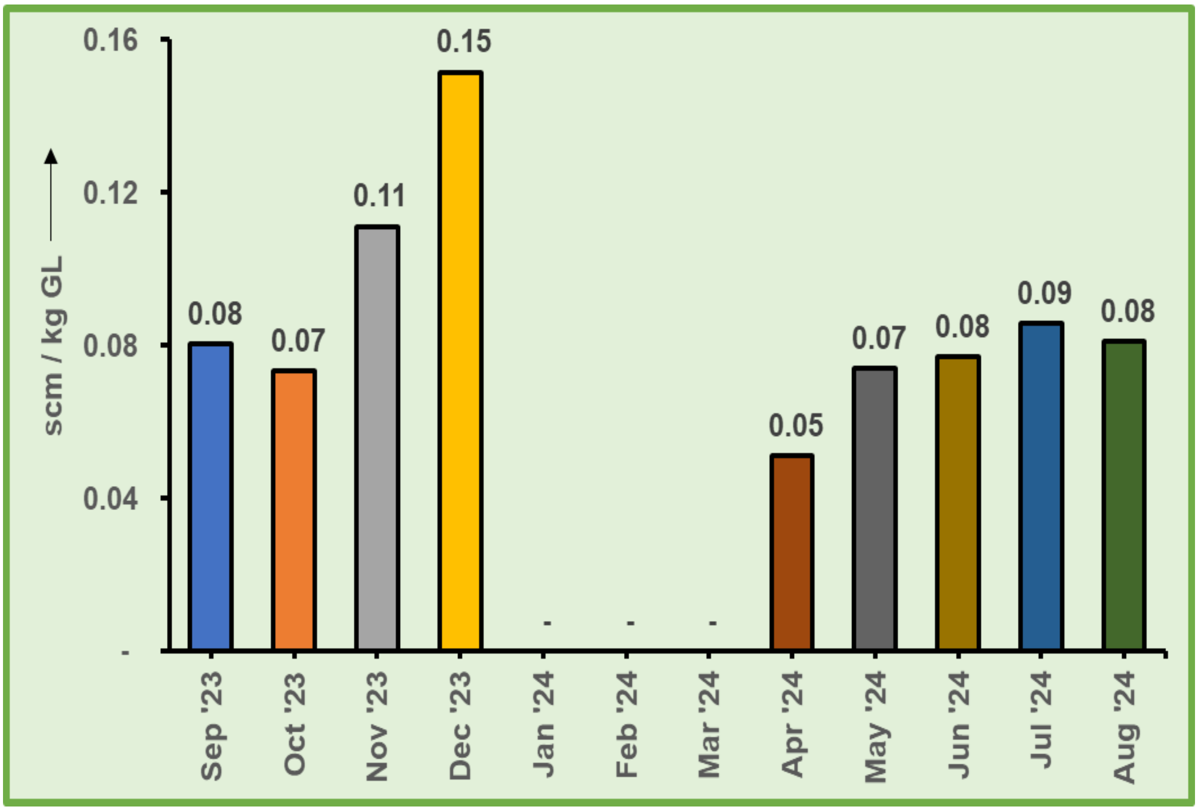


Fig 5.6 : S F C Computed : Green Leaves Basis - Sep '23 - Aug '24 | CAG

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

Table 5.3 : S F C Established w r t Green Leaves Processed

No	Period	Green Leaves kg	C N G consumed scm	S F C scm / kg GL
1	Sep'22 - Aug'23	21 28 147	1 60 436	**0.075**
2	Sep'23 - Aug'24	27 00 003	2 19 895	**0.081**
Total		48 28 150	3 80 331	**0.078**

∉ The S F C with respect to Green Leaves processed has been computed as **0.078 scm / kg GL** which is a 2 - year average value

5.3.2 : S F C : Made Tea Basis

- On 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 & Fig 5.8 respectively.

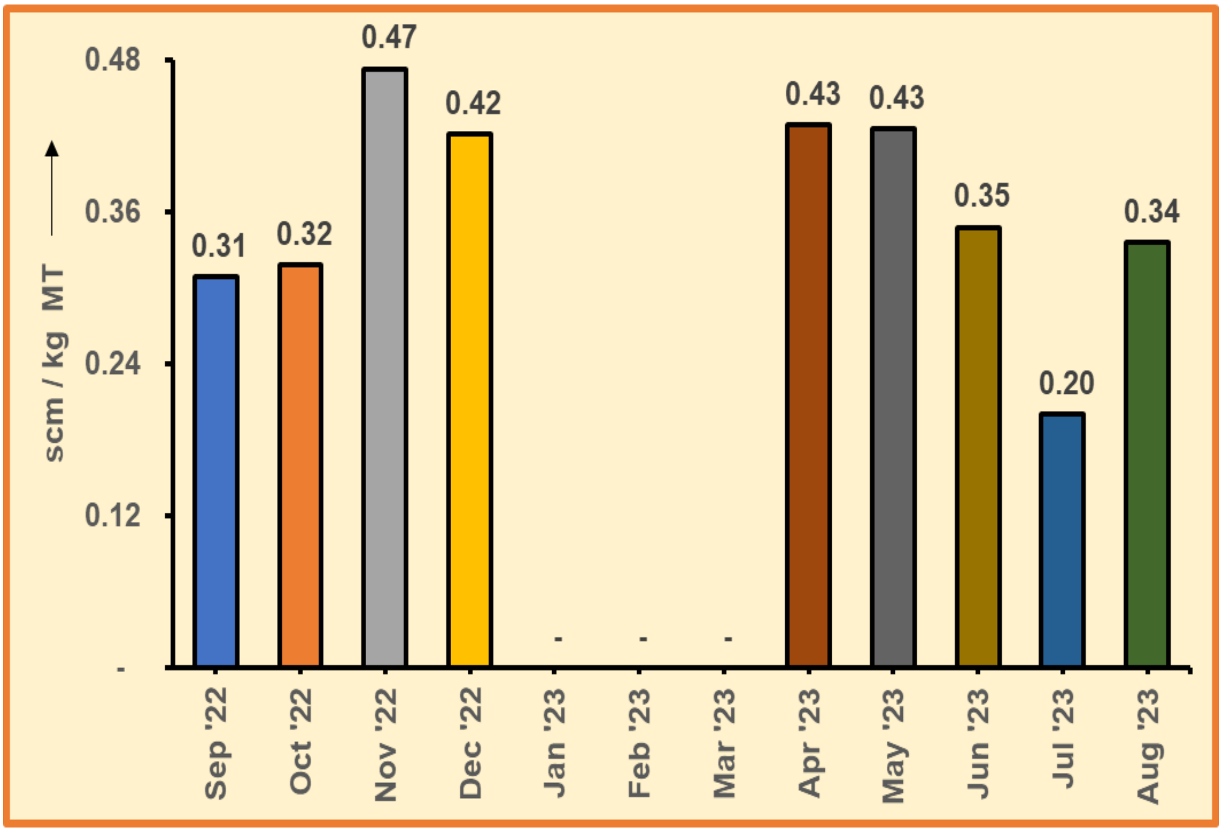


Fig 5.7 : S F C Computed : Made Tea Basis - Sep '22 to Aug '23

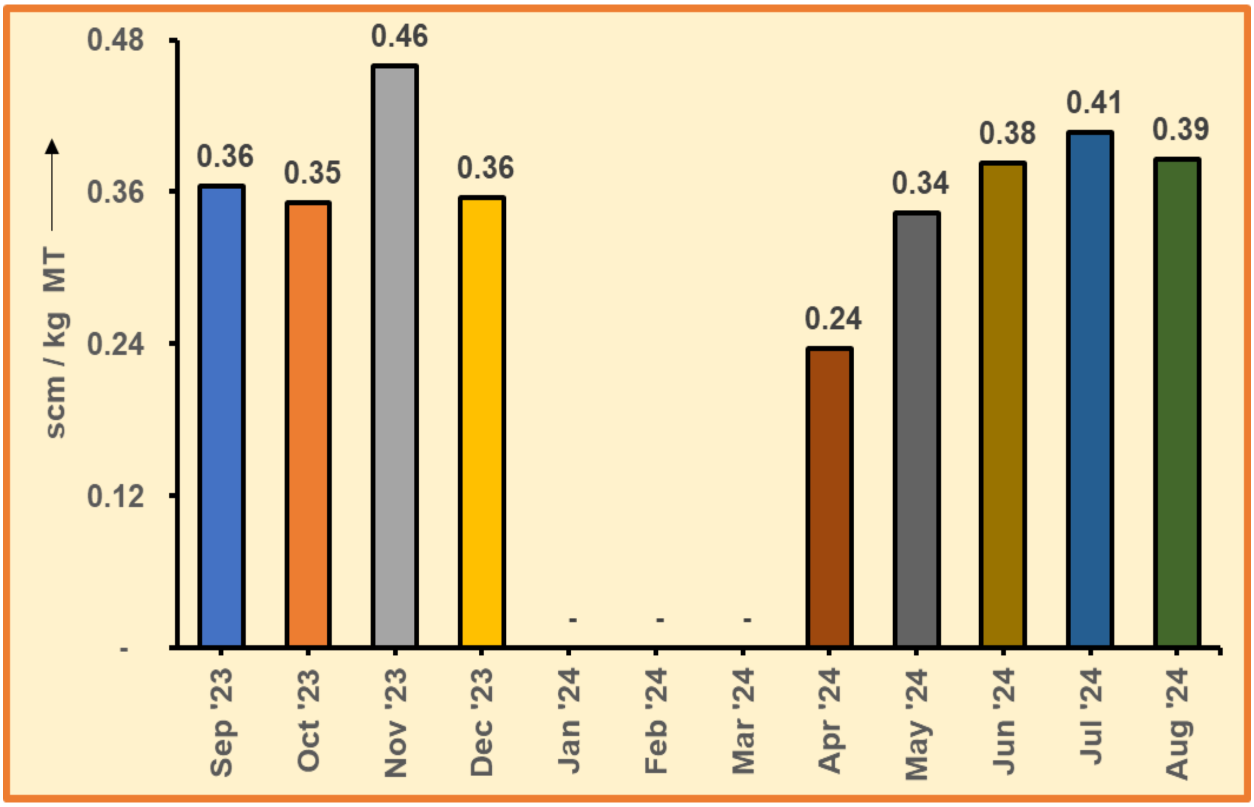


Fig 5.8 : S F C Computed : Made Tea Basis - Sep '23 to Aug '24 | CAG

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

No	Period	Made tea kg	CNG consumed scm	SFC scm / kg MT
1	Sep'22 - Aug'23	4 62 040	1 60 436	**0.35**
2	Sep'23 - Aug'24	5 93 020	2 19 895	**0.37**
Total		10 55 060	3 80 331	**0.36**

- The S F C has been computed as **0.36 scm / 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 the Specific CNG consumption, an attempt is made here establish the cost incurred due to electricity and CNG towards tea production.
- 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		C N G		Total	₹ / kg MT
			₹	%	₹	%		
1	Sep'22 - Aug'23	4 62 040	25 49 436	20.7	97 57 070	79.3	1 23 06 506	**26.6**
2	Sep'23 - Aug'24	5 93 020	29 25 415	18.0	1 33 39 668	82.0	1 62 65 083	**27.4**
Total		10 55 060	54 74 851	19.2	2 30 96 738	80.8	2 85 71 589	**27.1**

- The energy cost of tea production has been estimated as ₹ 27.1 / kg Made Tea
- About 19 % of the energy cost is due to electricity and the rest 81 % is due to CNG.
- This is - despite the Drier being efficient enough - due to the higher procurement cost of C N G energy combined with the penalty charges paid invariably month on month. This has to be optimized to bring down the specific cost of CNG utilized in tea making.
- The cost share diagram is presented in Fig 5.9

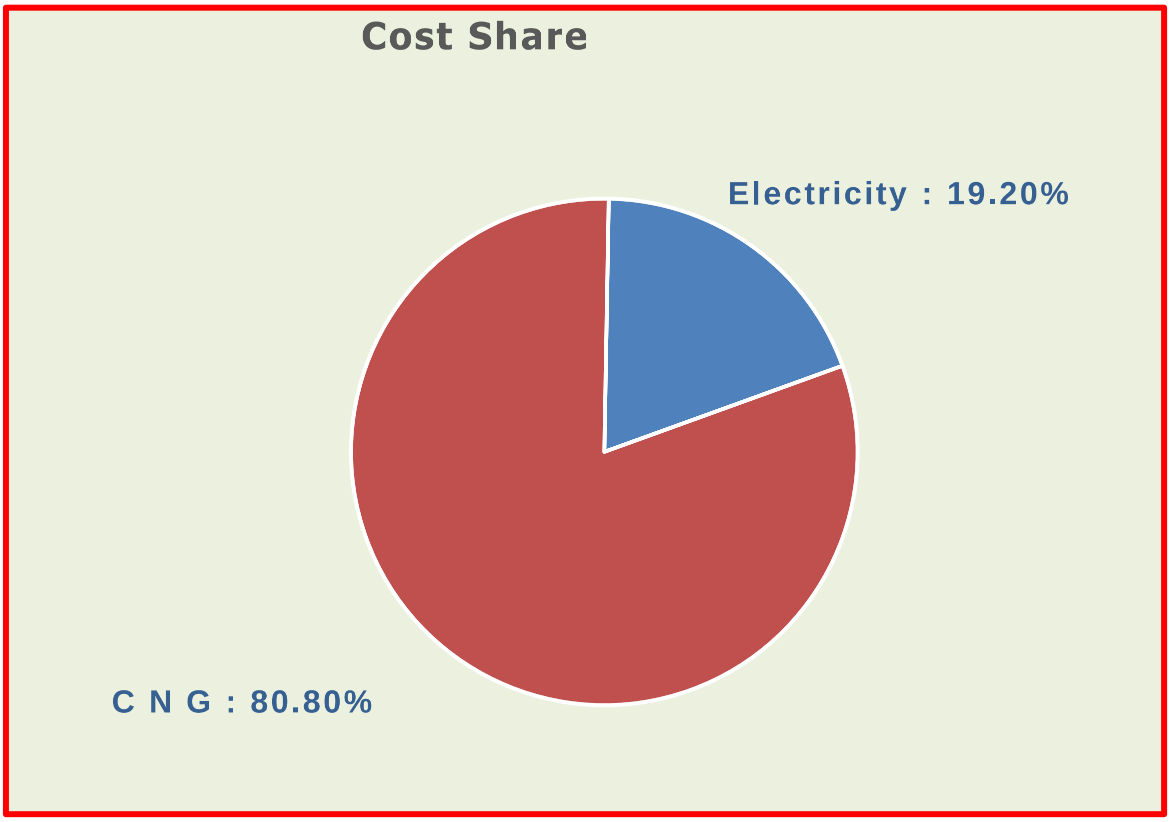


Fig 5.9 : Energy Cost Computed : per kg of Made Tea : 2 year Avg | CAG

- The aggregated cost of both the energy [electricity + CNG] of tea production - Month on Month - is presented in Fig 5.10 & 5.11 for clarity's sake

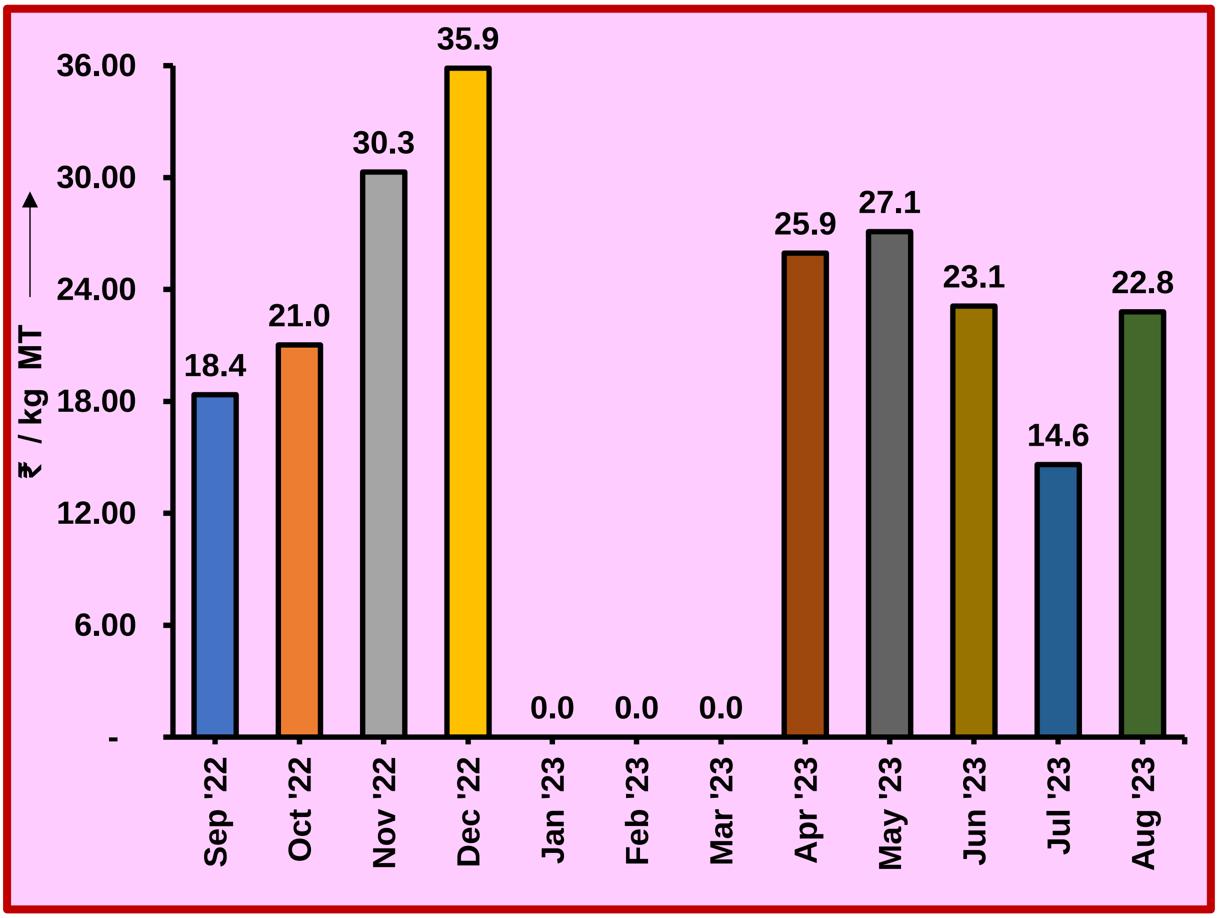


Fig 5.10 : Overall Energy Cost : Month wise - Sep '22 to Aug '23 | CAG

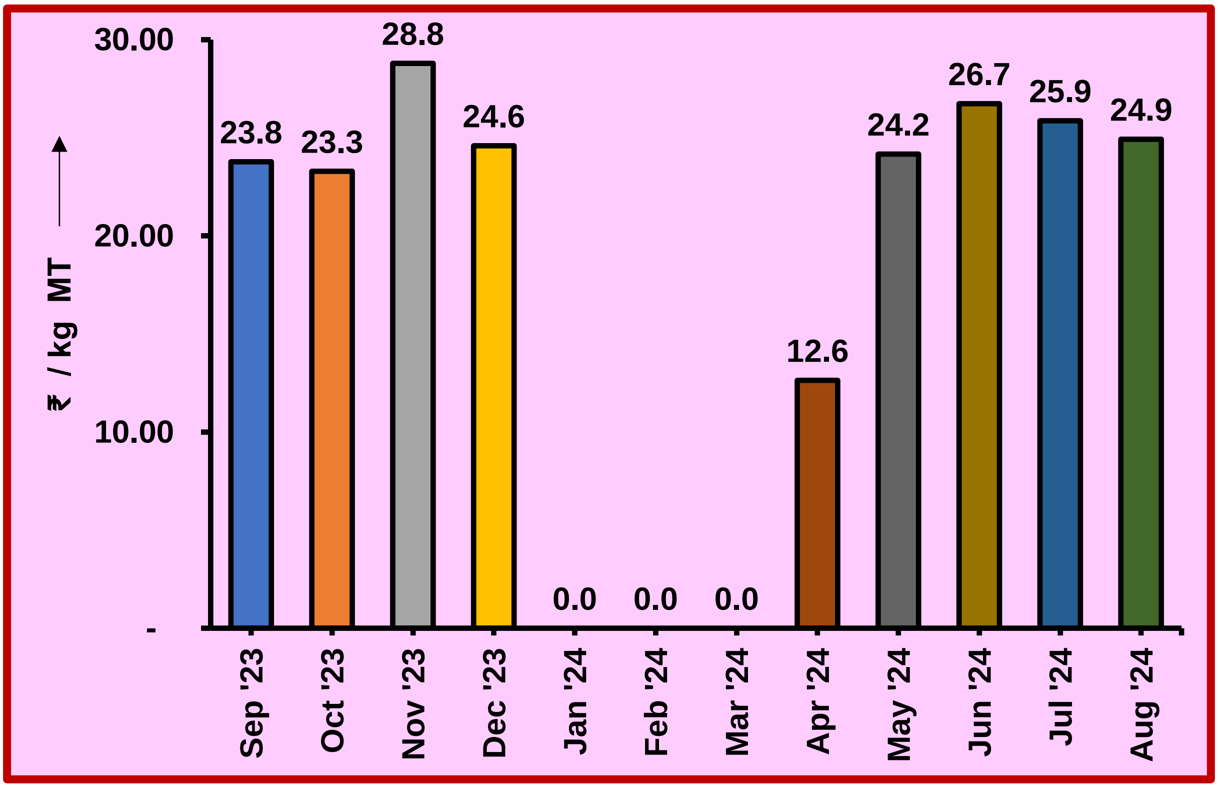


Fig 5.11 : Overall Energy Cost : Month wise - Sep '23 - Aug '24 | CAG

- In conclusion, it can be said - that on an average - ₹ 27 is the total energy cost for the production of 1 kg of Made Tea that comprises both electrical and fuel 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		
1) w.r.t Green Leaves	:	**0.126 kWh / kg GL**
	:	**0.078 scm of CNG / kg GL**
2) w.r.t Made Tea	:	**0.578 kWh / kg MT**
	:	**0.36 scm / kg MT**
Total Energy Cost	:	**₹ 27.1 / Kg Made Tea**

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 of the factory, namely, Withering, CTC, Drying, and Sorting.
- The electrical measurements on the motors were logged for a period of **15 - 30** mins to establish a correct and replicable power drawl trend
- This longer duration power logging had eliminated the possible ups & downs in the power drawl pattern of the motors and ensured the reliability of measurements recorded
- This exercise has been undertaken as part of the energy conservation action, as it is well known that poorer the motor loading, lower is the operating efficiency and power factor, that eventually leads to higher energy consumption for the given product output.
- It has to be noted that poor loading of motors can result in higher drawl of current, thus reducing the lifetime of motor winding. In other words, the kW loading of motors - also at times - can prove 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 4 sections identified in the factory and the load study has been conducted on motors of these.
- 44 motors have been earmarked for load study in these 4 sections and the outcome is presented in the ensuing sections

6.1 WITHERING SECTION

- The withering section has 6 troughs powered by 12 fans. Two troughs are powered by 3.7 kW fan motors, while the remaining 4 troughs are fitted with 2.2 kW fan motors.
- The break - up details, power measurements recorded and computed are tabulated below :

Table 6.1: Motor Loading Details – Withering Section

No	Motor ID		Rated			Measured			% Loading	
			kW	Amps	η %	kW	Amps	PF	kW	Amps
1	Withering Trough Fan Motor	1A	3.70	8.00	85.0	3.8	7.8	0.78	87.3	97.1
2		1B	3.70	8.00	85.0	3.3	7.3	0.77	75.0	90.8
3		2A	3.70	8.00	85.0	3.1	6.3	0.76	71.2	78.8
4	Withering Trough Fan Motor	2B	3.70	8.00	85.0	3.2	6.5	0.77	74.3	80.8
5		3A	2.20	5.70	78.5	1.8	4.2	0.65	64.2	73.7
6		3B	2.20	5.70	78.5	1.8	4.3	0.64	64.2	75.4
7		4A	2.20	5.70	78.5	1.6	4.0	0.66	58.3	69.6
8		4B	2.20	5.70	78.5	1.7	3.9	0.69	60.7	69.0
9		5A	2.20	5.70	78.5	1.2	2.3	0.86	44.0	39.8
10		5B	2.20	5.70	78.5	1.1	2.2	0.87	40.4	38.0
11		6A	2.20	5.70	78.5	1.9	4.3	0.74	66.6	74.9
12		6B	2.20	5.70	78.5	1.8	4.1	0.74	65.4	71.9
Total			32.4			26.4				

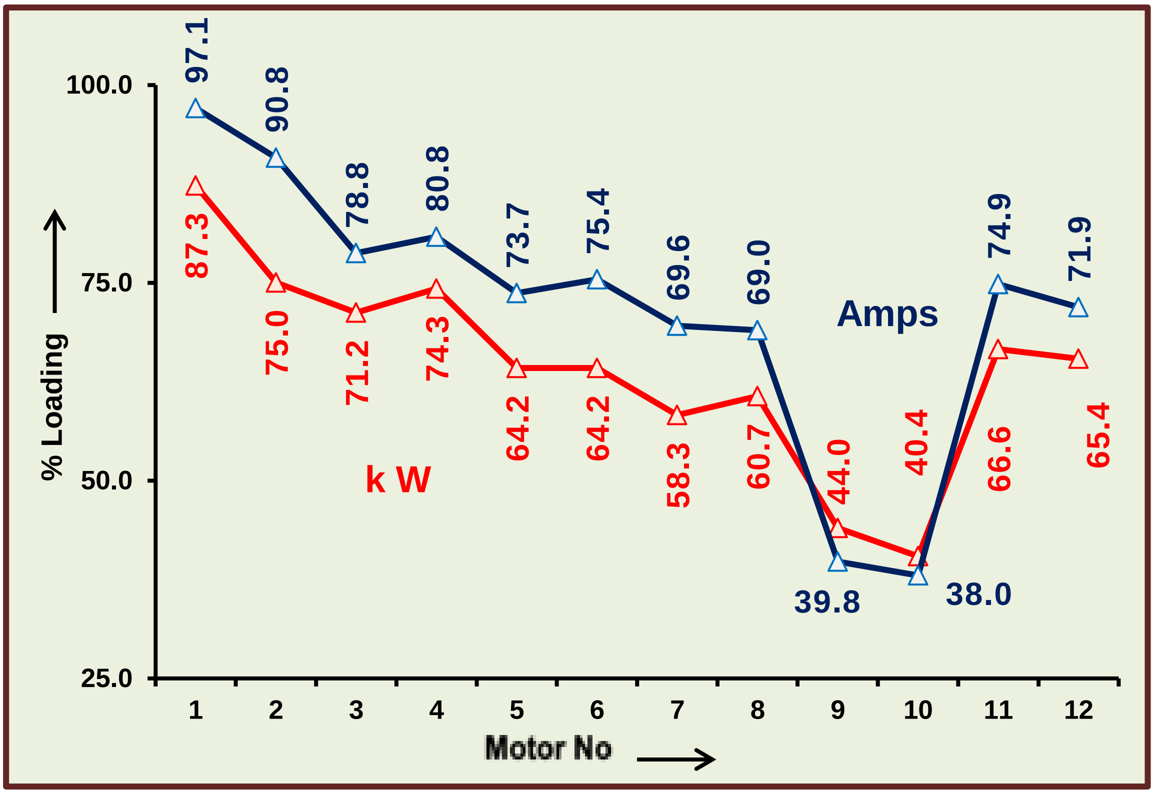


Fig 6.1: Motor Loading Details – Withering Section | CAG

Observations

- **10** out of the **12** withering trough fan motors are loaded beyond **55%** on both kW and Ampere front which indicates the optimal loading of motors which is appreciable
- The power factors recorded exceeded 0.70 for majority of motors which is acceptable although may not be optimum and thereby indicating scope for improvement.
- Withering Trough Fan Motors 5 A & 5 B (Motor Nos. 9 & 10) are loaded below **50%** on both kW & Ampere front although the motor rating is the same at 2.2 kW. This calls for introspection.
- The PFs recorded for these motors (Motor Nos. 9 & 10) are surprisingly on the higher side, despite the poor loading. This pulls down the ampere loading below that of kW, which indeed is a rare occurrence. This too shall be taken up for scrutiny.
- In conclusion, the power measurements recorded and computed show that the motors of this section are mostly 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 ultimately result in the drawl of reasonable and optimum power by the motors.

6.2 CTC SECTION

- The CTC section has two production lines, with **7** motors in each line, power rating ranging from **1.5 kW** to **18.5 kW.**
- The loading pattern - established for all the 14 motors - is tabulated below:

Table 6.2: Motor Loading Details – CTC Section

No	Motor ID		Rated			Measured			% Loading	
			kW	Amps	η %	kW	Amps	PF	kW	Amps
1	CTC - Line 1	RV	15	28.0	89.0	4.7	11.1	0.67	28.1	39.8
2		Cut 1	18.5	35.0	91.2	7.6	17.6	0.69	37.7	50.3
3		Cut 2	15	27.6	90.6	13.8	25.9	0.85	83.6	93.8
4		Cut 3	15	27.6	90.6	9.7	18.5	0.84	58.6	67.1
5		Cut 4	15	27.6	90.1	10.2	19.5	0.84	61.0	70.6
6		Ghoogy	2.20	4.00	82.8	0.3	1.7	0.32	12.5	43.3
7		Blower	1.50	3.10	76.0	0.7	1.5	0.76	33.8	47.3
8		RV	15	28.0	89.0	4.7	13.5	0.48	27.9	48.1
9		Cut 1	18.5	35.0	91.2	10.4	19.8	0.73	51.2	56.6

10	CTC - Line 2	Cut 2	15	27.6	90.6	12.9	21.8	0.84	77.9	79.0
11		Cut 3	15	27.6	90.6	9.4	13.6	0.99	56.7	49.2
12		Cut 4	15	27.6	90.1	11.9	18.6	0.92	71.4	67.3
13		Ghoogy	2.20	4.61	82.0	0.4	2.2	0.29	14.9	48.4
14		Blower	1.50	3.10	76.0	1.0	1.9	0.80	50.7	60.2
Total			**164**			**97.7**				

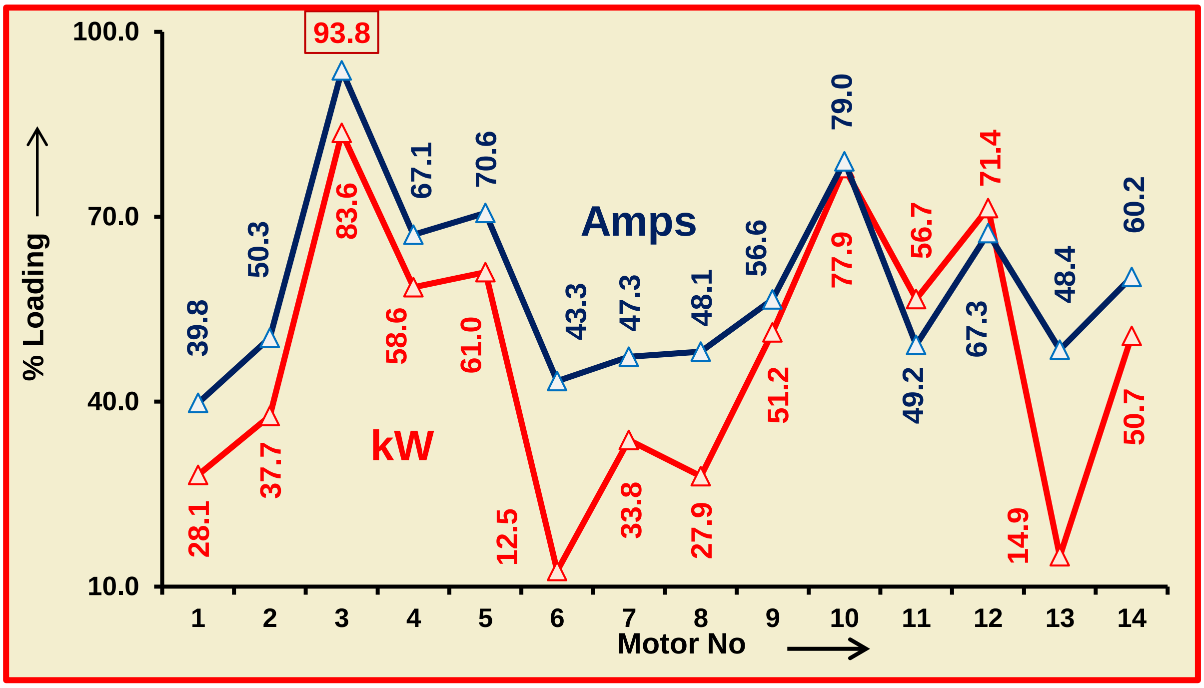


Fig 6.2: Motor Loading Details – CTC Section | CAG

Observations

- There are **14** motors in operation in this section and **6** out of these **14** are loaded below **50%** on the kW front ; in some cases the loading is too low (**<15%**), requiring substantial improvement (Ghoogy).
- Googhey motors [**3** out of the **6**] are poorly loaded and also exhibited very low power factors - less than **0.5**.
- The power factor is above **0.65** for the remaining motors of CTC section despite experiencing lower loading in some cases.
- Further, it was noticed that **4** out of the **6** lowly loaded motors belong to CTC Line 1. This might be due to the fact that Line 1, being the older production line, is likely to have more number of oversized motors, as the concept of oversizing fades away with time.

- To conclude, the loading cannot be said to be optimum in the CTC section especially in respect of 6 motors – mentioned earlier - which needs to be looked into.

6.3 DRIER SECTION

- In this section, there are **7** motors having power rating ranging from **0.75** to **11 kW.**
- The loading pattern established for these motors is tabulated below :

Table 6.3: Motor Loading Details – Drier Section

No	Motor ID		Rated			Measured			% Loading	
			kW	Amps	η %	kW	Amps	PF	kW	Amps
1	Hot Air Fan Motor	Drier 1	11	21.3	87.5	2.4	10.2	0.34	**19.2**	47.8
2		Drier 2	11	21.3	87.5	2.0	7.2	0.41	**15.5**	33.9
3		Drier 3	11	21.3	90.0	9.7	14.6	0.96	**79.6**	68.4
4	Tray Carrying Motor	Drier 1	2.20	4.00	82.8	0.6	2.6	0.34	**21.3**	64.2
5		Drier 2	3.70	8.00	85.0	0.4	1.0	0.71	**10.0**	12.5
6		Drier 3	2.20	4.00	82.8	0.2	0.8	0.58	**8.8**	19.2
7	Conveyor Motor	Drier Mouth	0.75	1.85	74.5	0.2	1.1	0.27	**16.6**	59.5
	Total		**42**			**15.5**				

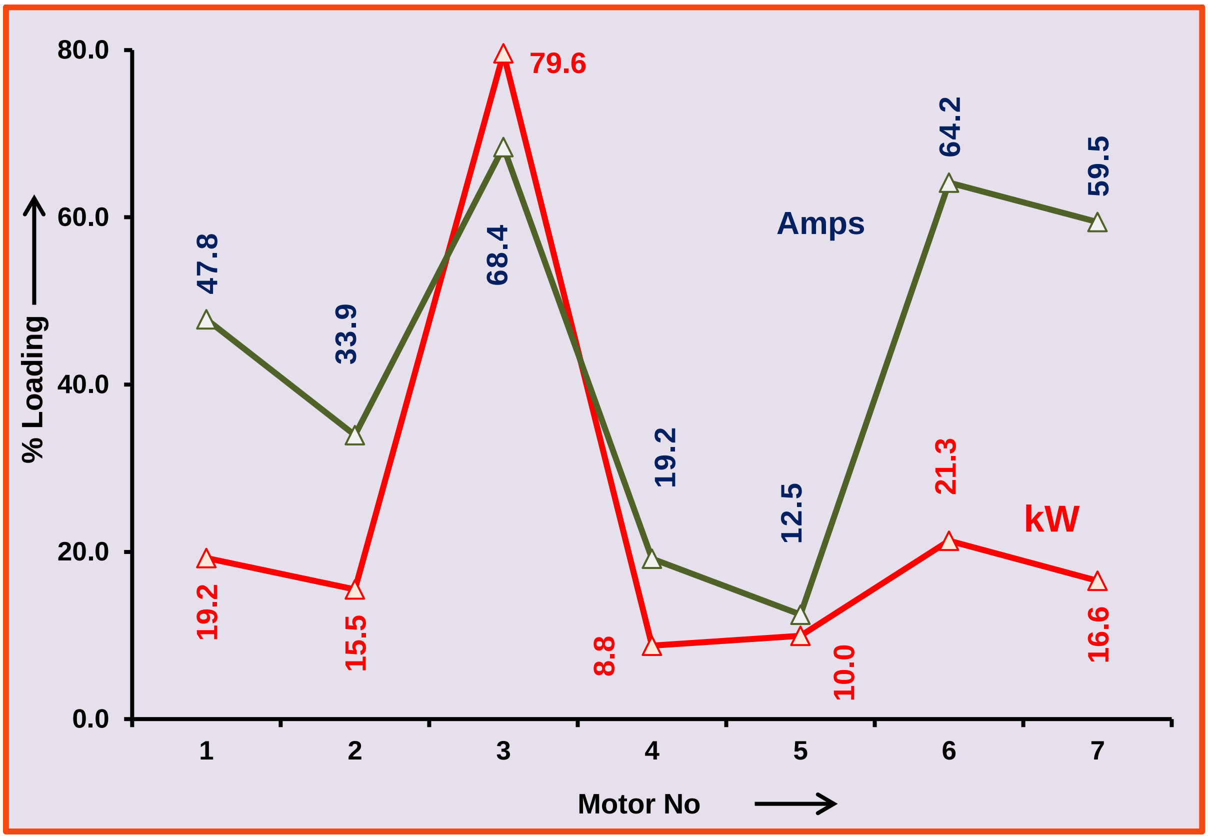


Fig 6.3: Motor Loading Details – Drier Section | CAG

Observations

- The loading of the motors in this section is significantly as well as uniformly low - less than **25%** - but for one which is the Hot Air Fan Motor of Drier 3.
- The power factors recorded are also in the lower spectrum in most of the cases, which is obvious as that can be attributed to the poor loading of motors.
- Lower kW loading has a detrimental effect on the operational efficiency of the motors, and the impact is more rapid when the loading is below 50 % mark. This effect - decrease in motor efficiency - is more pronounced in smaller capacity motors.
- In conclusion, the loading of the motors in the Drier section is on the lower gamut. This needs to be taken care of from the viewpoint of enhancing their efficiency level.

6.4 SORTING SECTION

- This section has **12** motors with power ratings in the range of **0.37** to **1.5 kW**. The name plate details of one motor, namely the "Conveyor Motor - M1 - Weighing Scale Input", were not known, thereby making it impossible to analyse its loading pattern.
- The loading pattern evaluated for the remaining 11 motors is tabulated below :

Table 6.4: Motor Loading Details – Sorting Section

No	Motor ID		Rated			Measured			% Loading	
			kW	Amps	η %	kW	Amps	PF	kW	Amps
1	Conveyor Motor	M2 - Weighing Scale Output	0.37	1.00	72.7	0.1	0.6	0.32	19.6	56.7
2	Sorter Machine 1	Vibro Motor	1.50	3.28	76.0	0.4	1.8	0.35	18.6	53.9
3	Sorter Machine 3	Starter 1	1.50	3.80	76.0	0.2	1.9	0.19	10.1	50.0
4		Starter 2	0.75	1.85	74.5	0.1	1.2	0.23	13.2	66.7
5		Starter 3	1.50	3.20	80.0	0.3	1.5	0.31	14.2	45.8
6		Starter 4	1.50	3.30	77.0	0.3	1.9	0.23	15.4	57.6
7		Starter 5	1.50	3.30	77.0	0.3	1.6	0.27	13.7	49.5
8		Starter 6	1.50	2.25	77.0	0.3	1.8	0.28	15.4	80.0
9		Starter 7	1.50	3.20	77.0	0.3	1.7	0.27	13.7	54.2
10	Sorter Machine 3	Starter 8	0.75	1.85	74.5	0.2	1.3	0.19	16.6	70.3
11		Starter 9	0.75	1.85	74.5	0.9	1.2	0.17	89.4	66.7
Total			**13.12**			**3.3**				

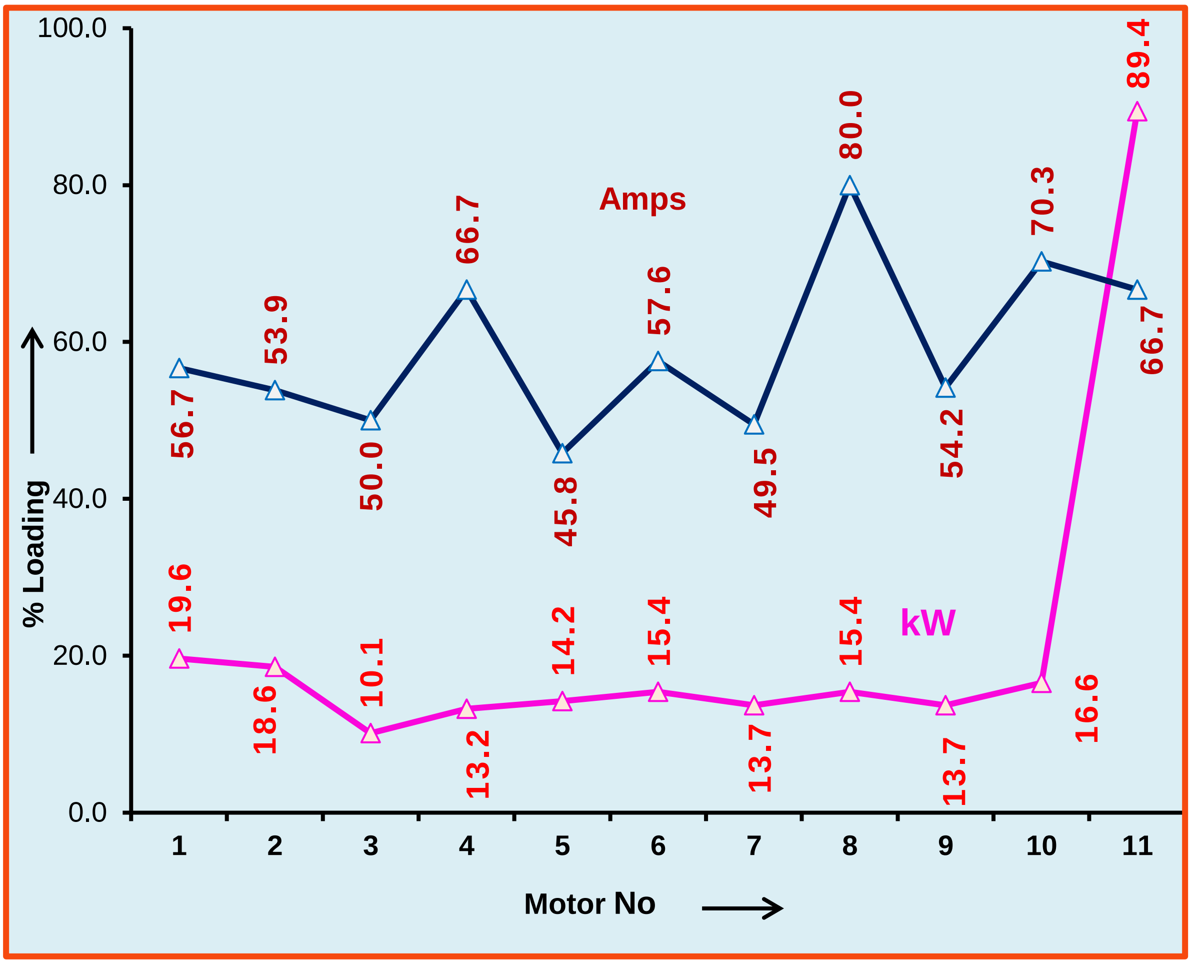


Fig 6.4: Motor Loading Details – Sorting Section | CAG

Observations

- The loading pattern - on kW of **10** out of the **11** motors that have been analysed in this section - is below **20%**, necessitating the need to pull it up considerably.
- The power factors recorded for all the motors is 0.35 or less, which is due to low kW loading experienced in the motors. Surprisingly, the PF measured for Motor No. 11 - where the kW loading is quite appreciable - is only 0.17. this needs to be looked into.
- 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 an energy efficiency perspective.

6.5 SUMMATION

- The consolidated details of kW recorded for all the motors of the **4** sections are tabulated below and shown through a pie chart.

Table 6.5: kW Loading of Motors – Section wise Details

No	Section	Power Drawl kW		No of Motors
		Recorded	%	
1	Withering	26.4	18.4	12
2	CTC	97.7	68.3	14
3	Drier	15.5	10.8	7
4	Sorting	3.5	2.5	11
	Total	**143.2**	**100**	**44**

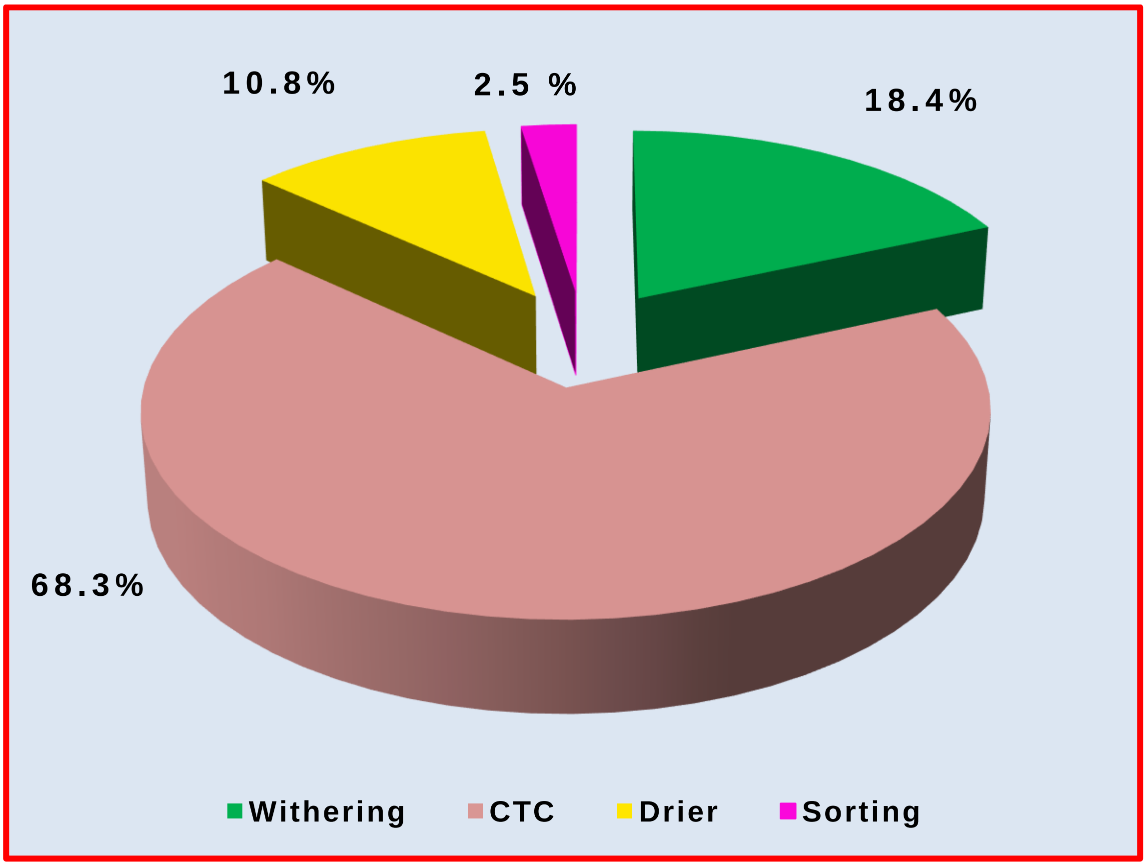


Fig 6.5: kW Loading - Section wise Details

- 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 electrical energy 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 Sorting section.
- The order (from highest to lowest power drawl) is as below:

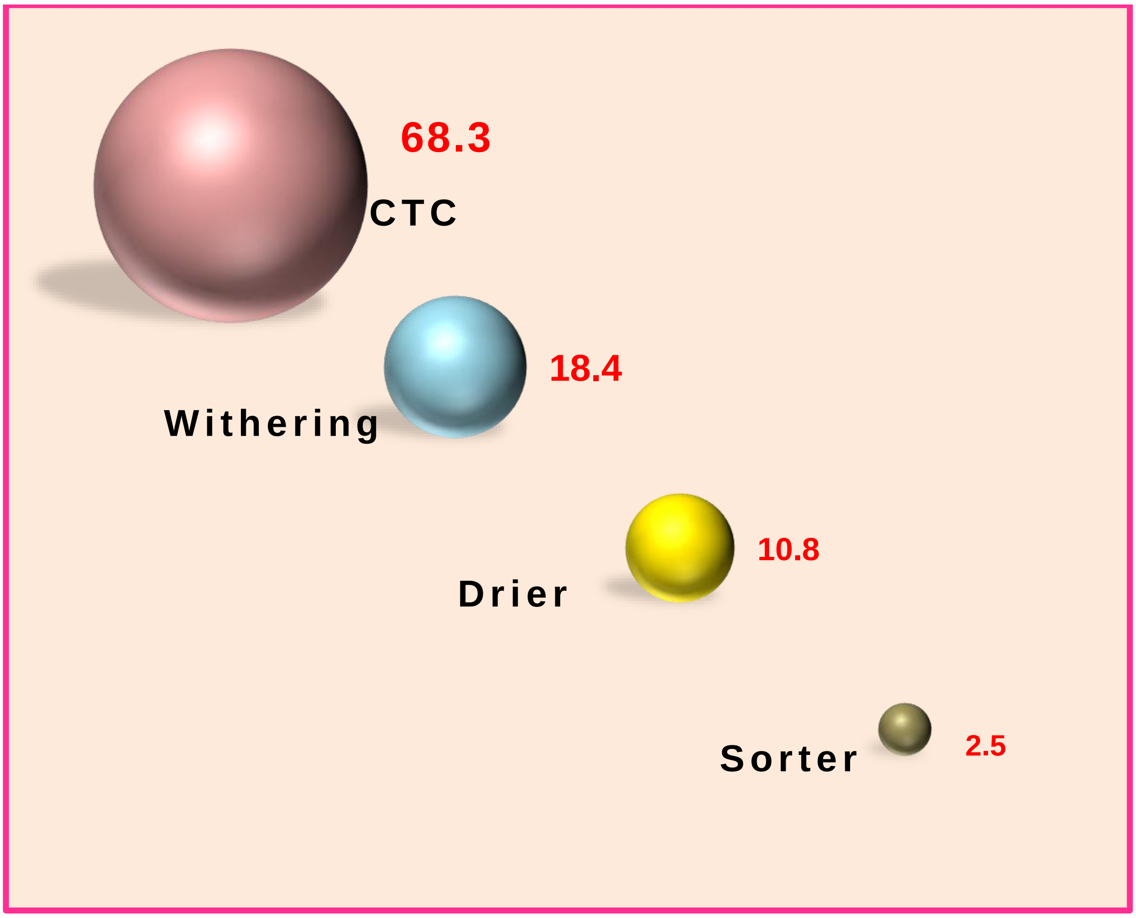


Fig 6.6: kW Loading : % Contribution : Section wise

- The power drawl / energy consumption in the CTC section is close to 70 % 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. Transformers : 2 Nos
  2. Withering Fans : 12 Nos
  3. CTC Section Motors : 10 Nos (Belt Slip Analysis)
  4. Hot Air Fans : 3 Nos
- The outcome of the performance study is discussed in this chapter.

7.1 TRANSFORMERS

- The factory has two transformers installed in its premises. The rating of the transformers is 200 kVA each. The manufacturer of one transformer is **M&B Switchgears Pvt Ltd, Indore** and that of the 2nd one is **Transformers & Electricals India, Kolkata.**
- The loading pattern was recorded for both transformers for a period of 2 hours during the factory operation time and this data was used as the basis for computation of their operating efficiency.
- The No Load Loss and Full Load Loss values for the transformers have been obtained from the standard manual, as test certificates could not be made available to the energy audit team. Moreover, the name plate details of the transformers were also not clear enough to note down the transformer losses.
- The name plate details of the transformers are:

Table 7.1: Technical Details - Transformers

No	Parameters	Unit	T R - 1	T R - 2
1	Make	-	M and B Switch Gears Pvt Ltd, Indore	Transformers & Electricals India, Kolkata
2	Rating	kVA	200	
3	H V	V / A	11 000 / 10.496	

4	L V	V / A	433 / 266.67	
5	No load loss	kW	0.59	
6	Full load loss	kW	4.05	
7	Yr of Mfg		2004	2007

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

Table 7.2: Operating Efficiency Prediction - Transformers

No	Parameter	Unit	TR 1	TR 2
1	Voltage	V	360	365
2	Current	Amps	141.6	116.8
3	Load	kVA	87.5	80.0
4	Power Factor	-	0.80	0.97
5	Load	kW	69.9	77.5
6	Total Loss	kW	1.37	1.24
7	Loading	%	43.8	40.0
8	Operating Efficiency	%	98.1	98.4

- The loading pattern of the two transformers - based on our logging of their electrical characteristics for 2 hours each - is provided hereunder :

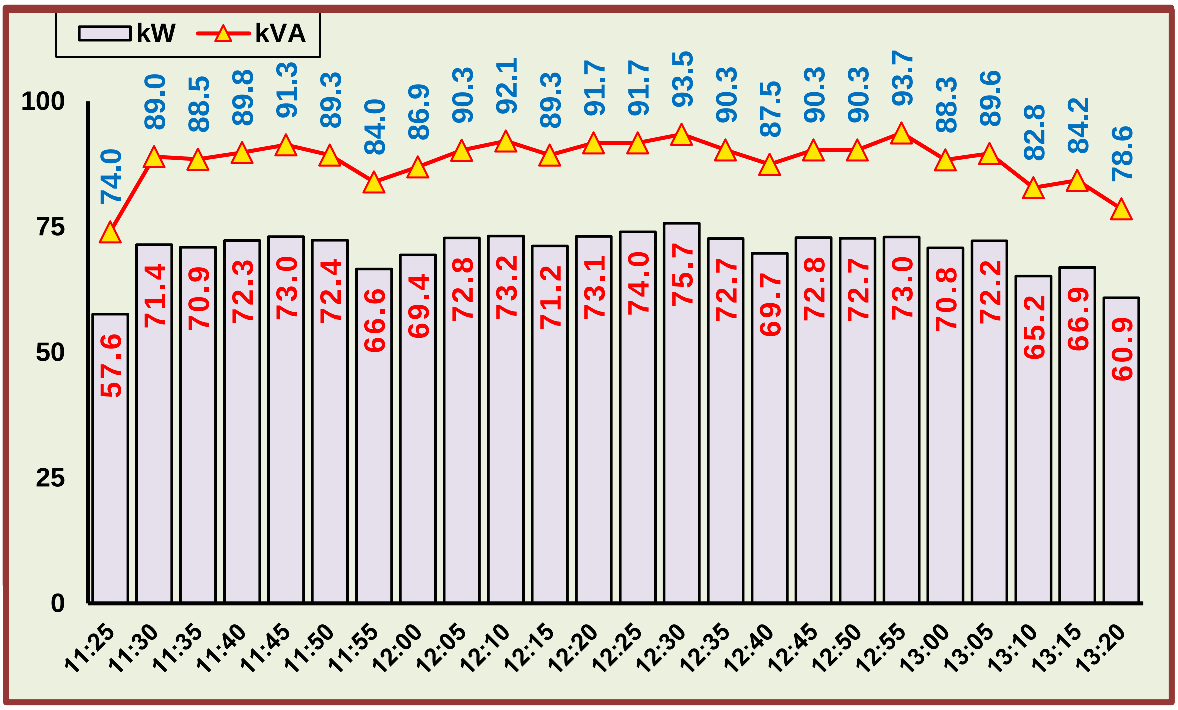


Fig 7.1: Active Power & Apparent Power Trend – Transformer 1 | CAG

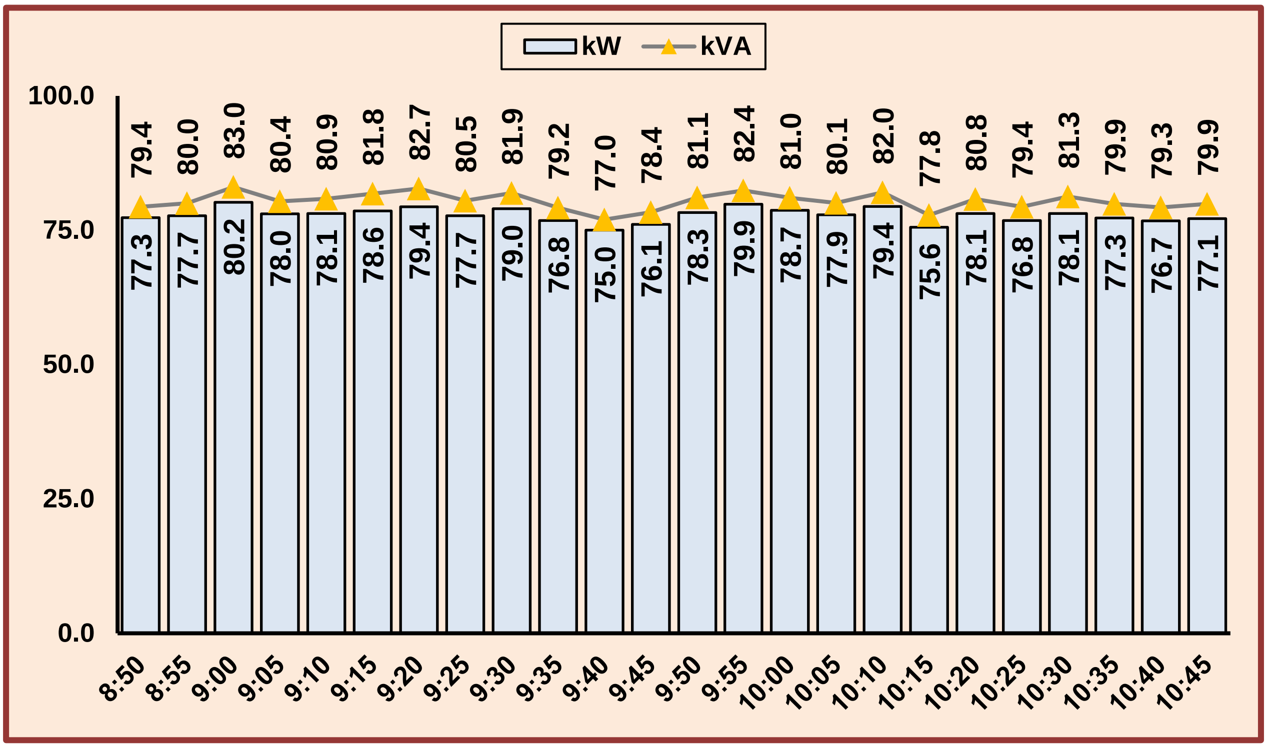


Fig 7.2: Active Power & Apparent Power Trend – Transformer 2 | CAG

- The loading of the two transformers is observed to be more or less similar. As evident from the plots above, the closeness between the kW and kVA profiles in Transformer 2 (i.e., the smaller width of the gap between the two trends) is a reflection of its high power factor which is close to unity.
- Whereas, the average PF recorded for Transformer 1 is 0.80 which could be improved further with the collective enhancement in the PF of inductive loads connected to it.
- A loading of around 43.8 % was observed in transformer 1 and a similar loading of 40 % was noted in transformer 2
- The total loss in transformer 1 is estimated as 1.37 kW, and that in transformer 2 is computed at 1.24 kW
- The efficiency of transformer 1 is computed at 98.1 % and that of transformer 2 at 98.4 %, which seems to be acceptable although not optimum enough.
- This is understandable taking into consideration that the maximum efficiency of the 2 transformers occurs at a loading of 38.2 % [based on the no load and load loss characteristic] and that actual loading of the transformers is quite close to the optimum loading; hence the attainment of reasonable higher operational efficiency level.

7.2 WITHERING FANS

7.2.1 Specific Air Flow Rate

- As indicated in Chapter 6, this section has 12 Withering Fans supplying air to 6 troughs for green leaf withering.
- At the time of study, only a couple of troughs were in operation as the withering process depends on the time of arrival and quantity of green leaves. There were times when majority of the troughs would be empty, waiting for the arrival of fresh load of tea leaves.
- However, we were able to capture the performance of all the withering fans - with load - over the span of 2 - 3 days spent, by instructing the leaf handling personnel to load the troughs in line with our requirement.
- Performance of the fans is evaluated in terms of their Specific Air Flow / Throughput.
- These details are presented in the following table.

Table 7.3: Withering Fan – Specific Air Flow Rates

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	3.8	22 583	5 943
2		1 B	3.70	3.3	17 250	5 280
3		2 A	3.70	3.1	19 323	6 233
4		2 B	3.70	3.2	19 949	6 170
5		3 A	2.20	1.8	21 979	12 211
6		3 B	2.20	1.8	21 644	12 025
7		4 A	2.20	1.6	23 123	14 157
8		4 B	2.20	1.7	23 931	14 077
9		5 A	2.20	1.2	24 210	19 630
10		5 B	2.20	1.1	21 840	19 270
11		6 A	2.20	1.9	18 939	10 146
12		6 B	2.20	1.8	21 672	11 821

- The cfm delivered by Fans 1,2,3 and 4 ranges from 17 000 to 22 000 which is just satisfactory considering that they have the same fan motor rating of **3.7 kW.**
- The remaining 8 fans deliver air in the bandwidth of 18 000 to 25 000 cfm which is quite an optimum performance for a fan rating of **2.2 kW**

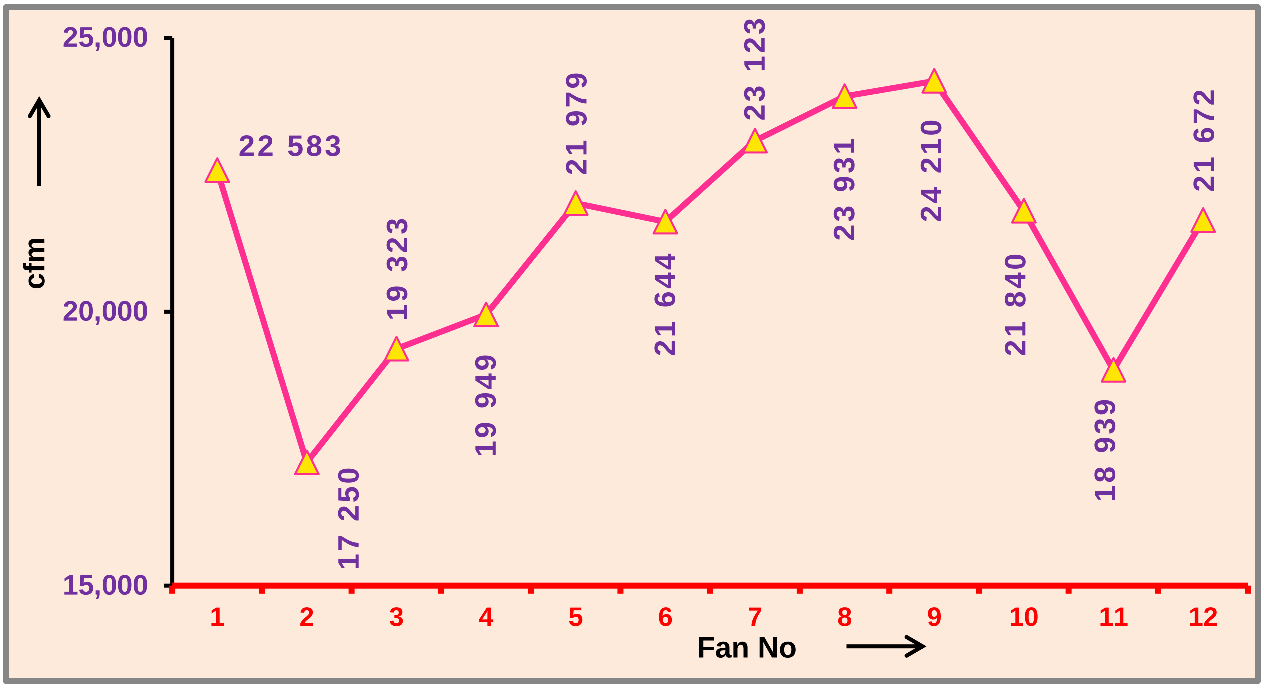


Fig 7.3: Air Flow Rate - Withering Trough Fans | CAG

- 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, namely, specific air flow (in terms of cfm / kW) has been computed and drawn below :

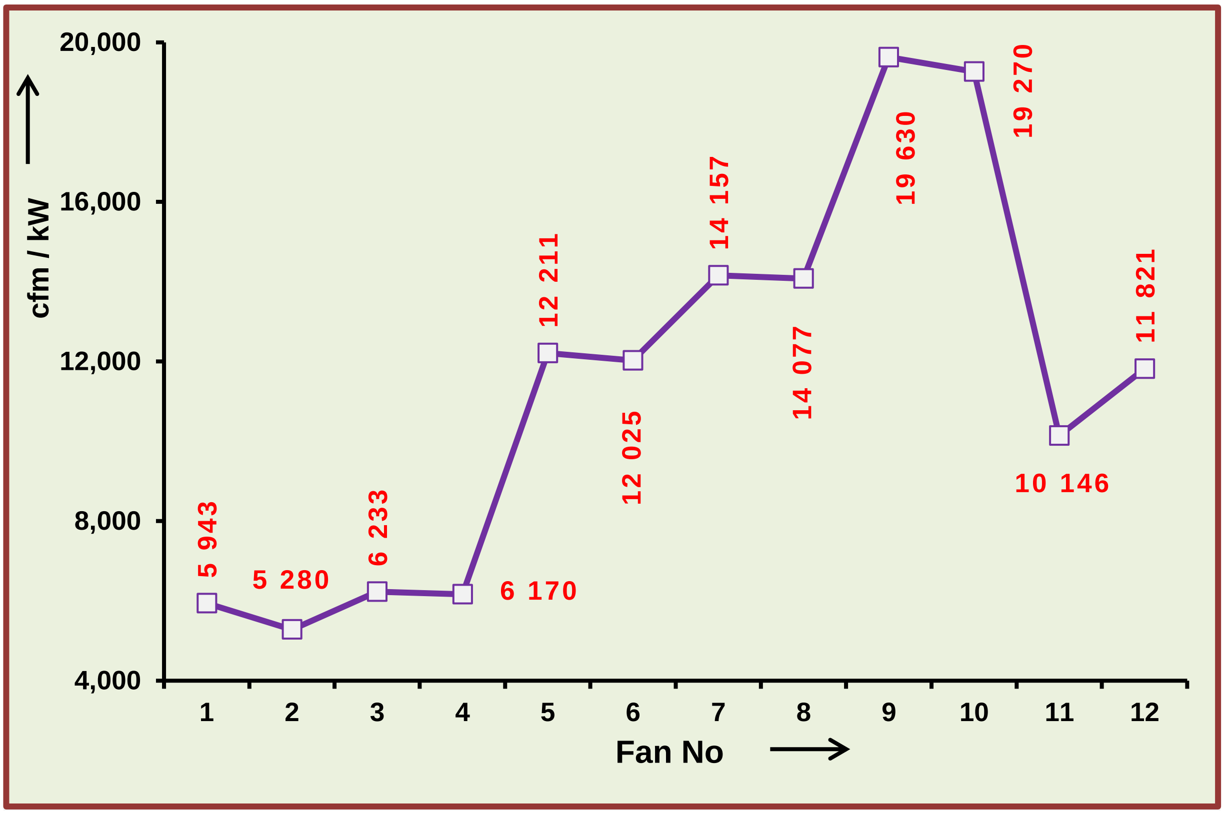


Fig 7.4: Specific Air Flow – Withering Trough Fans | CAG

- The further breakup is as below:

Table 7.4: Withering Fan – Sp Air Flow Rates :Break Up

No	Specific Air Flow Rate cfm / kW	No of Fans
1	5 000 – 8 000	4
2	8 000 – 12 000	2
3	> 12 000	6

- It appears that the performance of the 4 fans with rated capacity of 3.7 kW is a few notches below the mark.
- The specific air flow computed for the Fans 5 to 12 is significantly higher than the fans in troughs 1 & 2 ; about 2 - 3 times the KPI computed for the Fans 1 to 4
- To be more specific, the fans belonging to the Withering Troughs 3 to 5 (6 fans) have outperformed the remaining fans in terms of their specific output.
- It is therefore advised to preferentially load the troughs 3 to 5 more - in the descending order of computed specific throughput - considering that this would improve the quality of withering, hence the tea produced.
- Also, this mode of operation will simultaneously result in the withering section consuming lesser electrical energy, despite the fact that the time allocated for withering is more or less a fixed parameter irrespective of the choice of the withering trough / its output in terms of air delivered

7.3 CTC MOTORS - BELT SLIP ANALYSIS

- The factory processes withered leaves through two CTC lines. Each line hosts 5 major motors, of which one is for 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 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) No of grooves in the pulley, the corresponding No. of belts & belt ID.

4) Speed in rpm at the motor and machine end

- A tachometer was used to measure the speed of the driving and driven element
- The information collected / measured are presented in Table 7.5 for easy reference:

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	CTC Line 1	R V	120	360	1 494.5	492.8	498.2	1.1	5	4
2		Cut 1	170	340	1 482.1	699.8	741.1	5.6	4	4
3		Cut 2	170	360	1 450.4	669.4	684.9	2.3	4	3
4		Cut 3	170	360	1 471.5	675.1	694.9	2.8	4	4
5		Cut 4	170	360	1 467.7	667.7	693.1	3.7	4	4
6	CTC Line 2	R V	140	340	1 487.9	515.8	612.7	15.8	5	4
7		Cut 1	160	340	1 485.4	690.7	699.0	1.2	4	4
8		Cut 2	160	340	1 468.3	687.1	691.0	0.6	4	4
9		Cut 3	160	340	1 491.5	692.3	701.9	1.4	4	4
10		Cut 4	160	340	1 484.9	691.8	698.8	1.0	4	4

- The following are the notable observations made:

  1) Some of the grooves were missing a belt (i.e., in 3 out of the10 cases), of which one system, namely, that of the Rotor Vane of Line 2 exhibited considerable belt slippage. The remainder seemed to operate fine somehow, despite the off-design element. Nevertheless, it is advised to stay in line with the designed installation procedure.

  2) 3 systems - including the one described in point 1 - exhibiting sizeable slippage, have been chosen as target candidates for performance improvement in terms of enhancing the transmission efficiency, to optimize motor power drawl.

- Cogged V - belts score over standard V-belts by at least 2 percentage points by design. Considering the age of the V - belts installed, the anticipated level of improvement in efficiency is quite significant. This is discussed in detail in Chapter 10 of this report, with comprehensive cost to benefit analysis.

7.4 HOT AIR FANS OF DRIERS

- There are 3 Driers installed in the factory and each of them is provided with one Hot Air Fan (Induced Draft) - having a designed motor capacity of 11 kW - to facilitate the drying process.

Fig 7.5 : Hot Air Fans - Drier Section | CAG

- CNG is utilized as the source of thermal energy in these driers, which explains the absence of a distinct furnace section. Also, being a clean fuel, the entire volume of hot flue gas participates in the drying process, coming in contact with wet dhool in a counter-flow heat transfer process to evaporate the moisture in it.
- A performance study was conducted on the Hot Air Fans through :
  a) measurement of flow area and air velocity to compute the volume flow rate of air, and thereby flue gas handled by the fans, and,
  b) measurement of the power drawn by the Hot Air Fan motors to compute the specific flue gas flow / throughput of the individual fans.
- The details regarding fan performance are tabulated below:

Table 7.6 : Hot Air Fans - Specific Air Flow Rates

No	Motor ID		Fan Power kW		Flue Gas Flow Rate	Specific Gas Flow
			Rated	Measured	cfm	cfm / kW
1	Hot Air Fan	Drier 1	11	2.4	4 912	2 030
2		Drier 2	11	2.0	7 972	4 084
3		Drier 3	11	9.7	19 394	1 993

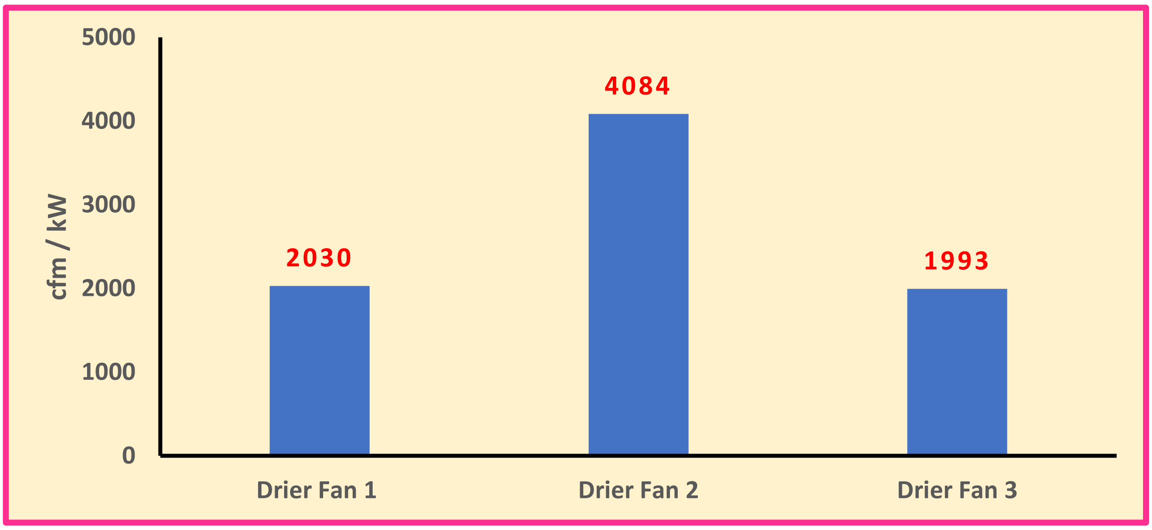


Fig 7.6 :Hot Air Fans - Drier Section: Sp Air Flow Rates : cfm / kw | CAG

- The HAFs of Drier 1 and Drier 2 are loaded very lowly on kW (19.2 % and 15.5 % respectively) . The air delivered by Drier Fan 1 is much lower than that by Drier Fan 2.
- The specific gas flow computed for the H A F of Drier 2 is twice that for Drier 1 & Drier 3 and the reason behind this needs to be understood as this seems a bit unreal.
- Fan of Drier 3 delivers quite an enormous air flow of 19 394 cfm and draws equally high power of 9.7 kW. The specific throughputs of Drier 1 and Drier 3 - Hot Air Fans match closely
- The flue gas volume flow rate computed for all the 3 HAFs differ significantly. This needs to be interpreted from a wholesome perspective, considering other related parameters such as wet & dry dhool MC, dhool feed rate, gas temperature at the drier inlet & outlet.
- In short, Drier fans demand a detailed technical performance evaluation study.
- The possible variables amongst the ones considered above - across the 3 driers - are air temperature at drier inlet and outlet, which needs further introspection in relation to the computed flue gas flow rates

8 PERFORMANCE STUDY ON THE DRIER

8.0 INTRODUCTION

- In this section, an attempt is made to establish the overall thermal efficiency of the Drier System (comprising 3 Dries), considering the annualised CNG consumption and Drier Mouth Tea (DMT) production values as inputs.
- The moisture content of Drier Mouth Tea and Wet Dhool is counted at 3 % and 70 % respectively and computations have been carried out.

8.1 PERFORMANCE ASSESSMENT

- The CNG consumption on a monthly basis for the period Sep '23 - Aug '24 is presented in Fig 8.1.
- The aggregated C N G Consumption has been estimated as **2 19 895 scm** for the period Sep '23 - Aug '24.

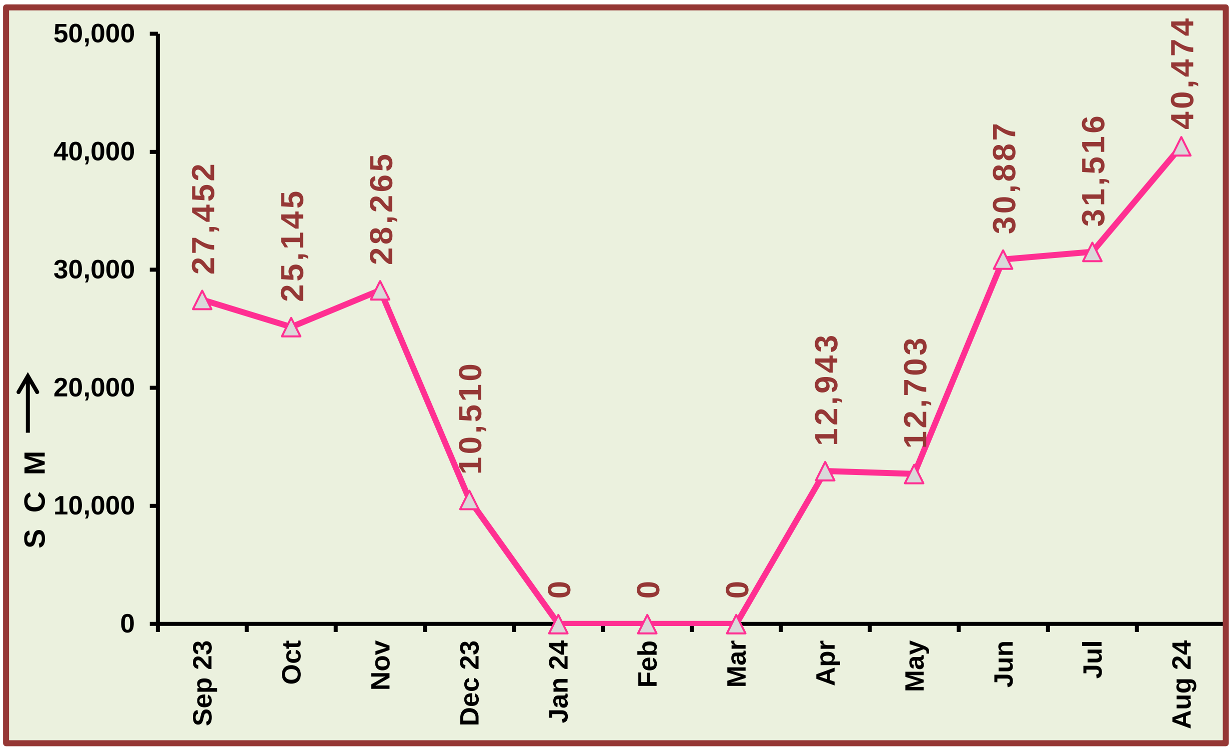


Fig 8.1: CNG Consumption – Month wise (Sep '23 – Aug '24) | CAG

- The quantity of Drier Mouth Tea produced during the same period is given in Fig 8.2.
- Drier Mouth Tea Output for the period Sep '23 to Aug '24 is **6 24 232 kg**

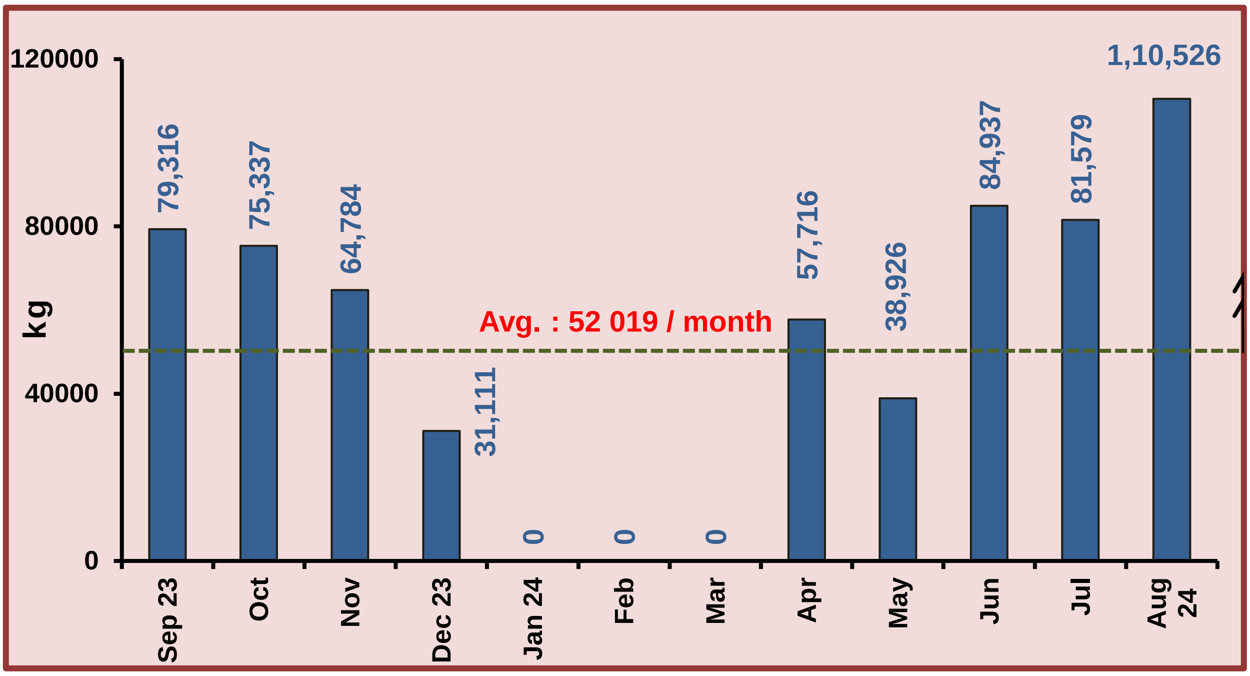


Fig 8.2: Made Tea Produced – Month wise (Sep '23 – Aug '24) | CAG

- The CNG consumption and DMT trends are majorly in sync with one another.
- Now, taking into consideration the annual DMT output, the theoretical amount of heat required to evaporate the moisture contained in Wet Dhool (**70%**) 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 Driers (Sep 23 - Aug 24)

No	Description	kg / y		
		Quantity	Moisture	Solids (Tea)
1	Wet Dhool	20 18 350	14 12 845	6 05 505
2	Drier Mouth Tea	6 24 232	18 727	6 05 505
		Moisture Evaporated	**13 94 118**	

- The annualised quantity of moisture evaporated collectively in the 3 Driers period has been computed at **13 94 118 kg**. The quantity of CNG utilized during this period is **2 19 895 SCM.**
- The thermal energy input utilized in drying is quantified as **2025.23 million kcal.**
- The theoretical amount of heat required to evaporate this amount of moisture would be **865.5 million kcal.** The above assessment reveals that the Drier system operates at a thermal efficiency of **42.7%** which is fairly the optimum value.

Table 8.2: Thermal Efficiency of the Drier : Overall

Moisture Removal kg	Theoretical Heat Reqt	Fuel Energy Input	Overall Thermal Efficiency %
	Million kcal		
13 94 118	**865.5**	**2 025.23**	**42.7**

- This higher overall efficiency is the result of the complete and clean burning characteristic of C N G. Being a gaseous fuel, it offers excellent operational control and the ability to completely automate the fuel handling aspect.
- The thermal losses that formed around **57%** of the heat input comprise the following:
  1) Heat Lost in the Exhaust / Flue Gas,
  2) Heat in the Drier Mouth Tea,
  3) Surface Radiation and Convection Heat Losses,
  4) Heat Loss from the Drier Surface
  5) Possible Hot Flue Gas Leakage to the atmosphere
  6) Other Minor / Immeasurable / Unaccounted losses

8.2 SUM - UP

- The overall thermal efficiency of the drier system at **42.7%** is quite good.
- Being a gaseous fuel fired system, the heat loss components that normally contribute to lower efficiency levels in solid fuel fired furnaces, such as:
  1) Heat loss due to incomplete combustion / CO formation,
  2) Moisture heat loss
  3) Heat lost in ash
  4) Heat transfer efficiency across the heat exchanger tubes (flue gas to air), etc.,

  are absent.
- The thermal energy [C N G] cost - in the period Sep 23 to Aug 24 - works out to **₹ 22.5 / kg** of Made Tea, which constitutes about **80%** of the total energy cost of tea production. This is in comparison to the electricity cost share of only **19 %**
- Despite being on the higher side, the favourable aspects of CNG, such as flexibility, convenience, efficiency, clean ambience, automation / man less operation, etc., supersede the financial implications.
- Nevertheless, efforts shall be made to optimise the C N G purchase cost as it is felt that presently it is not optimum.

9

COST CONSERVATION

PROPOSALS IDENTIFIED

C C M 1	MERGING THE LT SC WITH HT-1 SC COMBINED WITH MARGINAL REDUCTION OF THE CONTRACTED DEMAND ENABLING OPTIMSED USE OF CONTRACTED DEMAND AS WELL ENSURING REDUCED ENERGY COST OUTFLOW

Cost Savings ₹/ y	Investment ₹	Payback Period Months
84 754	Meagre	Immediate

OBSERVATIONS

- The factory has
  1. two HT Service Connections that cater to the Process Loads.
  2. one LT Service Connection that powers electrical loads of the Office and Colony.
- The details are as below:

Table 9.1: Service Connection Details

No	Service Connection	Cons No.	C D kW	Demand Charges ₹ / kW / m	Energy Charges ₹ / kWh	T & D Loss Levied kWh / m
1	H T - 1	203604267999214267	160.0	105	7.73	0
2	H T - 2	2036040886249079908	136.0	105	7.73	0
3	L T	203604264590407877	30.9	80	7.84	307.7

- Points to Note in respect of LTSC :
  a) has contracted a demand of 30.9 kW and pays a fixed demand charge at the rate of ₹ 80 / kW / month.
  b) Further, it is levied with a fixed energy loss of 307.7 kWh / m (T / F Loss Units)
  c) Energy charges are ₹ 7.84 / kWh which is slightly higher than that of HT.
- The loading pattern of **HT 1 SC obtained during the study is depicted in Fig 9.1**
- It is observed that the maximum load attained in the 2 - hr timeframe of logging the transformer is **75.7 kW** as against a Contracted Demand of **160 kW**.

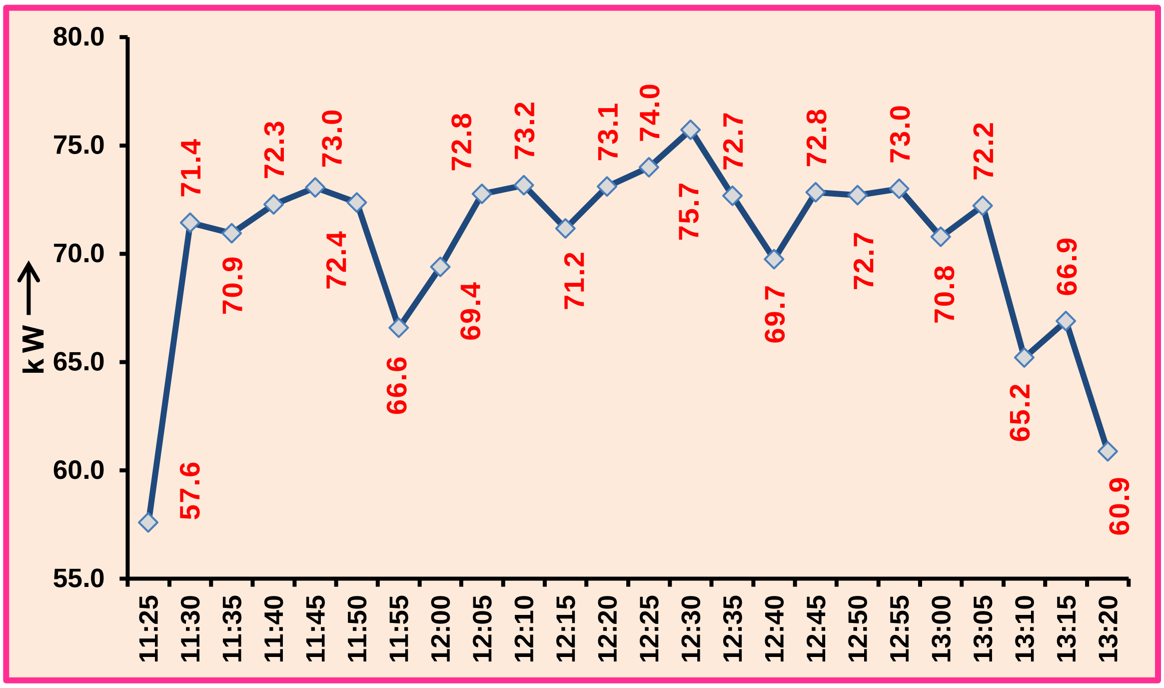


Fig 9.1: Loading Pattern Recorded : HT 1 SC: 2 h of Operating Period | CAG

- At the time of measurement, the **CTC - Line 2** and **Drier No. 3** were in operation. The Withering Troughs (3 Nos.),Motors of Sorting Section and Drier No. 2 were not in operation that are connected to this power network

COMMENTS

- It was realised that the loads of all the non - operational motors - hooked to HT1 SC - at the time of measurement would not exceed **40 kW**. Further, it shall be borne in mind that this argument revolves around the simultaneous operation of all the loads, which is a very unlikely occurrence.
- This is to infer that there is enough elbow room available to accommodate another **30.9 kW** of Connected Load from the LT service connection on to this HT1 SC.
- Upon addition of these 2 loads, namely, (1) operation load of non - operational motors and (2) Load of LTSC, the expected demand is not likely to go beyond 140 kW

Note :

> If there is a need to ascertain the numbers for a longer duration before implementation from a validation perspective, a detailed analysis of the loading pattern of the two HT service connections can be undertaken, and that of the LT during the appropriate season of the year when production is at its peak (Jun - Oct).

> This exercise shall also serve as proof to the FEDCO officials that the additional load from LT would not overload the HT1 SC, that will make it easier to get the required approvals.

RECOMMENDATIONS

- Hence, our recommendations are as below :
  1) migration of the LTSC electrical loads to the HT1 SC
  2) Reduction of Contacted Demand by 10 kW to start with

  due to the fact that this HT 1 SC is lowly loaded
- This manoeuvre would generate cost savings in 4 parts, as follows:
  1. Demand Charges on the LTSC
  2. Transformer Loss Units that are specific to the LTSC
  3. Incremental lesser unit energy charges on the LTSC.
  4. Reduction of the present C D
- Hence our recommendation

ECONOMICS

Part 1: Merger of LTSC with HTSC 1 resulting in payment of NIL C D Charges

> Contract Demand of the LTSC = 30.9 kW

> Demand Charges Levied = ₹ 80 / kW / month

> Savings in Demand Charges payable = (30.9 kW x ₹ 80 / kW / month **x 12 m / y)**

= ₹ 29 664 / y --- (a)

Part 2: Avoidance of payment of T F loss charges

> Transformer Losses currently levied = 307.72 kWh / m

> Energy Charges = (307.72 kWh / m x **12 m / y** x ₹ 7.84 / kWh**) = ₹ 28 950 / y**

Hence, anticipated avoidable cost savings = **₹ 28 950 / y --- (b)**

Part 3: Incremental Cost Savings in Energy Charges [kWh]

> LT Energy Charges: = ₹ 7.84 / kWh

> HT Energy Charges: = ₹ 7.73 / kWh

> Cost Savings = (7.84 – 7.73) = ₹ 0.11 / kWh

> Energy Consumption in LT SC = 10 257 kWh / month

Cost Savings = (10 257 kWh / m x **12 m / y** x ₹ 0.11 / kWh **)= ₹ 13 540 / y --- (c)**

Part 4 : Reduction of CD by 10 kW [from 160kW to 150 kW]

> **C D Reduction sought = 10 kW**

Cost Savings possible = (10 kW x 12 m / y x ₹ 105 / kW / m] = **₹ 12 600 / y--- (d)**

- Overall cost savings = [**29 664 +₹ 28 950** + **₹ 13540** + **₹ 12600**] = **₹ 84 754 / y**
- Investment = **Meagre**
- Payback Period = **Immediate**

C C M 2	RATIONALIZATION [REDUCTION] OF CONTRACT DEMAND OF THE HT SC 2 IN ORDER TO OPTIMISE THE DEMAND CHARGES PAYABLE TO TSECL

Cost Savings ₹/ y	Investment ₹	Payback Period Months
32 760	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 160 k W (HT SC 1) and 136 k W (HT SC 2) and ₹105 / kW / month is being paid as the fixed charges for availing this demand.
- It was noticed that the electricity bill of FEDCO has no mention of MD reached during the operation and as a result the MD reached is unknown to the user. That is , the MD reached is neither monitored nor displayed in the electricity bill.
- Hence, it was decided to record the loading pattern of the HT SC -2 that has a CD of 136 kW. The outcome is shown below in Fig 9.2

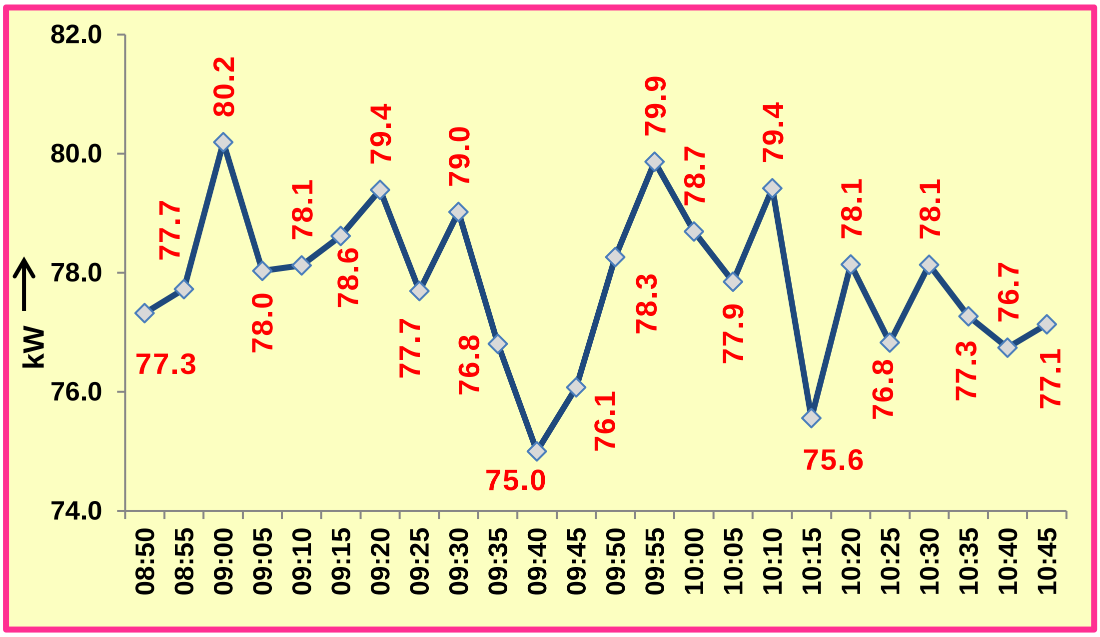


Fig 9.2: Loading Pattern Recorded : HT 2 SC: 2 h of Operating Period | CAG

COMMENTS

- The loading pattern established for a period of 2 hours on the HT 2 transformer shows a maximum recorded load of 80 kW,
- Further, adding the loads that were not operational at that point of time, the total maximum load on this transformer shall not exceed about 100 kW.
- This gives us a bandwidth of at least 36 kW that can be trimmed on the HT2 SC

RECOMMENDATION

- We therefore recommend trimming down the C D of the **HT2** service connection from **136 kW to 110 kW to start with.**

ECONOMICS

- Contracted Demand planned to clip = (136 – 110) = 26 kW
- Demand Charges levied for CD = ₹ 105 / kW / month
- Anticipated Savings in Demand Charges = (26 kW x ₹ 105 / kW / m x 12 m / y)
  = ₹ 32 760 / y
- Investment: = **Nil**
- Payback Period = **Immediate**

C C M 3	RATIONALIZATION [REDUCTION] OF CONTRACTED "BOOKED QUANTITY " OF THE C N G WITH TNGCL IN ORDER TO OPTIMISE THE CHARGES PAYABLE TOWARDS ITS USAGE

Cost Savings ₹/ y	Investment ₹	Payback Period Months
3 16 814	Nil	Immediate

OBSERVATIONS

- The factory uses **CNG** for drying wet fermented tea powder in the driers.
- The wet powder enters the drier at a moisture level of 70 % and gets dried to 3.5 % while leaving it. This dried material then goes for further processing and ultimately to packing section for dispatch.
- The factory has contracted a procurement of C N G at a **B**ooked **Q**uantity (**BQ**) of **439 SCM / day.**
- The Monthly Minimum Guaranteed C N G Off-take is **90%** of the BQ which implies that the factory is obligated to pay for **90 %** of the BQ corresponding to the month at the normal unit price whether it is consumed or not.
- If the consumption of CNG exceeds the monthly BQ, the factory pays for the excess quantity at the rate of **120 %** of the normal base price.
- The perusal of the C N G procurement invoices has shown that the factory has consumed C N G in excess of that BQ 13 times in the 2 year time frame and correspondingly paid higher charges.

ANALYSIS

- The graphs shown indicate the relationship between the Cost of CNG and average CNG consumption - on a monthly basis - over a 2 - year time frame, segregating "***normal to over consumption***" months & under consumption months from the analytical perspective.

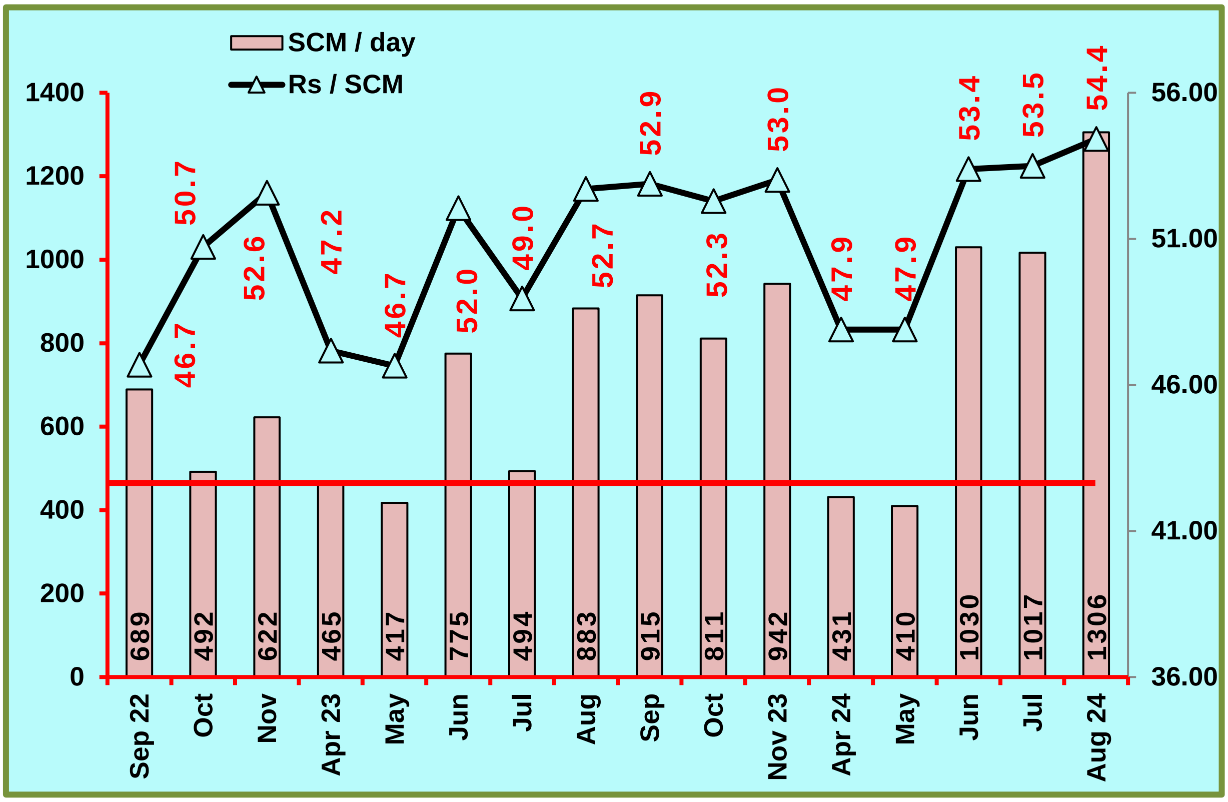


Fig 9.3 : Cost of CNG vs CNG : Over drawl : Sep '22 - Aug '24 [16 /24] | CAG

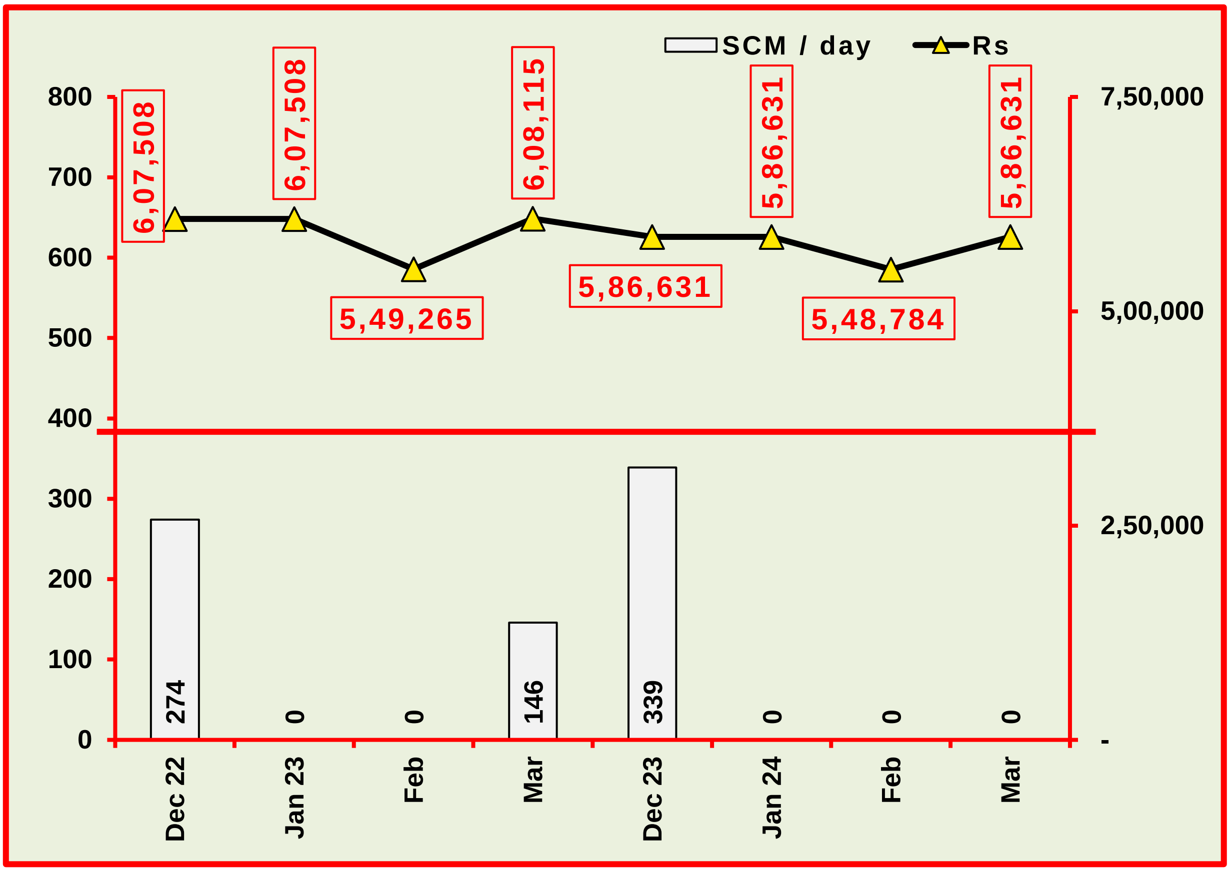


Fig 9.4: Cost of CNG vs CNG :Under drawl :Sep '22 - Aug '24 [8 /24] | CAG

- From the above, the average cost of C N G was deduced as
  1. **₹ 52 / SCM** during the 16 months of **"normal to over drawl"** period
  2. **₹ 200 / SCM** during the 8 months of **under drawl** period [this is about **4 times** the price compared to normal / over drawl]
- It was therefore decided to analyse the impact of reducing the BQ in phases - say in steps of 50 SCM / day - on the annual CNG cost, based on the monthly CNG consumption during the period Sep '23 - Aug '24, to understand the cost economics of underplaying the CNG booked quantity.

ECONOMICS

- The Table 9.2 demonstrates the economics related to the reduction in CNG Bill corresponding to tuning down the B Q by 50 SCM / day in each case. In this case example, we have gone down to a BQ of **289 SCM / day**.

Table 9.2: Impact Analysis – CNG BQ over Annual CNG Cost

No	Month	Average Cons.	Monthly CNG Bill ₹			
			Base Case BQ – 439	Case 1 BQ – 389	Case 2 BQ – 339	Case 3 BQ – 289
		SCM / day				
1	Sep 23	915	14 51 640	14 66 009	14 80 378	14 94 747
2	Oct	811	13 14 841	13 29 689	13 44 536	13 59 384
3	Nov	942	14 98 367	15 12 736	15 27 105	15 41 474
4	Dec 23	339	5 86 631	5 19 816	5 03 393	5 18 240
5	Jan 24	0	5 86 631	5 19 816	4 53 002	3 86 187
6	Feb	0	5 48 784	4 86 280	4 23 776	3 61 272
7	Mar	0	5 86 631	5 19 816	4 53 002	3 86 187
8	Apr	431	6 19 913	6 32 108	6 46 476	6 60 845
9	May	410	6 08 418	6 14 587	6 29 435	6 44 283
10	Jun	1 030	16 49 066	16 63 435	16 77 804	16 92 172
11	Jul	1 017	16 86 163	17 01 049	17 15 936	17 30 822
12	Aug 24	1 306	22 02 582	22 17 469	22 32 355	22 47 241
Total		**2 19 895**	**1 33 39 668**	**1 31 82 810**	**1 30 87 197**	**1 30 22 854**
		Reduction in Bill (₹)		**1 56 858**	**252 471**	**316 814**

RECOMMENDATION

- Hence, it is recommended to act upon the suggestion made by us.
- The extent to which the Booked Quantity can be practically tweaked down needs to be discussed and agreed upon with the concerned officials of TNGCL, the agency that supplies CNG to the factory.
- In other words, the CNG bill reduction can happen to an extent of **₹ 3 16 814 / y** if planned and used optimally.

C C M 4

RECASTING OF THE PRESENT OFF - GRID SPV POWER PLANT INTO ON - GRID SYSTEM TO CATER TO THE ENERGY NEEDS OF THE ADMINISTRATION OFFICE AND TO EXPORT THE SURPLUS ENERGY TO GRID THEREBY REAP THE FINANCIAL BENEFITS PERENNIALLY

Cost Savings ₹ / y	Investment ₹	Payback Period Months
12 700	20 000	19

Observation

∉ A Stand - alone (off-grid) Solar Power Plant of 1.3 kWe capacity has been installed on the roof of the Admin Building of the factory.

∉ This Solar PP comprises 4 Nos of SPV Modules of power rating 330 W each, a Solar PCU (Inverter) and two Lead Acid Batteries (12 V, 150 Ah rating each).

∉ The scheme of operation envisaged at the time of installation is as below:

⇒ The Solar PP powers the Inverter and the stored power in the Inverter meets the electrical load of the admin building at the time of power outage. The Inverter gets charged by Solar only when it runs out of charge.

- It was understood that the state of Tripura is a power surplus one and the power outages are generally a rare occurrence that too typically nonexistent in Tea Factories.
- On account of this rare power outage occurrence, the utility of the inverter becomes quite limited / questionable technically meaning that it hardly derives energy from Solar to charge self.
- Since the necessity to charge the Inverter is literally limited (say a maximum of 20 hours in a month) as far as this factory is concerned, the Solar PP delivers energy only to the extent of that needed by the inverter.
- In other words, we estimate the Solar PP to operate only for 20 hours vis - a - vis 350 hours in a month limiting the energy generation to a meagre 6 % of its installed capacity

Comment

- The presently envisaged system of **Off - Grid** type will be useful in places that are prone to frequent power outages which is not the scenario at Durgabari.

- Hence, the present scheme of operation is a misfit as far as this factory is concerned as the energy generation potential of SPP is not utilized to the fullest capacity
- To make use of the SPP system to generate energy to its full capacity, an On - grid inverter is suggested in lieu of Solar PCU and this will enable the export of excess energy generated to the grid.
- The SPP will generate electricity to its fullest capacity if we resort to this.

Recommendation

- It is recommended that a **1 kW On - Grid Inverter** - instead of solar PCU - shall be installed along with a **Net Meter**.
- The existing Battery Bank can be directly connected to the grid with a separate backup inverter system. This would enable the system to utilize both solar energy during the day and provide backup power during outages.
- This SPP will generate an average of 4.5 kWh / day (135 kWh / m) of electricity. This can be utilized to power the electrical gadgets like fan, light, computers in the admin block during day time.
- Further, the surplus power generated by SPP can be exported to the grid and that can offer a revenue stream
- Also, the existing battery backup system can provide power supply during power outages.
- Thus, this proposed scheme is technically a very robust one addressing all the power related issues and meeting the power demand at the user end always.

Economics

- Energy Generation possible from Roof top SPP @ 4.5 kWh / day = 135 kWh / m
- Energy Charges levied by FEDCO for LTSC = ₹ 7.84 / kWh
- Hence, revenue outflow avoided = [135 kWh / m x 12 m / y x ₹ 7.84 / kWh]
  = ₹ 12 700 / y
- Cost of 1 kW On - Grid Inverter = ₹ 20 000
- Simple payback period = 19 months

C C M 5	INSTALLATION AND COMMISSIONING OF 200 kWp ON - GRID SOLAR P V ROOF TOP POWER PLANT ADOPTING "RESCO" MODEL

Cost Savings ₹ / y	Investment ₹	Payback Period Months
9 75 000	Nil	Immediate

OBSERVATION

- Tea manufacturing is an energy intensive process using both electrical and thermal energy in substantial quantities.
- As far as this factory is concerned, the Specific Electrical Energy Consumption is **0.530 kWh / kg Made Tea** for the year '23 - '24 which is reasonable enough.
- Currently 100 % of its electricity requirement is sourced from the DISCOM through two H T Service Connections.
- The electricity consumption is **3.2 lakh kWh / y (= 900 kWh / day)** and the energy bill is close to **₹ 30 lakhs per annum.**
- The average cost of electricity is estimated as ₹ 9.31 / kWh [inclusive of all charges] and ₹ 7.74 / kWh [only energy alone]
- During power outage period, DG sets are used which is a rare occurrence

COMMENT

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

RECOMMENDATION

- Installation of a 200 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 10 000 sq ft and the factory has this area.

MODALITIES

- There are many Govt approved Renewable Energy Service Company (RESCOs) in the market for funding and execution of Solar PP. These RESCOs will invest on the SPV power plant and integrate with the grid after obtaining necessary approval from the concerned DISCOM. The maintenance and monitoring of the SPV power plant will be done by the RESCO at its own cost.
- The factory will have to pay a pre - agreed charge (can be ₹ 4 or 5 / kWh) to these RESCOs for a pre agreed period for the energy supplied from the SPV power plant.
- The contact period shall be 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.

Economics

- Capacity of On - Grid SPV Power Plant suggested = 200 kWe
- Energy generation possible = 900 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 900 kWh / d x 350 d / y) = ₹ 9 45 000 / y
- Investment required in RESCO model = Insignificant
- Simple payback period = Immediate

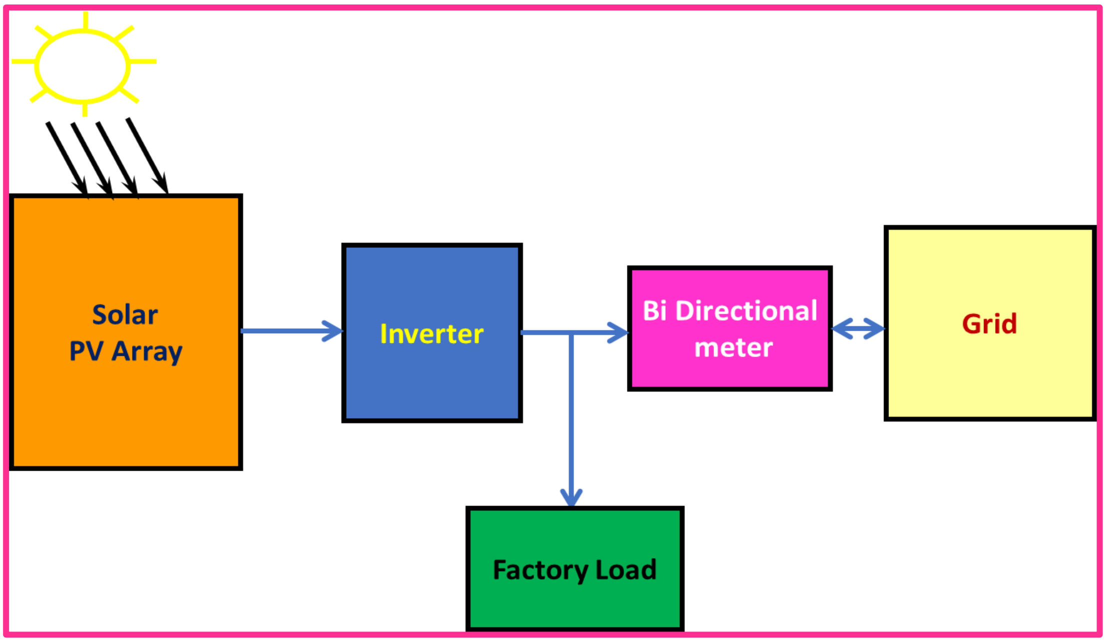


Fig 9.5: Typical Solar ON -GRID System Configuration | CAG

Fig 9.6 : Satellite image of Durgabari Tea Factory & Garden | CAG

10

ENERGY - CUM - COST CONSERVATION PROPOSALS IDENTIFIED

E C M 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
32 540	Meagre	Immediate

OBSERVATIONS

- Electrical measurements have been recorded on both the transformers for a period of 2 hours each on 2 different days that too during the peak hour processing operation.
- It was recorded that the incomer voltage was in the range of 360 in Transformer

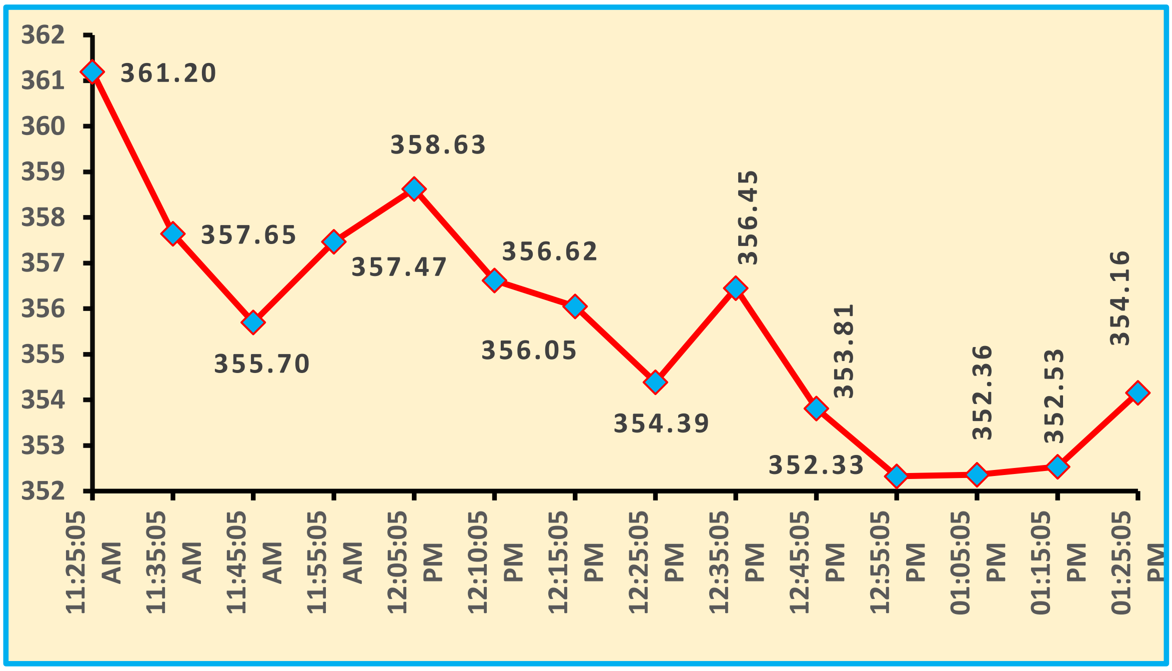


Fig 10.1: Voltage Variation Recorded: T R 1: Unacceptable | CAG

- This is to infer that the Motors connected to TR 1 are fed with an input voltage of only 360 for their operation. This is quite unacceptable.
- This low voltage input to the rotating machineries - for their operation - is certain to affect not only the performance of the motors but also can result in reduced life time.

- In addition, this low voltage operation can also - at times - pose safety problems by way of motor getting overheated.

ILL EFFECTS OF LOW VOLTAGE OPERATION

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 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 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 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

<table>
<tr><td>Voltage Variation</td><td rowspan="3">%</td><td>- 5</td><td>- 10</td><td>- 15</td></tr>
<tr><td>Efficiency</td><td>- 1</td><td>- 2</td><td>- 4</td></tr>
<tr><td>Energy Consumption</td><td>+ 2</td><td>+ 4</td><td>+ 5</td></tr>
</table>

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.
- 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 TR 1 as it is noticed that TR 2 delivers the required voltage for utilities operation [Fig 10.2]

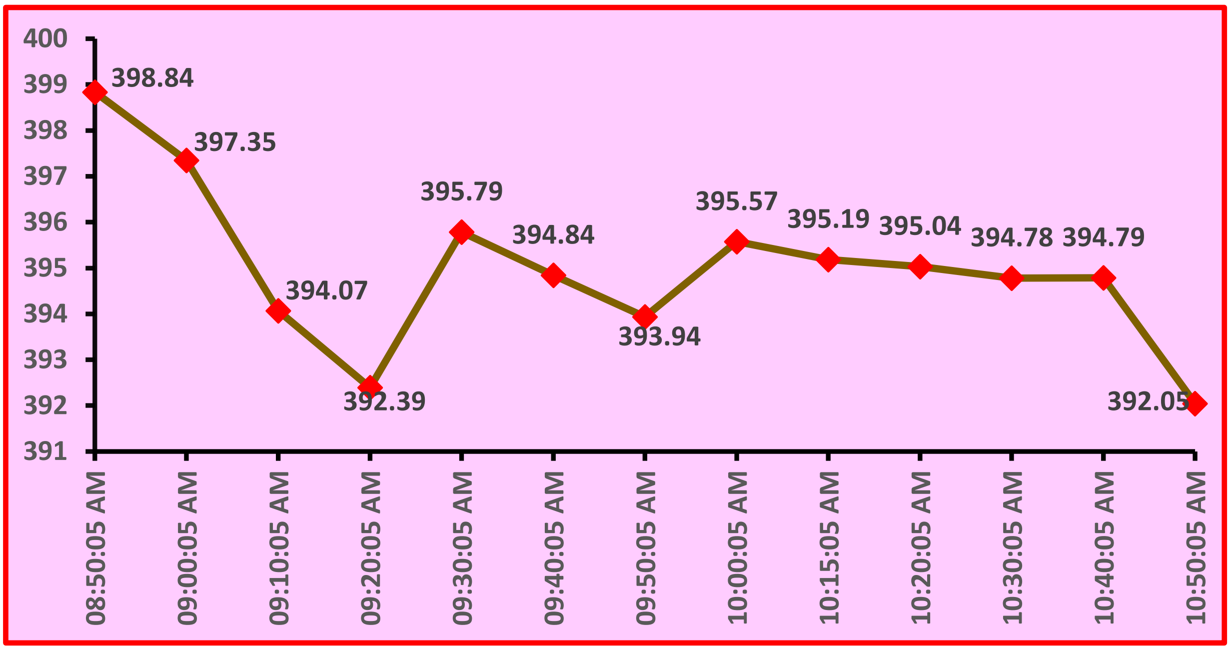


Fig 10.2 : Voltage Variation Recorded : Transformer 2 :Acceptable | CAG

ECONOMICS

- Energy Consumption in Transformer 1 = 1 05 300 kWh / y
- Energy loss anticipated due to operation of motors at 360 V [10 % less] = 4 %
  = [1 05 300 kWh / y x 4%] = 4 210 kWh / y
- Energy Savings possible by setting correct the Voltage = 4210 kWh / y
- Cost Savings = (4 210 kWh / y x ₹ 7.73 / kWh) = ₹ 32 540 / y
- Investment = Meagre
- This is in addition to all other benefits that shall accrue due to maintenance of appropriate voltage

ECM 2

PRIORITIZE THE WITHERING OF FRESH GREEN LEAVES IN TROUGHS THAT HAVE HIGH SPECIFIC AIR FLOW RATE FOR ENHANCED ENERGY EFFICIENCY AND IMPROVED WITHERING OUALITY

Cost Savings ₹ / y	Investment ₹	Payback Period Months
7730	Nil	Immediate

OBSERVATIONS

- The following measurements were recorded for the Withering Fans of all the6 troughs:
  - Air velocity at multiple points in the flow path
  - Fan diameter
  - Power drawn by the fan motors
- These parameters enabled the assessment of Specific Air Flow Rate / Throughput in **cfm / kW** for all the 12 fans and are tabulated in Table 10.2 .

Table 10.2: Withering Fans:12 Nos: Specific Air Flow Rates Recorded

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	3.8	22 583	5 943
2		1 B		3.3	17 250	5 280
3		2 A		3.1	19 323	6 233
4		2 B		3.2	19 949	6 170
5		3 A	2.20	1.8	21 979	12 211
6		3 B		1.8	21 644	12 025
7		4 A		1.6	23 123	14 157
8		4 B		1.7	23 931	14 077
9		5 A		1.2	24 210	19 630
10	Withering Trough Fan Motor	5 B	2.20	1.1	21 840	19 270
11		6 A		1.9	18 939	10 146
12		6 B		1.8	21 672	11 821

- This Key Performance Indicator hinted that the operation of the Withering Fans shall be prioritized in descending order of Air Volume / Output delivered by the fans (cfm / kW) rather than loading all 6 troughs in a cyclic manner, which is the standard operation approach followed in all factories presently.
- This shall not only result in energy saving but also in improved withering quality.

RECOMMENDATION

- It is therefore recommended the operation of the troughs in the manner illustrated in the table below be followed:

Table 10.3: Recommended Operational Philosophy – Trough Loading

No	Trough No	Power Drawn kW	Specific Flow Rate cfm / kW	Preferred Operational Philosophy %
1	1	7.1	7 019	10
2	2	6.3	6 234	10
3	3	3.6	12 118	20
4	4	3.3	14 259	20
5	5	2.3	20 022	20
6	6	3.7	10 976	20

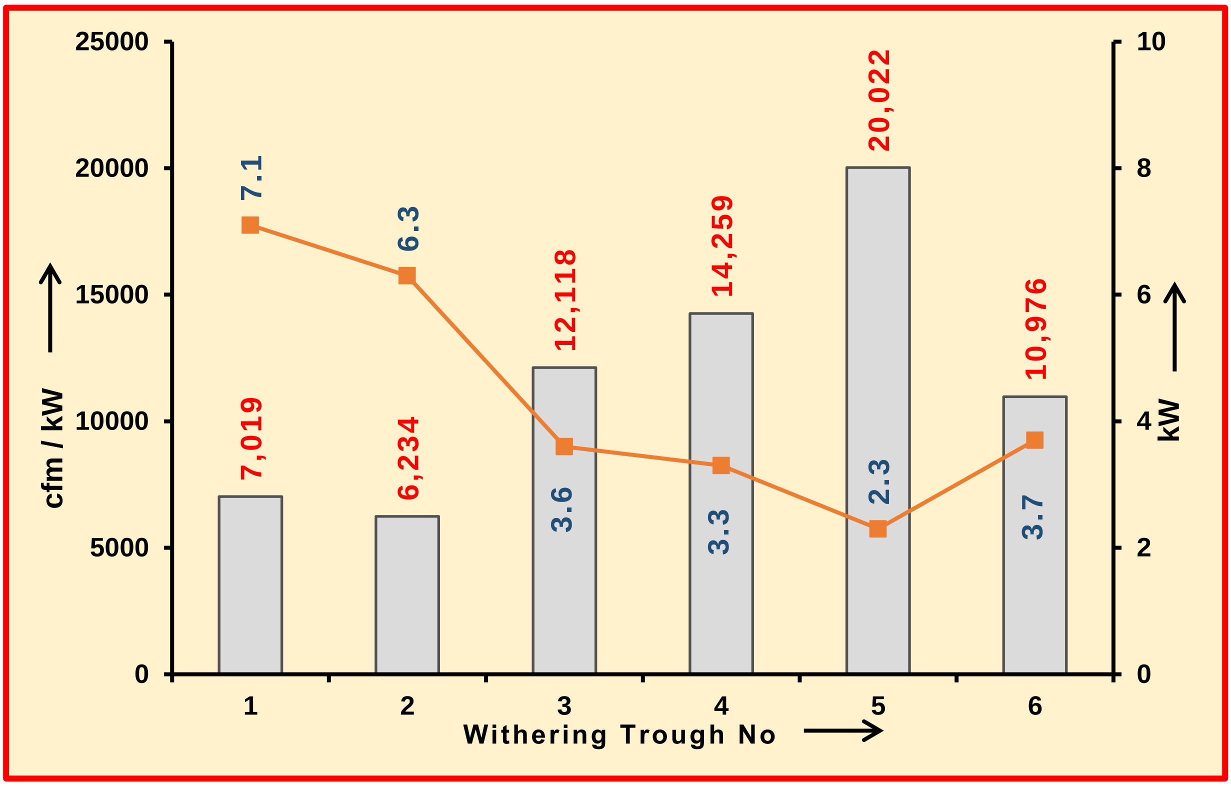


Fig 10.3: Specific Air Flow and Power Drawn : Withering Troughs | CAG

- This preferred approach of allocation of green leaves - from the viewpoint of loading the Withering Troughs in a scientific, energy conscious manner - is designed taking into consideration the worst - case scenario of accommodating the fresh load of green leaves in the peak season, taking note of the trough capacity of **2 000 kg**.
- To elaborate on the above point, it is noticed that the maximum quantity of green leaves processed in the 2 year timeframe of Sep 22 – Aug 24 is in the month of Aug 24 at about **5 00 000 kg**.
- Considering the average load of 16 130 kg / d for Aug 24, 20% of the daily load works out to 3 226 kg which can be handled by each of the troughs 3 - 6 @ 2 loads per day, as the withering time is only 6 - 8 hours.
- This estimate is considered as the basis for our proposition - to ensure that it works at all times - while it would be possible to accommodate 100 % of the daily load in just the troughs 3 - 6, without loading troughs 1 and 2 in the leaner seasons.

ECONOMICS

Table 10.4: Operational Philosophy – Present vs Proposed

Trough No	Power Drawn kW	Specific Flow Rate cfm / kW	Operational Philosophy %	
			Present	Preferred
1	7.1	7 019	16.67	10
2	6.3	6 234	16.67	10
3	3.6	12 118	16.67	20
4	3.3	14 259	16.67	20
5	2.3	20 022	16.67	20
6	3.7	10 976	16.67	20

- Power Drawl by Troughs : Present = 4.38 kW
- Weighted average power Drawl : Anticipated = 3.88 kW
  (through proposed mode of operation)
- Power savings = (4.38 – 3.88) = 0.5 kW
- Energy savings = (0.5 kW x 8 h / d x 250 d / y) = 1 000 kWh / y
- Cost savings = (1 000 kWh / y x ₹ 7.73 / kWh) = **₹ 7 730 / y**
- **Investment = Nil**
- **Simple Payback Period = Immediate**

E C M 3

DOWNSIZE AND USAGE OF ENERGY EFFICIENT MOTORS FOR REDUCED ENERGY CONSUMPTION AND IMPROVED PF IN THE ROTOR VANES OF LINES 1 & 2 OF C T C SECTION FOR THE SAKE OF COST SAVINGS

Cost Savings. ₹ / y	Investment ₹	Payback Period Months
23 190	60 000	31

OBSERVATIONS

- The factory has incorporated 2 lines of CTC Cut employing a total of 10 Nos of higher rated motors for carrying out the intended activities. This comprises 4 CTC cut motors and a Rotor Vane per line. 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 power measurements carried out on 2 Rotor Vane Motors were found to be quite low on kW front.. [Table 10.5]

Table 10.5 : Loading Pattern of Rotor Vane Motors

No	Motor ID	Rated			Measured			% Loading	
		kW	Amps	η %	kW	Amps	PF	kW	Amps
1	CTC Line 1 : R V	15	28	89	4.7	11.1	0.67	28.1	39.8
2	CTC Line 2 : R V	15	28	89	4.7	13.5	0.48	27.9	48.1

COMMENTS

- **It is quite clear from the above table that the Rotor Vane Motors are poorly loaded.**
- **As a consequential effect of this, the PF recorded were also lower(0.67 & 0.48)**
- **It appears that these motors are 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 these 2 identified poorly loaded Rotor Vane Motors - at an appropriate time - with Energy Efficient (**IE3**) 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 with standard motors. The suggested motor rating can be 10 hp (7.5 kW)
- The P F recorded for the motors are also observed to be quite low and this is bound to improve as well through appropriate sizing.

ECONOMICS

- Total Power Drawn presently by these 2 Rotor Vane motors = 9.4 kW
- Anticipated Power Consumption – post replacement: = 8.4 kW
- Power Savings = 1.0 kW
- Energy Savings = (1 kW x 3 000 h / y) = 3 000 kWh / y
- Cost Savings = (3 000 kWh / y x ₹ 7.73 / kWh). = ₹ 23 190 / y
- Investment towards installation of 2 E E Motors of 10 hp rating = ₹ 60 000
- Simple payback Period = 31 months

ECM 4

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

Cost Savings ₹ / y	Investment ₹	Payback Period Months
23 190	75 000	39

OBSERVATIONS

- There are 3 Driers installed in the Drier section and each of them is provided with one Hot Air Fan (Forced Draft w r t Tea Drier) - having a designed motor capacity of 11 kW - to facilitate the drying process.
- This HAF sucks the burnt flue gas through the burner and sends it to the Drier at a temperature of 120ºC.
- The HAFs of Drier 1 and Drier 2 are loaded very lowly on kW (19.2 % and 15.5 % respectively) as can be seen in the Table below:

Table 10.6: Motor Loading Details – Drier Section

No	Motor ID		Rated			Measured			% Loading	
			kW	Amps	η %	kW	Amps	PF	kW	Amps
1	Hot Air Fan Motor	Drier 1	11	21.3	87.5	2.4	10.2	0.34	**19.2**	47.8
2		Drier 2	11	21.3	87.5	2.0	7.2	0.41	**15.5**	33.9
3		Drier 3	11	21.3	90.0	9.7	14.6	0.96	**79.6**	68.4

- Surprisingly, Motor of Drier 3 seems to have been loaded properly

COMMENTS

- The lower kW loading indicates to the possible oversizing of the motors of the HAFs.
- 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 motors.
- Fitment of Variable Frequency Drive [V F D] to the Motor of HAF 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 motors of HAF 1 & 2 as their kW loading is abysmally low needing corrections at once.
- The input to the VFD drive shall be the moist flue gas temperature leaving the drier outlet chimney. Higher this temperature, slower shall be the motor speed and vice - versa
- VFD fitted fans are expected to provide considerable energy savings and that has been our experience.
- A 10 % savings in energy can be anticipated through this scheme of VFD installation.

ECONOMICS

- Power Savings Anticipated = 1 kW
- Energy Savings = (1 kW x 3 000 h / y) = 3 000 kWh / y
- Cost Savings = (3 000 kWh / y x ₹ 7.73 / kWh). = ₹ 23 190 / y
- Investment [Fitment of VFD :2 Nos] = ₹ 75 000
- Simple payback Period = 39 months

E C M

5

DOWNSIZE AND USAGE OF ENERGY EFFICIENT MOTORS FOR REDUCED ENERGY CONSUMPTION AND IMPROVED PF IN THE SORTING/ GRADING / PACKING SECTION FOR THE SAKE OF COST SAVINGS

Cost Savings ₹ / y	Investment ₹	Payback Period Months
11 595	45 000	47

OBSERVATIONS

- Sorting is a crucial step in tea processing that separates bulk tea (dryer mouth tea) into different grades based on size. This process is achieved using machinery equipped with various sized meshes.
- Sorting section incorporates several small motors to power the vibration of the meshes and the movement of conveyors towards tea grading.
- The factory employs majorly the following motors :
  1) Fiber Extractor Machine (3 hp). : 1 No
  2) C M Ho Complete Sorter Machine : 9 Nos (6 Nos x 2 hp , 3 Nos x 1 hp)
- As expected, the kW loading is quite low in all these motors (mostly < **50 %**)
- As a consequence to this poor loading, the PF recorded was also lower (**< 0.60**)
- The electrical parameters measured in respect of the lesser capacity motors of this section are tabulated below :

Table 10.7: Loading Pattern of Motors: Sorting / Grading / Packing

No	Motor ID		Rated			Measured			% Loading	
			kW	Amps	η %	kW	Amps	PF	kW	Amps
1	Tray Carrying Motor	Dryer 3	2.20	4.00	82.8	0.2	0.8	0.58	8.8	19.2
2		Dryer 2	3.70	8.00	85.0	0.4	1.0	0.71	10.0	12.5
3		Dryer 1	2.20	4.00	82.8	0.6	2.6	0.34	21.3	64.2
4	Conveyor Motor	Dryer Mouth	0.75	1.85	74.5	0.2	1.1	0.27	16.6	59.5
5		M2- Weighing Scale	0.37	1.00	72.7	0.1	0.6	0.32	19.6	56.7

No	Motor ID		Rated			Measured			% Loading	
			kW	Amps	η %	kW	Amps	PF	kW	Amps
6	Sorter Machine 1	Vibro Motor	1.50	3.28	76.0	0.4	1.8	0.35	**18.6**	53.9
7	Sorter Machine 3	Starter 1	1.50	3.80	76.0	0.2	1.9	0.19	**10.1**	50.0
8		Starter 2	0.75	1.85	74.5	0.1	1.2	0.23	**13.2**	66.7
9		Starter 3	1.50	3.20	80.0	0.3	1.5	0.31	**14.2**	45.8
10		Starter 4	1.50	3.30	77.0	0.3	1.9	0.23	**15.4**	57.6
11		Starter 5	1.50	3.30	77.0	0.3	1.6	0.27	**13.7**	49.5
12		Starter 6	1.50	2.25	77.0	0.3	1.8	0.28	**15.4**	80.0
13		Starter 7	1.50	3.20	77.0	0.3	1.7	0.27	**13.7**	54.2
14		Starter 8	0.75	1.85	74.5	0.2	1.3	0.19	**16.6**	70.3

- It can be observed from the above Table that almost all the motors are invariably lowly loaded.

COMMENTS

- All the 14 motors listed above have a kW loading less than 20 % that indicate the oversizing of the motors for the duty intended.
- Since these motors operate for not less than 3000 h / y, suggestion is made to bring down the operating energy consumption by replacing these motors with Energy Efficient ones at an appropriate time.

RECOMMENDATION

- It is recommended to replace these identified 14 lowly loaded motors - at an appropriate time and in a phased manner - with Energy Efficient 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 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.

ECONOMICS

- The following motors are earmarked for downsizing with EE Motors at an opportune time.

Table 10.8 : Power Drawn : Present vs Anticipated : Motors of Sorter Section

No	Motor ID		Rtd. η %	kW		Load %	Max. η at this Load	Proposed Rated		Anticipated	
				Rated	Meas.	kW	%	kW	η %	kW drawn	Load %
1	Tray Carrying Motor	Dryer 3	82.8	2.20	0.23	8.8	69.6	**0.5**	77.3	**0.21**	43.9
2		Dryer 2	85.0	3.70	0.43	10.0	72.3	**1.0**	80.8	**0.40**	56.9
3		Dryer 1	82.8	2.20	0.57	21.3	71.2	**1.0**	82.5	**0.50**	53.8
4	Conveyor Motor	Dryer Mouth	74.5	0.75	0.17	16.6	61.1	**0.37**	71.1	**0.15**	50.9
5		M2 - Weighing Scale Output	72.7	0.37	0.10	19.6	58.9	**0.37**	64.8	**0.10**	49.1
6	Sorter Machine 1	Vibro Motor	76.0	1.50	0.37	18.6	63.8	**0.5**	77.3	**0.32**	63.3
7	Sorter Machine 3	Starter 1	76.0	1.50	0.20	10.1	63.1	**0.37**	71.1	**0.18**	63.1
8		Starter 2	74.5	0.75	0.13	13.2	61.1	**0.37**	71.1	**0.11**	40.7
9		Starter 3	80.0	1.50	0.27	14.2	67.2	**0.37**	77.3	**0.24**	48.4
10		Starter 4	77.0	1.50	0.30	15.4	64.7	**0.37**	77.3	**0.26**	52.4
11		Starter 5	77.0	1.50	0.27	13.7	64.7	**0.37**	77.3	**0.22**	46.6
12		Starter 6	77.0	1.50	0.30	15.4	64.7	**0.37**	77.3	**0.25**	52.4
13		Starter 7	77.0	1.50	0.27	13.7	64.7	**0.37**	77.3	**0.22**	46.6
14		Starter 8	74.5	0.75	0.17	16.6	61.1	**0.37**	71.1	**0.14**	50.9
Total				**21.22**	**3.8**	**17.8**		**6.70**		**3.3**	

- Power Savings Anticipated = (3.8 – 3.3) = 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 [Replacement by EE motors : 14 Nos] = ₹ 45 000
- Simple payback Period = 47 months

ECM 6

REPLACEMENT OF CONVENTIONAL V-BELTS DRIVES WITH COGGED V-BELTS DRIVES IN THE IDENTIFIED MOTORS TO REDUCE BELT SLIP THEREBY ENHANCING THE TRANSMISSION EFIICIENCY

Cost Savings. ₹ / y	Investment ₹	Payback Period Months
27 828	36 000	16

PREAMBLE

- The speed of the Blower / Fan will be normally 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, namely, pulley - belt drive.
- The commonly used one is the pulley driven mechanism and based on the speed requirement at the driven location, the diameter of the pulley is sized.
- The power delivered at the driven utility 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 [encountering a very meagre 'Slip']
- Apart from this, many - a - times, non-effective number of belts are used for transmission (ex 2 belts instead of 3 and so on) that adds to the transmission inefficiency

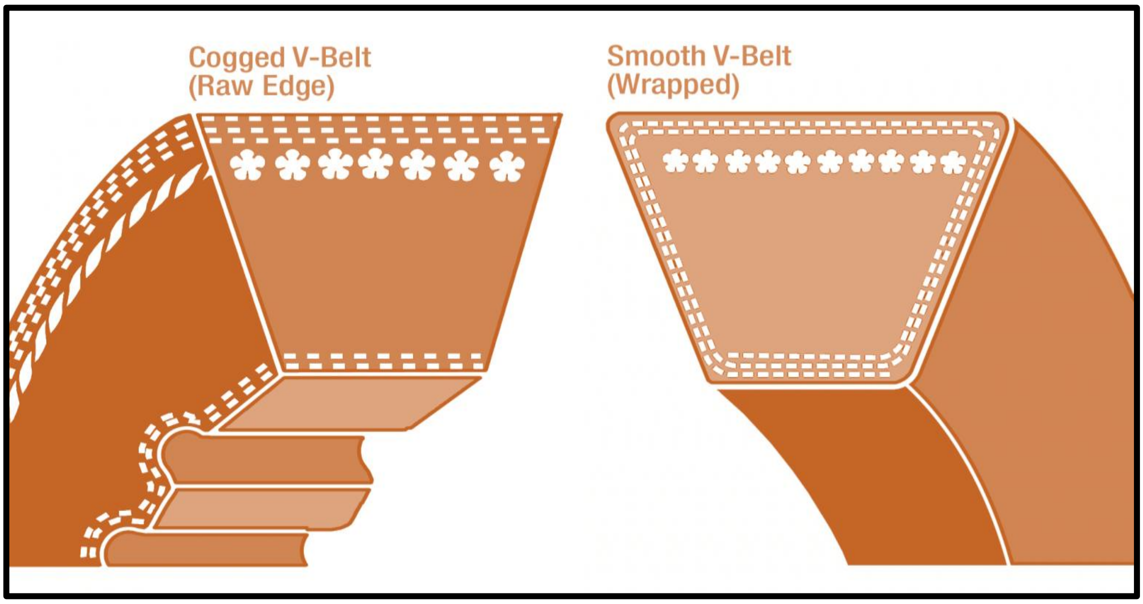


Fig 10.3 : Cogged V belt and Taper lock pulley, Baart Group | CAG

OBSERVATIONS

- The factory has installed two CTC lines for the processing of withered leaves. Each line consists of 5 major motors, of which one is that of the Rotor Vane and the rest are for the 4 cuts (Cut 1 to 4) of the CTC machine.
- V - belts have been utilized for the transmission of power from the drive motor to the driven element.
- A comprehensive assessment was carried out to estimate the slippage level at which the belts operate, which involved measurement of the following parameters:
    1) Pulley diameter of the motor and the driven 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 in Table 10.9 :

Table 10.9 : Belt Slippage – An Analysis

No	Name		Pulley Dia mm		Measured rpm		Ideal M / c Speed rpm	% Slip	Belt - Pulley Specs	
			Motor	M / c	Motor	M / c			Groove	Belt
1	CTC - Line 1	R V	120	360	1494.5	492.8	498.2	1.1	5	4
2		Cut 1	170	340	1482.1	699.8	741.1	5.6	4	4
3		Cut 2	170	360	1450.4	669.4	684.9	2.3	4	3
4		Cut 3	170	360	1471.5	675.1	694.9	2.8	4	4
5		Cut 4	170	360	1467.7	667.7	693.1	3.7	4	4
6	CTC - Line 2	R V	140	340	1487.9	515.8	612.7	15.8	5	4
7		Cut 1	160	340	1485.4	690.7	699.0	1.2	4	4
8		Cut 2	160	340	1468.3	687.1	691.0	0.6	4	4
9		Cut 3	160	340	1491.5	692.3	701.9	1.4	4	4
10		Cut 4	160	340	1484.9	691.8	698.8	1.0	4	4

COMMENTS

- Three candidates, namely, **Cut 1 & Cut 4 of C T C Line 1 and Rotor Vane of C T C Line 2** - are chosen for replacement with cogged V - belts, from the viewpoint of reducing slippage and enhancing power transmission efficiency.
- Further, it was also noticed that the Pulley and Belts were found to be in a worn - out condition.

RECOMMENDATION

- We therefore recommend the replacement of the V - belts in Cut 1 & 4 of line 1 (**L1-CTC-1 & L1-CTC-4**), and on the Rotor Vane of Line 2 (**L2-RV**), with cogged V-belts in a phased manner starting with **L2 - RV,** in the descending order of slippage.
- Based on the success of this concept could be propagated to the remaining motors as well.

ECONOMICS

- The economics of the scheme proposed in shown in Table 10.10 below

Table 10.10: Power Drawn: Present vs Anticipated

No	Motor ID		Power Drawn kW	Measured Slip %	Energy Saving %	Anticipated Power Drawl kW
1	CTC - Line 2	R V	4.7	15.8	10	4.2
2	CTC - Line 1	Cut 1	7.6	5.6	5	7.3
3		Cut 4	10.2	3.7	3	9.9
Total			**22.5**			**21.3**

- Power Drawn - at present - by the identified 3 motors = 22.5 kW
- Anticipated Power Consumption - post retrofit = 21.3 kW
- Anticipated power savings with the incorporation of Cogged V-belts = 1.2 kW
- Energy Savings = (1.2 kW x 3 000 h / y) = 3 600 kWh / y
- Cost Savings = (3600 kWh / y x ₹ 7.73 / kWh). = ₹ 27 828 / y
- Investment = ₹ 36 000
- Simple payback Period = 16 months

E C M 7

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
9 895	24 500	30

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 these fans have extremely low heat dissipation and therefore lesser associated power loss.

OBSERVATIONS & COMMENTS

- There are **11** Nos of Ceiling Fans installed in the factory and in the office premises.
- The Locations are:

  a) Administration Office : **8** b) Factory i / c Room : **2** c) Machine Shop :**1**
- 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 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 required for the existing fans
- Further, the motors of the fans - that are rewound more than twice - can also be targeted for replacement with the EE fans

RECOMMENDATION

- The existing old inefficient ceiling fans can be replaced with BLDC - EE fans
- These fans have a power consumption of only 30 W
- Hence, considerable energy savings can be anticipated

- However, these fans are costlier by 2 - 3 times of the conventional ones and hence economic viability has to be ensured prior to implementation

Economics

- No of Ceiling Fans targeted for replacement = 11
- Cumulative Running Hour of all Fans :

  = (8 fans x 10 h / d + 3 fans x 16 h /day) x 250 d / y = 32 000 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 32 000 h /y). = **1 280 kWh / y**
- Cost Savings = (1 280 kWh / y x ₹ 7.73 / kWh). = **₹ 9 895 / y**
- Investment towards procurement of 11 BLDC Fans = ₹ 30 000
- Salvage Value of 11 old Fans = ₹ 5 500
- Net Investment = **₹ 24 500**
- Simple Payback Period = **30 months**

11 CONSOLIDATION AND CONCLUSION

11.1 SUMMARY OF IDENTIFIED ENERGY CONSERVATION PROPOSALS

- The Detailed Energy Assessment engagement at D T F has revealed decent scope available for improvement in the electrical energy usage pattern in the factory
- Also, identified are a couple of Cost Conservation Proposals which are capable of bringing in cost savings with NIL investment.
- At present, **5 Cost Conservation Proposals and 7 Energy Conservation Proposals** have been identified, the details of which are presented below:

Table 11.1: Cost Conservation Proposals: 5 Nos

<table>
<tr><th>No</th><th>Cost Conservation Proposals</th><th>Cost Savings ₹ / y</th><th>Investment ₹</th><th>Payback Period Months</th></tr>
<tr><td>1</td><td>Merging the LTSC With H T-1 S C combined with marginal reduction of the Contracted Demand enabling the optimized use of Contracted Demand as well ensuring reduced energy cost outflow</td><td>84 754</td><td>Meagre</td><td rowspan="3">Immediate</td></tr>
<tr><td>2</td><td>Rationalization [Reduction] of Contract Demand of the HT SC 2 in order to optimize the Demand Charges payable to TSECL</td><td>32 760</td><td rowspan="2">Nil</td></tr>
<tr><td>3</td><td>Rationalization [Reduction] of Contracted “Booked Quantity “ of the C N G with TNGCL in order to optimize the charges payable towards its usage</td><td>3 16 814</td></tr>
<tr><td>4</td><td>Recasting of the present Off - Grid SPV Power Plant into On - Grid System to cater to the energy needs of the Administration Office and to export the surplus energy to grid thereby reap the financial benefits perennially</td><td>12 700</td><td>20 000</td><td>19</td></tr>
</table>

No	Cost Conservation Proposals	Cost Savings ₹ / y	Investment ₹	Payback Period Months
5	Installation and commissioning of **200 kw$_p$** On - Grid Solar P V Roof Top Power Plant through "**RESCO**" model of Govt of India	**9 75 000**	Meagre	Immediate
	Total	**14 22 028**	**20 000**	**< 1**

Table 11.2: Energy Conservation Proposals: 7 Nos

No	Energy Conservation Proposals	Cost Savings ₹ / y	Invest ₹	Payback Period Months
1	Operation of electric motors at the rated /near rated Voltage in order to effect optimum energy drawl and to contain the damage to motors	**32 540**	**Meagre**	**Immediate**
2	Prioritize the Withering of Fresh Green Leaves in Troughs with high specific air flow rate for enhanced energy efficiency and improved withering quality	**7 730**	**Nil**	
3	Downsize and Usage of Energy Efficient Motors and simultaneous improvement of PF in the Rotor Vanes of Lines 1 & 2 of C T C Section for the sake of Energy / Cost savings	**23 190**	**60000**	
4	Fitment of VFD to the Hot Air Forced Draft Fan - whose operation shall be controlled by the exiting moist flue gas temperature - enabling Energy Efficient operation of the fan resulting in cost savings	**23 190**	**75000**	**39**
5	Downsize and Usage of Energy Efficient Motors and simultaneous improvement of PF in the Sorting / Grading / Packing Sections for the sake of Energy / Cost savings	**11 595**	**45 000**	**47**
6	Replacement of conventional V - Belts drives with Cogged V – Belts drives in the identified motors to reduce Belt Slip thereby enhancing the transmission efficiency	**27 828**	**36 000**	**16**

No	Energy Conservation Proposals	Cost Savings ₹ / y	Invest ₹	Payback Period Months
7	Replacement of existing 75 W conventional Ceiling Fans with Energy Efficient 30 W "**BLDC**" Fans for the sake of Energy / Cost Conservation	**9 895**	**24 500**	**30**
Total		**1 35 968**	**240 500**	**21**

- The overall anticipated savings is computed at **₹ 15 57 996 / y** at an investment of **₹ 2 61 500** which shall be paid back in about **2** months.
- On the energy front, the overall savings is expected to be **179 590 kWh / y** on Electrical, equivalent to a cost saving of **₹ 1 35 968 / y**.
- Of the **12** schemes identified in total, **3** schemes do not call for any investment, while **3** proposals ask only for a meager outlay. All these **6 Nil / Meager Investment Schemes** can be implemented with ease.
- It is emphasized here that top priority shall be accorded to the implementation of 200 kWe Solar PP under RESCO Model with the support of both State and Central Govt Support as the returns are tremendous

11.2 AUDIT OBSERVATIONS

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

Table 11.3: Audit Observations

No	Section	Remarks
1	Thermal System	• The operational efficiency of the drier system is quite adequate at about.**42.7%**. • The thermal insulation tidiness of the drier system seems to be good, devoid of any significant heat loss sections. • Strategic rationalization / reduction of the contracted booked quantity of CNG will result in optimizing the charges paid without any investment.

No	Section	Remarks
2	Withering Section	• The loading of the motors seemed quite reasonable. • Only 2 out of the 12 withering fan motors were loaded below 50 % on kW, which indicates good overall performance requiring just a few tweaks. • On the specific air flow front, the fans fitted with 2.2 kW motors perform better than the 3.3 kW motor fitted fans. Hence, the usage of the fans of 2.2 kW rating shall be encouraged. • *Prioritizing the trough operation in line with the specific air flow rate / throughput is advised in the ENCON section*. [ECM 2]
3	CTC Section	• 6 out of the 14 motors of this CTC section are loaded below 50% on kW, which needs to be improved through phased downsizing with EE motors, as and when feasible : Especially, the Rotor Vane Motors (Cut 1 & 2) are recommended for downsizing. [ECM 3] • Belt slip analysis was performed on the 10 major CTC motors (R V + 4 Cuts in each line), revealing decent scope for improvement in 3 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 significantly as well as uniformly low - less than 25% - but for one which is the Hot Air Fan Motor of Drier 3. • This issue needs to be addressed.
5	Sorting Section	• The loading pattern - on kW of 10 out of the 11 motors that have been analysed in this section - is below 20%, necessitating the need to enhance it considerably. • Downsizing with appropriately sized E E motors is recommended

No	Section	Remarks
6	Thermography – Electrical Safety & Motors	• Altogether, abnormality existed in 20 out of the 29 locations surveyed for possible discrepancy in electrical connection tightness; quite a large fraction, and shall be taken care of. • The surface temperature profiles of the motors revealed the absence of any abnormality

11.3 SUM - UP

- As a whole, majority of the motors, especially the ones operating in the Drier and Sorting section, were loaded sub-optimally, indicating considerable potential to fine-tune in terms of enhancing the loading performance, through suitably downsizing them with Energy Efficient motors
- Once the underperforming motors are set right, the benchmarking performance is bound to improve
- The economics of carrying out remedial actions is quite reasonable as can be seen in the section of " **Cost Conservation Proposals** ", and " **Energy Conservation Proposals** ", with an overall payback of only 2 Months, which is very encouraging
- In short, the performance of the utilities can be ranked at 8 in a scale of 10 and effort shall be made to upgrade it further.

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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.
- The Thermal Images captured on electrical systems include Panel Boards, Cables, Bus Bars, Transformer Yard, CTC section Motors, Drier section Motors etc.
- In all, thermo mapping was carried out at 49 locations.
- Based on the observations made, it is suggested that the electrical system issues are sorted out at the earliest as they impact the safety.
- The thermal images captured are expected to bring in safety in electrical systems operations, savings in terms of energy (though not significant) as well as reduction in maintenance cost to the management.
- The **I**nternational **E**lectrical **T**esting **A**ssociation [**I E T A**] provides the guidelines [shown below in the Table] that aid in determining the degree of severity of a problem typically associated with electrical power transmission.
- The severity is categorized into 4 categories, namely,

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

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

Table 12.1 : Severity Prediction : Remedial Action Suggested

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

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

Table 12.2 : Severity Assessment : Recommended Action

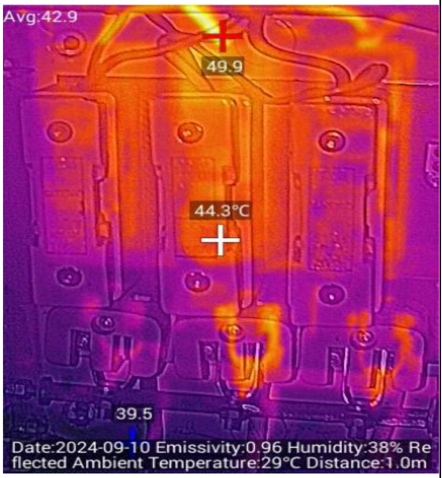
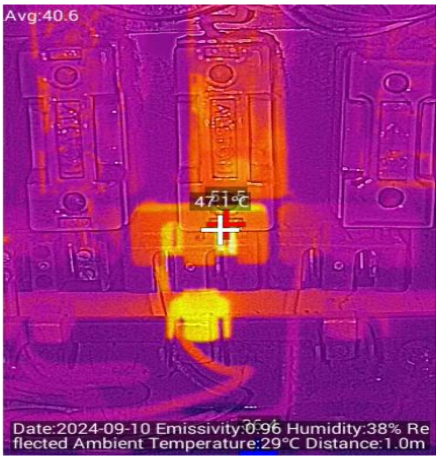
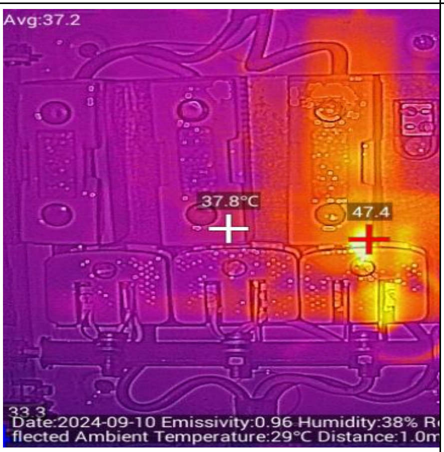
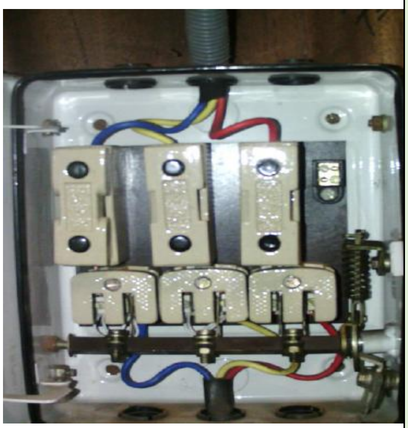
Priority	ΔT between similar components under similar load	ΔT over ambient air temperature	Recommended Action
4	1 to 3 °C	1 to 10 °C	Possible deficiency; warrants investigation
3	4 to 15 °C	11 to 20 °C	Indicates probable deficiency; repair as time permits
2	– – –	21 to 40 °C	Monitor until corrective measures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

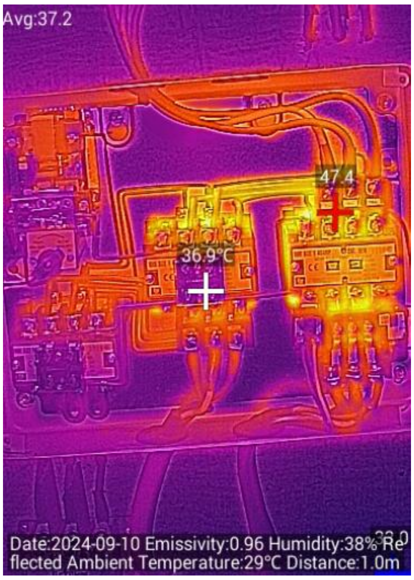
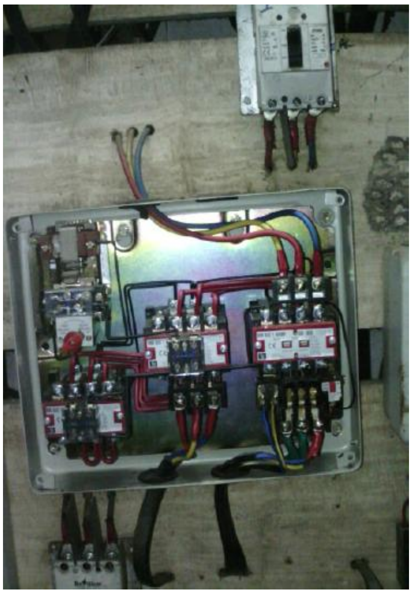
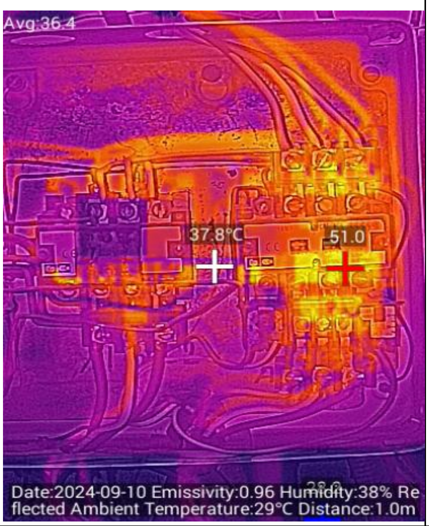
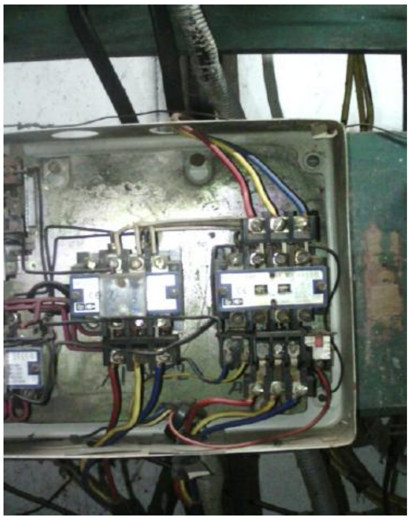
12.2 ABNORMALITIES NOTICED: 20 LOCATIONS : OVERALL

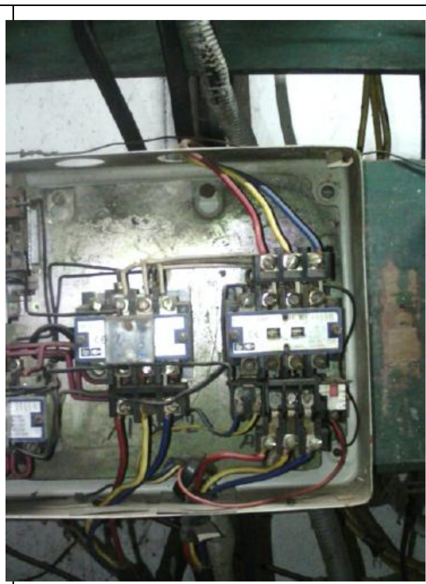
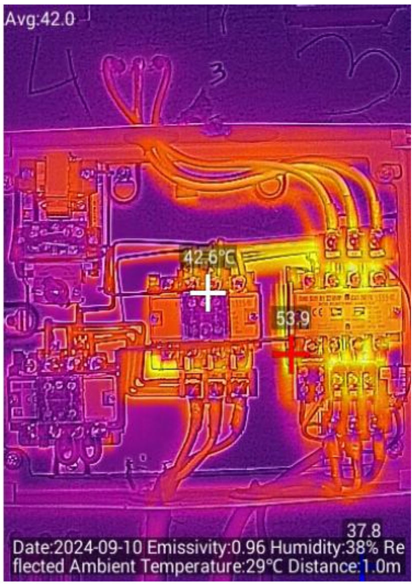
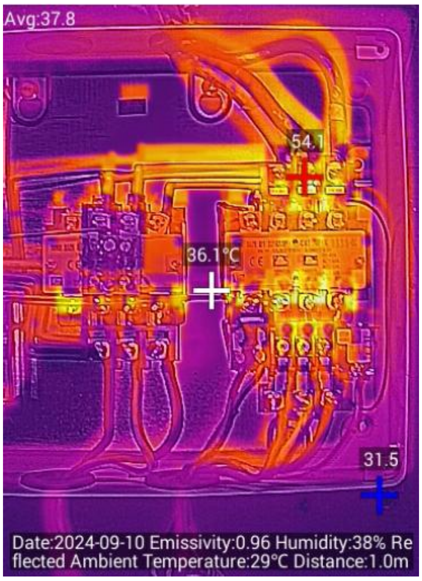
- The outcome is presented in this section as per the categorization made.
- Abnormalities have been noticed at 20 out of 29 locations surveyed based on the Thermal Imaging Study conducted.
- Remedial action may be initiated accordingly. The remedial action could be
  - a) Check and Reterminate corresponding Cable / Busbar
  - b) Provide Adequate Cooling, etc., and many more such actions etc.

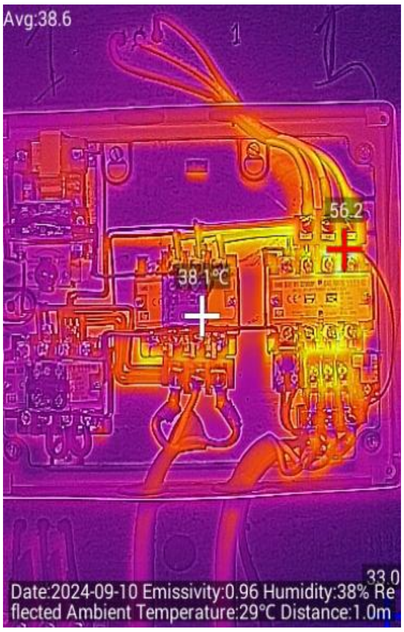
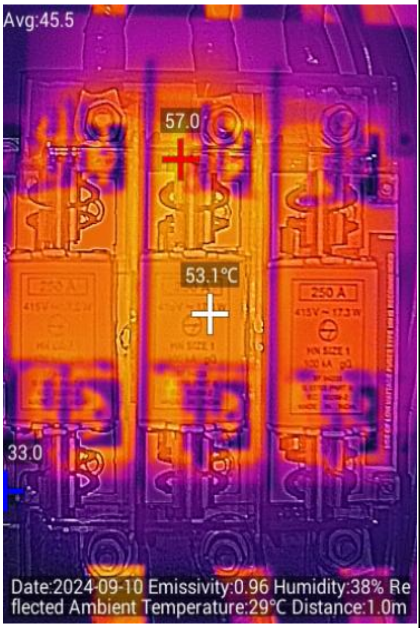
12.2.1 Category : Mild : No of Locations : NIL : Temp: 30 - 40 °C

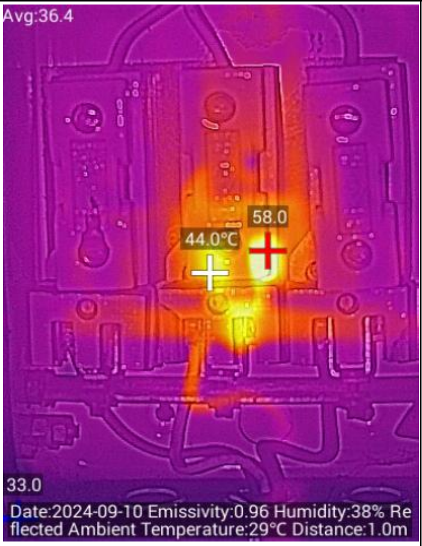
12.2.2 Category: Moderate: No of Locations: 13: Temp: 41 - 60 °C

No	Location	Thermal image	Normal image	Temp°C
1	Drier - 3 Incoming			44.3 °C in Y Phase
2	Drier - 2 Incoming			47.1 °C in Y Phase
3	Sorting Section Starter No. 6			47.4 °C in R Phase

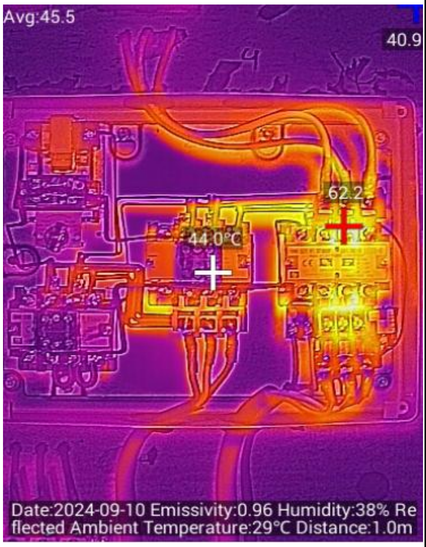
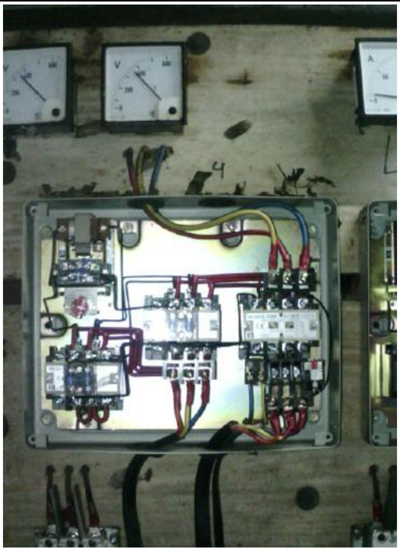
4	**Line 1 – Rotor Vane Incoming**			**47.4 °C in R&Y Phase**
5	**Line 2 – Rotor Vane Incoming**			**48.2 °C in the Incomer**
6	**Line 2 – CTC 4 Incoming**			**48.2 °C in R Phase**

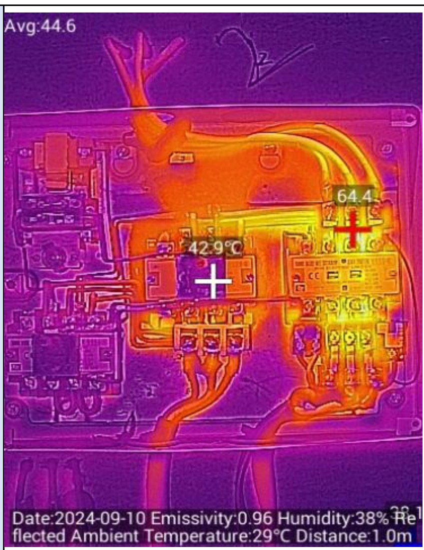
<table>
<tr><td>7</td><td>Line 2 – CTC 4 Incoming</td><td>
</td><td></td><td>51 °C in Incomer</td></tr>
<tr><td>8</td><td>Line 1 – CTC 3 Incoming</td><td>
</td><td></td><td>53.9 °C in Incomer</td></tr>
<tr><td>9</td><td>Line 2 – CTC 2 Incoming</td><td>
</td><td></td><td>54.1 °C in Y phase</td></tr>
</table>

10	Line 1 Main Incoming 2			55.7 °C in R phase
11	Line 1 – CTC 1 Incoming			56.2 °C in R phase
12	Line 1 Main Incoming 1			56.2 °C in Y phase

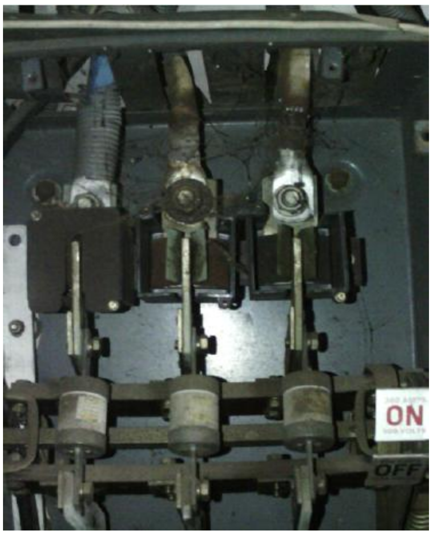
13	Sorting Section Starter No. 8			58 °C in Y phase

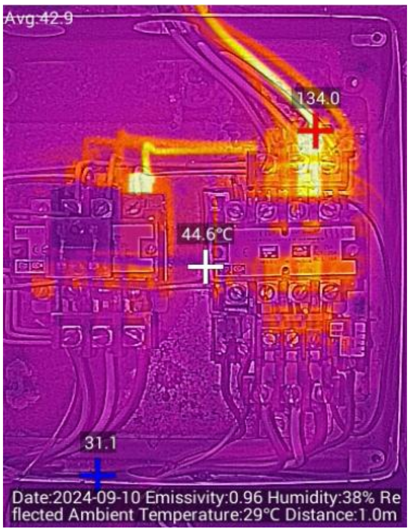
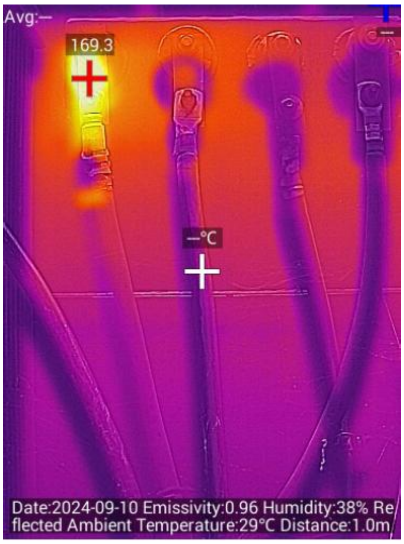
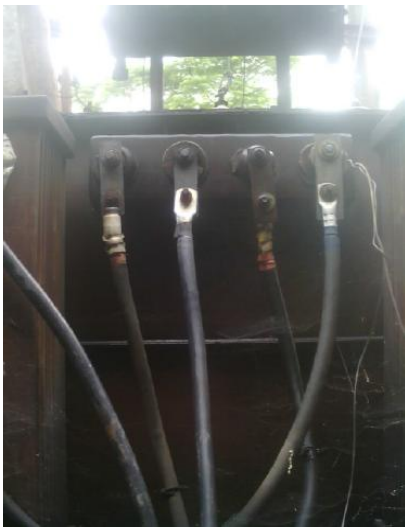
12.2.3 Category: Serious : No of Locations : 4 : Temp: 61 - 70 °C

1	Line 1 – CTC 4 Incoming			62.2 °C incomer
2	Transformer - 1 : Incoming			62.9 °C in B Phase

3	Line 1 – CTC 2 Incoming			64.4 °C in the Incomer
4	Line 2 – CTC 3 Incoming			69.6 °C in Y & R Phase

12.2.4 Category: Critical : No of Locations : 3 : Temp: above 70 °C

1	Line 2 Main Incoming			72.5 °C in Y Phase

2	**Line 2 – CTC 1 Incoming**			**134 °C in Y Phase**
3	**Transformer 2**			**169 °C in R Phase**

- The abnormalities noticed are summed up below as per the severity status:

Table 12.3: Abnormalities Noticed: Categorization

No	Severity	No. of Locations
1	Mild	0
2	Moderate	13
3	Serious	4
4	Critical	3
	Total	**20**

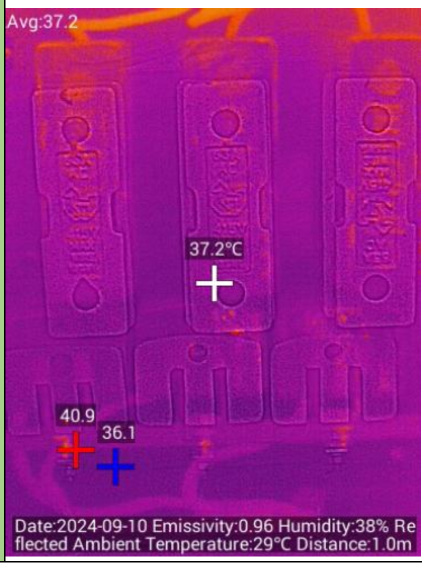
- The occurrence of faults can be attributed to

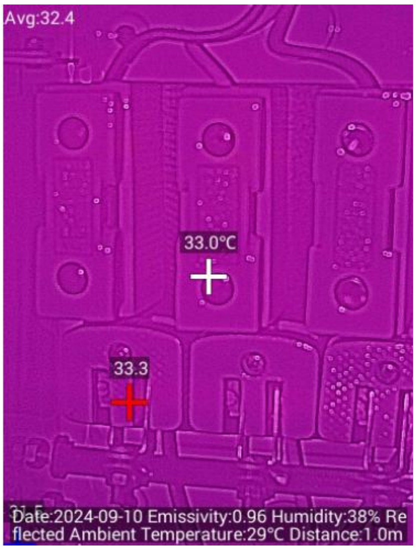
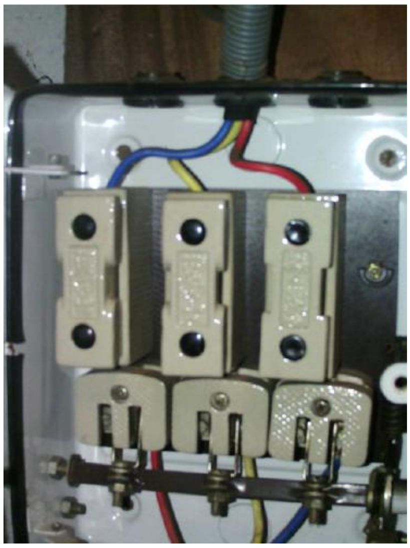
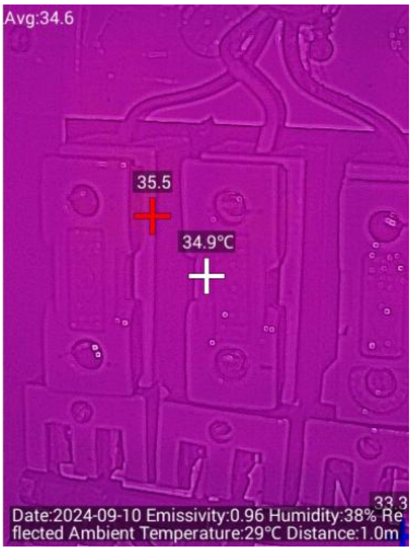
  I. Loose connections.

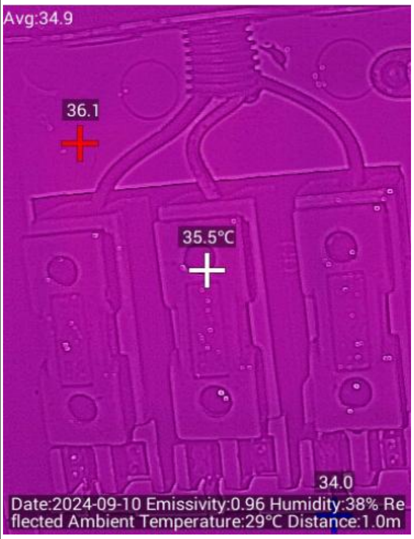
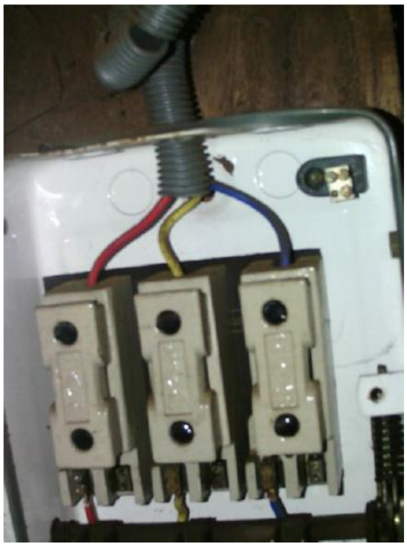
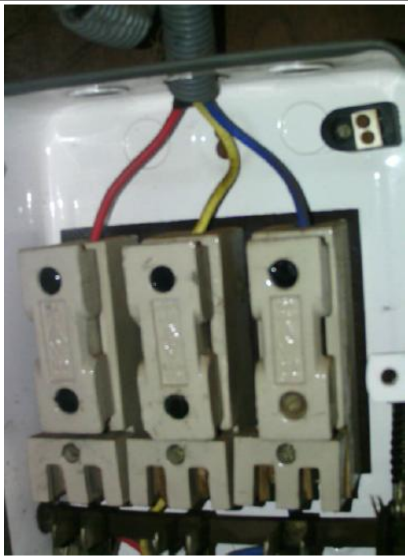
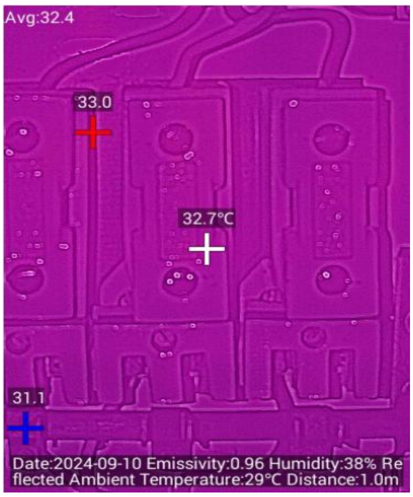
II. Deterioration of distribution lines (Cables)

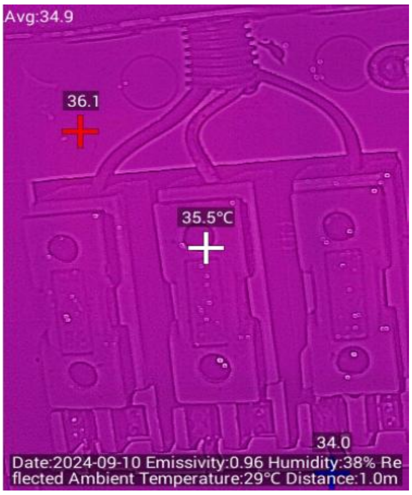
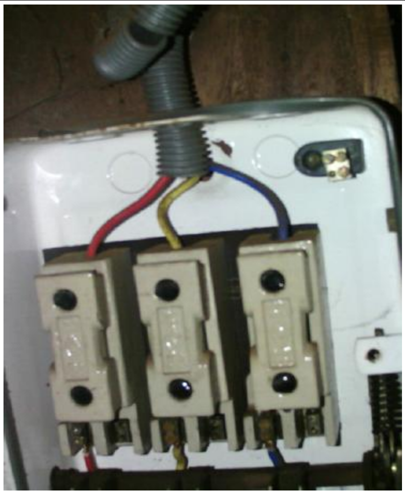
- The possible remedies are
  - ⇒ Check & Re do/Re terminate the cables / busbars etc. as per the observations made.
  - ⇒ Provide adequate cooling.
  - ⇒ Provide new & properly sized (Current carrying capacity) cables
- These abnormalities shall be attended to at the earliest opportunity

12.3 NIL ABNORMALITIES RECORDED: 9 LOCATIONS : ELECTRICAL

<table>
<tr><th>No</th><th>Location</th><th>Thermal Image</th><th>Visible Light Image</th></tr>
<tr><td>1</td><td>Line 2
Main Incoming</td><td>
</td><td></td></tr>
<tr><td>2</td><td>Drier 1
Incoming</td><td>
</td><td></td></tr>
</table>

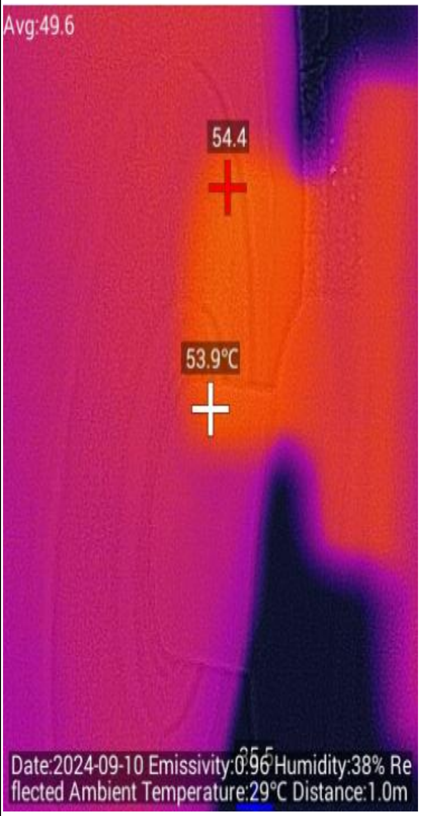
No	Location	Thermal Image	Visible Light Image
3	Sorting Section Starter No. 1		
4	Sorting Section Starter No. 2		
5	Sorting Section Starter No. 3		

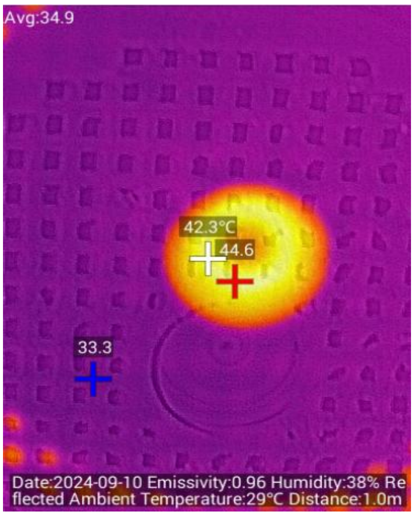
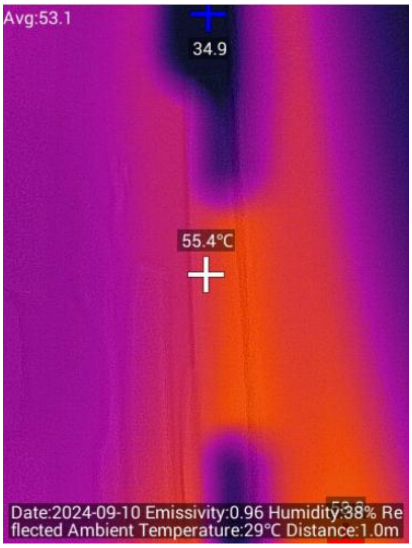
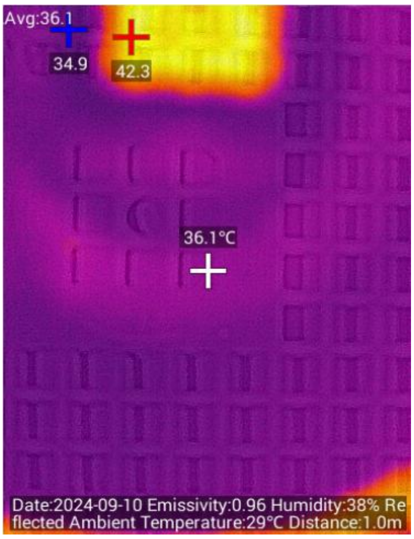
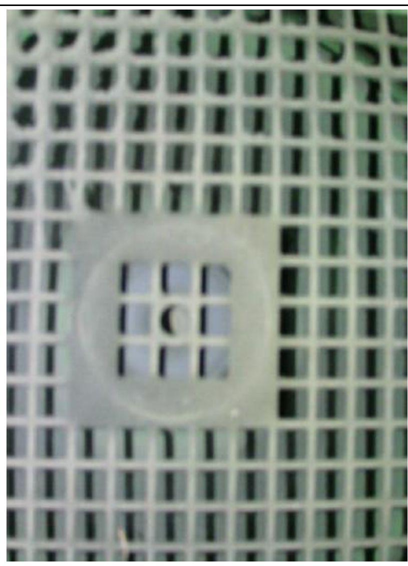
No	Location	Thermal Image	Visible Light Image
6	Sorting Section Starter No. 4		
7	Sorting Section Starter No. 5		
8	Sorting Section Starter No. 7		

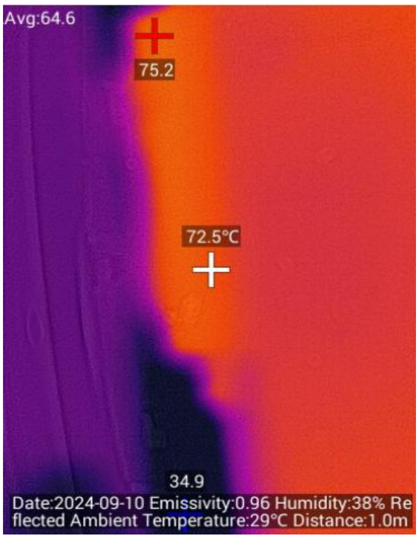
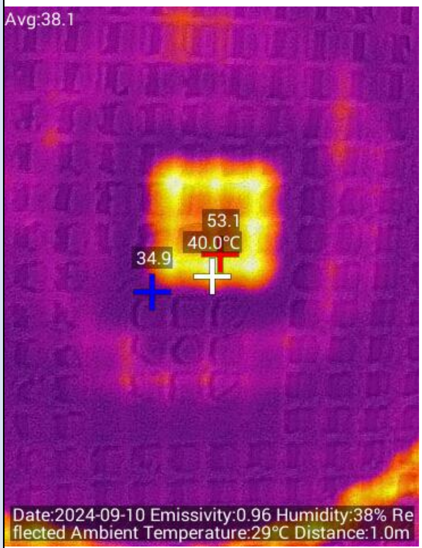
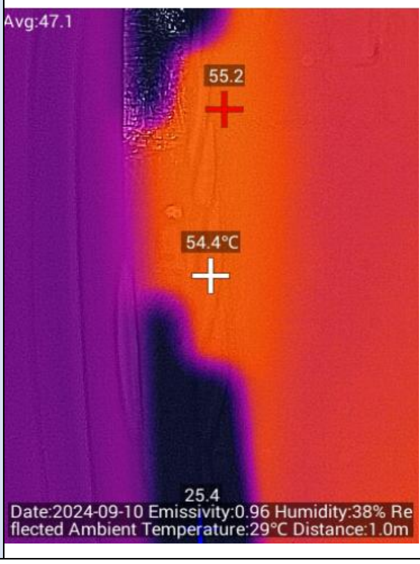
No	Location	Thermal Image	Visible Light Image
9	Sorting Section Starter No. 9		

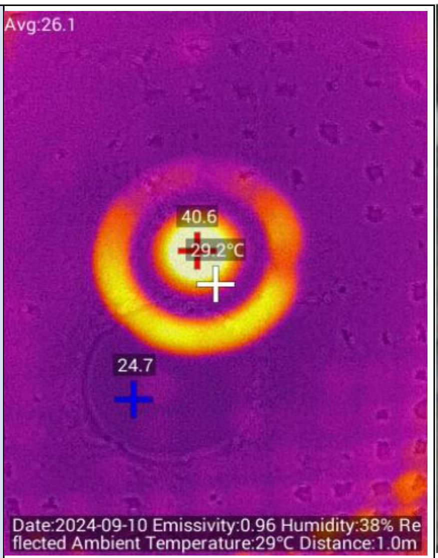
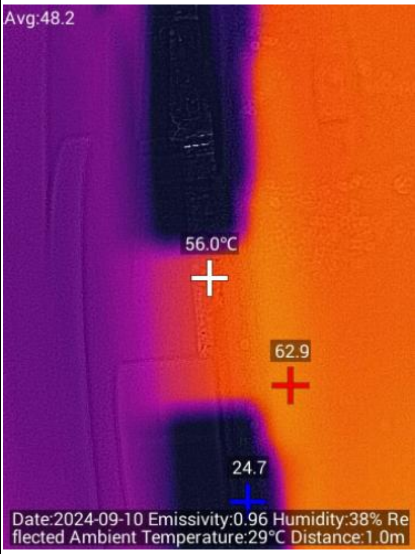
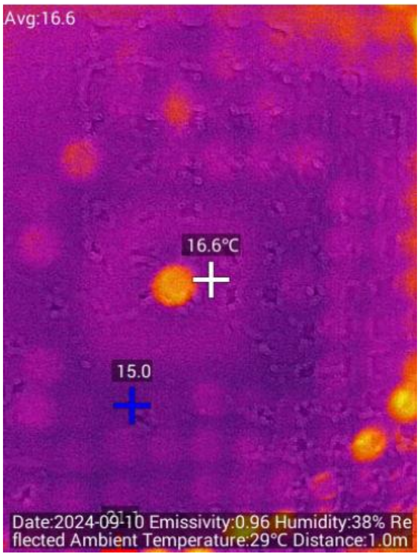
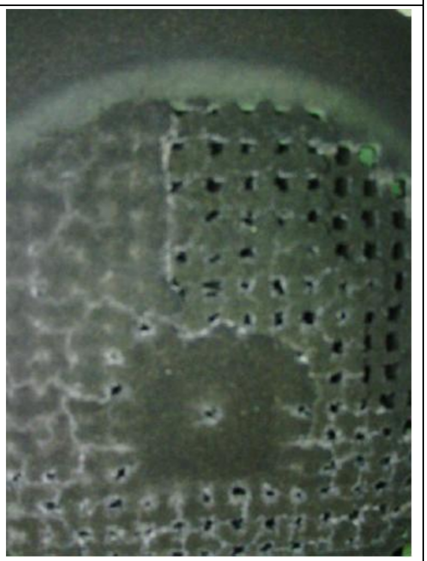
12.4 NIL ABNORMALITIES RECORDED: 20 LOCATIONS : CTC MOTORS

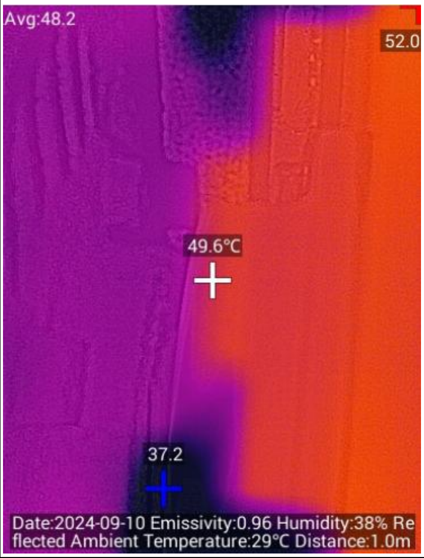
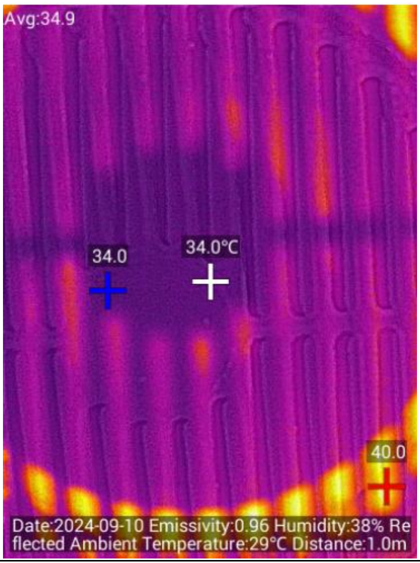
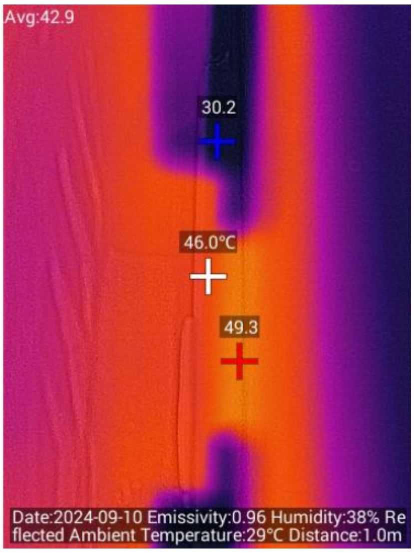
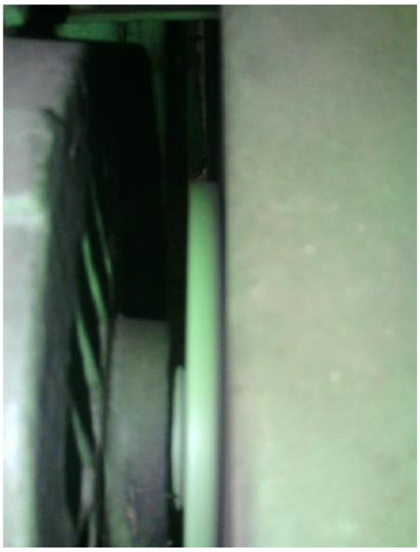
- Thermal Imaging Study conducted for the motors to assess the presence / absence of abnormalities with reference to surface temperature profiles are presented below .
- It can be said with confidence that the comprehensive assessment carried out on all major motors in the factory revealed **no abnormalities**.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

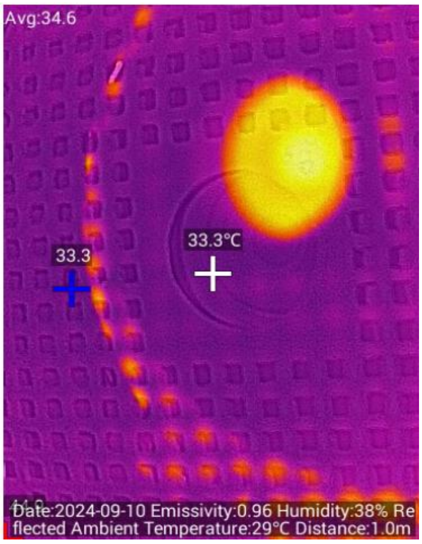
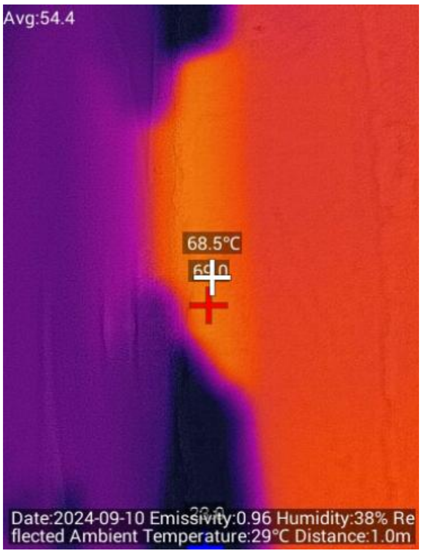
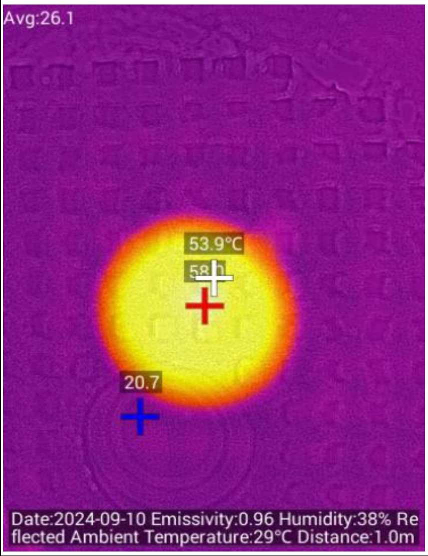
1	Line 1 – Rotor Vane Driving End		

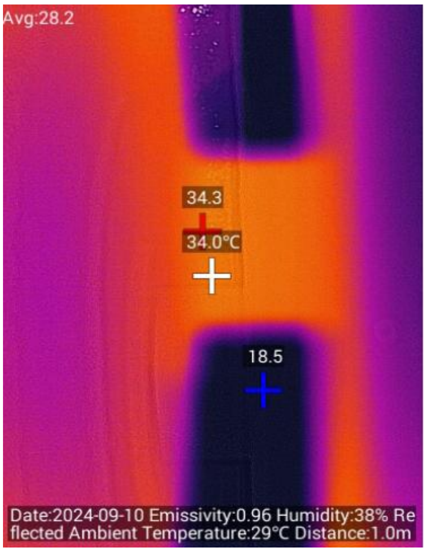
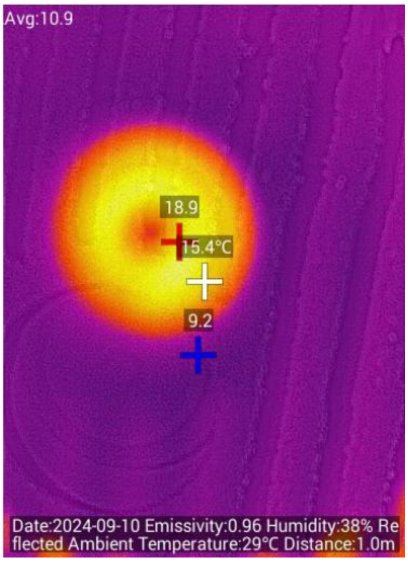
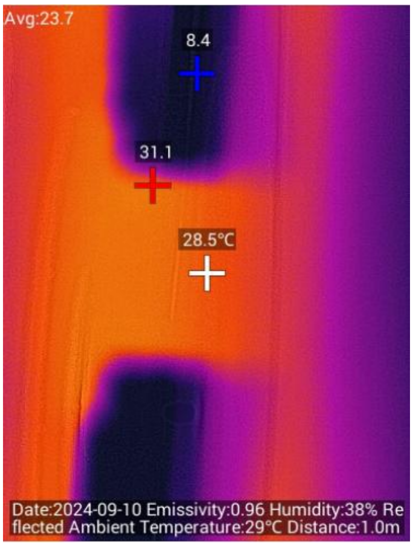
<table>
<tr><td>2</td><td>Line 1 – Rotor Vane Non-Driving End</td><td>
</td><td></td></tr>
<tr><td>3</td><td>Line 1 – CTC 1 Driving End</td><td>
</td><td></td></tr>
<tr><td>4</td><td>Line 1 – CTC 1 Non-driving End</td><td>
</td><td></td></tr>
</table>

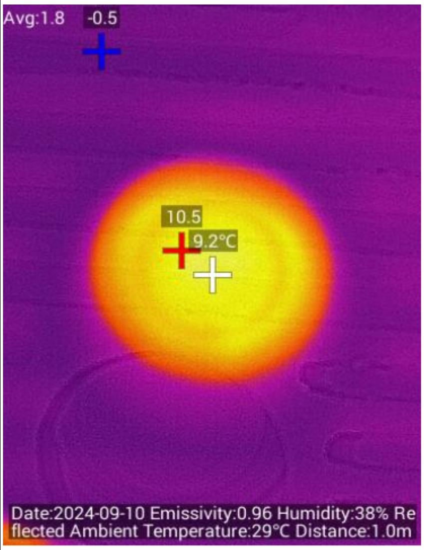
<table>
<tr><td>5</td><td>Line 1 – CTC 2 Driving End</td><td></td><td></td></tr>
<tr><td>6</td><td>Line 1 – CTC 2 Non - driving End</td><td></td><td></td></tr>
<tr><td>7</td><td>Line 1 – CTC 3 Driving End</td><td></td><td></td></tr>
</table>

8	Line 1 – CTC 3 Non-driving end		
9	Line 1 – CTC 4 Driving end		
10	Line 1 – CTC 4 Non-driving End		

11	Line 2 – Rotor Vane Driving End		
12	Line 2 – Rotor Vane Non-driving End		
13	Line 2 – CTC 1 Driving End		

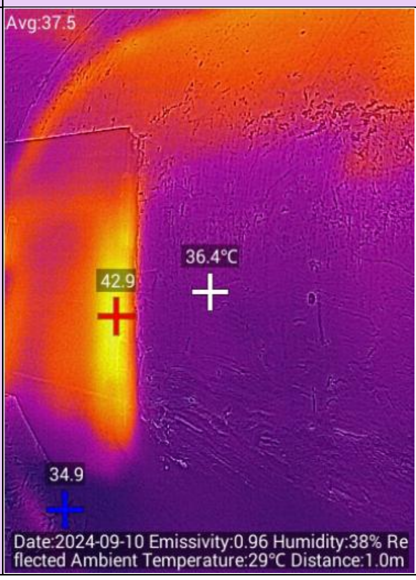
14	**Line 2 – CTC 1 Non-driving End**		
15	**Line 2 – CTC 2 Driving End**		
16	**Line 2 – CTC 2 Non-driving End**		

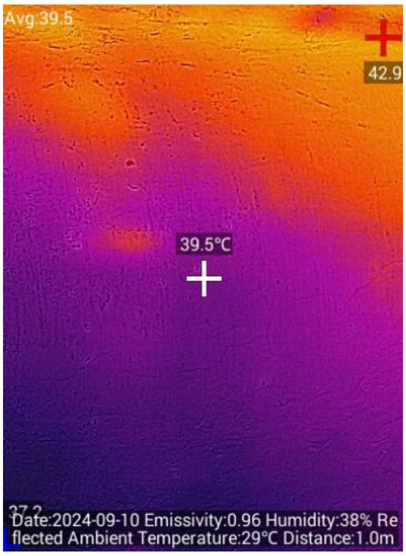
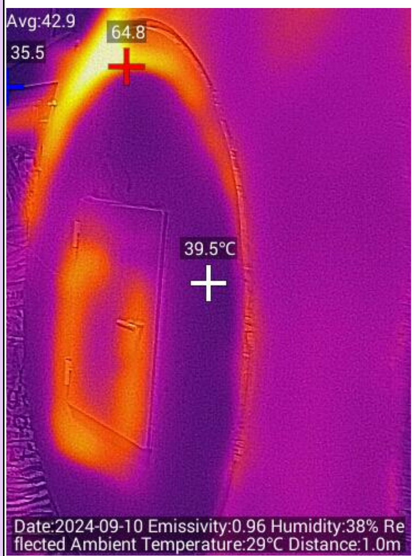
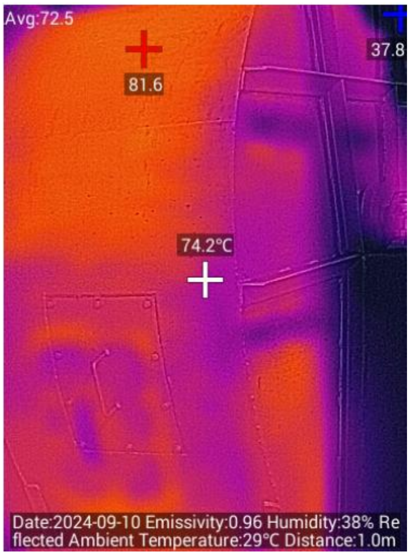
17	**Line 2 – CTC 3 Driving End**		
18	**Line 2 – CTC 3 Non-driving End**		
19	**Line 2 – CTC 4 Driving End**		

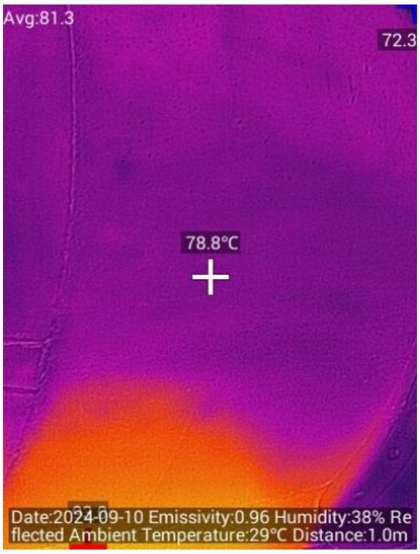
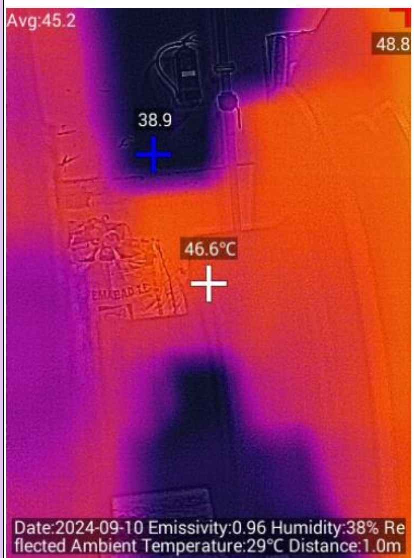
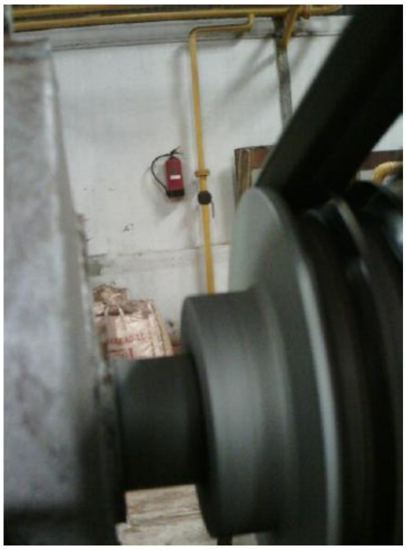
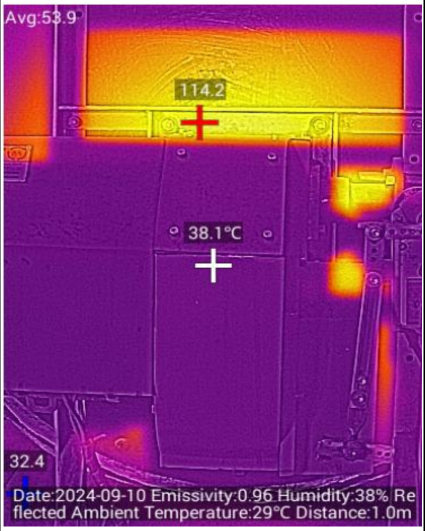
20	**Line 2 – CTC 4 Non-driving End**		

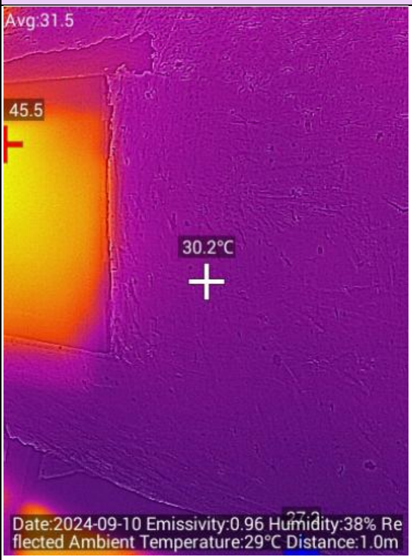
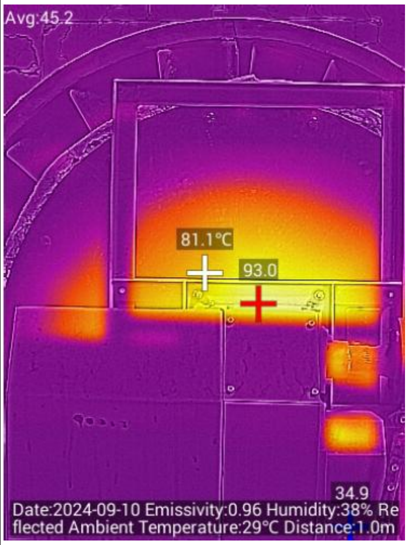
12.5 NIL ABNORMALITIES RECORDED: 17 LOCATIONS : DRIERS

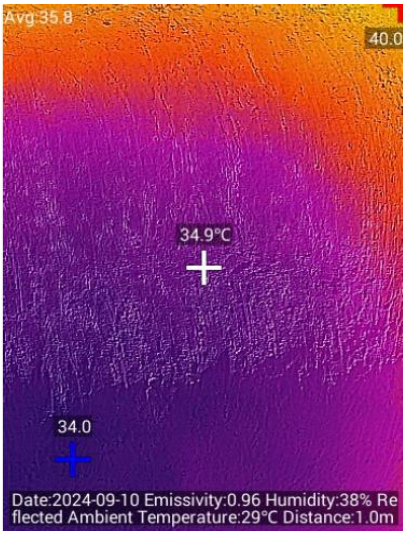
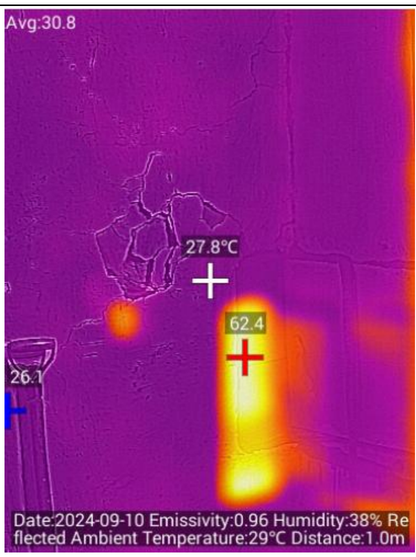
- Thermal Imaging Study conducted on the 3 driers - to check for possible thermal insulation related improvements - has revealed the absence of such discrepancies / locations with significant heat energy drain / loss.
- This comprehensive assessment of the drier surface temperature profile has uncovered **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.

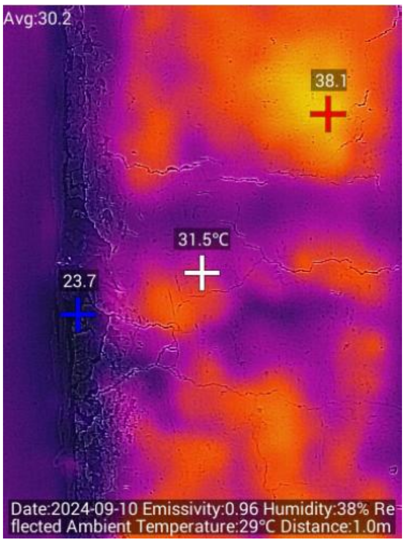
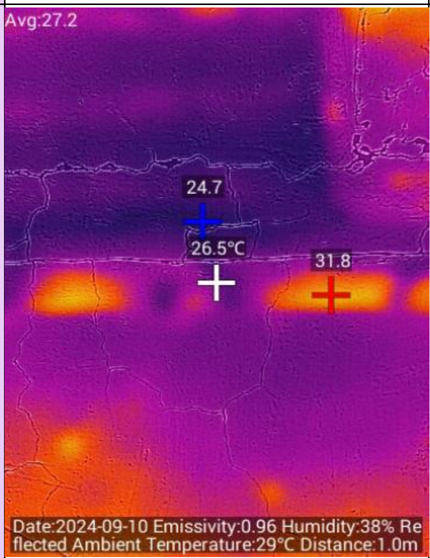
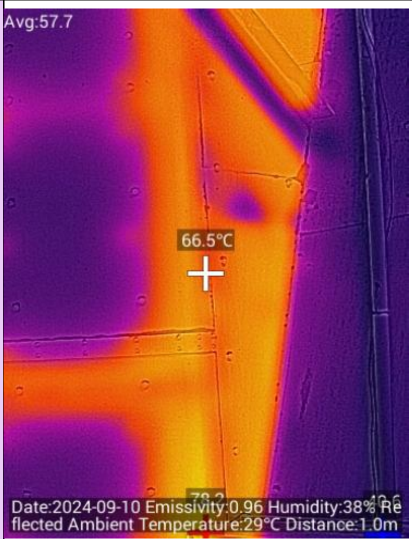
No	Location	Thermal Image	Visible Light Image
1	**Drier 1 – near CNG firing zone – picture captured from the R H S of the Drier**		

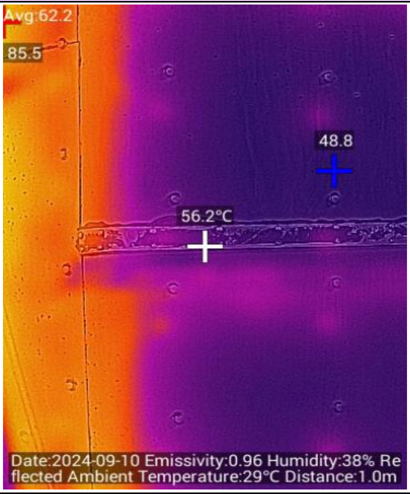
No	Location	Thermal Image	Visible Light Image
2	**Drier 1 – near CNG firing zone picture captured from the L H S of the Drier**		
3	**Drier 1 – close to the HAF – picture captured on the R H S of the Drier**		
4	**Drier 1 – at the HAF – picture captured on the L H S of the Drier**		

No	Location	Thermal Image	Visible Light Image
5	Drier 1 – HAF side of the drier – picture captured from the front		
6	Drier 1 – Hot Air Fan Driving End		
7	Drier 2 – C N G Burner Zone		

No	Location	Thermal Image	Visible Light Image
8	Drier 2: near CNG Firing Zone – picture captured from the R H S of the Drier		
9	Drier 2: near CNG Firing Zone – picture captured from the L H S of the Drier		
10	Drier 3 - C N G Burner Zone		

No	Location	Thermal Image	Visible Light Image
11	Drier 3: near CNG Firing Zone – picture captured from the R H S of the Drier		
12	Drier 3: near C N G firing zone picture captured from the L H S of the Drier		
13	Drier 3 – below the HAF – picture captured of the R H S of the Drier from the front		

No	Location	Thermal Image	Visible Light Image
14	**Drier 3 : below the HAF – picture captured of the L H S of the Drier from the front**		
15	**Drier 3 : close to the HAF – picture captured from the front**		
16	**Drier 3 : underneath the HAF – picture captured of the L H S of the Drier from behind**		

No	Location	Thermal Image	Visible Light Image
17	Drier 3 – underneath the HAF – picture captured of the R H S of the Drier from behind		

12.6 SUM UP

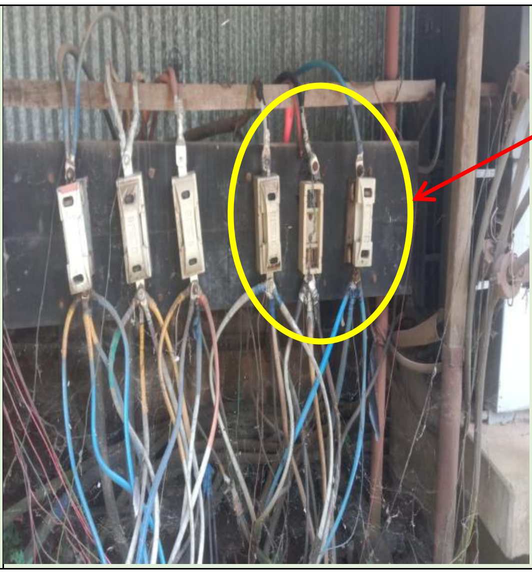
- Altogether, abnormality existed in only 20 out of the 66 locations surveyed for possible discrepancy in electrical connection tightness; quite a large fraction, and shall be taken care of.
- The remaining 46 locations had showed no abnormality.
- It is therefore suggested that the 20 locations identified - where abnormality existed – are 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 meagre only and hence can be taken on for rectification at the earliest.
- The motor surface temperature at the driving / non - driving end seemed fine. The bandwidth considered for scrutiny here is higher, as 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.

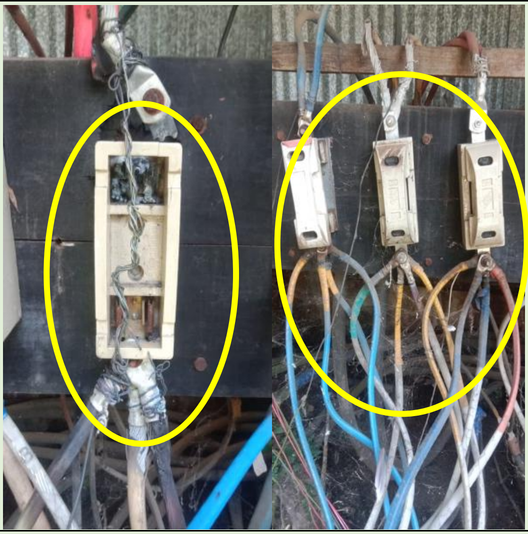
13 SAFETY CONSIDERATIONS AND UPKEEP

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. To be exact, it was a task to identify the power supply to numerous lower capacity motors in the Sorter Section. Hence, this suggestion.
- Record Maintenance found wanting in respect of Transformer, Higher Capacity Motors, DG Sets etc., It is mandatory to maintain the records for the sake of attending to the Preventive Maintenance of these production related critical Utilities
- The Earth Resistance and Relays are not tested. Hence testing is recommended.
- There is no fire extinguisher near the panel in power house. Fix the DCP type portable fire extinguisher.
- 14 locations have been identified that demand adherence to safety aspects / protocol
- The electrical safety issues will have to be resolved in the identified 9 locations while the rest 5 locations call for mechanical related safety protocol
- The detailing is as below

13.2 SAFETY ISSUES : ELECTRICAL

No	Location	Image	Comment
1	Transformer Yard		1) Fuse cover is missing 2) Fuse wire is broken / bypassed 3) Untidy / poorly organized cable routing

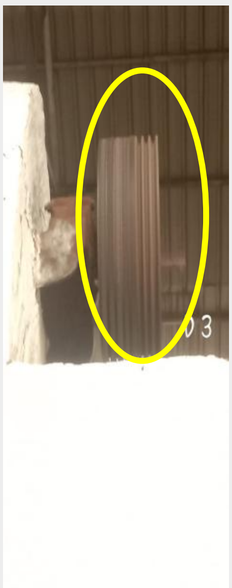
No	Location	Image	Comment
2			1) Bare / Exposed Cable 2) Shall be taped for the time being & insulated during next maintenance schedule
3	Transformer Yard		1) Connection shall be inspected / tightened 2) Captured as a severe hotspot in Chapter 12 with a temp of 170 ºC
4			CT is not insulated

No	Location	Image	Comment
5			Exposed / uncovered cabling
6	Transformer Yard		
7			• Calls for Tidiness, Overall Upkeep, Better and an Organized Layout / Routing of the Cables
8			

No	Location	Image	Comment
9	Drier / Sorting Section		• Panel Cover is missing

13.3 SAFETY ISSUES: MECHANICAL

1	**Line 1 Rotor Vane**	 	• **Groove: Missing a Belt**

No	Location	Image		Comment
2	Line 2 Rotor Vane			• Missing a Belt
3	Drier 1 Hot Air Fan			1) **Picture on the left – Missing a belt** 2) **Picture on the right - Poor belt condition**
4	Drier 2 & 3 Hot Air Fan			**1) Picture on the left - Missing a belt** 2) **Picture on the right – Missing 3 belts**

No	Location	Image	Comment
5	**Drier 1**		• **The cover for the burner section is missing**

13.4 SUMMATION

- It is important that safety considerations are given due importance and priority and resolved at the earliest.
- 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

1.ELECTRICAL PARAMETERS – 2 INSTRUMENTS

1) 3 Power ϕ Quality Analyzer

2) Clamp - on Power Analyzer

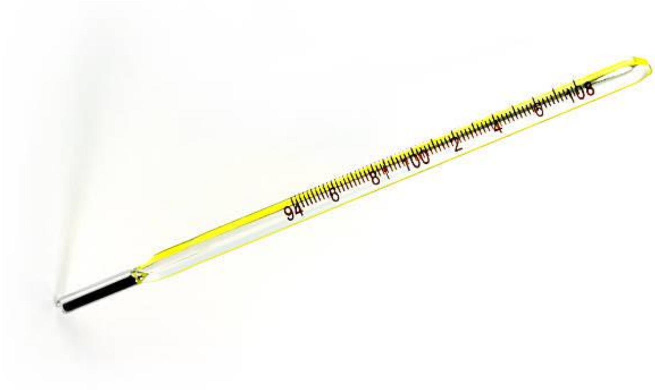
2. THERMAL PARAMETERS – 5 INSTRUMENTS

1) Thermal Imager

2) Thermo Hygrometer

3) Digital Thermometer

4) Sling Psychrometer



5) Mercury in glass thermometer

3. FLOW PARAMETERS – 1 INSTRUMENT

1) Vane Type Anemometer

END

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