Energy Audit in Ethiopian Sugar Industry: A case of Wonji/Shoa Sugar Factory

Abebaw Gebeyaw Brhanie

A Thesis Submitted to

The Department of Chemical Engineering

School of Mechanical, Chemical & Material Engineering

Presented in Partial Fulfillment of the Requirement for the Degree of Masters

in Chemical Engineering (Specialization in Process Engineering)

Office of Graduate Studies

Adama Science and Technology University

February, 2024

Adama, Ethiopia

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DECLARATION

I hereby declare that this Master Thesis entitled **"Energy Audit in Ethiopian Sugar Industry: a case of Wonji/Showa Sugar Factory"** is my original work. That is, it has not been submitted for the award of any academic degree, diploma, or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

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RECOMMENDATION

We, the advisors of this thesis, hereby certify that we have read the revised version of the thesis entitled **"Energy Audit in Ethiopian Sugar Industry: a case of Wonji/Showa Sugar Factory"** prepared under our guidance by Abebaw Gebeyaw submitted in partial fulfillment of the requirements for the degree of Masters of Science in Chemical Engineering. Therefore, we recommend the submission of the revised version of the thesis to the department following the applicable procedures.

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APPROVAL PAGE

We, the advisors of the thesis entitled "**Energy Audit in Ethiopian Sugar Industry: a case of Wonji/Showa Sugar Factory**" and developed by Abebaw Gebeyaw, hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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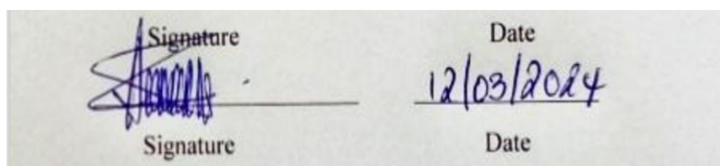

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Abstract

Energy Audit is the systematic accounting of all energy inputs; it is utilized as a tool for energy optimization and emission reduction in different industrial units, especially in sugar cane industry; Because sugarcane is an essential crop in the world for sugar and renewable energy production. The generation of electrical and thermal energy from sugarcane fiber (bagasse) is highly significant due to its renewable nature, ensuring energy security, and the economic advantages. The energy auditing was conducted based on data collected from site measurement of material and energy flows using Infrared temperature guns , meltimeter, clamp meter, voltmeter, and based on data collected from auto record of distributed control system (DCS) & control panels of each unit operations as well as by laboratory analysis & from laboratory log books . The assessment and performance evaluations of Wonji/ Shoa sugar factory (WSSF) boiler and evaporator efficiency is 66.9% 74.2 respectively. The total thermal energy losses of WSSF is 111,754.6 KW, through vent vapor(steam), dry flue gas, vent steam of different areas, leakage of condensate water and blow down. The total electrical energy lost due to absence of energy efficient motors and turbine is 5,803.2 KW &20,930,690 KW respectively. The higher thermal and electrical energy consumption were found in boiler unit with dry flue gas which is 24,716.81 KW and extraction unit at roller mills which is 21.15 Tera Joules. The total output crystalline white sugar in the selected audit year is 36,812.02 Ton, but the recoverable sugar is 34,325.02 Ton (336,385,196.0 ETB/month). The lost crystalline white sugar with by products is 2,487 ton due to lack and wastage of thermal energy. By recovering lost thermal energy can generate 750 ton and 1,152 ton sugar in filter cake and bagasse respectively and The lost money with these two by products in the selected audit year is 16,875,600 ETB/month. By integrating pipeline from boiler ID fan to bagasse elevator for the purpose of evaporate (minimize) moisturized bagasse, the loss of 24,716.81KW thermal energy through dry flue gas can generate and then increase the boiler efficiency as well as reduce carbon dioxide emission. Implementing the proposed energy-saving measures has the potential to significantly reduce energy loss, reduce Greenhouse gas (GHG) emission, *increase profitability, and enhance sustainability in the sugar industry.*

Keywords: *Renewable Energy, Sugarcane, Bagasse, Electrical &thermal energy audit, Energy and product (money) saving, Thermal heat recovery,*

Acronym

DCS	Distributed control system
TCD	Ton crushed per day
TPH	Ton per hour
ID FAN	Induced draft fan
GHGE	Greenhouse gas emission
PRDS	Pressure reduction and de supper heater system
Kg/cm^2	Kilo gram per square centimeter
IR	Infrared thermometer
HT	High tension
Qt	Quintal
GW	Giga watt
MW	Mega watt
MWh	Mega watt hour
KW	Kilo watt
KWh	Kilo watt hour
ACC	Auxiliary cane carrier
BBC	Belt bagasse conveyor
BCC	Belt cane conveyor
WSSF	Wonji/Shoa sugar factory
CO	Carbon monoxide
$\dot{m}_{Blowdown}$	Mass flow rate of blow down
$\dot{m}_{Feed\ water}$	Mass flow rate of feed water
$\dot{m}_{Steam}$	Mass flow rate of steam
GCV	Gross calorific value
NCV	Net calorific value
$Q_{f\ (bagasse)}$	Chemical energy of the fuel
$\dot{m}_f$	Mass flow rate of the fuel
C_w	Specific heat of water
T_f	Temperature of feed water
Ta	Ambient temperature
Qw	Energy of feed water

h_{gs}	Enthalpy of super-heated steam
h_g	Enthalpy of dry super saturated steam
C_{ps}	Specific heat of dry saturated steam at constant pressure
T_{sup}	Temperature of superheat steam
T_s	Saturated temperature
Q_{flue}	Heat (thermal) energy of flue gas
$\dot{m}_{flue}$	Mass flow rate of flue gas
hfg@25ºC	Enthalpy of water
γ_A	Absolute humidity factor
AAS	Actual air supplied
TA	Theoretical air
EA	Excess air
hfg@110ºC	Enthalpy of blow down
CO_2	Carbone dioxide
CSTR	Continuous stirred tank reactor
GHG	Greenhouse gas
HP	High pressure
MCC	Main cane conveyor
PWS	Plantation white sugar
TCH	Ton crushed per hour
VFD	Variable frequency drive
VSD	Variable speed drive
ETB	Ethiopian birr

CHAPTER ONE

1. INTRODUCTION

1.1 Background and Justification

Energy holds the greatest potential for cost reduction, making the energy audit a vital undertaking. Energy audit enables a comprehensive understanding of energy usage in the industry, pinpointing areas prone to energy waste and highlighting opportunities for improvement (Sharma et al., 2021). The ever increasing energy costs, fast depleting energy resources and inability to decrease the cost of finished products call for regular energy audit (M. Soppimath & G. Hudedmani, 2017). Optimizing energy in industrial sites and buildings is a prudent practice, involving the examination of operational issues that may impact efficient energy utilization (Al Momani et al., 2023).

Bioenergy is recognized as a renewable and sustainable energy source, deriving from the conversion of lignocellulosic biomass. This process boasts a lower-carbon life cycle compared to fossil fuels, producing heat, electricity, and less emission fuels. Biomass conversion to energy employs two main methods: thermo chemical (including combustion, gasification, and conventional and microwave pyrolysis) and biochemical (such as anaerobic digestion and microbial fermentation) processes. The choice of conversion method is pivotal for the type of by-products to be formed and recovering energy efficiently.

Lignocellulosic biomass composed of cellulose, hemicelluloses, and lignin, exhibits varying fiber compositions based on biomass nature. For instance, sugarcane bagasse has a higher cellulose content (46.55 wt%) than rice husk (30.42 wt%) (Allende et al., 2022). In 2021, the United States emerged as the top global biofuel producer, with production reaching 1,436 petajoules. Brazil and Indonesia secured the second and third positions, contributing approximately 840 and 312 petajoules, respectively (*Global Biofuel Production by Country 2021 | Statista*, n.d.). Sugarcane is an essential crop in the world for sugar and bioenergy production (Mancini et al., 2022). It is considered as both a food and a renewable energy source crop. The generation of electrical energy from sugarcane fiber (bagasse) is highly significant due to its renewable nature, ensuring energy security, and the economic advantages it provides to the sugar industry (Mbohwa, 2013).

The sugarcane processing industry demonstrates remarkable sustainability by utilizing its wastes and by-products to meet energy and agricultural needs. Currently, electric power derived from bagasse is predominantly utilized within the industrial process itself, with no significant surplus of energy (Osaki, 2022). The industry possesses substantial electricity-generating potential using bagasse burning, and in certain countries, sugar factories are connected to the public electricity grid (Kabeyi & Olanrewaju, 2022)

In Ethiopian sugar industries, particularly at the Wonji/Shoa Sugar factory, there is evident wastage of electrical, thermal and bagasse energy through various means, including: Lack of proper sealing for some pipelines used for steam transportation, furnaces, and hot juice tanks Absence of insulation for heat exchangers. Poor selection of process units e.g.: pumps and motors, improper bagasse storage system and lack of bagasse drying unit are the main cause of energy waste in the industry.

In this study, examining the current thermal and electrical energy utilization efficiency of the industry through an energy audit of individual manufacturing equipment's were done with the aim to propose alternative measures for energy savings and waste minimization.

1.2. Statement of the problem

This research was conducted an energy audit at Wonji/Shoa Sugar Factory in Ethiopia, situated in the Oromia region near Adama city, approximately 110 km away from Addis Ababa. The factory's main product, crystalline white sugar, serves as an ingredient for various industries such as soft and alcohol beverage, pharmaceuticals, while its by-products, including bagasse, filter cake, and molasses, used for paper industry, fertilizer and biogas generation, and alcohol production, respectively. Despite the high market demand for the factory's products, it operates at a loss due to inefficient energy consumption. The major reasons for the inefficient energy utilization are due to lack of awareness to energy purpose from bottom to top managemen. But the primary energy-related issues could emerge from unaddressed steam leaks, unknown combustion and thermal efficiency of furnaces and boiler, poorly insulated steam distribution lines, visible steam waste, the discharge of effluent at a temperature of 90°C directly into the river and flue gas with a temperature of about 150°C that is released into the atmosphere through the chimney without any heat recovery. This emphasizes the importance of conducting an "Energy Audit" to know the potential energy wastage units in the industry and apply different techniques to achieve reduction in energy expenses and maximize energy savings. Therefore, this research aims to identify and address these energy-related challenges in wonji/Shoa sugar factory to enhance the factory's overall efficiency and economic performance. In every sugar factory in Ethiopia, the challenge of proper energy utilization persists. So far, there has been no initiative to implement energy audits, and there is a lack of knowledge regarding energy consumption patterns due to: Limited awareness about energy management among factory personnel, from top management to bottom-level workers, the absence of modern measuring instruments for energy audit, absence of an energy management policy, resulting in overall poor energy management in the factory.

These issues underscore the urgent requirement for an energy audit and the exploration of energy-conserving opportunities in the factory. Therefore, it is found important to address this problem in this thesis. This thesis had given information about the factory’s energy consumption patterns and assesses the efficiency of major energy-consuming systems and devices to address the gaps in energy efficiency. It will also identify opportunities for energy conservation, and propose opportunities of energy saving for further measures.

1.3. Objective of the Study

1.3.1. General Objective

The general objective of the study is to conduct thermal and electrical energy audit, and propose possible alternative for energy saving opportunities in Wonji-Shoa sugar industry.

1.3.2. Specific Objectives

- To perform thermal and electrical energy audit of the individual manufacturing equipment’s
- To quantify electrical energy consumption of offices in the processing unit
- To estimate energy saving potential of the industry and
- To recommend possible energy saving possibilities

1.4. Significance of the Study

This study holds significant importance, as its outcomes have the potential to yield remarkable results in terms of energy conservation, leading to increased productivity and profitability. Efficient energy utilization could result in substantial savings and also excess bagasse, which can be a raw material to the paper industry. Additionally, when thermal and electrical energy are abundantly available, uninterrupted factory operations can be sustained, and surplus electricity can be sold to the national grid. Conducting an energy audit in the sugar industry is crucial to identify deviations in boiler efficiency from optimal levels and pinpointing areas for corrective measures. Insulation emerges as a key aspect, playing a vital role in energy conservation and bolstering plant profitability by minimizing energy losses to the surroundings. The application of insulation to hot surfaces, including steam and vapor pipelines and boiler furnaces, serves to reduce external surface temperature losses. This reduction in energy losses contributes to a decrease in the overall energy consumption required. Generally; an energy audit process will act as a catalyst in energy management of utilizing the fossil fuels and renewable energy efficiently as well as effective usage of those resources which will reduce the environmental impact, like greenhouse gas emissions, air pollution and global warming.

1.5. Scope of the Study

The scope of the study is to study the thermal and electrical performance of Wonji/Shoa sugar factory process units. The overall assessment mainly focuses on the evaluation of the sugar process plant. The thermal energy has been recorded by using instrumental devices from the heat losses on un-insulation pipeline, insulated steam and vapor pipelines whereas electrical energy has been evaluated by checking the electric energy utilizing appliances and bills.

CHAPTER TWO

2. LITERATURE REVIEW

Sugarcane Bagasse is the fibrous residue of sugar cane stalk coming from the mills after crushing and extraction of juice. It is used as a fuel for boiler to generate energy. In Wonji/Shoa sugar factory a sugarcane bagasse of 52% moisture content which is very high moisture content in history of the sugar factory is used as a fuel for boilers to generate steam. If the moisture content of bagasse is high its heat generation capacity or calorific value is lower; indirectly that means the boiler efficiency become low, because it's heating value is reduced and it cause the largest loss in the boilers due to the moisture carries the latent heat of vaporization up the stack (Girma, 2018).

Electrical energy and thermal energy are the primary energy types used for sugar processing and the benefits of energy efficiency and conservation are commonly accepted in the sugar industry. Cogeneration power plants using bagasse in sugar factories produce steam and electricity for use in the sugar processing and also export the excess power to the grid. For the generation of excess power there is continuous analysis required for the economical balance for input and output power. The success of cogeneration depends on efficient use of energy. The steam generation in boiler unit have very low efficiency (on average 63.59%) when compared to the minimum acceptable efficiency of boiler that uses bagasse as a fuel (70 %) (Bahiru, 2019).

An energy assessment and evaluation is the procedure to analyze the energy balance of a system in order to define possible improvements of its energy efficiency, to achieve the mitigation of its environmental impact and to reduce energy costs. The assessment and performance evaluations of Wonji Shoa sugar factory (WSSF) boiler efficiency is 67.066%. The surface heat losses of WSSF steam pipe line due to un-insulation is working 45.1KW and 67.3KW when the turbine is working and not working respectively (Amare, 2019).

Sugarcane Bagasse is the fibrous residue of sugar cane stalk coming from the mills after crushing and extraction of juice. It is used as a fuel for the boiler to generate energy. In the Wonji/Shoa sugar factory sugarcane bagasse of 52%, moisture content which is the very high moisture content in the history of the sugar factory is used as a fuel for boilers to generate steam. If the moisture content of bagasse is high its heat generation capacity or calorific value is lower;

indirectly that means the boiler efficiency becomes low because its heating value is reduced and it cause the largest loss in the boilers due to the moisture carries the latent heat of vaporization up the stack. The Fluidized Bed Bagasse Dryer uses the hot flue gases that come from the boiler to the chimney which is the optimum solution to enhance the thermal efficiency of the boiler. In another way, re-using these flue gases for bagasse drying improves environmental pollution. The bagasse and the hot flue gases mixed in the drying chamber of the Fluidized-Bed Bagasse Dryer to evaporate the water contained in the bagasse. Finally, this designed Fluidized Bed Bagasse Dryer enables to reduction of bagasse moisture content from 52% to 41% and also increases the efficiency of the boiler by 5.5% from 70 to 75.5% (Tesemma, 2018).

The pulp and paper, cement, and clothing industries are just a few that could benefit from the energy audit. In sugar factories, there are a plenty of energy consuming equipment for extracting sugar from sugarcane. Numerous studies have been done based on the amount of energy used in the agricultural section of a sugar beet or sugarcane factory (Abroshan et al., 2023).

In the contemporary scenario, there is a noticeable trend of increasing electricity consumption in sugar manufacturing plants each year. This can be attributed to the prolonged usage of equipment under inefficient operating parameters, as well as the overall rise in production levels. The sugar manufacturing process inherently incorporates a significant design safety factor, which, after the stabilization of processes, needs to be fine-tuned for optimal power consumption. Given that energy costs account for approximately 15 to 20% of production costs, ranking second only to raw materials, and the sugar industry places a crucial emphasis on energy consumption, particularly at the load end. The overarching goal is to optimize the energy usage of sugar manufacturing machines for improved efficiency and cost-effectiveness (Parveen & Jagdeep, 2017).

The sugar factory has become a multipurpose factory simultaneously producing food, energy, and biofuels. As a transition product in the energy and economic transition, sugarcane is used in production of sugar and many other byproducts in more than 100 countries globally (Jeremiah & Kabeyi, 2023).

The contemporary sugarcane industry is characterized by diversification and high integration, yielding a diverse array of products including sugar, molasses, ethanol, electric power, pulp and paper, charcoal briquettes, and biogas. These products maintain sustainability and competitiveness in the market. Bagasse, an energy-rich byproduct of sugarcane factories, holds considerable economic and technical potential for grid power generation (Jeremiah & Kabeyi, 2023).

Cogeneration based on bagasse has demonstrated its reliability as a grid electricity source in nations that have upgraded their sugar factories to enhance energy efficiency. Drawing insights from the success stories of countries such as Mauritius, Brazil, and India, establishing export-oriented bagasse cogeneration as a dependable grid electricity source requires the collaboration of numerous stakeholders. It involves substantial investments in energy-efficient technology and capital within a supportive legal and policy framework (Jeremiah & Kabeyi, 2023).

Several countries like Mauritius, India, and Brazil have the sugar industry connected to the public power grid which earns the industry extra revenue in exchange for clean electricity. India has over 500 sugar factories with bagasse-based power generation of over 3,221 MW, while the untapped potential remains more than 5,000 MW (Jeremiah & Kabeyi, 2023).

In Brazil, the sugarcane mills are the fourth leading sources of electricity supply to the Brazil's grid electricity mix, even though it is just 15% of the industrial capacity of the sugar industry with estimates showing that sugarcane residues, through bioelectricity can supply up to 148,000 GWhrs to the grid (Jeremiah & Kabeyi, 2023).

In Pakistan, the electricity potential is estimated about 1,598 GWhrs to 2,894 GWhrs. This is an indicator of the huge electricity potential of the sugar cane industry in the global energy transition(Jeremiah & Kabeyi, 2023).

It is generally expected that a sugar factory should be an independent source of energy. This implies that it should produce its own electricity and heat using available materials, mainly filter cake, molasses, bagasse, and trash(Jeremiah & Kabeyi, 2023).

Although just 10 countries account for over 80% of sugarcane production, the crop is grown in more than 100 countries globally. The electricity demand for a typical sugar factory is between 20 and 30 kWh/ton of cane processed. A typical traditional and low efficient sugar factory can produce 60 to 70 kWh/tc, but modern and more efficient sugar factories can generate between 100 and 130 kWh/tc operating at higher steam pressure of up to 88 bars. Evaluation of bagasse cogeneration shows that it is as competitive as fossil fuel power plants in performance indicators(Jeremiah & Kabeyi, 2023).

The Kenyan sugar industry provides about five million direct and indirect jobs accounting for about 16% of the country's population. The sector also provides a livelihood to over 120,000 smallholder sugarcane farmers who account for about 88% of factory cane deliveries, with the remainder being supplied by the sugar factories themselves from their factory-owned nucleus estates which provides employment more than 40,000 employees. Sugar remains an important food item in all household while refined sugar is a major raw material for many food-based industries creating jobs and creating wealth for the producing as well as importing countrie. This shows that the sugar industry has significant socioeconomic benefits and should therefore be supported particularly for developing countries(Jeremiah & Kabeyi, 2023)

2.1 Types of Energy Audit

Energy audit provides the best solution to reduce energy bills and energy consumption whether it is a commercial or non-commercial sector. The type of energy audit that needs to be performed depends on:

- To what extent the penetration and depth required for the final inspection
- The industry used; its function and type and
- The size of the audit and the desired amount reached.

So, depend on the above mentioned there can be three types of energy audits and they are walk-through energy audits, target energy audits, and detailed energy audits.

2.1.1 Preliminary Energy Audit (Walk-through Energy Audit)

It is defined as the simple surveying audit in which the auditor only investigates the energy consumption of an organization and in this type of energy audit no major steps will be taken for consuming energy, it is also known as a preliminary audit. It is the first step of auditing and it is the simplest and quickest type of audit and is focused on the major energy consumption area. The walk-through energy audit is completed in the lesser time of spam. The auditor will find the energy consumption area and developed the full list of the energy-saving measures. Walkthrough energy audit is not sufficient for searching for an energy-saving solution. The auditor can take action in less time with great accuracy and profitability. From this type of energy audit, the auditor gets all the details of an organization which is further needed for a detailed energy audit.

The scopes of the preliminary (walk-through) energy audits are:

- In the company to found the consumption of energy.
- Minimal interview with the concerned person in the company.
- The only major problem area will be covered during this type of auditing.
- To identify the most easiest area of attention
- To find out the most likely ways to reduce consumption.
- Establish energy conservation in the company
- To find out the improvements and savings (in special way/in low cost).
- Estimate the scope for energy saving

2. 1.2 Targeted energy audit

The target energy audit starts with the finding of the walk-through energy audit. It provides detailed analysis on specific projects. This type of audit provides a detailed analysis of a specific project. This energy audit approach differs depending upon the structure type whether it is a commercial structure, residential, or industrial structure, but in all the structures more detailed information and data are needed. The outcomes are the recommendations regarding the actions to be taken. A clear and brief energy report should be submitted including the action plan "how to improve energy efficiency".

The scopes of targeted energy audits are almost similar to preliminary energy audit. Such that it helps, to establish the energy consumption in the company, minimal interview with the concerned person in the organization, only the targeted area will be covered during this audit, to find out the most likely ways to reduce the consumption (the easiest of interest) and to find out the improvements and savings

2.1.3 Detailed energy audit (Diagnostic Energy Audit)

This audit is also known as an investment-grade or comprehensive energy audit. In the detailed energy, the audit may need a complete analysis of possible capital-intensive modifications, including modeling and simulation. The detailed energy audit may need the collection of data over a long period for high accuracy and provide detailed energy consumption reports and detailed saving reports so that it becomes easy for the contractors to understand what exactly the measures to install. The detailed energy audit has been carried out in **three phases**, i.e., pre-audit phase, audit phase, and post-audit phase.

2.1.3.1 Phase 1-Pre-audit phase

A pre-audit phase is the first phase or first step of a comprehensive energy audit. In the pre-audit phase, the energy auditor organizes and plans for the energy audit. In this phase, a formal interview is conducted with the chief executive officer (CEO), plant manager, energy manager, and production manager. In this phase, a brief meeting is also conducted with all the heads and the concerned person. During the pre-audit phase, the energy auditor or accredited energy auditor intends to take the following measure:

- Discusses with the Energy manager or factory manager informally about the aim of the comprehensive energy audit
- Conduct of brief meeting / awareness programme with all divisional heads and persons about 2-3 hrs.
- Explains the meaning of the comprehensive energy audit and data needed during the audit phase
- Analyzes the major area of energy consumption
- Obtains the factory drawings such as factory lay out and designing some specific area. For instance, integrating flue gas line to bagasse dryer.

The outcomes of this phase should help to finalize the audit team, the expectation of the management from the comprehensive energy audit, and to plan the whole comprehensive energy audit within a period.

2.1.3.2 Phase 2-Audit phase

An audit phase is the second phase or second step of a comprehensive energy audit. The audit phase depends upon the nature and complexity of the site. In this phase, the audit can take days, weeks, or a month, as well as non-working hours and nights, are also included; to ensure that nothing is overlooked completely in the audit.

The following information will collect during the audit phase:

- Collecting of the information about the source of the energy supply
- Collect the energy bills to find out the tariff data and thermal & electrical energy cost
- Collecting of the load sector data

- ❖ Review of present energy management procedure and training program
- ❖ Energy and material flow diagram

The outcomes of the collected data will be:

- ➢ Preparing process & energy flow diagram
- ➢ Preparing general a well as specific material balance.
- ➢ Identification of Energy Conservation (ENCON) opportunities.
- ➢ Energy conservation options and recommendations**.**
- ➢ Energy-saving and payback period.
- ➢ Technical and feasibility report.
- ➢ Implementation plan for energy-saving measures and projects for the third phase (post-audit phase).
- ➢ Identification and development of Energy Conservation (ENON) opportunities

2.1.3.3 Phase 3-Post audit phase

For the evaluation of a capital budgeting decision, a set of procedures must require after the fact. The plan of action for the post-audit phase is implementation and follow-up. The result is to assist and implement energy consumption (ENCON) recommendation measures ad monitor the performance.

2.2 Importance of energy audit

In any industry, the three top operating costs are often found to be energy (electrical and thermal), labour and materials. Among the three, energy has the highest potential for cost reduction.

Energy audit will help to understand more about the ways energy is used in the industry, and help in identifying the areas where waste can occur and where scope of improvement exists .Such an audit program will review variations in energy costs, availability and reliability of supply of energy, decide on appropriate energy mix, identify energy conservation technologies, retrofit for energy conservation equipment's etc. In general energy audit is a translation of conservation ideas in to realities, by evolving technically feasible solutions with economic and other organizational considerations with specified time.

2. 3 Sugar Manufacturing Process

A flow diagram of a sugar manufacturing is shown in Figure 2.1 followed by brief description.

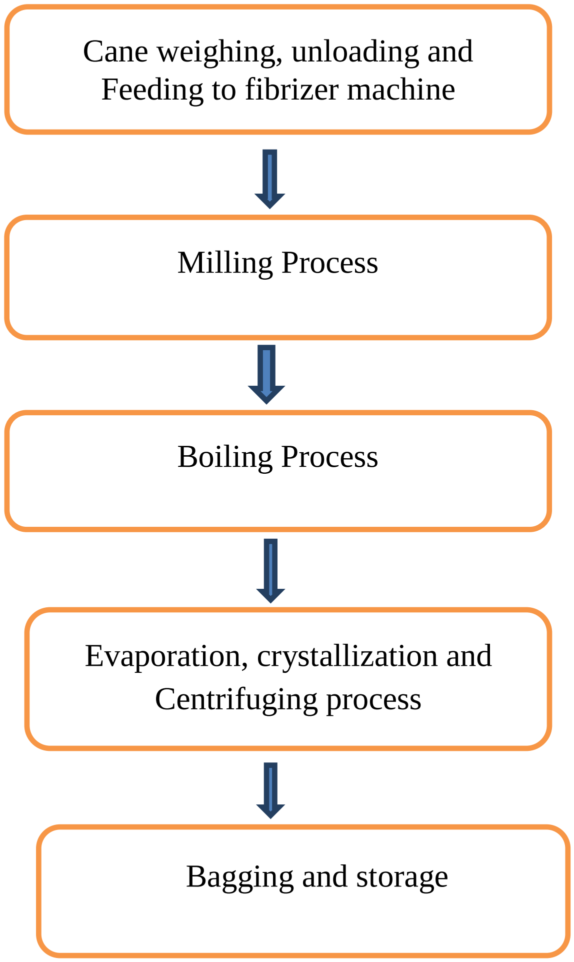


Figure 2.1: Flow Diagram of Sugar Manufacturing (Soppimath & Hudedmani, 2017)

The sugar manufacturing process normally comprises of juice extraction, juice clarification, and evaporation, crystallization, centrifuging, drying, and packing. To obtain the juice, sugar cane must be crushed, and this procedure breaks up the hard flatten the stems and the cane's nodes. To remove extra water, the collected juice is sometimes heated and then filtered. Bagasse, a dried cane byproduct, is frequently used as fuel to generate steam in cogeneration units.

2.4. Electrical Energy Audit in Sugar Industry

Electricity is one of the most convenient forms of energy among others because of clean and clear nature. The use of electricity for various needs is increasing every day but the cost of electricity rising due to increase in the fuel cost. Truly the energy usage index represents standard of living and economy. Preliminary energy audit is essentially a quick walk through energy survey identifying the scope and opportunities to improve energy efficiency. An optimistic and scientific approach to measure, monitor and manage industrial energy consumption to identify and arrest sources of wastage is known as Energy management system (Soppimath and Hudedmani, 2017). Energy Audit figures out the energy consumption of all the energy streams in an area. Thus key to a systematic approach for decision-making in the area of Energy Management. The present works use the following steps in carrying out electrical energy audit of sugar industry.

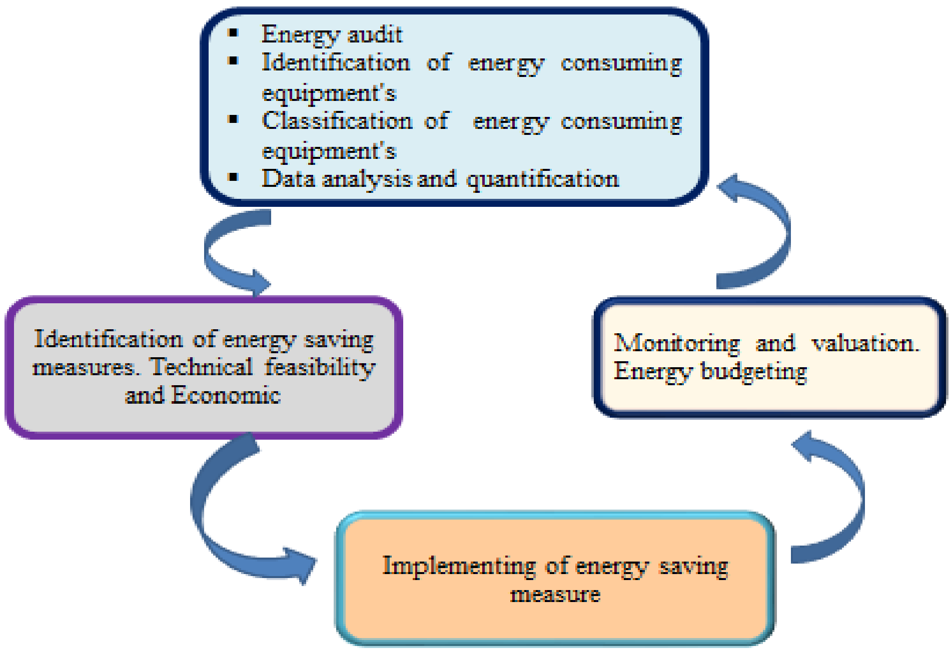


Figure 2.2: Energy audit Methodology and steps in Energy audit (Soppimath & Hudedmani, 2017)

Energy audit will help to generate energy utilization patterns and practices followed and best practices. Energy audit educates and gives greater awareness of energy usage to obtain better profit. Figure 2.2 outlines the energy audit methodology followed in the sugar industry.

As above mentioned, the literatures about sugar industry especially in boiler unit operation were studied well. But there is a gap due to study on specific area (on boiler) because sugar industry is a very vast. In other unit operation such as evaporation, extraction and crystallization unit operation there is huge amount of thermal and electrical energy wastage which utilizes for processing products and by products in order to more profitable and minimize an excess losses.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1 Materials and Reagents

Materials/Equipments: Some of the materials or equipment's which were used: multimeter, voltmeter, Infrared radiation (IR), Clamp meter, Combustion Gas Analyzer, ABBE refractometer, polari meter, analytical balance, oven, spoon, measuring cylinder, funnel, filter paper, beaker.

Reagents: For clarification of intermediate and by product materials of the factory only three reagents were used: Basic lead acetate and Keislguhr (99%, alpha chemicals Pvt Ltd Leading manufactured and exporter in Mumbai, India) and distilled water which is available (produce) from laboratory of wonji/shoa sugar factory. The main aim of clarification of above listed material was for the purpose of determination of material balance and thermal energy balance of each unit operations.

For measuring the electrical parameters, a multi-meter is required to measure current, voltage, power and instant power demand of a given machine part, motors and electric system. Infrared thermometers will be used to measure temperatures from a distance by sensing the thermal radiation from hot surface and insulation areas to estimate the wasted energy. Combustion Gas Analyzer- will be used to measure the emission gasses of O_2.

3.2. METHODS

The methods and procedures to be followed in the energy audit will be summarized in the following table.

Table3. 1. Methods and procedures of energy audit

Step no.	Plan of action	Purpose/result
	Phase I-Pre audit phase	
1	Plan and organize Walk-through audit Informal interview with, production/	• Organize instrument and time frame • Macro data collection • First hand observation and assessment of

	plant managers	current level of operation and practice
2	Introductory meeting with all division heads and person concerned with energy management	• To build up cooperation • Orientations and awareness creation • Issue questionnaire tailored for each department
	Phase II- Audit phase	
3	Primary data gathering, process flow diagram and energy utility diagram	• Historical data collection and analysis for setting up base line energy consumptions • All service Utilities system diagram (Single line power distribution diagram, water and compressed air and steam distribution • Prepare process flow chart • Design, operating data and schedule of operation • Annual energy bill and energy consumption patter (refer manual, logbook , nameplate etc.

4	Conduct survey and monitoring	• **Measurements:**
		  • Motor survey, insulation, energy loss survey, etc. with portable instruments for operating data
		  • Confirm and compare operating data with design data.

5	Conduct of detailed trials/tests for selected major energy equipment	• Trials/test: • 24 hrs. power monitoring • Load variation trends of machineries • Equipment performance tests etc
6	Analysis of energy use	• Energy and material balance (In milling, Evaporation, Crystallization and Boiler Plant)

		• Energy loss/waste analysis
7	Identification and development of energy conservation (ENCON) opportunities	• Conceive, develop and refine ideas • Review ideas suggested by unit personnel • Review ideas suggested in previous energy audit report if any • Brain storming and value analysis technique
8	Cost benefit analysis	• Assess technical feasibility, economic viability and options for implementation • Select the most promising projects • Priorities by low medium- and long-term measures
9	Report and presentation	• Documentation

3.2.1 Primary data gathering

Before going to detail energy audit of process unit operation the following fact data that was collected from WSSF in 2014 E.C production year are necessary. Such as: The designed capacity of WSSF is 6,250 ton crushed per day (TCD). But currently (2014 E.C) its average crushing capacity is 5,062.23 ton/day. Total crushed cane and Sugar produced of WSSF in 2014 E.C (2021/2022) was 349,647.90 & 34,325.02Ton/69.07 working days respectively. Total down time was 2,062.25 hr/155 days, Total working time was 1,657.75 hr/155 days, Factory started time 27/10/2021 G.C, Factory ended time was 30/04/2022 G.C, for one month (February 2022 G.C) was break.

By using the above basic data all process unit operation material and energy balance has been shown in detail in result and discussion section. The collected data were not only the above but also listed as follows:

Table: 3.2 collected data from Boiler unit of wonji/shoa sugar factory

Items	Quantity	Unit
Boiler feed water flow	130	TPH (ton per hour)
Boiler steam flow	125	TPH

Boiler steam temperature	485	ºC
Feed water temperature at de-aerator outlet.	105	ºC
Boiler steam pressure	63.4	Kg/cm^2
Flue gas temperature after ID FAN	141	ºC
Flue gas pressure	150	mmWc (millimeter per water column)
Pressure reduction and de-super heater system (PRDS) 1.5kg/cm^2 Pressure	0.94	Kg/cm^2
Pressure reduction and de-super heater system (PRDS) 1.5kg/cm^2 temperature	120	ºC
Pressure reduction and de-super heater system (PRDS) 1.5kg/cm^2 flow	71.1	TPH
Pressure reduction and de-super heater system (PRDS) 7kg/cm^2 pressure	6.12	Kg/cm^2
Pressure reduction and de-super heater system (PRDS) 7kg/cm^2 temperature	181	ºC
Pressure reduction and de-super heater system (PRDS) 7kg/cm^2 flow	16.8	TPH
Exhaust steam (introduce to first semikestener) pressure	1.25	Kg/cm^2
Exhaust steam temperature	120	ºC

The above table data are used for calculation of energy balance in boiler unit operation. These data were collected from boiler DCS, control panel and by direct measuring.

Then for calculating the energy balance of all heaters, pan house and steam consumption of first evaporator as well as overall evaporation station steam consumption the sample of clear juice and second vessel outlet brix was taken. To determine the energy consumption, inlet and outlet brix of clear juice was determined by laboratory.

Figure 3.1 ABBE refractometor

Figure 3.2 C.J & Syrup brix analysis by ABBE refractometor

All crystallization unit operation samples were also analyzed in laboratory. Each material data of laboratory analysis result were determined by: Refractometer and Polarimeter as juice.

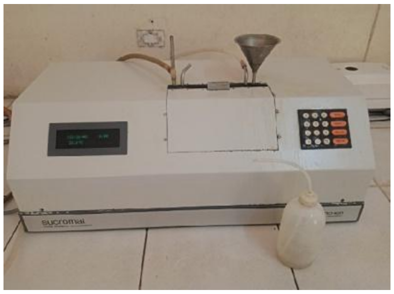


Figure 3.3 Polarimetor

Figure 3.4 Dry Basic lead acetate, Funnels and filter paper

Figure 3.5 analysis of pol by polarimetor

The materials brix% and pol reading were clarified by clarifying agent chemicals, filter paper and funnel before introduce to the above listed lab equipments: Pol was clarified by Basic lead acetate and brix was clarified by Keiselguhur.

3.2.1.1 Flue Gas data in boiler unit operation

Non portable Combustion Analyzer was used to analyze combustion continuously when flue gas passes to chimney. Then it can be read the percentage of O_2.

Table 3.3 Flue Gas recorded Data

Serial number	Gas %/ ºC /ppm recorded	Value obtained
1	Ambient Temperature	28
4	Flue gas temperature after ID Fan ºC	150
5	Oxygen % before economizer	10.8
Free stream air composition by volume		
Oxygen 21%	Nitrogen 79%	

3.2.1.2 Boiler Surface, Blow down and Feed Water Temperature Data

To estimate the energy lost from the boiler surfaces, surface temperatures of the boiler (cylindrical surface, the front and back surfaces), blow down and feed water were measured by infrared thermometer.

Table 3.4 Boiler Surface, Blowdown and Feed Water and Ambient Temperature Data

Serial number	Item	Temperature measured in⁰C
1	Boiler Cylindrical Surface	59
2	Boiler Front Surface	42 since covered by brick
3	Boiler Back Surface	118
4	Boiler furnace temperature	629
5	Blowdown Temperature	105
6	Ambient Temperature	27

Figure 3.6 inside temperature of boiler furnace

3.2.1.3 Steam Line Surfaces' Data Collection of boiler station

In order to conduct the energy performance evaluation of steam line surfaces data were collected in boiler unit operation by using portable instruments like infrared thermometer, meter (length) and by inspection.

Table 3.5 Steam line surface measured data of boiler unit operation of WSSF

S/N	Measured data	Obtained value	Unit
1	Ambient temperature	25	⁰C
2	Insulated surface Temperature	45	⁰C
3	Un insulated surface Temperature	80	⁰C
4	Length of bare line	4	M
5	Length of insulated line(Taken for analysis)	4	M
6	Diameter of insulated line	1.2	M
7	Diameter of un insulated line	1.2	M

3.2.1.4 Steam Leakage Collected data in WSSF of boiler station

To examine the proper functioning of steam lines with steam transportation data were collected by using portable instruments like infrared thermometer, meter (length) and by inspection.

Table 3.6 Steam leakage measured data of boiler unit operation of WSSF

S/N	Measured data	Obtained value	Unit
1	Number of leakage holes	At least 15	-
2	Leaking holes diameter	1.3	Mm
3	Leakage Temperature	128	^{0}C

3.2.1.5 Electrical energy bill data

Bills and all energy consumption data of the factory were listed within the factory logbook for many years. From these only 12-months (from July 2013 E.C to June 2014 E.C) data regarding the factory consumption of electricity, and produced crystalline white sugar (main product) as well as by products are presented in table 3.7 and 3.8:

Table 3.7 Monthly electricity used at WSSF in 2014 E.C

Months [E.C]	**Monthly electricity consumption [KWh]**	**Monthly electricity cost [ETB]**
July 2013	187,597.72	195,158.20
August 2013	191,731.95	671,325.20
September 2014	332,639.64	308,689.59
October 2014	1,223,838.70	1,135,722.31
November 2014	3,756,131.25	3,485,689.80
December 2014	5,299,094.23	4,917,559.44
January 2014	4,110,999.48	3,815,007.45
February 2014	1,074,444.55	997,084.54
March 2014	4,747,712.28	4,405,876.99
April 2014	4,083,057.53	3,789,077.39
May 2014	1,508,049.93	1,399,470.34
June 2014	514,619.39	477,566.79
Total	**27,029,916.6**	**25,598,228.04**

Table 3.8 Main product (Crystalline white sugar) and by product (final molasses, bagasse and filter cake) produced in the audit year

Month E.C	Main product (White sugar) in Qt	By product (Final molasses) in Qt	By product (Bagasse) in Qt	By product (Filter cake) in Qt
July 20113	Maintenance month	Maintenance month	Maintenance month	Maintenance month
August 2013	Maintenance month	Maintenance month	Maintenance month	Maintenance month
Sep 2014	Maintenance month	Maintenance month	Maintenance month	Maintenance month
Octo 2014	Maintenance month	Maintenance month	Maintenance month	Maintenance month
Nov 2014	82,615.2	22,000.0	278,317.0	31,759.05
Dec 2014	98,904	39,895.0	393,950.0	34,578.75
Jan 2014	40,159	19,350	142,874	16,667.7
Feb 2014	Break	Break	Break	Break
March 2014	69,588	22,764	237,459	27,650.6
April 2014	51,984	18,593	174,804	20,075.14
May 2014	Stopped due to lack of sugarcane	Stopped due to lack of sugarcane	Stopped due to lack of sugarcane	Stopped due to lack of sugarcane
June 2014	Stopped due to lack of sugarcane	Stopped due to lack of sugarcane	Stopped due to lack of sugarcane	Stopped due to lack of sugarcane
Total	**343,250.2**	**122,602**	**1,227,404**	**130,731.24**

3.2.1.6 Data of electrical energy consumption by motors and its quantification

There are 250 motors in WSSF. So, in order to clear and safe analysis & calculation, I have classify motors to three groups with reference to power rated capacity as described in table 3.9 bellow. The actual power consumption and load factor of each group comprising the motors is calculated and analyzed.

Table 3.9: Grouping of Energy Consuming Equipments in number

Group	Power Rating of the motor (KW)	Description	No of Motors
Group A	Above 90	Higher rating motor	22
Group B	22 to 90	Medium rating motor	60
Group C	Below 22 (0.045 to 21.99)	Lower rating motor	169

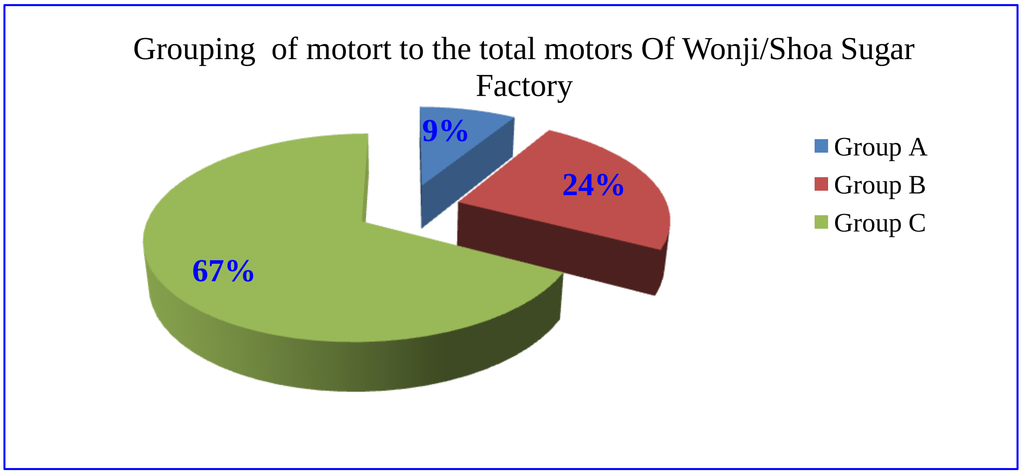


Figure 3.7: Grouping of Motors in WSSF

Table 3.10: Grouping of Energy Consuming Equipments in total KW

Group	Power Rating of the motor (KW)	Description	Total KW
Group A	Above 90	Higher rating motor	8,857
Group B	22 to 90	Medium rating motor	3,048.5
Group C	Below 22 (0.045 to 22)	Lower rating motor	1,015.88

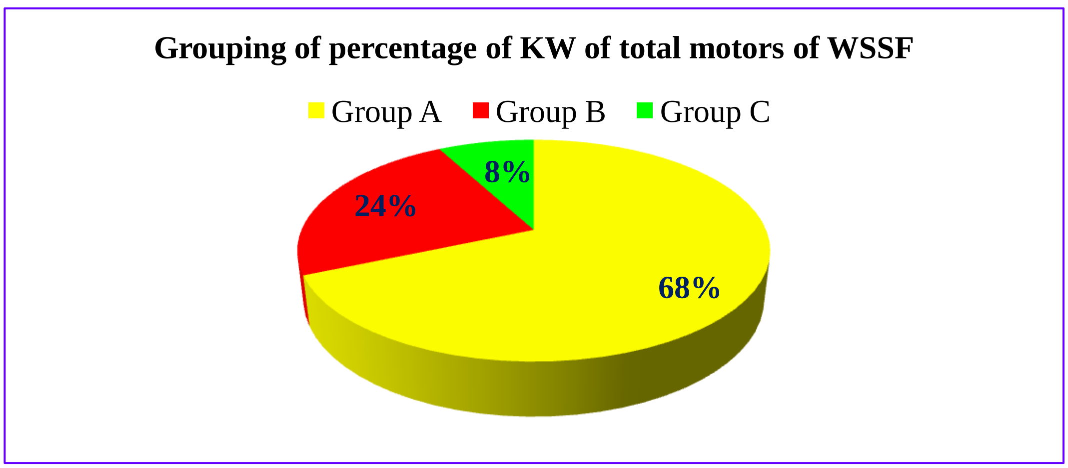


Figure 3.8: Grouping of Motors Load in WSSF

For determination of power and load factor of each motor of the factory, current and voltage were measured by clamp meter and voltmeter respectively.

Figure 3.9: Measuring of current load by clamp meter for weighed raw juice pump motor

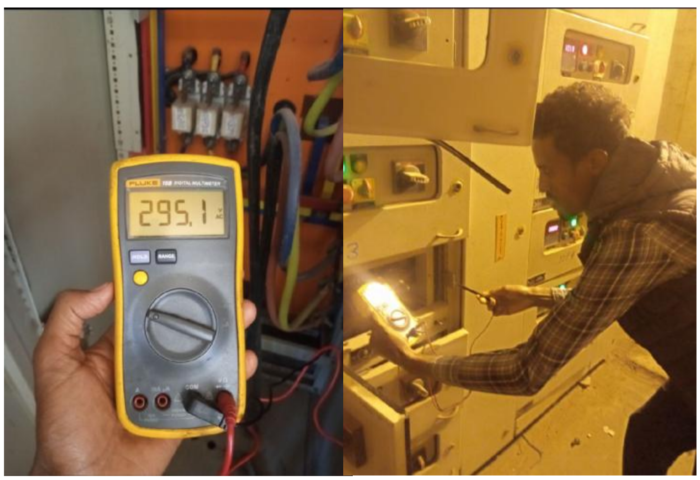


Figure 3.10: Measuring of voltage by voltmeter

CHAPTER FOUR

4. RESULT AND DISCUSSION

The process unit operations of sugar factory such as extraction unit, evaporation and crystallization units used both thermal and electrical energies to carry out sugar process. Higher electrical energy (21.15 Tera Joules) was consumed in extraction unit where as higher thermal energy (71.1 TPH steam from boiler) was consumed in evaporation unit in WSSF.

By using the collected data in methodology section all process unit operation material balance has been shown in detail in this section.

N.B: The detail electrical energy audit has been discussed at the end of this section as a whole (by including all unit operation of the factory).

4.1 Material balance and thermal energy audit of Extraction unit

4.1.1 General Material Balance

Cane(C) + **Imbibition water (I)** = **Mixed juice (M.J)** +**Bagasse (B)**………………….. (4.1)

- Imbibition water %cane and bagasse %cane are known by International commission for uniform method of sugar analysis (ICUMSA) Standard.
    - Imbibition water% cane = 33.5%
    - Bagasse% cane = 30%
- Based on 2014 E.C production year we can determine how many of Bagasse flows to boiler and mixed juice flow to clarification unit.

$$\text{Bagasse\% cane} = \frac{\text{Mass of Bagasse}}{\text{Mass of Cane}} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(4.2)}$$

So, by substituting the ICUMSA value the mass of bagasse becomes = <u>63.28 T/hr.</u>

<u>63.28</u> ton per hour bagasse can be flow to boiler unit in order to generate steam since bagasse is used as a fuel in sugar industry so sugar factory is **a very important resource of the country.**

<u>N.B</u> 63.28 is on average.

$$\text{Imbibition water\% cane} = \frac{\textbf{Mass of Imbibition}}{\textbf{Mass of Cane}} \times 100 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(4.3)}$$

Mass of imbibitions = 33.5 ×5,062.23 TCD/100=1,695.85 T/D = 70.66 <u>T/hr.</u>

So, 70.66 M^3 /hr can be flow between 4^{th} & 5^{th} mill.

Then we can determine mass of mixed juice by using general material balance. That means:

M.J = Cane(C) + Imbibition water (I) - Bagasse (B)

M.J = 5,062.23 TC/D + 1,695.85 TI/D – 1,518.67 TB/D = 5,239.41 T MJ/D = 218.31 T/hr.

Density of mixed juice is 1.06. if so:

Flow rate of M.J = <u>205.95 M^3/hr</u>

So, <u>205.95 M^3/hr</u> of mixed juice can be flow to clarification unit.

N.B it is an average flow rate, because mixed juice flow rate can be reach up to 300 M^3/hr.

Sugar balance in Final Sugarcane bagasse

Due to applied cold imbibition (less thermal energy) between fourth and fifth mill of WSSF an excess amount of sugar was lost in 2014 E.C as well as in previous year. Let us obtain the amount of lost in this year (2014 E.C):

Average moisture% bagasse was 52.5, which is determined by moisture teller at laboratory.

Average pol reading (Sucrose, fructose and glucose) % bagasse was 0.91, which also determined by laboratory with polarimetor equipment.

Pol% bagase = pol reading (2.6 + 0.0026(M))

Where

M – Moisture% bagasse

2.6 & 0.0026 – constant numbers which are given by ICUMSA

Pol% bagasse = 0.91(2.6 + 0.0026 (52.5))

Pol% bagasse = 2.50

We have been calculated before the amount of bagasse that is flow to boiler unit per hour, which is 63.28 ton per hour. So we can determine mass of pol (sugar),

$$\text{Pol\% bagasse} = \frac{mass\ of\ pol}{mass\ of\ bagasse} * 100 \qquad (4.4)$$

$$2.5 = \frac{mass\ of\ pol}{63.28\ tph} * 100$$

Mass of sugar = 1.58 ton per hour = 15.8 Quintal per hour = 379.2 Quintal/day.

The standard value (ICUMSA value) of pol% bagasse is bellow 2. So, minimum 0.5 pol% bagasse has been lost in 2014 E.C of WSSF.

So, we can determine the lost of sugar;

0.5 * 63.28 tph /100 = 0.32 ton per hour = 3.2 Quintal per hour = 76.8 Qt/day =7,680 Kg/day.

The factory sales 1 Kg sugar by 49 ETB

So, 7,680 Kg * 49 = 376,320 ETB/day = 11,289,600 ETB/ month = **56,448,000 ETB/ 5month**

So, above 56,448,000 ETB has been lost in 2014 E.C crushing year of WSSF.

The lost of that high amount of sugar is two disadvantages;

- When burn at the boiler furnace, it is main cause of rust of boiler water tubes
- Decrease the productivity, then goes down to risk

In addition to above; there are so many materials balances in extraction unit, let skip it since they take so many pages, you can see in detail at www.SugarprocrssTech.com.

4.1.2 Thermal energy of extraction unit

In extraction unit all process is driven by electrical energy, the only applying of thermal energy is for mill sanitation. The mill sanitation steam is 3 Kg/h, but which applies only twice a week. So we can say thermal energy is not applied in Extraction unit of WSSF. The detailed flow chart of extraction unit is described in appendix.

4.3 Material balance and thermal energy audit of clarification unit

4.3.1 Material balance of lime station:

Lime% cane = 0.17%, ICUMSA standard.

So, $0.17 \times \frac{5{,}062.23\ TCD}{100}$ = 8.61 T/D = 0.36 T/hr = 360 kg/hr = 2,880 kg/shift (8 hr)

Therefore 2,880 kg solid lime per shift was consumed in WSSF in 2014 E.C.

This amount of lime was prepared in preparation tank in order to produce calcium hydroxide (Milk of lime (MOL)).

So, we can calculate flow rate of $Ca(OH)_2$:

MOL% Mixed Juice (M.J) = 1.5%, ICUMSA standard.

So, $1.5 \times \frac{205.95\ M^3/hr}{100}$ =3.09 M^3/hr = 30.9 HL (hecto liter)/hr = 3,090 Ltr/hr.

30.9 HL/hr or 247.2 HL/shift milk of lime was prepared in WSSF.

4.3.2 Material balance and energy loss of Sulphur station:

SO_2% cane = 0.07%, ICUMSA standard.

So, $0.07\times \frac{5{,}062.23\ TCD}{100}$ = 3.54 T/D = 0.15 T/hr = 150 kg/hr = 1,200 kg/shift (8 hr)

1,200 kg solid sulphur per shift was consumed in WSSF in 2014 E.C.

4.4 Material balance of filtration unit

The settled mud from the clarifier with 6.8 - 7.0 PH and 22 - 24 Bx contains the muddy juice temperature above 80^{O}C. For better filtration temperature should be on higher side. Viscosity of juice is inversely proportional to temperature. Low viscosity favors the filtration.

General Operational Parameters for vacuum filters:

% Pol in filter cake (F.C) $\leq \mathbf{1}$

- High vacuum = 350 to 450 mm of Hg
- Low vacuum = 200 to 250 mm of Hg
- Mud (filter cake) thickness = 6.5 mm – 10 mm
- Wash water pressure = 2.0 -2.5 kg/cm^2
- Wash water temperature = 60 – 75^{O}C.
- Speed rotation = 3 – 5 min. per rotation
- Amount of bagacillo = 5 – 7 kg per ton of cane
- Filter cake (F.C) % cane = 3.5 – 4 % on cane

Pol% filter cake at WSSF in 2014 E.C production year was 1.8 up to 5.5. But as above mentioned the ICUMSA value of the content of pol in filter cake should be $\leq$ 1 .So, when we take if the amount of lost pol% filter cake is 2 to a minimum; we can calculate the quantity of pol lost through filter cake.

Filter cake (F.C) % cane = 3.5 -4 = 3.75

The average crushed cane per day in 2014 E.C was 5,062.23 TCD = 210.93 TCH (tone crushed per hour). So, F.C% Cane = $\frac{Mass\ of\ F.C}{Mass\ of\ Cane}$*100……………………………………………………………… (4.5)

3.75 = $\frac{Mass\ of\ F.C}{5{,}062.23\ TCD}$*100

Mass of F.C = $\frac{3.75 \times 5{,}062.23\ TCD}{100}$ = 189.8 ton/day = 7.9 ton/hr = 79 Qt/hr

Now let us calculate the amount of loss of pol in filter cake:

Pol% F.C = $\frac{Mass\ of\ pol}{Mass\ of\ F.C}$ * 100……………………………………………………………… (4.6)

2 = $\frac{Mass\ of\ pol}{189.8TCD}$ * 100

Mass of pol = $\frac{2 * 189.8\ tcd}{100}$ =.3.8 ton/day = 38 Qt/day = 3,800 Kg/day.

The price of 1Kg sugar currently is 49 ETB. So, 3,800 Kg sugar = 186,200 ETB. Therefore; 186,200 ETB was lost per day in 2014 E.C crushing year of WSSF.

The main reason of lost of that excess amount of sugar with filter cake in WSSF is due to:

i. Lack of bagacilo (fine bagasse)
ii. Decreasing vacuum pressure
iii. Increasing rpm
iv. Increasing mud thickness
v. Absence of hot sweetening water
vi. Poor clarification performance

Therefore; to bring the pol% filter cake to a standard value the following main parameters should be apply:

I. Bagacillo quantity should be 6 to 8 kg per tonne of cane.
II. Higher & Lower vacuum pressure should be 450mmHg and 250mmHg respectively
III. The mud thickness not more than 0.8mm
IV. The sweetening wash water temperature should be 75^{o}c
V. Clarification performance have to be excellent

4.5 Material and energy balance of Evaporation unit

4.5.1 Material balance of evaporation unit

The input material (clear juice) from dorr clarifier to first effect evaporator was 200TPH and the output material (syrup) was 60TPH. The amount of evaporated water was determined by the following formula (Hugot's Formula):

Let:

E = weight of water to be evaporated % clear juice

J = weight of clear juice obtained % cane

S = weight of syrup % cane, leaving the multiple effects

Bj = brix of juice

Bs = brix of syrup.

Since the weight of dissolved material is the same before and after evaporation, we may equate these quantities as follows:

$$J*Bj, = S*Bs \qquad \text{(Hugot, 1960) (4.7)}$$

Hence: $$S = J * \frac{Bj}{Bs}$$

And: $$E = J - S = J\left(1 - \frac{Bj}{Bs}\right) \qquad (4.8)$$

If: J = 100, Bj = 15.5, Bs = 60, we have:

$$E = 100\left(1 - \frac{15.5}{60}\right) = 74.2\%$$ So, amount of water is 74.2% clear juice.

This is poor efficiency. Since evaporator efficiency should be above **80%.**

In sugar factory evaporation eliminates by far the greatest weight of material, if high efficiency it will reach up to 80% of the weight of cane. By reason of the high latent heat of vaporization of water, this will also obviously be the operation which involves the greatest number of heat units.

4.5.2 Energy balance of evaporation unit

By using the data in methodology section the energy balance of all heaters, pan house and steam consumption of first evaporator as well as overall evaporation station steam consumption has been calculated.

Now let us determine steam consumption of first effect (first semi-kestener).

To determine this consumption, inlet and outlet brix of clear juice was determined by laboratory. As I have been analyzed clear juice, syrup and first effect outlet juice brix by laboratory for seven days (10/04/2022 - 16/04/2022):

Table: 4.1 One week juice and syrup brix & its flow rate analysis result

Date	Brix of Clear juice in %	Brix of first semi-kestener outlet juice in %	Brix of syrup in %	Flow rate of clear juice in TPH (Ton per hour)
10/04/2022	15.73	22.20	60.18	200
11/04/2022	15.87	22.39	60.41	200
12/04/2022	15.17	21.81	59.81	200
13/04/2022	15.17	21.85	59.83	200
14/04/2022	15.10	21.67	59.69	200
15/04/2022	15.56	22.00	60.03	200
16/04/2022	15.72	22.13	60.10	200
Average	**15.5**	**22.0**	**60**	**200**

Then to calculate the consumption of steam at first evaporator:

$$\text{S (steam)} = \frac{\textbf{outlet brix} - \textbf{inlet brix}}{\textbf{outlet brix}} \times \text{clear juice flowrate} \ldots\ldots.. (4.9)$$

$$= \frac{22\% - 15.5\%}{22\%} \times 200 \text{ TPH} = 59.1 \text{ TPH}$$

Therefore **59.1 TPH** of exhaust steam from boiler has entering to WSSF of first evaporator (first semi kestener effect).

Then we can calculate the overall percentage of evaporation station.

$$\text{i.e. } \textbf{\%E} = \frac{\textbf{Outlet concentrated juice brix(syrup)} - \textbf{inlet brix (clear juice brix)}}{\textbf{Outlet concentrated juice brix}} * 100 \ldots. (4.10)$$

$$= \frac{60\% - 15.5\%}{60\%} \times 100 = \underline{\underline{\textbf{74.2\%}}}$$

So, the performances of wonji/shoa sugar factory (WSSF) evaporators are poor, since good performance evaporators are above **80%**.

Then we can calculate the total evaporation station of WSSF:

$$\text{Total evaporation} = \frac{\text{Syrup brix} - \text{clear juice brix}}{\text{syrup brix}} \times \text{clear juice flow rat} \ldots\ldots\ldots\ldots (4.11)$$

$$= \frac{60\% - 15.5\%}{60\%} \times 200 \text{ TPH}$$

$= \underline{148.3 \text{ TPH}}$

Then after, let us calculate the amount (mass) of vapor flow to pan house (crystallization plant) and to juice heaters as well as vapor loss to canal through melti-jet condenser.

V = X

IV = X + 12.82 TPH

III = X + 12.82 TPH + 7 TPH

II = X + 12.82 TPH + 7 TPH + 8 TPH – 12 TPH → minus 12 TPH is due to come from boiler.

I = X + 12.82 TPH + 7 TPH + 8 TPH – 12 TPH + P

Total = 5X + 51.28 TPH + 21 TPH + 16 TPH – 24 TPH + P

= 5X + 64.28 TPPH + P

N.B, we have got total evaporation as above calculated.

i.e. = 148.3 TPH and evaporation at only first evaporator = 59.1 TPH

Then we can determine the value of X (Vapor loss to canal through condenser) and the value of P (vapor move to crystallization unit)

⇒ 5X + 64.28 TPH = 148.3 TPH

X + 12.82 TPH +7 TPH + 18 TPH – 12 TPH + P → Vapor bleed (give up) from I (first evaporator)

⇒ 5X + 64.28 TPH + P = 148.3 TPH

X + 15.82 TPH + P = 59.1 TPH } -1 by symentleous equation. When we multiply The lower part by -1we will get:

⇒ 4X + 48.46 TPH = 89.2 TPH

4X =89.2 TPH – 48.46 TPH

4X = 40.74 TPH

X = 10.20 TPH

Therefore **10.20 TPH** Vapor has been loosed to canal through Evaporator melti-jet condenser in WSSF.

Then to calculate the value of **P:**

10.20 TPH +15.82 TPH + P = 59.1 TPH

⇨ P = 59.1 TPH – 26.02 TPH

P = 33.08 TPH

Therefore 33.08 TPH vapor has been transferred to pan house for the purpose of: Massecuit boiling (for both high & low grade massecuit), Molasses reconditioning, pan body washing, Centrifugal washing & Cut-Over line cleaning

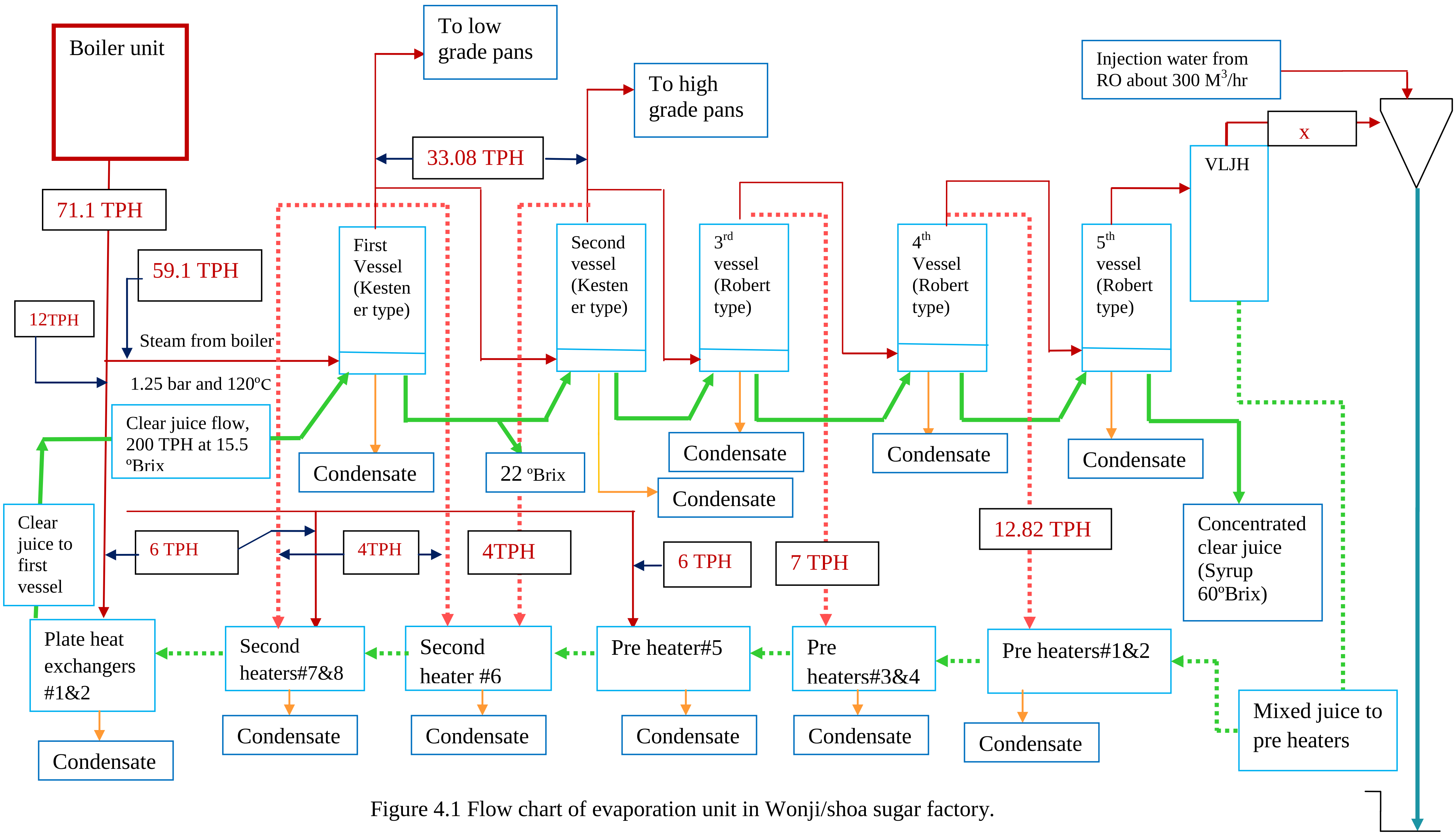


Figure 4.1 Flow chart of evaporation unit in Wonji/shoa sugar factory.

4.6 Material and Energy balance of Crystallization unit

4.6.1 Material balance of Crystallization unit

The following data were average of seven days analyzed from WSSF in Laboratory:

Table 4.2 Crystallization unit materials brix%, pol% and purity analysis result

Material Name	Brix%	Pol%	Purity
Syrup	60	51.9	86.5
A massecuite	89.4	78.8	88.1
B1 massecuite	94.3	72.9	77.3
B2 massecuite	95.5	58.4	61.1
C massecuite	96.7	57.8	59.8
AH molasses	79.5	58.7	73.8
AL molasses	71.5	65.6	91.8
B1H molasses	83	50.2	60.5
B2H molasses	84.4	50.6	60
Sugars and final molasses			
A sugar	99	98.9	99.9
B1 sugar	92	86.9	94.5
B2 sugar	93.1	85.9	92.3
CFW	94.3	85.9	91.1
CAW	95.00	86.3	90.8
Final molasses	89.1	36.1	40.5

The feeding system of vacuum pan boiling scheme is seems like bellow:

“B” Sugar was used as seed and as melt for “A” massecuite boiling “C” After worker sugar as melt was used for “A” massecuite boiling “A” Heavy molasses was used for “B” massecuite boiling only “B” heavy molasses was used for “C” massecuite boiling “C” Light molasses was used as graining material for “C” massecuite boiling. but now WSSF CAF (C massecuite after worker) continuous centrifugal machine out of service. Due to this reason C-Light molasses is not available. “A” Light molasses and syrup are used for “A” massecuite boilingSyrup is used only in A-massecuite boiling.

4.6.1.1 Capacity of Batch and Continuous pans

Crushing Capacity of wonji/shoa sugar factory (WSSF) in 2014 E.C = 210.93 TCH = 5,062.23 TCD.

“A” massecuite%cane = 25 to 30%

“B1” & “B2” massecuite%cane = 12 to 13%

“C” massecuite%cane = 6 to 8%

” A” Massecuite Quantity = 210.93 TPH x 30% = 63.23 T/hr = 1,517.52 T/day

” B1” & “B2” Massecuite Quantity = 210.93 x 13% = 27.42 T/hr = 658.08 T/day

Developed B1 grain at continuous pan = 40 TPH

” C” Massecuite Quantity = 210.93 x 8% = 16.87 T/hr = 404.88 T/day

4.6.1.2 Discussion and Analysis of Final molasses

Final molasses is the end by-product of the processing in the sugar factory. It is also called C molasses or blackstrap molasses. Final molasses generally consist of 30-35% sucrose, 10-25% fructose and glucose, 16.5 – 17.5% ash, 2-3% non-sugar compounds, &minerals and about 45-55% of total fermentable sugars.

Final molasses is used as an ingredient in the bakery industry also as an animal feed additive and as a fermentation feedstock (Alcohol factory to produce wine and other drinkable alcohols); but in Wonji/shoa sugar factory (WSSF) in 2014 E.C the average final molasses sucrose to a minimum was 39%.

Therefore to a minimum about 2.5 of sucrose% final molasses was lost. Let us calculate the amount of lost:

Final molasses (F.M)% cane is 3.5 – 4.5, average = 4, ICUMSA standard.

The average crushed cane per day in 2014 E.C was 5,062.23 TCD = 210.93 TCH (tone crushed per hour). So,

$$\text{F.M\% Cane} = \frac{Mass\ of\ F.M}{Mass\ of\ Cane} * 100 \qquad (4.12)$$

$$4 = \frac{Mass\ of\ F.M}{5{,}062.23\ TCD} * 100$$

Mass of F.M = $\frac{4 \times 5,062.23\ TCD}{100}$ = 202.5 ton/day = 8.4 ton/hr = 84 Qt/hr

Now let us calculate the amount of losses of sucrose in final molasses:

Sucrose% F.M = $\frac{Mass\ of sucrosel}{Mass\ of\ F.M}$ * 100…………………………………………………… (4.13)

2.5 = $\frac{Mass\ of sucrosel}{202.5\ TCD}$ * 100

Mass of sucrose = $\frac{2.5 * 202.5\ tcd}{100}$ =.5.1 ton/day = 51 Qt/day = 5,100 Kg/day.

The price of 1Kg sugar currently was 49 ETB. So, 5,100 Kg sugar = 249,900 ETB. Therefore; 249,900 ETB was loosed per day in 2014 E.C crushing year of WSSF.

The main reason of los of that excess amount of sugar with final molasses in WSSF was due to: Feeding of high purity material to C-massecuite, like A heavy molasses and syrup. Improper boiling of massecuite (higher or lower temperature and high or low vacuum pressure), working with damaged centrifugal sieve at CFW continuous centrifugal machine & absence of cooling system at twin vertical crystallizer.

4.6.2 Energy balance of Crystallization unit

About 33.08 TPH or 33,080 Kg/hr steam transfer to crystallization unit as calculated at evaporation energy balance. At crystallization unit this amount of steam was distributed to:

i. Both high- and low-grade pans for the purpose of massecuite boiling
ii. All heavy molasses conditioner for the purpose of dissolve crystal content
iii. All vacuum pan body for the purpose of washing massecuites which remain during discharge to crystallizer
iv. Melter for the purpose of melting low grade sugars (magma).

When lack of sugarcane and syrup happen, all high-grade vacuum pans steam line have to be shut of which introduce in to steam chest where as low-grade vacuum pans can boil the massecuite since availability of molasses. During this time an excess amount of steam (thermal energy) loss in to atmosphere. Let us calculate the mass of loss steam.

According to SivaRamaKrishna Alluri:

- For Pan washing is 0.2 to 0.25 % cane
- For Seed (B1, B2& C sugar) melting is 0.4 to 0.6 % cane.

- For molasses reconditioning is 0.4 to 0.6 % cane

The average crushed cane per day in 2014 E.C was 5,062.23 TCD = 210.93 TCH (tone crushed per hour). So,

Mass of steam for vacuum pan body part washing $\frac{0.23 * 5,062.23 \text{ TCD}}{100}$ = 11.64 T/day = 0.49 T/h = 490 Kg/h.

Mass of seam for low grade sugar melting $\frac{0.*5,062.23 \text{ TCD}}{100}$ = 225.31 T/day = 1.05 T/hr = 1,050 Kg/hr.

The same is true for molasses reconditioning which is 1,050 Kg/hr.

According to SivaRamaKrishna Alluri:

Vapour required for massecuite boiling =

$$\frac{\text{K x M x [(Brix of massecuite – Brix of feed material)}}{\text{Brix of massecuite}} \ldots\ldots (4.14)$$

K = 1.5 for Batch Pan and 1.2 for Continuous Pan.

M = Quantity of massecuite in Ton/hr.

In WSSF there are four high grade (A massecuite boiling) vacuum pans, one continuous pan and four low grade (B1, B2 & C massecuite boiling) vacuum pans. The capacity of:

- High grade vacuum pans are 100Tonn except vacuum pan no 3 which is 80T
- Continuous pan 240 Ton
- All low-grade vacuum pans are 80 Ton

So, we can calculate vapor (steam) required for low grades including continuous vacuum pan by using equation 7.20 and you see the brix in table 7.3 and also quantity of massecuite in TPH has been calculated at section 7.6.1.3

Vapour required for developed B1 massecuite boiling = $\frac{\text{1.2 x 40 TPH x [(96.3– 79.5)}}{96.3}$ = 8.4 T/hr = 8,400 Kg/hr

Vapour required for undeveloped B1 & B2 massecuite boiling =

$\frac{\text{1.5 x 27.42 TPH x [(94.9– 81.53)}}{94.9}$ = 5.8 T/hr = 5,800 Kg/hr

Vapour required for C massecuite boiling = $\frac{1.5 \text{ x } 16.87 \text{ TPH x } [(96.7-84.4)}{96.7}$ = 3.3 T/hr = 3,200 Kg/hr

Therefore total vapor required for vacuum pan body, molasses reconditioning, magma melting, continuous pan, B1 & B2 and C massecuite boiling is = 19,990 Kg/hr.

Hence, only 19,990 Kg/hr steam is functional (save) out of 33,080 Kg/hr during lack of cane and lack of syrup. So, loss of steam can be determined by subtracting 19,990 Kg/hr from 33,080 Kg/hr = **13,090 Kg/hr** steam can be loss to atmosphere.

Figure 4.2 image of an excess amount of steam loss to atmosphere in WSSF

These records are taken for different day and night. This amount of energy can be save by integrating to overhead clarified water tank or by installing new tank at the bottom for the purpose of hot imbibitions in extraction unit because our factory use cold imbibitions. **Cold imbibition is never recommended** in order to prevent loss of sucrose through bagasse to boiler and for preventing excess moisture content in bagasse.

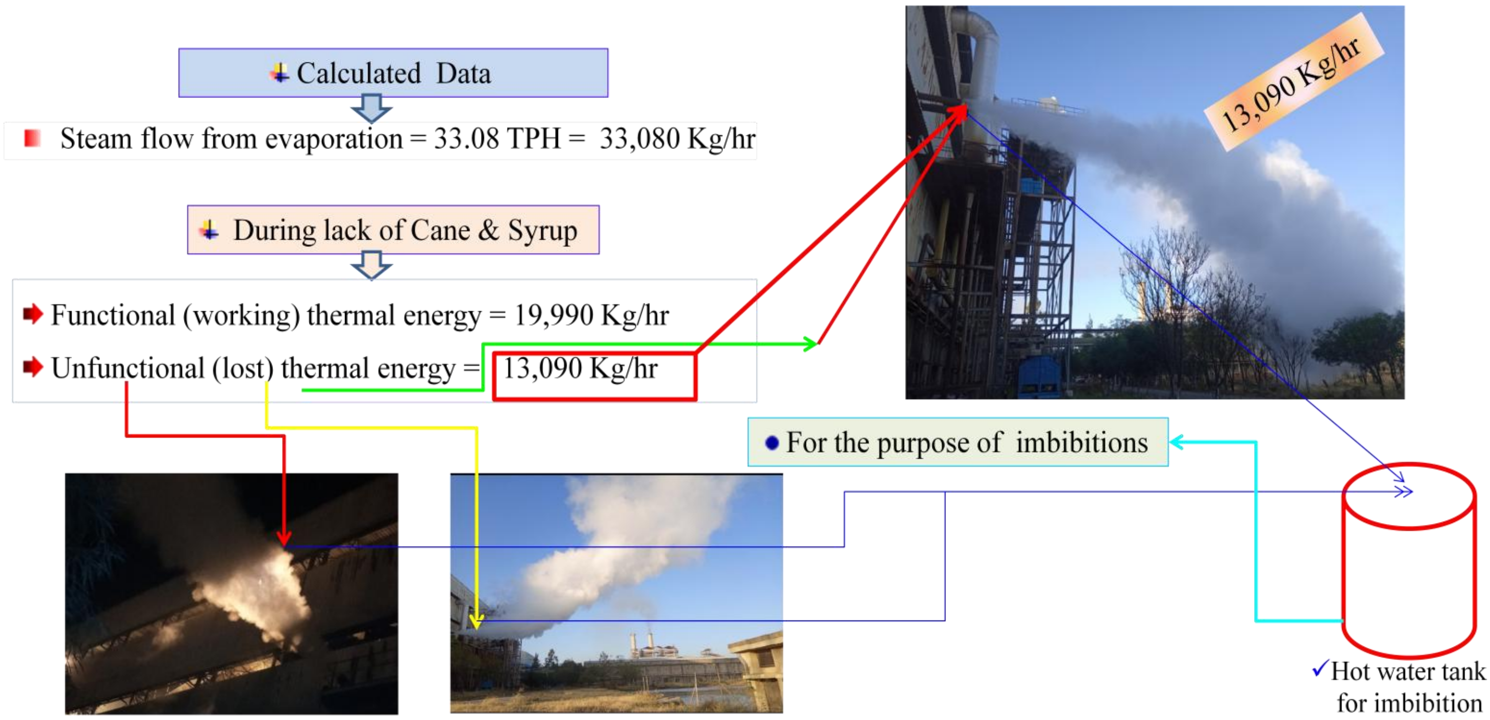


Figure 4.3 Selected areas for thermal energy (condensate) production of WSSF.

4.7 Result and Discussion of Thermal Energy in Boiler

The type of boiler used by the factory is water tube steam-generator and it is manufactured by an UTTAM India company in 2013 G.C. In Wonji/Shoa sugar factory there are two numbers bagasse fired boilers, each of the designed capacity of the boiler is steam flow rate 130 t/hr, pressure 65 bars and temperature 510 +/- 5 ˚C.

Its main function is to supply superheated steam to the turbine and then the exhaust steam transfer to sugar process unit operations. However turbine is not functional since 2016 G.C up to now.

4.7.1 Mass Balance of the Combustion System

1) Mass Balance of Fuel (Bagasse) Combustion

In order to calculate the amount of energy liberated during bagasse combustion, the mass of bagasse, the combustion air and the combustion products are very important.

A) Air Fuel Ratio of bagasse Combustion

The actual mass of air supplied/ kg of fuel (AAS),theoretical air fuel ratio and excess air of bagasse are computed so that the mass flow rate of flue gases can be obtained.

Actual mass of air supplied/ kg of fuel (AAS) = $\{1 + \frac{Excess\ air}{100}$x theoretical air

But, Theoretical Air = [(11.6 x C) + {34.8 x (H 2 - O2 /8)} + (4.35 x S)]/100 kg of air /kg of bagasse. To calculate the theoretical air, composition of bagasse and ultimate analysis (%) given in the table 4.3 below are used.

Table 4.3 Composition of bagasse and Ultimate Analysis (%)

Composition of bagasse	Ultimate Analysis in (%)
Carbon (C)	25.83
Hydrogen (H2)	6
Oxygen (O2)	16.90
Sulphur(S)	0.85
Nitrogen (N2)	0.45
Moisture M	50

Table 4.4 Molecular weight of the constituents of the bagasse

Element or Compound	**C**	**O_2**	**H_2**	**S**	**N_2**	**CO_2**	**SO_2**	**H_2O**
Molecular Weight	12	32	2	32	28	44	64	18

Theoretical Air = [(11.6 x C) + {34.8 x (H2 - O2 /8)} + (4.35 x S)]/100 kg of air/kg of bagasse……………………………………………………………………………… (4.15)

TA= (11.6 x0.26) + {34.8 x (0.06 – 0.17 /8)} + (4.35 x 0.0085) =4.41kg of air/kg of bagasse

Excess air supplied (EA) = $\frac{O\%}{21\% - O\%} * 100$…………………………………….. (4.16)

To calculate the excess air, flue gas data measured by flue gas Analyzer (both at non portable flue gas analyzer and record directly on Boiler DCS) was used.

Excess air supplied (EA) = $\frac{10.8\%}{21\% - 10.8\%} * 100 = 105.9\%$

For bagasse fired boiler the recommended percent of excess air is 20% with the volume percent of CO_2 20% while the calculated average excess air supplied to the furnace of the WSSF factory‘s boiler is 105.9%.This high excess air affects energy loss due to dry flue gas. From this discussion, the volume percent of $C0_2$ is in required range and the excess air can be controlled by reducing motor capacity of FD fan of the boiler.

Then; Actual mass of air supplied/ kg of fuel (AAS) = [1 + Excess Air/100] x theoretical air
AAS= [1 + 105.9/100] x 4.41= 9.08 kg of air/kg of bagasse………………………….. (4.17)

B) Mass of Dry Flue Gases

The mass flow rate of the flue gases must be calculated to have energy losses due to flue gases. To do this the molecular weight of the constituents of the fuel and composition of bagasse and their ultimate analysis are crucial for the actual chemical reaction (the combustible elements in bagasse are carbon, hydrogen and sulphur) in the boiler.

1kg of fuel + Dry air → CO_2 + H_2O+ SO_2 + N_2………………………………………… (4.18)

When a kg of fuel is completely burnt by dry air, carbon dioxide, water vapor and sulphur dioxide, with inert nitrogen are produced as shown in the above reaction.

i) Mass of Carbon dioxide(kg) per 1kg of fuel

$C + O_2 \rightarrow CO_2$

12 + 32 → 44 ; From this equation ,12 kg of C requires 32 kg of O_2 to form 44 kg of CO_2 therefore 1 kg of C requires (32/12 kg=2.67 kg) of O_2. Then by taking ultimate analysis of C percentage in bagasse (Table 4.3 = 25.83%)

$0.26xC + 0.26x2.67O_2 \rightarrow 0.95CO_2$

ii) Mass of Sulphur dioxide (kg) per 1kg of bagasse

$S + O_2 + \rightarrow SO_2$

32 + 32 → 64

From the above reaction 32 kg of S requires 32 kg of O_2 to form 64 kg of SO_2, therefore 1 kg of S requires (32/32 kg = 1 kg)of oxygen. Then by taking ultimate analysis of S percentage in bagasse (Table 4.3 = 0.85%)

$0.0085S + 0.0085x1O_2 \rightarrow 0.017SO_2$

iii)Mass of Water(kg) per 1kg of bagasse

$2H_2 + O_2 \rightarrow 2H_2O$

4 kg + 32kg → 36kg

From the above reaction 4 kg of hydrogen requires 32 kg of Oxygen to form 36 kg of water vapor (H_2O), therefore 1 kg of H_2 requires 8 kg of O_2. Then by taking ultimate analysis of H_2 percentage in bagasse (Table 4.3 = 6%)

$0.06H_2 + 0.06x8O_2 \rightarrow 0.54H_2O$, Here mass of water=$m_v$, H2O = 0.54kg of water vapor/1kg of bagasse

$\dot{m}_{\text{Flue gas}}$: Mass flow rate of dry flue gas.

m = mass of CO_2 + mass of SO_2 + mass of N_2 + mass of O_2

$m = (0.26*44)/12 + (0.0085*64)/32 + (AAS * 79)/100 + EA \frac{21}{100}$

But, EA=AAS-TA= 9.08 - 4.41= 4.67 kg of air per kg of bagasse

$m = (0.26 * 44)/12 + (0.0085 * 64)/32 + (9.08 * 79)/100 + 4.67 * \frac{21}{100} = 9.12$ kg of flue gas per kg of bagasse

Excess O_2 = 9.12kg x 0.21(by mass) = 1.92kg

Excess N_2 = 9.12kg x 0.79(by mass) =7.20kg + 1.373kg = 8.57 kg

Mass flow rate of dry flue gas =m x mass flow rate of bagasse

$\dot{m}_{\text{Flue gas}} = \text{m} * \dot{m}_{\text{bagasse}}$ = 9.12 kg of flue gas per kg of bagasse * 16.06 kg bagasse/s

$\dot{m}_{\text{Flue gas}}$ **= 146.47 kg of flue gas/s**

Figure 4.3 mass flow of boiler flue gas in WSSF

4.7.2 Mass Balance of Steam System

As table 3.2 mentioned boiler feed water and steam flow rate are 130 TPH and 125 TPH respectively. Which are taken as average value during recorded on boiler DCS. So, we can determine the flow rate of blowdown.

I. Mass Flow Rate of Blowdown

Mass flow rate of blow down is essential to compute energy loss due to blow down. In wonji/shoa sugar factory blow down is continuously remove out, which is called continuously blow down (CBD). Since all flow rate (feed water, steam and CBD) continuous; CBD can be determine simply by subtracting steam flow from feed water.

Mass of Feed Water input = Mass of water blow down + Mass of Steam

Mass of water blow down = Mass of Feed Water input – Mass of steam

Feed water flow rate = 130TPH = $\frac{36.1\text{ kg}}{s}$ Steam flow rate ≈ 125 TPH = $\frac{34.7\text{ kg,}}{s}$

$\dot{m}_{\text{Blowdown}} = \dot{m}_{\text{Feed water}} - \dot{m}_{\text{steam}} = \frac{\mathbf{1.4\ kg,}}{\boldsymbol{s}}$

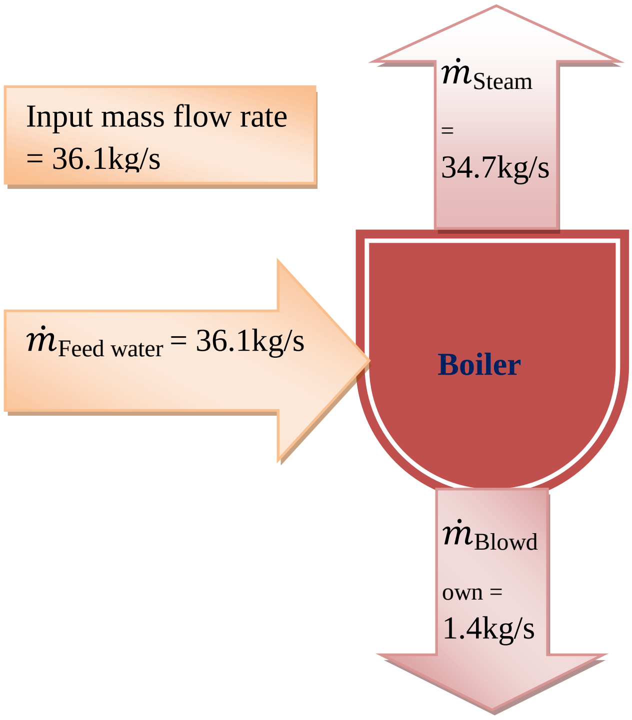


Figure 4.4 Steam system mass balance of Boiler

4.7.3 Energy Analysis of the Boiler

To perform the thermal energy audit of the boiler and thereby obtain the first law combustion and boiler efficiency, thermal energy analysis of the boiler must be conducted. The energy analysis is done based on the energy input and output of the boiler. All the input-output energy of the boiler are shown in Figure 4.4

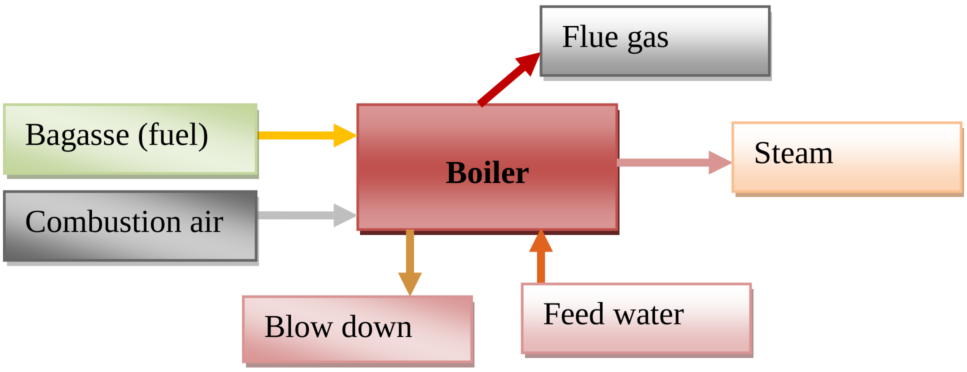


Figure 4.5 input-output of the boiler

4.7.3.1 Analysis of the Input Energy in the Boiler

As illustrated in Figure 4.4 bagasse, combustion air and feed water are the input energy of the boiler. Each input energy source of the boiler is discussed below.

a. Chemical Energy of Bagasse

The chemical energy of the bagasse is quantified using its heating value. To calculate the energy efficiency of the boiler on GCV, the chemical energy of the bagasse must be found.

The chemical energy of the bagasse is obtained by multiplying GCV of the fuel with the mass flow rate of the fuel. The calorific value at 50% moisture in WSSF is:

- Gross calorific value: 9.5 MJ/kg
- Net calorific value: 7.5 MJ/kg

The chemical energy of the fuel can be obtained by using below Equation (4.19).

$Q_f = \dot{m}_f$ (GCV)(Abiye, 2011)……………………………….(4.19)

Where

Qf – Chemical energy of the fuel

$\dot{m}_f$ – Mass flow rate of the fuel = 16.06 $\frac{\mathbf{kg}}{\boldsymbol{s}}$

GCV – Gross calorific value of the fuel = 9,500$\frac{\mathbf{KJ}}{\boldsymbol{Kg}}$

Substituting the above data in Equation (4.19) the chemical energy of the fuel is:

$Q_f = \dot{m}_f$ (GCV) = **152,570KW**

b. Energy of Feed Water

The energy of feed water is the enthalpy of water by virtue of its temperature elevation relative to the atmospheric temperature. The enthalpy of feed water due to its pre-heating from the ambient temperature to pre-heating temperature can be obtained using the following thermodynamic path.

$[Feed\ water]25^oC \longrightarrow [Feed\ water]105^oC$ (Mariam, 2009)……………. (4.20)

The energy due to pre-heating temperature can be obtained using the following equation (4.21)

$Q_w = \dot{m}_w \times C_w \times (T_w - T_a)$ (Mariam, 2009) ……………………………..…….. (4.21)

Where

Q_w – Energy of feed water

$\dot{m}_w$ – Mass flow rate of feed water

C_w - Specific heat of water = 4.187 KJ/Kg^{o}C

T_w - Temperature of feed water = 105^{o}C

T_a -Ambient temperature = 25 ^{o}C

Substituting the value of the above data in Equation (4.21) the heat content in feed water becomes:

$$Q_w = \dot{m}_w \times C_w \times (T_w - T_a) = \mathbf{12{,}092.1\ KW}$$

4.7.3.2 Analysis of the Output Energy in the Boiler

When feed water entered to the boiler is converted to steam, the produced steam carry away huge amount of output energy (heat) and can be calculated as follow.

Q_{steam} = Mass Flow Rate of Steam x Enthalpy of super-heated steam at a temperature of 510^{o}C and pressure 64bar.

$$Q_{Steam} = \dot{m}_{steam} \times h_{gs} \text{ (Abiye, 2011)} \qquad (4.22)$$

Where:

Q_{Steam} – Energy (heat) of steam

$\dot{m}_{Steam}$ – mass flow rate of steam

h_{gs} – Enthalpy of super heated steam

Mass flow rate of steam = 125 TPH = 34.7 Kg/s (Table 3.2)

$$h_{gs} = hg + Cps\ (Tsup - Ts)$$

Where:

h_g – enthalpy of dry super saturated steam = 2,778.14KJ/Kg(from steam table)

C_{ps} – specific heat of dry saturated steam at constant pressure =2.1 KJ/Kg^{o}C

T_{sup} – temperature of superheat steam = 510^{o}C (from WSSF DCS)

T_s – Saturated temperature = 279.80^{o}C at 64 bar (from steam table)

Hence

Enthalpy of super heated steam at 510ºC &64 bar = $h_g + C_{ps}$ ($T_{sup} - T_s$ **= 3,261.56** $\frac{\mathbf{KJ}}{\boldsymbol{Kg}}$

$$\dot{Q}_{Steam} = \dot{m}_{Steam} \times h_{gs} = \underline{\mathbf{113{,}176.123\ KW}}$$

4.7.3.3 Energy Losses of the Boiler

The energy losses of the boiler are dry flue gases loss, heat loss due to hydrogen in fuel oil, heat loss due to moisture content of combustion air, heat loss due to radiation and convection from the boiler surface and heat loss due to moisture content of the fuel.

1 Heat Loss Due to Dry Flue Gas

The energy loss due to dry flue gas leaving the boiler can be obtained using the mass flow rate of dry flue gas and enthalpy change of dry flue gas at flue gas temperature relative to the ambient temperature. The analysis is carry out using equation (4.23)

$$\dot{Q}_{flue} = \dot{m}_{flue} C_p (T_{flue} - T_a) \text{ (Tesemma, 2018)} \ldots\ldots\ldots\ldots\ldots\ldots \text{(4.23)}$$

Where

Q_{flue} – Heat energy of flue gas

$\dot{m}_{flue}$ – Flow rate of flue gas

C_p - Specific heat capacity of flue gas = 1.35$\frac{KJ}{Kg^0C}$

T_{flue} – Temperature of flue gas

T_a – Ambient temperature

But $\dot{m}_{flue}$ is $\dot{m}_{Flue\ gas}$ = 146.47$\frac{\text{Kg of dry flue gas}}{s}$. Substitute the above data in (4.23) energy loss due to dry flue gas is:

$$Q_{flue} = \dot{m}_{flue} C_p (T_{flue} - T_a) = \mathbf{24{,}716.81\ KW}$$

2 Heat Losses Due to the Presence of H_2 in Fuel

During combustion process of the bagasse the hydrogen contained in it reacts with oxygen and water will be formed. The water formed takes away some of the energy librated during the combustion process. This energy loss due to presence of hydrogen in the bagasse can be calculated as:

$Q_{H2} = (M)_{H_2O} * \dot{m}_f[h_{fg@25^oC} + C_P (T_{flue} – T_{amb})]$ (Mariam, 2009)……. (4.24)

Where:

$\dot{m}_f$ – Mass flow rate of fuel = 16.06 $\frac{kg}{s}$

$(M)_{H_2O}$ - mass of water per Kg of fuel = 0.54kg water/kg fuel

$h_{fg@25^oC}$ - Enthalpy of water = 2441.12 $\frac{KJ}{Kg}$

C_P - Specific heat capacity of water = 1.88$\frac{KJ}{Kg^oC}$

T_{flue} – Flue gas temperature after ID Fan = 150ºC

T_{amb} – Ambient temperature = 25ºC

Substituting the above data in Equation (4.24) the heat loss due to evaporation of water formed due to hydrogen in the fuel is:

$Q_{H2} = (M)_{H_2O} * \dot{m}_f[h_{fg@25^oC} + C_P (T_{flue} – T_{amb})]$ = **232.08 KW**

3 Heat Loss due to Moisture Content of Air

The air used for combustion under standard condition contains moisture. The energy loss due to moisture content of the air is similar to the moisture content of the bagasse described above. The energy loss due to moisture in the combustion air is given by:

$Q_{moi} = AAS \times \gamma_A \times (\dot{m}_f)[C_p(T_{flue} – T_{amb})]$ (Mariam, 2009)…………… (4.25)

Where:

AAS – Actual air supplied = 9.08 kg of air/kg of bagasse

γ_A – Absolute humidity factor ≈ 0.01211 kg of H_2O/kg of dry air

Substituting the above data in Equation (4.25) the energy loss due moisture content in the combustion air is given by: **= 415 KW**

4 Heat Loss due to Moisture Content of fuel

During combustion process of the bagasse, due to the presence of moisture in it water will be formed. The water formed takes away some of the energy librated during the combustion process. This energy loss due to moisture in the bagasse is given by:

$$Q_M = (M)^* (\dot{m}_f)[h_{fg@25^oC} + C_P (T_{flue} - T_{amb})] \ldots\ldots\ldots\ldots (4.26)$$

Where:

Q_M – Heat energy in fuel moisture

$\dot{m}_f$ – Mass flow rate of fuel = 16.06 $\frac{kg}{s}$

(M – Moisture of fuel = 50 – 54% = 52% average

$h_{fg@25^oC}$ - Enthalpy of water = 2441.12 $\frac{KJ}{Kg}$

C_P - Specific heat capacity = 1.88$\frac{KJ}{Kg^0C}$

T_{flue} – Flue gas temperature after ID Fan = 150ºC

T_{amb} – Ambient temperature = 25ºC

Substituting the above data in Equation (4.26), the heat loss due to evaporation of water formed due to moisture in the fuel can be calculated: = **21,489.24 KW**

5 Heat losses due to Radiation and Convection from the Boiler Surface

As wind crosses over the boiler surface, energy will be lost from the boiler surface to the wind by convection. In addition to this, due to difference in temperature between the ambient air and the boiler surface there is also radiation energy loss. The energy loss due to convection and radiation in watt per unit area of the boiler surface exposed to the ambient temperature condition is given by:

$Q_{(i)s}$ =

$$\left\{0.548\left[\left(T(i)_s/55.55\right)^4 - \left[\left(T(i)_a/55.55\right)^4\right] + 1.957\left(T(i)_s - T(i)_a\right)^{1.25}\frac{\sqrt{196.85V+68.9}}{68.9}\right\}\frac{w}{m2} * S_{(i)A}\ldots$$

(Mariam, 2009)

$$Q_{(tot)s} = Q_{front} + Q_{bck} + Q_{ccylindrical}$$

Where:

$T_{(i)s}$ = Surface temperature: T_{front} =42ºC =315.15ºK, T_{back} = 114ºC=387.15ºK and $T_{cylindrical}$ = 59ºC = 332.15ºK (Table 7.7)

$T_{(i)a}$: Ambient temperature (local): $T_{front\ local\ ambient}$ = 27ºC = 300.15ºK, $T_{back\ local\ ambient}$ = 29ºC =302.15ºK and $T_{cylindrical\ local\ ambient}$ = 30ºC = 303.15ºK

V = Wind velocity at light air taken to be 2.56 m/s

$S_{(i)A}$- Front, cylindrical and back surface areas with values of 81m^2 , 533.8m^2 and 81m^2 respectively.

Substituting the values of the above data in the equation(7.33) and the total heat loss due to convection and radiation from boiler surface will be:

Case1:

$$Q_{fs}= \left\{0.548\left[\left(T(front)_s/55.55\right)^4 - \left[\left(T(front)_a/55.55\right)^4\right] + 1.957\left(T_{(front)s} - T_{(front)a}\right)^{1.25}\frac{\sqrt{196.85V+68.9}}{68.9}\right\}\frac{w}{m2}*S_{(front)A}$$

$$Q_{fs}= \left\{0.548\left[\left(315.15/55.55\right)^4 - \left(300.15/55.55\right)^4\right] + 1.957\left(315.15 - 300.15\right)^{1.25}\frac{\sqrt{196.85(2.56)+68.9}}{68.9}\right\}\frac{w}{m2}*81m^2$$

= 14.08 KW

Case2:

$$Q_{bs}= \left\{0.548\left[\left(T_{(back)s}/55.55\right)^4 - \left[\left(T_{(back)a}/55.55\right)^4\right] + 1.957\left(T_{(back)s} - T_{(back)a}\right)^{1.25}\frac{\sqrt{196.85V+68.9}}{68.9}\right\}\frac{w}{m2}*S_{(front)A}$$

$$Q_{bs}= \left\{0.548\left[\left(387.15/55.55\right)^4 - \left[\left(302.15/55.55\right)^4\right] + 1.957\left(387.15 - 302.15\right)^{1.25}\frac{\sqrt{196.85(2.56)+68.9}}{68.9}\right\}\frac{w}{m2}*81m^2$$

= 12.90 KW

Case3:

$Q_{(cyl)s} = \{0.548[(T_{(cyl)s}/55.55)^4 - [(T_{(cyl)a}/55.55)^4] + 1.957(T_{(cyl)s} - T_{(cyl)a})^{1.25} \frac{\sqrt{196.85V+68.9}}{68.9}\} \frac{w}{m2} * S_{(cyl)A}$

$Q_{(cyl)s} = \{0.548[(332.15/55.55)^4 - [(303.15/55.55)^4] + 1.957(332.15 - 303.15)^{1.25} \frac{\sqrt{196.85V+68.9}}{68.9}\} \frac{w}{m2} * 533.8m^2$

= 210.4 KW

Therefore; the total heat loss from boiler surface due to radiation and convection will be:

$Q_{(tot)s} = Q_{front} + Q_{bck} + Q_{ccylindrical}$

$Q_{(tot)s}$ = **14.08 KW + 12.90 KW + 210.4 KW**

= <u>237.4 KW</u>

6 Heat loss due to Boiler Blow down Water from the Boiler Drum

Dissolved solids contained in the water remain in the boiler when water is boiled and steam is generated. Above a certain level of concentration, these solids encourage foaming and cause carryover of water into the steam. The deposits also lead to scale formation inside the boiler, resulting in localized overheating and finally causing boiler tube failure. Hence blow down is significant for these removing of deposits, however can be source of heat loss, if improperly carried out and given by:

Energy loss due to boiler blow down = Mass flow rate of blow down $\times$ *Enthalpy of blow down*

$Q_{blow\ down} = \dot{m}_{Blowdown} \times h_{fg@110^oC}$ (Girma, 2018)………………….. (4.27)

Where:

$Q_{blow\ down}$ -Thermal energy in blow down

$h_{fg@110^oC}$ - Enthalpy of blow down = 461.3 $\frac{KJ,}{Kg}$

$\dot{m}_{Blowdown}$ - Mass flow rate of blowdown = $\frac{1.4\ kg,}{s}$

Substituting the above data in Equation (4.27) the energy loss due to blow down is given:

$Q_{\text{blow down}}$ = $\dot{m}_{\text{Blowdown}} \times h_{fg@110^{o}C}$ = **645.82 KW (Kilo watt)**

In order to analyze the input energy to the boiler and the output energy from the boiler with the assumption, energy can neither be created nor destroyed, the energy balance calculated is summarized as below.

Table 4.5 Energy Balance Analysis of the Boiler

S/N	Input energy [kW]	S/N	Output energy [kW]
1	Energy of Feed Water = 12,092.1	1	Heat loss due to dry flue gas = 24,716.81
2	Input Energy of fuel = 152,570	2	Heat loss due to presence of hydrogen in bagasse = 232.08
3	Combustion air = 0	3	Heat loss due to moisture in air = 415
5	$\sum_{i=1}^{3} Energy\ inputs = 164{,}662.1$	4	Heat loss due to moisture in fuel = 21,489.24
		5	Heat loss by radiation & convection on the boiler surface =237.4
		6	Blowdown loss = 645.82
		7	Heat carried away by the steam = 113,176
			$\sum_{i=1}^{4} Energy\ loss = 46{,}853.13$
			$\sum_{i=1}^{6} Energy\ loss = 47{,}736.35$
			$\sum_{i=1}^{6} (loss + useful\ heat = 160{,}912.35$

As we see from the above table, the total input energy to the boiler and output energy from boiler are 164,662.1kW and 160,912.35kW respectively. The difference between inputs and outputs is 3,749.75kW (2.3%) which is the result unaccounted losses.

In order to represent the losses in percentage the following calculation is necessary:

i. Percentage heat loss due to dry flue gas $= \frac{[mflue * CP(Tf - Ta)]}{GCV\ fuel} \times 100$

Where:

m - Mass of dry flue gas in kg/kg of fuel

Cp – Specific heat of superheated steam (0.45 kcal/kg =1.88kJ/kg)

So, Percentage heat loss due to dry flue gas = $\frac{[9.12*1.88(150-25)]}{9{,}500} \times 100$ = 22.6%

ii. Percentage heat loss due to H_2 in fuel = $\frac{[9*H2(584+CP(Tf-Ta))]}{GCV\ fuel} \times 100$

Where:

H_2 – kg of H_2 in 1 kg of fuel

Cp – Specific heat of superheated steam (0.45 kcal/kg =1.88kJ/kg)

584 is the latent heat corresponding to the partial pressure of water vapor

So, Percentage heat loss due to H_2 in fuel = $\frac{[[9*0.06(584+1.88(150-25))]}{9{,}500} \times 100$ = 4.7%

iii. Percentage heat loss due to moisture present in fuel = $\frac{[M(584+CP(Tf-Ta))]}{GCV\ fuel} \times 100$

Where:

M – Kg of moisture in 1kg of fuel

So, Percentage heat loss due to moisture present in fuel

$= \frac{[0.5(584+1.88(150-25))]}{9{,}500} \times 100$ = 4.3%

iv. Percentage heat loss due to moisture present in air

$= \frac{[AAS*humudity\ factor*CP(Tf-Ta))]}{GCV\ fuel} \times 100$

$= \frac{[9.08*0.01211*1.88(150-25)]}{9{,}500} \times 100$ = 0.3%

v. Radiation, convection and blowdown losses are approximated to be 2%.

4.7.4 Energy Sankey Diagram (Energy Balance) of the Boiler

The following Sankey diagram is used to represent an entire input, output and losses (percentage) energy calculated of the boiler.

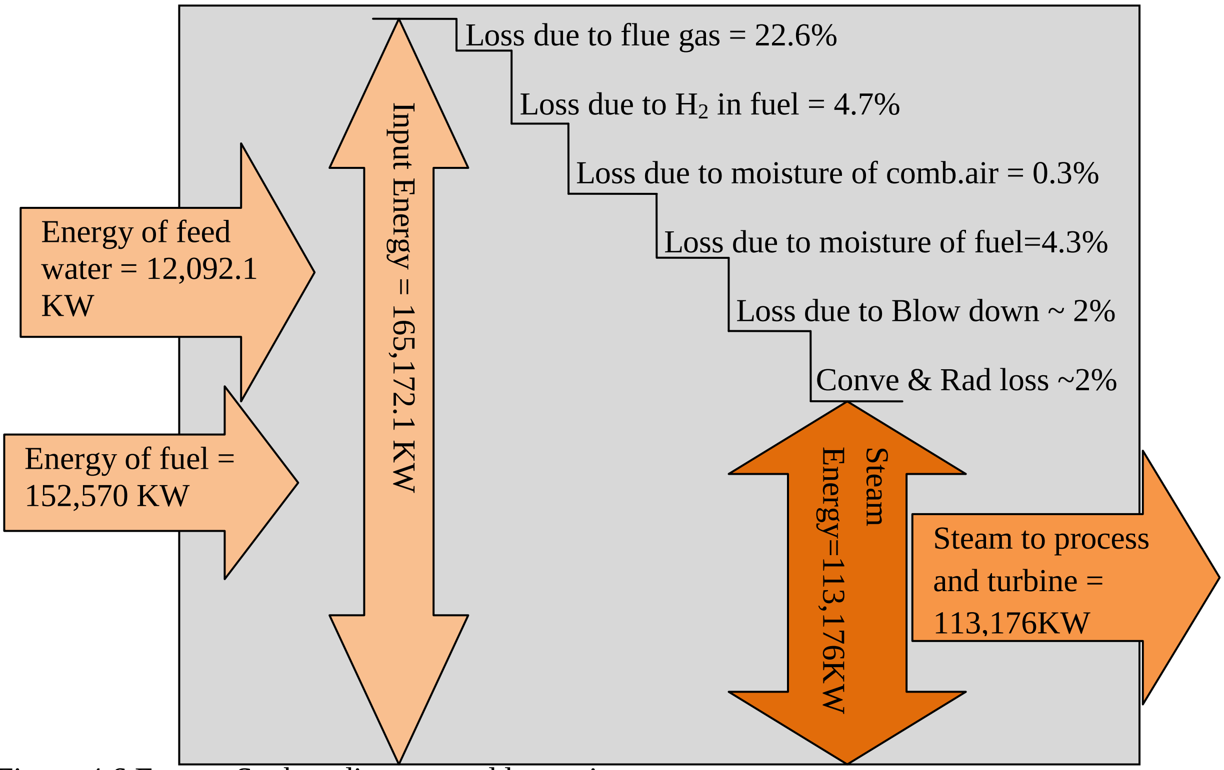


Figure 4.6 Energy Sankey diagram and losses in percentages

4.7.5 Efficiency of the Boiler

Boiler efficiency, which does account for radiation and convection loss, is a true indication of overall boiler efficiency. It accounts for the effectiveness of the heat exchanger as well as the radiation and convection losses. The boiler efficiency can be determined by two method; the input-output Method.

4.7.5 .1 Efficiency of the Boiler Based on Input-Output Method

In this method the energy gains of the working fluid (feed water and steam) are compared with the energy content of the boiler fuel. This is also known as 'input-output method' due to the fact that it needs only the useful output (steam) and the heat input (i.e. fuel) for evaluating the efficiency. This efficiency can be evaluated using the formula (4.28).

Boiler efficiency $\eta = \frac{\dot{m}s(hgs-hfs)}{\dot{m}f(GCV)}$ (Bahiru, 2019)…....………… (4.28)

Where:

$\dot{m}s$ - Is quantity of steam generated per second =34.7 $\frac{Kg}{s}$

$\dot{m}f$ - Is quantity of fuel used per second = 16.1$\frac{Kg}{s}$

GCV- Gross calorific value of bagasse = 9,500 $\frac{KJ}{Kg}$

hfs @105ºC- Enthalpy of feed water is =440.30 KJ/Kg

hgs @105ºC -Enthalpy of super heated steam is = 3,383.46 kJ/kg

The boiler working pressure and temperature is 63 bar and 485ºC respectively and also the temperature of feed water is 105°C.

Substituting the above data in Equation (4.28) the first low of efficiency by using input-output method is given by:

$$\text{Boiler efficiency } (\eta) = \frac{\dot{m}s(hgs-hfs)}{\dot{m}f(GCV)} = \mathbf{66.9\%}$$

Therefore; the efficiency of Wonji/Shoa sugar factory is very low since the respected efficiency is above 71%.

4.7.5 .2 Energy Efficiency of the Boiler Based on Heat Loss Method

The heat balance efficiency measurement method is based on accounting of all the heat losses of the boiler. The actual measurement method consists of subtracting from 100 percent the total losses. The resulting value is the boiler fuel to steam efficiency. This method further classified as thermal efficiency f the boiler and combustion efficiency of the boiler.

a. Thermal Efficiency of the Boiler

The thermal efficiency of the boiler based on heat loss method on GCV is given by:

$$\eta_{thGCV} = \left(1 - \frac{\sum_{i=1}^{6}\text{Energy loss}}{\sum_{i=1}^{3} Energy\ input}\right)*100\% \quad (4.29)$$

Substituting the values of the summations of energy losses and energy inputs from Table 4.5 the thermal efficiency is given by **= 71.01%**

b. Combustion Efficiency of the Boiler

The combustion efficiency of the furnace based on heat loss method on GCV is given by:

$$\eta_{combGCV} = \left[1 - \frac{\sum_{i=1}^{4} \text{Energy loss}}{\sum_{i=1}^{3} Energy\ input}\right] *100\% \ldots\ldots (4.30)$$

Substituting the values of the summations of energy losses and energy inputs from Table 4.5 the thermal efficiency is given by: **= 71.55%**

4.7.6 Estimation of Boiler Shell Losses

As it is clearly indicated in the heat balance sheet and conclusion remarks of the boiler, the summation of energy input to boiler and the summation of energy output are not equal. As the result, the net heat librated in the furnace and the actual heat gain by the feed water are different. This is due to energy loss at the boiler shell. Hence, boiler shell loss is calculated as below:

$$Q_{b.shell\ loss} = \eta_{th} \left[\left[\sum_{I=1}^{6} Energy\ loss + Qsteam\right] - \left[\sum_{I=1}^{3} Energy\ input\ \right]\right] \ldots\ldots (4.31)$$

The shell energy loss is given by:

$$Q_{b.shell\ loss} = 71.01\% \ (160{,}912.35\ KW - 164{,}662.1) = -2{,}662.3\ KW.$$

As the negative sign indicates that amount (2,662.3) thermal energy is loss (remain) on boiler shell.

Then, by including boiler shell loss, the boiler overall efficiency is given as follow:

$$\eta_{tot\ boiler\ efficiency} = \left[1 - \frac{[(\sum_{i=1}^{6} \text{Energy loss}) + \text{Boiler shell loss}}{\sum_{i=1}^{3} Energy\ input}\right] *100 = \mathbf{72.8\%}$$

The possible reasons for efficiency drop of the boiler are:

- Loss due to dry flue gas =22.6% (energy conservation opportunities).
- Loss due to the presence of H_2 in fuel=4.7% (unavoidable losses)
- Loss due to the moisture content of combustion air=0.3% (unavoidable losses).
- Loss due to the moisture content of fuel=4.3% (unavoidable losses).
- Boiler shell loss (energy conservation opportunities)
- Loss of heat by radiation and convection from boiler surface ~ 2% (energy conservation opportunities)
- Loss due to blow down ~ 2% (energy conservation opportunities)

4.7.7 Identified Energy Conservations opportunities (ECOs)

Among the ECOs identified above loss due to the presence of hydrogen in fuel, loss due to the moisture content of fuel and loss due to the moisture content of combustion air are unavoidable losses While loss due to dry flue gas, boiler shell loss, loss of heat by radiation and convection from boiler surface are energy conservation opportunities.

ECOs for boiler are identified from inspection, interview, and detail energy audit conducted as follows:

a. Housekeeping ECOs:
   - Lack of awareness on energy management to the factory workers
   - The soot is not removed with a regular time interval
   - Excessive blowdown is done by operators

b. ECOs Identified from detail audit:
   - Some Part of boiler surface is not insulated
   - Some part of the steam distribution systems are not insulated
   - The combustion efficiency of the boiler is low due to excess air admitted (102.1) (beyond the recommended value of 15)
   - Boiler feed water treatment plant RO membrane is almost damaged. As a result, the boiler operates with improperly treated feed water which leads it to energy loss.

4.7.8 Technical and Economic Analyses for the Proposed ECOs

4.7.8.1 Insulating Boiler Surface

Boiler surface temperature is high relative to the ambient temperature. As a result, boiler lost 237.4 kW heat to the environment. To avoid this lose, insulating boiler surface is taken as ECO. Technically it is not a difficult task for the factory to apply this as energy management opportunity. But, it should be checked for the cost effectiveness of it.

4.7.8.1 .1 Saving Analysis

By assuming 75% of the surface loses will be recovered by the adequate insulation, the saved energy will be 178.1 kW. If turbine functional, we can save 217.8 ETB per hr and 156,816 ETB per month since 1KWh is 1.223 ETB in 2022 G.C. Another basic saving while we conduct insulation is environmental saving. That means emissions of greenhouse gases will reduce.

4.7.8.1 .2 Implementation Cost

According to factory cost analysis the estimated cost for covering the boiler surface by asbestos is ranges from 30,000birr - 40,000 birr. At the bottom part (furnace of boiler) have to be covered by bricks. To cover all side of furnace it requires 1,200 bricks to a minimum. The price of one bricks in 2022 at Addis Ababa is 14 ETB. So, 1,200*14 = 28,800 ETB to a minimum to cover the bottom part of boiler in order to save the loss of thermal energy. Total birr = 68,000 ETB.

4.7.8.1 .3 Payback Period

The payback period can be estimated as follows:

$$\text{Simple payback Period (SPBP)} = \frac{Implementation\ Cost}{Cost\ Saved\ per\ month} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (4.31)$$

$$\text{SPBP} = \frac{68{,}000}{156{,}816\ per\ month}$$

SPBP ≅ 0.5 Month.

Hence the payback period is less than half month.

4.7.9 Audit of Steam Distribution Systems

Some part of wonji/shoa sugar factory steam distribution systems are bare even they are exposed for rain in the rainy season. Steam distribution systems consist of piping lines and the steam traps from a boiler to points of use, condensate return lines, and other equipments like pumps needed for condensate return. The wearing and deterioration of these equipments may cause energy wastage. Energy management can affect this system by improving the insulation, detecting and repairing steam and condensate leaks, maintaining the steam traps and condensate pumps, and providing water treatment. The steam distribution system should be inspected at the same time the boiler is inspected and energy can be saved by insulating the pipes that carry either steam or condensate.

4.7.10 Energy Performance Evaluation of Steam Pipeline Surfaces

The objective of the steam pipeline is to supply steam at the correct pressure and temperature to the point of use. But uninsulated steam pipelines can cause significant heat energy loss as it is exposed to the surrounding. Hence, insulation is needed to avoid the loss of heat through radiation from steam pipes.

4.7.10.1Heat Loss from Insulated and Un-Insulated Steam Line Surfaces

In wonji/shoa sugar factory some place steam pipeline that is lined sugar process has uninsulated part with the data given in table 3.5. The heat loss from it can be calculated using the following equations:

Hot surface (Insulated surface) temperature = Th = 45ºC

Ambient Temperature=Ta= 25ºC

Surface area of insulated pipeline = $A = \pi DL = \pi \times 1.2m \times 4m$ = 15.1m^2

Where L is length = 4m and D is diameter = 1.2m of the insulated pipe.

Surface heat loss (S_{loss}) = $\frac{[10+(Th-Ta)]}{20} \times (Th - Ta)$…………………………..…… (4.32)

Where:

10 – Overall heat transfer coefficient for steam (U in BTU/hrm^{2o}C)

20 - Overall heat transfer coefficient for air

Th – Insulated hot surface

Ta – Ambient Temperature

S_{loss} = 55.44 Kcal/hrm^2

Total heat loss [kCal/hr] = $H_{loss\ 1}$ = SxA………………………………………………… (4.33)

== 837.14 Kcal/hr = **0.973 KW**

Hot surface (uninsulated surface) temperature = Th = 108ºC

Ambient Temperature=Ta= 25ºC

Surface area of uninsulated pipeline = $A = \pi DL = \pi \times 1.2m \times 4m$ = 15.1m^2

Surface heat loss (S_{loss}) = $\frac{[10+(Th-Ta)]}{20} \times (Th - Ta)$

S_{loss} = 86.81 Kcal/hrm^2

Total heat loss[kCal/hr] = $H_{loss\ 2}$ = SxA = 13,108.31Kcal/hr = **15.24 KW**

Total reduction in heat loss TRHL = H_{loss2} –H_{loss1}…………………….……………… (4.34)

= 13,108.31Kcal/hr - 837.14 Kcal/hr = **14.27 KW**

Equivalent Fuel loss (EFL) in Kg/year = $\frac{TRHL \times yearly\ hours\ of\ operation}{GCV\ of\ fuel\ in\ Kcal/Kg \times \eta boiler}$ = **69,903 Kg/year**

4.7.10.2 Energy Conservation Opportunities

From energy investigation of the factory's steam distribution lines energy conservation opportunities identified are:

- Some parts of steam distribution lines are not insulated.
- Regular inspection of steam lines need to be conducted

4.7.10.3 Technical Evaluation of Energy Conservation Opportunities

Among energy conservation opportunities identified, regular inspecting of steam lines can be done by staff of the factory without incurring any cost but with high importance. On the other hand, even if insulating steam lines need significant amount of costs; since it can reduce losses and bring efficiency it is technically feasible.

4.7.10.4 Economical Evaluation of Energy Conservation Opportunity (Insulating Steam Lines

In this section energy analysis, costs of materials and labor needed to implement the measures and computation of simple payback period are discussed. Assuming fuel (bagasse) cost = 1.2ETB/kg

Annual costs of heat loss (Birr) = EFL × Fuel cost (Birr/kg)……….………. (4.35)

= 69,903 Kg/year ×1.2ETB/kg = **83,883.6 ETB/year**

1. **Implementation Cost**

In order to insulate the steam lines, medium temperature insulator (include 85 percent magnesia, asbestos, calcium silicate and mineral fibers having temperature range of 90 – 325ºC), is going to be constructed. From the previous experience in the factory, the cost of insulating steam line per meter with 40mm thick is about 700birr.

Hence, the total average insulating cost will be: 4mx700birr/m = 2,800 ETB

2. **Simple Payback Period**

The simple payback period can be estimated as follow.

Simple Pay Back Period = $\frac{Implementation\ cost\ for\ insulation}{Energy\ saved\ from\ insulation}$ = 0.03Year = about two weeks.

4.7.11 Steam Leakages in the Factory

Steam leaks can be expensive if large amounts of steam are lost and are a source of energy loss and must be avoid. In wonji/shoa sugar factory there is so many steam leakage points. Its average hole diameters of 8mm(0.315inch)have been identified which are leaking steam at average temperature of 110ºC that goes to canals and spread to atmosphere.

The following figures were excess steam loss (**Thermal Energy loss**) points of different places in wonji/shoa sugar factory.

Figure 4.7 Steam loss through leakage at different unit operations of WSSF

4.7.11.1Heat Losses Due to Steam Leakages

The pounds of steam lost can calculated with a formula Grashof�genitive s formula gives the number of pounds of steam lost per hour through an orifice of area A as:

Steam Loss (lb/h) = 0.70 x0.0165x3600 x A x$P^{1.97}$

Where:

0.7 = coefficient of discharge for hole (for a perfectly round hole this coefficient is 1)

0.0165 = a constant in Grashof‘s formula

3,600 = number of seconds per hour

A = area of hole in square inches

$A = \pi r^2 = \pi 0.16^2$ = **0.080 square inch**

P = pressure inside steam line in psia

The average pressure of steam as I have checked and observed at different steam leakage point are ≈ 2 bar = 29.008 psia.

Then; Steam Loss (lb/h) = 0.70 x0.0165x3600 xA x$P^{1.97}$

$= 0.70 \times 0.0165 \times 3600 \times 0.080$ sq.inch $\times 29.008^{1.97} =$ 2,530.05 lb/h

At steam table Enthalpy of Btu/lb at 110 ºC (198ºF) and at 29.008 psia ≈ 1119 Btu/lb

So, Heat loss (Btu) = Steam Loss (lb/h) x (Btu/lb) x (operating hours/year)

= 2,530.05 lb/hr * 1119 Btu/lb * 1,657.75 hr/year in 2014 E.C

= 4,693,299,043.6 Btu/year

But, 1Btu=0.2931wh, Then Energy lost through the year from steam leak is 1,375,136,619.8 Whr/year

= **1,375,136.6 KWh/year**

4.7.11.2 Energy Conservation Opportunities

- Some parts of steam distribution lines are old and need replacement
- Some parts of steam distribution lines are not insulated.
- Each node and valve points of distribution lines need to be fitted properly
- Regular inspection of steam lines need to be conducted

4.7.11.3Technical Evaluation of Energy Conservation Opportunity

From energy conservation opportunities identified, fitting nodal points properly and regular inspecting of steam lines can be done by staff of the factory without incurring any cost. Conducting regular basis maintenances, insulating steam lines and replacing them can contribute to reduction of energy losses from steam leakages and increment of efficiency of the parts. Hence, it is technically feasible.

4.7.11.4 Economic Evaluation of Energy Conservation Opportunity

a. Energy saving analysis

The energy costs of the steam leaks can be estimated by the following equation

Heat loss (thermal energy lost) through the year from steam leak is 1,375,136.6 KWh

Cost/working time = Heat loss x electric energy bill flat rate

Taking 1.23ETB/kWh (bill flat rate from 2022 G.C)

Cost/working time = 1,375,136.6 kWhx1.23ETB/kWh = **1,691,418.02 ETB**, this is the amount of energy cost will be saved if properly managed.

b. Implementation Costs

To implement the insulation of lines/nodal points, replacement of some parts of lines/parts and other activities related to them, it is roughly estimated to cost about 90,000 ETB.(Interview)

c. Simple Payback Period (SPP)

$$\text{SPP} = \frac{Implementation\ cost}{Cost\ of\ energy\ saved} = \frac{90{,}000\ ETB}{1{,}691{,}418.02\ ETB/year}$$

= 0.05 year = 0.6 Month = 2.4 Weeks

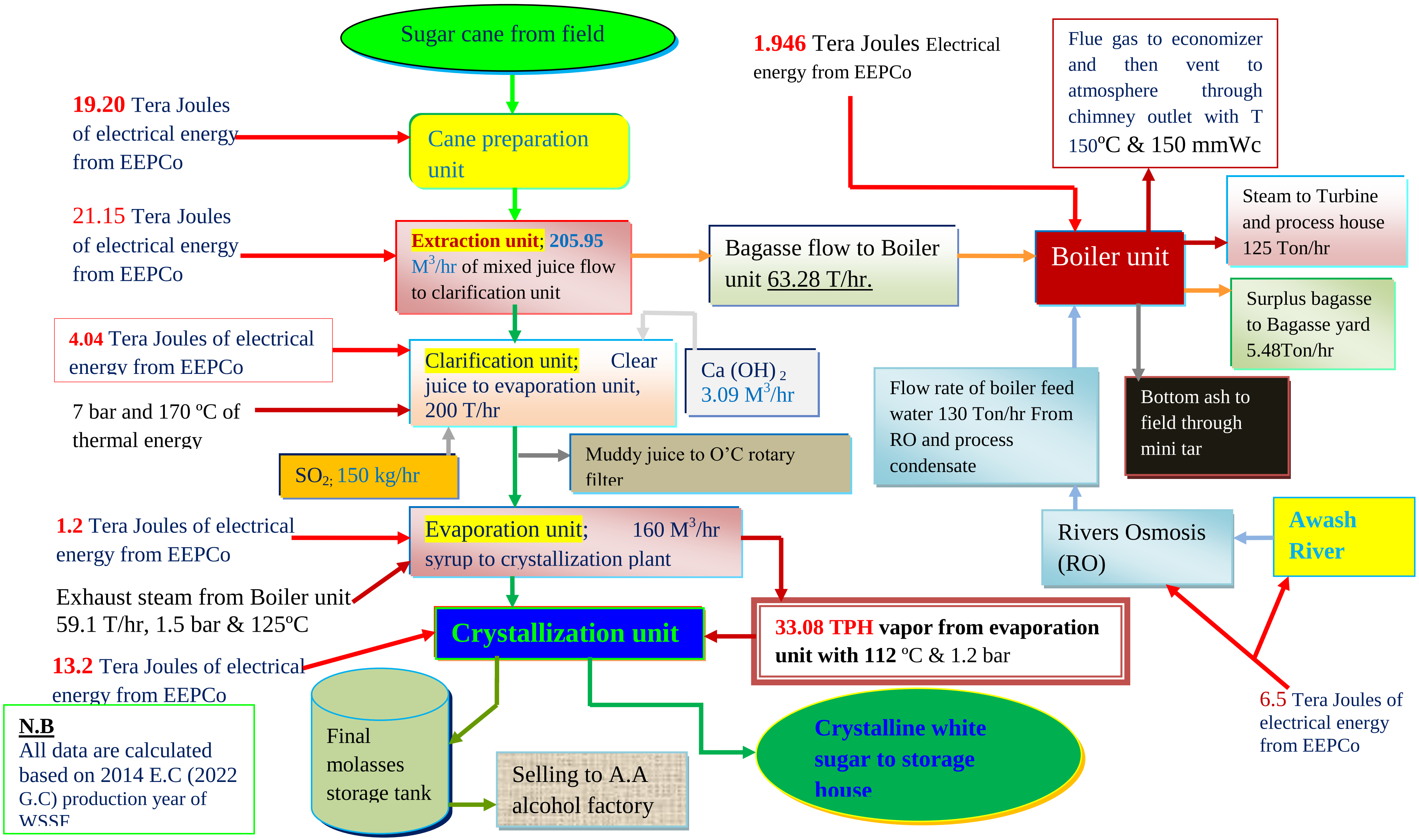


Fig 4.8 Result of Process flow diagram and energy utility diagram

4.8 Analysis result of WSSF collected data of motors

The motor considered in the study was Weighed Raw Juice Pump Motor of 147.5 HP.

4.8.1 Total power and load factor analysis per phase

Weighed Raw Juice Pump Motor of 147.5 HP, its actual load current in R Y B phases are 110.5 amps, 115.0 amps and 106.4 amps respectively. It is when the raw juice flow flowing fully.

$$\text{Power, } P = \frac{\text{VICOS}\Phi}{1000}$$

Where

P – Power in KW

V – Voltage in volts = 295.1

I – Phase current in amps

COSΦ - Power factor which is 0.8 in industry as a minimum

Actual Power in Red phase:

$$P_R = \frac{(295.1 \times 110.5 \times 0.8)}{1000} = 26.1 \text{ KW}$$

Actual Power in Yellow phase

$$P_Y = \frac{(295.1 \times 115 \times 0.8)}{1000} = 27.1 \text{ KW}$$

Actual Power in Blue phase

$$P_B = \frac{(295.1 \times 106.4 \times 0.8)}{1000} = 25.1 \text{ KW}$$

Total Actual Power Consumed by the motor:

$$P_{tot} = P_R + P_Y + P_B = 26.1 \text{ KW} + 27.1 \text{ KW} + 25.1 \text{ KW} = 78.3 \text{ KW}$$

$$\% \text{ Load factor, } L = \frac{\text{Actual Power}}{\textit{Rated power}} = \frac{78.3 \text{ KW}}{110.04 \text{ KW}} = 71.2\%$$

For all motors (250) of WSSF of actual voltage, power consumption and load factor was analyzed and put on Appendix

4.8.2 Evaluation of Seasonal Energy, Energy Cost Savings and Payback period

4.8.2.1 Sugar cane season and types of motors

Total duration of sugar cane crushing in a year is known as season. The duration in which there is no sugar cane crushing in a year is known as off-season. Here Seven month and ten days (220 days) is considered as one season. But in wonji/shoa sugar factory in 2014 E.C only 155 days including down time was working season due to shortage (lack) of cane available.

Standard Motor (SM): This type of motors are having considerable stray, stator and rotor losses with that will be low as compared with energy efficient motors.

Energy Efficient Motor (EEM): This type of motors is having considerably less losses due do to this, these motors are having more efficiency as compared with SM.

Table 4.6: Efficiencies of Standard Motor and Energy Efficient Motor

Rated HP	SM	EEM
1	73	83
2	77	83
3	80	86
5	82	87
7.5	84	88
10	85	89
15	86	90
20	87.5	90.5
25	88	91.5
30	88.5	92
40	89.5	92.5
50	90	93
50.3	90	93
60	90.5	93
75	91	93.5
100	91.5	94
125	92	94
150	92.5	94.5
147.5	92.7	94.5
200	93	94.5
Above 200	93.5	95

Source: Based on available published data

4.8.2.2 Comparative study of Group 'A' Motors

A comparative study is performed in this section with standard motor and energy efficient motor based on compare to Table 4.6 data

i. Calculations with Standard Motor

Energy consumption of standard motor/day:

E_{std} = Rated HP×L×0.746×hr×($\frac{100}{\eta std}$)

Where:

E_{std} – Energy consumption of standard motors

L – Load factor

0.746 – conversion 0f 1HP to KW

ηstd – Efficiency of standard motor

E_{std} = 147.5*0.712*0.746KW*hr*($\frac{100}{92.7}$)

= 84.61KWhr = 147.5*0.712*0.746KW*24*($\frac{100}{92.7}$) = 2,030.64KWhr/day

= 2,030.64KWhr*155 = **314,749.2 KWhr/season**

Cost of the energy consumption / season:

C_{std} = E_{std} x 1.223 ETB

= 314,749.2 KWhr/season x 1.223 ETB

= **384,938.3 ETB/Season (155 days)**

ii. Calculations with Energy Efficient motor:

Energy consumption of Energy Efficient motor/day,

E_{ee} = HP x L x 0.746 x hr (100/η_{ee})

= 147.5 x 0.712 x 0.746KW x 1hr (100/94.5) = 83.05KWhr

= 147.5 x 0.712 x 0.746KW x 24hr (100/94.5)

= 1,993.2KWhr/day

= 1,993.2KWhr/day*155 = **308,946KWhr/season**

Cost of the energy consumption / season,

$$C_{ee} = E_{ee} \text{ x } 1.223 \text{ ETB} = 308{,}946\text{KWhr/season}*1.223 = \mathbf{377{,}840.96 \text{ ETB/Season}}$$

Total energy savings / season after the replacement of existing Standard Motor by Energy Efficient motor is as below,

$$E_{tot} = E_{std} - E_{ee} = 314{,}749.2 \text{ KWhr/season} - 308{,}946\text{KWhr/season} = 5{,}803.2 \text{ KWhr/season}$$

Total energy cost saved / season after replacement of Standard Motor by Energy Efficient motor is:

$$S_{tot} = E_{tot} \text{ x } 1.223 \text{ ETB}$$

$$= 5{,}803.2 \text{ KWhr/season x } 1.223 \text{ ETB} = \mathbf{7{,}097.3 \text{ ETB/Season}}$$

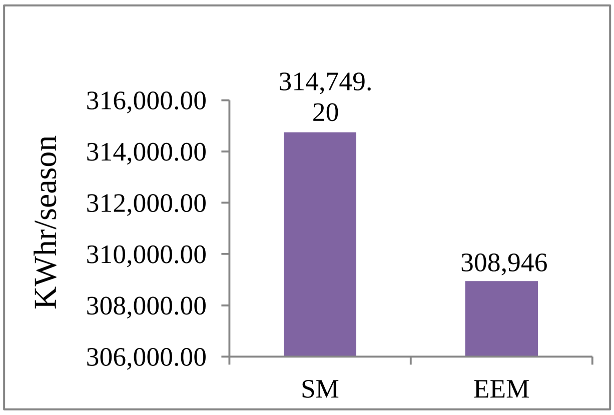
4.8.2.3 Payback period PP calculation

PP = Price of Motor / Seasonal amount savings = 80,000 ETB /7,097.3 ETB/Season = 11.3 Season.

Table 4.7 Results and comparison for Group 'A' Motor

	Equipment	HP	Load factor 'L'%	Energy consumption per season (Kwh / season)	Cost of the energy consumption in ETB / season	Energy Savings per season ,E_{tot}(Kwh / season)	Cost of the energy Saved, S_{tot} (ETB/Season)	Cost percent age savings
1	Standard Motor	147.5	71.2	314,749.2	384,938.3	5,803.2	7,097.3	1.84
2	Energy Efficient Moto	147.5	71.2	308,946	377,840.96			

With these (above table) result the following graphs are represent as shown bellow figure



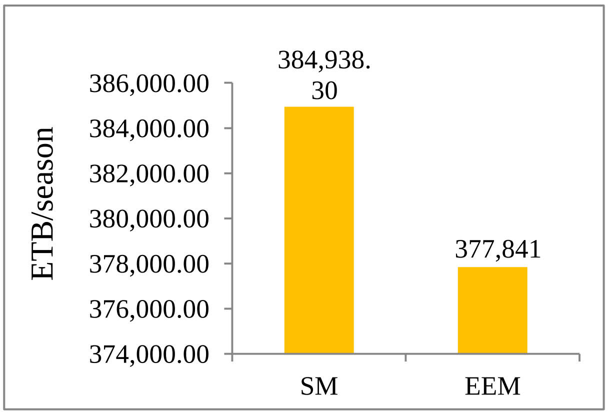


Figure 4.9 Group A motors comparative analysis Figure 4.10 Group A motors comparative analysis

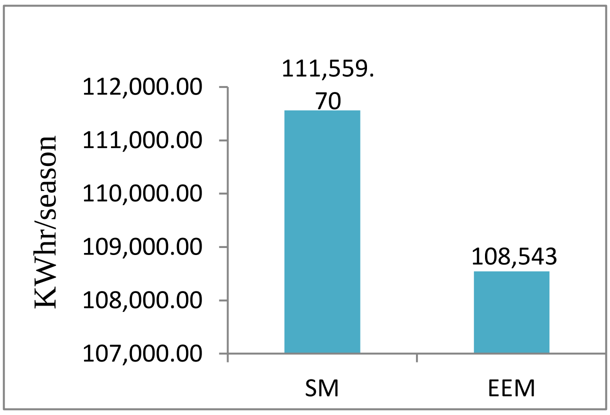
With this it can be concluded that in group A if existing standards motors(SM) are replaced by the energy efficient motors (EEM) the total energy about 467,108.42 KWh/season and total energy cost about 571,272.50 ETB can be achieved.

4.8.2.4 Calculations related to Group 'B' Motors

A comparative study is performed in this section with standard motor and energy efficient motor from the available Table 4.6. Let be take clear juice pump as reference in this group its HP value is 120.6

Table 4.8 Results and comparison for Group 'B' Motor

	Equipment	HP	Load factor 'L'%	Energy consumption per season (Kwh / season)	Cost of the energy consumption in ETB / season	Energy Savings per season ,E_{tot}(Kwh / season)	Cost of the energy Saved, S_{tot} (ETB/Season)	Cost percentage savings
1	Standard Motor	50.3	0.720	111,559.7	136,437.51	3,016.3	3,688.93	2.7
2	Energy Efficient Moto	50.3	0.720	108,543.4	132,748.58			



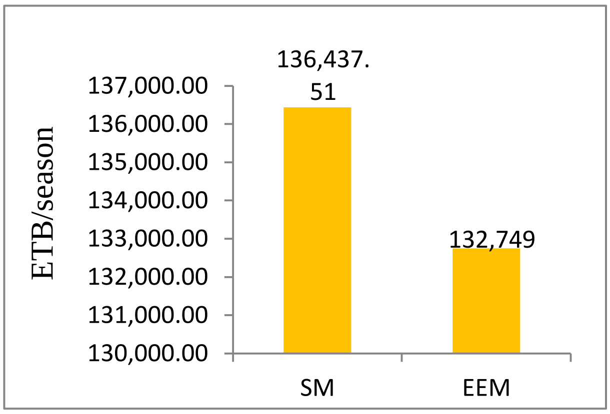


Figure 4.11 Group B motors comparative analysis   Figure 4.12 Group B Motors cost comparison

With this it can be concluded that in group B motor, if existing standard motors(SM) are replaced by the energy efficient motors (EEM), the total energy about 245,490.24 KWhr/season (units) and total energy cost about 300,234.17 ETB can be achieved.

4.8.2.5 Calculations related to Group 'C' Motors

A comparative study is performed in this section with standard motor and energy efficient motor from the available Table 4.6 and graphs are obtained. Clear Melt sugar pump was.

Table 4.9: Results and comparison for Group 'C' Motor

	Equipmen	HP	Load factor	Energy consumptio	Cost of the energy	Energy Savings per season	Cost of the energy Saved, S_{tot}	Cost percent

	t		'L'%	n per season (Kwh / season)	consumption in ETB / season	,E_{tot}(Kwh / season)	(ETB/Season)	age savings
1	Standard Motor	20	0.733	46,378.92	56,721.42	1,627.33	1,990.22	3.5
2	Energy Efficient Moto	20	0.733	44,751.59	54,731.19			

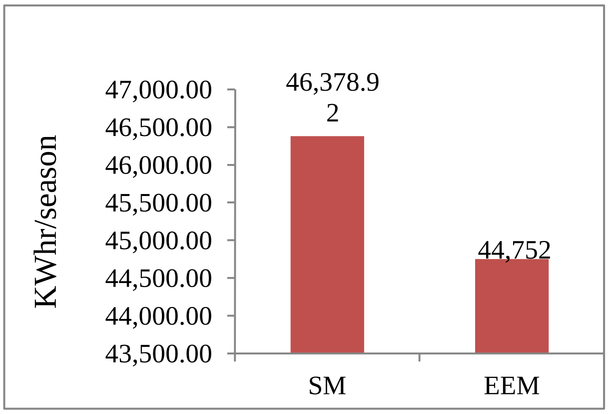


Figure 4.13 Group C motors comparative analysis

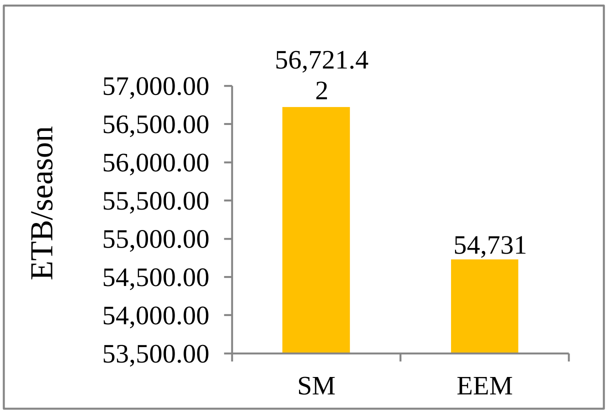


Figure 4.14 Group C Motors cost comparison

With this it can be concluded that for group C motor if existing standards motors (SM) are replaced by the energy efficient motors (EEM) the total energy about 111,307.74 KWhr/season and total energy cost about 136,129.06 ETB can be achieved.

4.8.3 Section wise Power Consumption in the Plant

The total powers consumed by each section for a season are given in Table 4.10.

Table 4.10 Power Consumption in various sections in the Plant

Items	**KW**	**KWhr**	**Joule in giga joule (GJ)**	**%KW**	**%KWhr**	**%Joule**
Cane preparation unit	3,215.6	5,330,660.9	19,200	25.0	25.0	25
Extraction unit	3,544.5	5,875,894.9	21,150	27.5	27.5	27.5
Clarification unit	676.8	1,121,965.2	4,040	5.3	5.3	5.3
Evaporation unit	194.0	321,603.5	1,200	1.5	1.5	1.5
Crystallization unit	2,204.1	3,653,846.8	13,200	17.1	17.1	17.1
Boiler unit	1,946.0	3,225,931.8	11,600	15.1	15.1	15.1
Water treatment unit	1,088.8	1,804,925.1	6,500	8.5	8.5	8.5
Total Power Consumed	**12,869.8**	**21,334,828.2**	**76,890**	**100**	**100**	**100**

Table 4.10 section wise consumption is plotted as in Figure 4.15. From the Figure 4.15 it can be concluded that mill house is the major power consuming section in the plant.

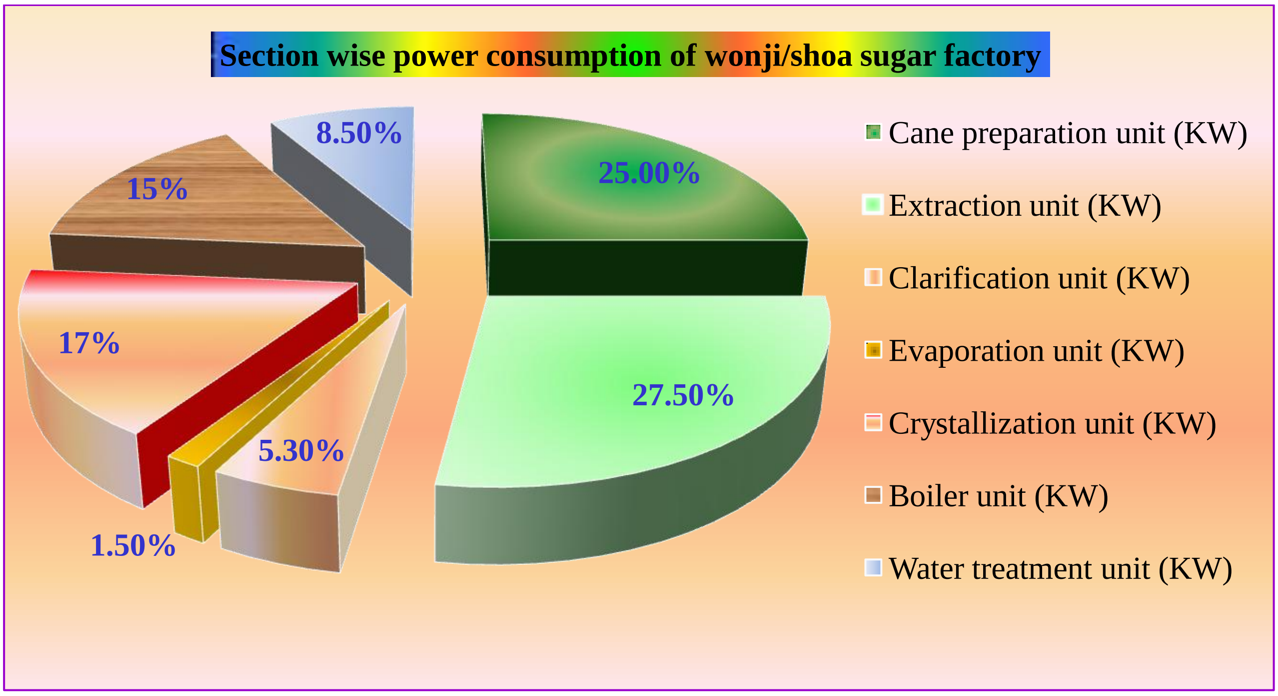


Figure 4.15 Section wise Power consumption in the Plant on a specific observation

After studying the entire electrical energy audit of the plant it is observed that extraction unit section is the major energy consuming section in the whole plant. Therefore it is necessary to take energy conservation measures in this section as well as in cane preparation unit.

4.9 Electrical energy bill Data Analysis

The collected data were processed into monthly factory paid for electricity consumption and monthly electricity energy intensity consumption patterns.

4.9.1 Monthly Energy Cost Analysis of WSSF

Based on the voltage consumption and number of phases (WSSF use three phases and high voltage line) used in the factory, cost of electricity varies from month to month. The data collected shows that as the factory consume the high voltage tariff with flat multiplying factor the consumed KWh with 0.9280 Birr/KWh.

Monthly electricity cost is given by Equation 5.1.

$$\text{MEC}=0.9280\frac{\text{Birr}}{\text{KWh}} \times \text{Monthly electric used in KWh} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad (4.36)$$

Where: MEC = Monthly Electricity cost in Birr/Month

We can calculate with these formulas or read directly from the factory logbook as tabulated in table 5.1 above.

4.10 Monthly Energy Intensity Consumption Pattern of WSSF

Monthly energy intensity consumptions of the factory are defined as an average monthly energy needed to produce one kg of crystalline white sugar which is given by the following equation.

$$\text{MEEI} = \frac{Monthly\ electricity\ used\ (KWh) \times 3600\ sec}{Monthly\ sugar\ produced} \text{ (Abiye, 2011)} \ldots\ldots\ldots\ldots \text{ (4.37)}$$

Where: MEEI – Monthly electric energy intensity

Substituting data from table 3.9 and 3.10 in equations 4.37 the value are given in table 4.11.

<u>**N.B:**</u> In 2014 E.C the production period was November up to April with the break of February; that is why done electricity energy intensity only for five months as bellow table 4.11 mentioned.

Table 4.11 Monthly electricity energy intensities of WSSF

Billing Period [E.C]	**Energy intensity of Electricity [KJ/Kg of sugar]**	**Total monthly produced sugar [Qt]**
November 2014	1,636.75	82,615.20
December 2014	1,928.81	98,904.00
January 2014	3,685.25	40,159.00
March 2014	2,456.14	69,588.00
April 2014	2,827.60	51,984.00

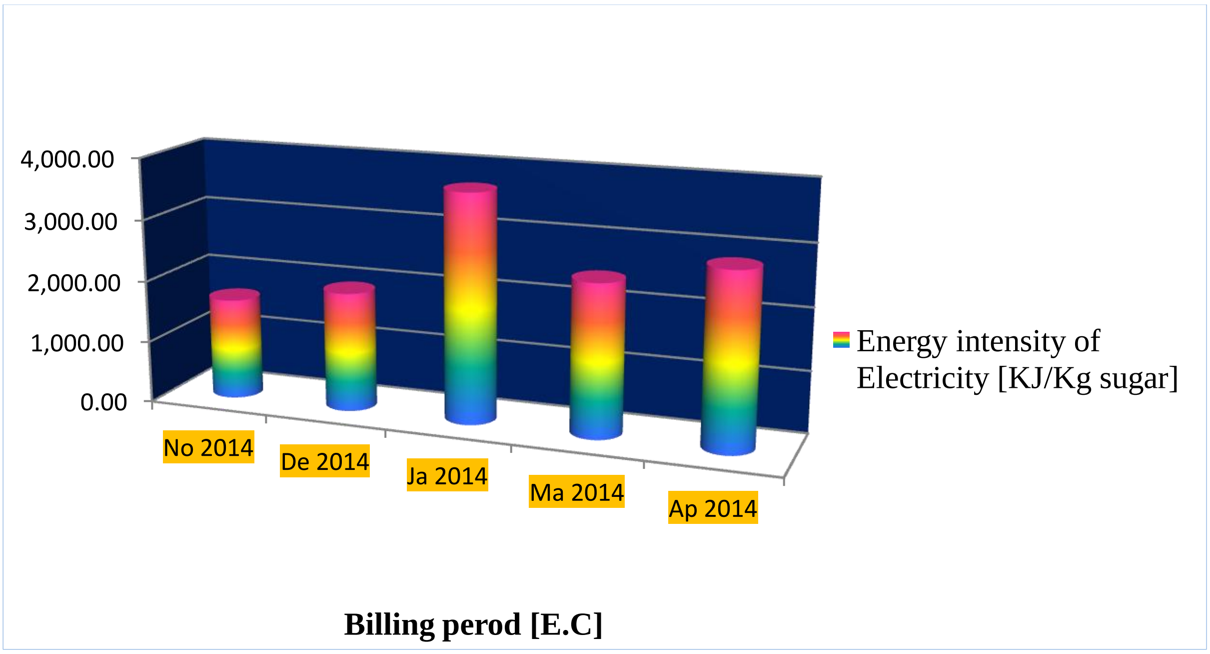


Fig 4.16 Electrical energy intensity of WSSF

Now let us see Annual cost due to improper utilization of electricity in the factory as given by equation (4.38) bellow. Before this the following are necessary data used to calculate annual cost occur on the factory due to lower energy intensity efficiency.

- WSSF Production in 2014 E.C = **343,250.2** Quintal of crystalline white sugar
- Average cost of electricity in the audit year = 0.9280 birr/KWh
- Average value of the difference in electricity energy intensity =2,506.91 KJ/Kg sugar – 2,506.41 KJ/Kg sugar = 0.5 KJ/Kg sugar.

Annual cost due to improper utilization of electricity in the factory is given by equation (4.38)

$$AC_{ele} = DEI_{ele} * FAPC * EC \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (4.38)$$

Where:

AC_{ele} - Difference in annual cost due to lower electricity energy intensity

DEI_{ele} - Difference of electricity energy intensity = 0.5 KWh/Kg sugar

FAPC - Factory annual production capacity = 350,000 Qt/Year

EC - Cost of electricity = 0.9280 Birr/KWh

Substituting the above value from the data in equation (5.3) annual energy cost due to lower electricity energy intensity of the factory is given by:

$$AC_{ele} = 0.5\,\frac{KWh}{Kg\ sugar} * 35{,}000{,}000\,\frac{Kg\ sugar}{Year} * 0.9280\,\frac{Birr}{KWh}$$

$$AC_{ele} = 16{,}240{,}000\,\frac{Birr}{Year}$$

Therefore; the total annual cost due to lower energy utilization efficiency of the factory is 16, 240,000$\frac{Birr}{Year}$.

Based on the above analyses, the factory costs 16,240,000 which occur due to poor energy utilization. This cost is in comparison assuming by any bench mark taken that of the above difference number. Though the benchmarks have their own limitation in energy utilization, it is a relative indication of un efficientness of the factory in energy utilization. So, the factory can conduct energy audit on its major energy producing unit and induce devices to know the basic energy losses. This helps the factory to find out energy conservation opportunities and take the energy conservation measures.

Summary table of analyzed and calculated data

Table 4.12 Summary table of Energy and Material balance of WSSF in 2014 E.C mill season

Items	Unit	Amount	ETB per month	ETB per mill season (in 5 month)
Crushed cane (Input)	Ton	349,647.90	-	-
Produced by product (bagasse)	Ton	112,888	-	-
Produced by product (filter cake)	Ton	13,111.80	-	-
Produced by product (Final molasses)	Ton	11,900.20	38,080,640	190,403,200 ($1.9*10^6$)
Total produced thermal energy	KW	633,379.4	155,811.3	779,056.7
Total thermal energy lost	KW	111,754.6	27,335.2	136,675.9
Total Rated electrical energy	TJ	76.89	-	-
Total actual electrical energy	MW	20,930.69	5,119,645.6	25,598,228.04
Total output of main product	Ton	36,812.02	360,757,796	1,803,788,980 ($1.8*10^9$)
Total recoverable of main product	Ton	34,325.02	336,385,196	1,681,925,980 ($1.6 *10^9$)
Total lost sugar in bagasse	Ton	1,152.0	**11,289,600**	**56,448,000**
Total lost sugar in filter cake	Ton	570	5,586,000	27,930,000
Total lost sugar in final molasses	Ton	765	7,497,000	37,485,000
Total lost sugar in **all by products**	Ton	2,487.0	24,372,600	121,863,000

N.B, The price of 1Kg crystalline white sugar in 2014 E.C WSSF sell by **49 ETB**, but now its 1Kg price is **74 ETB.**

The main cause of lost sugar in by products (bagasse and filter cake) was due to lack of thermal energy. Therefore; 111,754.6 KW lost of thermal energy have to recover and apply to process in order to save 11,289,000/month in bagasse and also 5,586,000/month in filter cake.

CHAPTER FIVE

5. CONCLUSION and RECOMMENDATION

5.1 CONCLUSION

In this study Thermal and Electrical energy in Wonji/Shoa Sugar factory was audited by using portable parameter measuring equipment, by taking actual data in DCS and control panel as well as by analysis the sample in laboratory. After studying the entire electrical energy audit of the plant it is observed that extraction unit section is the major energy consuming section in the whole plant whereas an excess amount of thermal energy loss was observed in all unit operations especially in boiler unit through flue gas. The potential heat recovery from these sources, an integrated system for bagasse dryer from dry flue gas and for hot water imbibitions for sucrose extraction was selected and designed. By implementing this system, a significant amount of thermal energy could be recovered and converted into steam, electricity and main product (Crystalline white sugar). The economic feasibility of hot water imbibitions heat recovery mechanism was also assessed, if imbibitions apply by hot water 11,289,600 ETB/ month can be save. .

The electrical energy audit assessment of each equipment in the process unit of Wonji/Shoa sugar factory was conducted, and the potential energy and monetary savings were evaluated by taking standard and energy efficient motor as a reference and used to identify energy-saving opportunities, estimate potential savings, and evaluate the financial impact of implementing energy efficiency measures. The result shows, in extraction unit operation has most electrical energy saving than other unit operations. The total energy and monetary saving is indicated accordingly and 26,092,494.886/season birr can be saved if heat exchanger for bagasse dryer apply and if turbine functional.

So, by applying both thermal and electrical energy audit, heat integrating system; un expected amount of money can be generate in Ethiopian sugar factory, especially in WSSF.

5.2 Recommendation

In Wonji/Shoa sugar factory there is an excess by products, **as they used as raw material to other industry** such as **Final molasses**, **filter cacke** and **bagasse**. From these materials can be produce different products; Such as **Ethanol** from final molasses, **biogas** from filter cacke, **ceramic**, **glass** and **black bricks** from **fly ash**, **activated carbon** and **Graphene oxide** as well as **green briquette** from **sugarcane bagasse.**

About 146.47 Kg of flue gas/s with Qflu = 24,716.8 Kw amount of energy has been analyzed. So, this energy is very important for bagasse dryer by **integrating** at boiler **ID fan** to **bagasse elevator.**

Wonji/Shoa sugar factory turbine needs a case study in order to functionalize it. If the turbine check in detail and work; **3** to **4 million** birr/month can be save.

6 Reference

Abiye, Y. (2011). *ENERGY AUDIT OF SEBETA ALCOHOL AND LIQUOR FACTORY*. *December*.

Abroshan, H., Rezaei, S., Golchoobian, H., Foladi, F., Rumizade, E., & Mirshams, A. (2023). Energy audit of a sugarcane plant to find out the main energy saving opportunities. *Bangladesh Journal of Scientific and Industrial Research*, *58*(1), 9–18. https://doi.org/10.3329/BJSIR.V58I1.61901

Al Momani, D., Al Turk, Y., Abuashour, M. I., Khalid, H. M., Muyeen, S. M., Sweidan, T. O., Said, Z., & Hasanuzzaman, M. (2023). Energy saving potential analysis applying factory scale energy audit – A case study of food production. *Heliyon*, *9*(3), e14216. https://doi.org/10.1016/J.HELIYON.2023.E14216

Allende, S., Brodie, G., & Jacob, M. V. (2022). Energy recovery from sugarcane bagasse under varying microwave-assisted pyrolysis conditions. *Bioresource Technology Reports*, *20*, 101283. https://doi.org/10.1016/J.BITEB.2022.101283

Conservation, E., Improvement, E., & Sugar, I. N. (2019). *ADDIS ABABA UNIVERSITY ADDIS ABABA INSTITUTE OF TECHNOLOGY School of Electrical and Computer Engineering*.

Engineering, E., & Engineering, E. (2017). *ENERGY AUDIT AND ENERGY MANAGEMENT IN THE*. *3*(1), 10–26.

Girma, B. (2018). *Addis Ababa University Addis Ababa Institute of Technology School of Mechanical and Industrial Engineering Thermal Engineering Stream*.

Global biofuel production by country 2021 | Statista. (n.d.). Retrieved April 27, 2023, from https://www.statista.com/statistics/274168/biofuel-production-in-leading-countries-in-oil-equivalent/

Hugot, E. (n.d.). Handbook of Cane Sugar Engineering. In *Elsevier Publishing Company* (First Edition, Vol. 1). Elsevier Publishing Company.

Jeremiah, M., & Kabeyi, B. (2023). *Bagasse Electricity Potential of Conventional Sugarcane Factories*. *2023*.

Kabeyi, M. J. B., & Olanrewaju, O. A. (2022). Performance analysis and electricity potential for Nzoia sugar factory. *Energy Reports*, *8*, 755–764.

https://doi.org/10.1016/j.egyr.2022.10.432

M. Soppimath, V., & G. Hudedmani, M. (2017). Energy Audit and Energy Management in the Sugar Industry. *MATTER: International Journal of Science and Technology*, *3*(1), 10–26. https://doi.org/10.20319/mijst.2017.31.1026

Mancini, M. C., Sforça, D. A., Pimenta, R. J. G., Cardoso-Silva, C. B., Aono, A. H., da Silva, C. C., & de Souza, A. P. (2022). Chapter 20 - Omics in sugarcane. In G. R. Rout & K. V Peter (Eds.), *Omics in Horticultural Crops* (pp. 449–465). Academic Press. https://doi.org/https://doi.org/10.1016/B978-0-323-89905-5.00017-3

Mariam, S. G. (2009). *ENERGY AUDIT OF MEKANISSA ALCOHOL FACTORY By*.

Mbohwa, C. (2013). Energy management in the south african sugar industry. *Lecture Notes in Engineering and Computer Science*, *1 LNECS*, 553–558.

Osaki, M. R. (2022). An energy optimization model comparing the use of sugarcane bagasse for power or ethanol production. *Industrial Crops and Products*, *187*, 115284. https://doi.org/10.1016/J.INDCROP.2022.115284

Parveen, E., & Jagdeep, E. (2017). *Energy Audit of Sugar Mill Using Neural Networks*. *5*(2), 48–54.

Sharma, P., Reddy Salkuti, S., & Kim, S.-C. (2021). Energy audit: types, scope, methodology and report structure. *Indonesian Journal of Electrical Engineering and Computer Science*, *22*(1), 45. https://doi.org/10.11591/ijeecs.v22.i1.pp45-52

Tesemma, B. (2018). *Design and Thermal Energy Analysis of Sugarcane Bagasse Dryer to Improve Thermal Efficiency of Boiler for Ethiopian Sugar Factory. (A Case for Wonji/Shoa Sugar Factory).*

APPENDICES

Table appendix 1: Actual Voltage, Power Consumption and Load Factor for Group 'A' Motors

S/N	Equipment	Rated Voltage (volt)	Rated Power (KW)	Rated Horse Power (HP)	Actual voltage (volt)	Actual power (KW)	%Load factor
1	First knife (Chopper)	400	300	402.1	301	250.2	83.4
2	Second knife (Leveler)	400	500	670.2	308	390	78
3	Fibrizer	11,000	2000	2,680.9	10,300	1,622	81.1
4	Mill#1	11,000	650	871.3	10,250	580	86.2
5	Mill#2	11,000	650	871.3	10,250	580	86.2
6	Mill#3	11,000	650	871.3	10,250	580	86.2
7	Mill#4	11,000	650	871.3	10,250	580	86.2
8	Mill#5	11,000	650	871.3	10,250	580	86.2
9	Weighed Juice Pump	400	110	147.5	302	78.3	71.2
10	Sulphured Juice Pump	400	110	147.5	302	86.5	78.6
11	Injection Water Pump#1	400	225	301.6	310	188	83.6
12	Injection Water Pump#2	400	225	301.6	310	188	83.6
13	Injection Water Pump#3	400	225	301.6	310	188	83.6
14	SA FAN#1	400	160	214.48	306	130	81.3
15	SA FAN#2	400	160	214.48	306	130	81.3
16	Start up water pump	11,000	240	321.72	10,250	190	79.2
17	ID Fan for boiler	690	360	482.57	580	280	77.8
18	FD Fan for boiler	690	132	176.94	580	95	73.1
19	Awash river Pump #1	11,000	250	335.12	10,250	190	76
20	Awash river Pump #2	11,000	250	335.12	10,250	190	76
21	Awash river Pump #3	11,000	250	335.12	10,250	190	76
22	Raw water pump for main fire hydrant	400	110	147.45	305	85	77.3

Table appendix 2: Actual Voltage, Power Consumption and Load Factor for Group 'B' Motors

S/N	Equipment	Rated Voltage (volt)	Rated Power (KW)	Rated Horse Power (HP)	Actual voltage (volt)	Actual power (KW)	%Load factor
1	Feeding Table#1	400	45	60.3	305	36	80
2	Feeding Table#2	400	45	60.3	305	36	80
3	Cane kicker at feeder table#1	400	45	60.3	308	38	84.4
4	Cane kicker at feeder table#2	400	45	60.3	308	38	84.4
5	Auxiliary cane carrier (ACC)	400	30	40.2	315	26	86.7
6	Cane Kicker for ACC#1	400	45	60.5	312	40	88.9
7	Cane Kicker for ACC#2	400	75	100.5	316	67	89.3
8	Pusher for Fibrizer	400	40	53.6	302	35	87.5
9	Air Blower for Juice Sulphitation	400	75	100.5	296	58	77.3
10	Air Blower for Syrup Sulphitation	400	75	100.5	296	58	77.3
11	Prepared cane belt conveyor	400	30	40.2	300	24	80
12	Inter Rack Conveyor#1	400	30	40.2	304	23	76.7
13	Inter Rack Conveyor#2	400	30	40.2	304	23	76.7
14	Inter Rack Conveyor#3	400	30	40.2	304	23	76.7
15	Inter Rack Conveyor#4	400	30	40.2	304	23	76.7
16	Juice Pump for mill#1	400	22	29.5	297	16	72.7
17	Juice Pump for mill#2	400	22	29.5	297	16	72.7
18	Clear Juice Pump	400	90	120.6	298	65	72.2
19	Condensate Pump for First Effect	400	75	100.5	295.6	54	72.0
20	Condensate Pump for Fifth Effect.	400	75	100.5	295.6	54	72.0
21	Mixed Juice pump	400	30	40.2	295.8	22	73.3
22	Imbibition water pump	400	37.5	50.3	297	27	72.0
23	Syrup Extraction Pump	400	22	29.5	298	16	72.7
24	Bagacillo Blower	400	22.5	30.2	298	16	71.1
25	Sulphured Syrup Transfer Pump	400	22	29.5	299	16	72.7
26	O'C Filter Vacuum Pump	400	90	120.6	302	75	83.3
27	'C' Massecuite Pumps	400	30	40.2	301	22	73.3
28	'B1' Massecuite Pump	400	22	29.5	297.5	17	77.3
29	Hot Water Circulation Pump for Vertical Crystallizer#1	400	45	60.3	304	34	75.6
30	Hot Water Circulation Pump for Vertical Crystallizer#2	400	45	60.3	304	34	75.6
31	Cold Water Circulation Pump for Vertical Crystalliser#1	400	45	60.3	302	32	71.1

32	Cold Water Circulation Pump for Vertical Crystalliser#2	400	45	60.3	302	32	71.1
33	Service Water Pump	400	90	120.6	306	76	84.4
34	Air Compressor	400	67	89.8	303	54	80.6
35	'B1' Continuous Centrifugal Machines #1	400	90	120.6	299.5	74	82.2
36	'B1' Continuous Centrifugal Machines #2	400	90	120.6	299.5	74	82.2
37	'B1' Continuous Centrifugal Machines #3	400	90	120.6	299.5	74	82.2
38	'B1' Continuous Centrifugal Machines #4	400	90	120.6	299.5	74	82.2
39	'B2' Continuous Centrifugal Machine#1	400	90	120.6	300	74	82.2
40	'B2' Continuous Centrifugal Machine#2	400	90	120.6	300	74	82.2
41	'CA' Continuous Centrifugal Machine#1	400	90	120.6	300	75	83.3
42	'CA' Continuous Centrifugal Machine#2	400	90	120.6	300	75	83.3
43	Sugar Grader	400	22	29.5	306	18	81.8
44	Crane long travel	400	22.5	30.16	298	16	71.1
45	P.S FAN	400	45	60.32	302	35	77.8
46	Spray water pump	400	55	73.73	305	44	80
47	Feed water transfer pump	400	75	100.54	305	61	81.3
48	Make up water pump	400	22	29.50	298	16	72.7
49	Bagasse belt conveyor #5	400	37	49.60	299	29	78.4
50	Bagasse belt conveyor #6	400	37	49.60	299	29	78.4
51	Bagasse belt conveyor #8	400	37	49.60	299	29	78.4
52	Bagasse belt conveyor #10	400	45	60.32	299	29	78.4
53	Bagasse elevator BE#4	400	55	73.73	308	46	83.6
54	Main bagasse carrier (MBC)	400	55	73.73	308	46	83.6
55	Cooling Tower	400	75	100.54	301	62	82.7
56	Service water pump	400	75	100.54	304	63	84
57	First MGF Feed pump	400	30	40.21	300	23	76.7
58	Clarified water to overhead pump	400	30	40.21	300	25	83.3
59	Mill Bearing cooling water pump	400	22	29.49	300	18	81.8
60	Vertical RO pump	400	22	29.49	303	19	86.4

Table appendix 3: Actual Voltage, Power Consumption and Load Factor for Group 'C' Motors

S/N	Equipment	Rated Voltage (volt)	Rated Power (KW)	Rated Horse Power (HP)	Actual voltage (volt)	Actual power (KW)	%Load factor
1	Equalizer	400	10	13.4	295.2	7.5	75
2	Iron separator	400	5.6	7.5	297	4.3	76.8
3	Juice Pump for mill#3	400	18.5	24.8	298	15	81.1
4	Juice Pump for mill#4	400	18.5	24.8	298	15	81.1
5	Juice Pump for mill#5	400	18.5	24.8	298	15	81.1
6	Rotary Screen	400	7.5	10.1	299	5.8	77.3
7	Mudd Mixer	400	5.5	7.4	295.3	4	72.7
8	Mud Recirculation Pumps	400	15	20.2	296	11	73.3
9	Cake Wash Water Pump	400	15	20.2	297	11	73.3
10	Mud Belt Conveyor	400	5.5	7.4	295.5	4	72.7
11	Lime Elevator	400	3.7	5.0	297	2.9	78.4
12	Lime Slaker	400	10	13.4	298	7.8	78
13	Milk of Lime (MOL) Vibro Screen	400	1.1	1.5	295	0.8	72.7
14	Milk of Lime Storage Tanks stirrer motor	400	10	13.4	298	7.8	78
15	Milk Of Lime Pump	400	11	14.7	298	8.1	73.6
16	Condensate Pump for Receiver No.1	400	11	14.7	298	8.1	73.6
17	Condensate Pump for Receiver No.2	400	11	14.7	298	8.1	73.6
18	Condensate Pump for Receiver No.3	400	5.5	7.4	297	4.2	76.4
19	Caustic Soda Pump	400	11	14.7	298	8.2	74.5
20	Pan Condensate Pump	400	18.5	24.8	298.5	14.3	77.3
21	'A' Vacuum Crystallizer	400	5.5	7.4	296	4.1	74.5
22	'B1' Vacuum Crystallizer	400	5.5	7.4	296	4.1	74.5
23	'B2' Vacuum Crystallizer	400	5.5	7.4	296	4.1	74.5
24	'C' Vacuum Crystallizer	400	5.5	7.4	296	4.1	74.5
25	'A' Receiving Crystalliser#1 for 100 t pan	400	9.3	12.5	299	7	75.3
26	'A' Receiving Crystalliser#1 for 100 t Pan	400	9.3	12.5	298	7	75.3
27	'A' Receiving Crystalliser#1 for 100 t Pan	400	9.3	12.5	298	7	75.3
28	'B1' Receiving Crystallizer for Continuous Pan	400	5.5	7.4	296	4	72.7
29	'B2' Receiving Crystallizer#1	400	5.5	7.4	296	4	72.7
30	'B2' Receiving Crystallizer#2	400	5.5	7.4	296	4	72.7
31	'C' Receiving Crystallizer#1	400	5.5	7.4	296	4	72.7

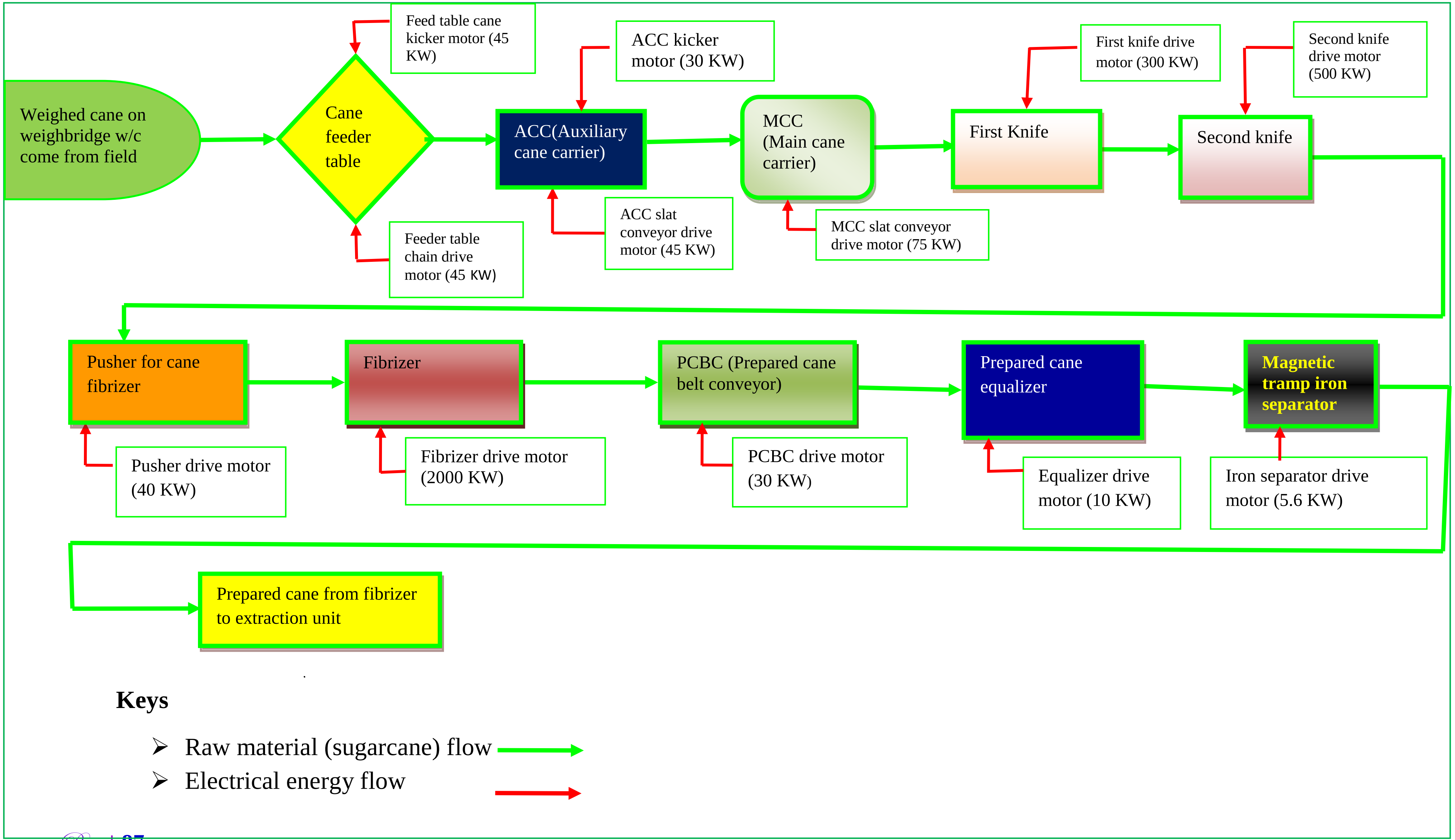
32	Liquidation Crystallizer for Continuous Pan	400	5.5	7.4	296	4	72.7
33	Sweet Water pump	400	18.5	24.8	299	14	75.7
34	‘B1’ Massecuite Seed Pump for Continuous pans#1	400	15	20.1	297	11	73.3
35	‘B1’ Massecuite Seed Pump for Continuous pans#2	400	15	20.1	297	11	73.3
36	‘B1’ Liquidation Pump	400	18.5	24.8	299	14	75.7
37	‘C’ Liquidation Pump	400	18.5	24.8	299	14	75.7
38	‘B1’ Vertical Crystallizer pump	400	7.5	10.1	296	5.5	73.3
39	‘C’ Vertical Crystallizer pump	400	9.3	12.5	297	7	75.3
40	AH Molasses Pump	400	15	20.1	297	11	73.3
41	AL Molasses Pump	400	5.5	7.4	296	4	72.7
42	‘B1’ Magma Pump	400	7.5	10.1	296	5.5	73.3
43	‘B2’ Magma Pump	400	7.5	10.1	296	5.5	73.3
44	‘B1’ Molasses Pump	400	5.5	7.4	296	4	72.7
45	‘B2’ Molasses Pump	400	5.5	7.4	296	4	72.7
46	C-After Magma Pump	400	7.5	10.1	296	5.5	73.3
47	CL Molasses Pump	400	5.5	7.4	296	4	72.7
48	C-Fore Magma Pump	400	7.5	10.1	296	5.5	73.3
49	FM Pump Below Machines	400	15	20.1	297	11	73.3
50	FM Pump Below Weighing Scale	400	15	20.1	297	11	73.3
51	Melt Pump	400	15	20.0	297	11	73.3
52	Final Molasses Transfer Pump	400	15	20.1	297	11	73.3
53	Sugar Elevator	400	11	14.7	297	7.8	70.9
54	Dry Seed Belt Conveyor	400	5.5	7.4	296	4	72.7
55	Rori Sugar Melter stirrer	400	2.2	2.9	295.7	1.7	77.3
56	Rori Melt Pump	400	5.5	7.4	296	4	72.7
57	Sugar Bag Handling System #1	400	9.9	13.2	296.5	7.3	73.7
58	Sugar Bag Handling System #2	400	9.9	13.2	296.5	7.3	73.7
59	Sugar Bag Handling System #3	400	9.9	13.2	296.5	7.3	73.7
60	Sugar Bag Handling System #4	400	9.9	13.2	296.5	7.3	73.7
61	Stacker set 16’	400	3.7	5.0	295.8	2.8	75.7
62	Stacker set 32’	400	5.5	7.4	296	4	72.7
63	Portable conveyors 3.5 m	400	2.2	2.9	295.7	1.7	77.3
64	Portable conveyors 6.5 m	400	2.2	2.9	295.7	1.7	77.3
65	Portable conveyors 9.5 m	400	2.2	2.9	295.7	1.7	77.3
66	Bagasse Feeder #1	400	5.5	7.4	296	4	72.7
67	Bagasse Feeder #2	400	5.5	7.4	296	4	72.7
68	Bagasse Feeder #3	400	5.5	7.4	296	4	72.7
69	Bagasse Feeder #4	400	5.5	7.4	296	4	72.7
70	Bagasse Feeder #5	400	5.5	7.4	296	4	72.7
71	Bagasse Feeder #6	400	5.5	7.4	296	4	72.7
72	Screw conveyor #1	400	3.7	5.0	295.8	2.8	75.7
73	Screw conveyor #2	400	3.7	5.0	295.8	2.8	75.7
74	Screw conveyor #3	400	3.7	5.0	295.8	2.8	75.7

75	Screw conveyor #4	400	3.7	5.0	295.8	2.8	75.7
76	Screw conveyor #5	400	3.7	5.0	295.8	2.8	75.7
77	Screw conveyor #6	400	3.7	5.0	295.8	2.8	75.7
78	Scratcher working	400	18.5	24.8	299	14	75.7
79	WICH #1	400	9.3	12.5	297	7	75.3
80	WICH #2	400	9.3	12.5	297	7	75.3
81	Telescopic chute	400	3.7	5.0	295.8	2.8	75.7
82	MCC Panel A-BC 7A	400	7.5	10.1	296.5	5.4	72.0
83	VFD Panel cross travel	400	2.2	2.9	295.7	1.6	72.7
84	AC-6-I	400	9.3	12.5	297	7	75.3
85	ꞓ SBC-1-I	400	5.5	7.4	296	4	72.7
86	AC-2-I	400	3.7	5.0	295.8	2.7	73.0
87	AC-3-I	400	3.7	5.0	295.8	2.7	73.0
88	AC-4-I	400	3.7	5.0	295.8	2.7	73.0
89	AC-5-I	400	3.7	5.0	295.8	2.7	73.0
90	Feed water heater #1 Boiler #1	400	3.7	5.0	295.8	2.7	73.0
91	Feed water heater #2 Boiler #1	400	3.7	5.0	295.8	2.7	73.0
92	Feed water heater #3 Boiler #1	400	3.7	5.0	295.8	2.7	73.0
93	Fed control station boiler #1	400	3.7	5.0	295.8	2.7	73.0
94	Feed water header #1	400	1.2	1.6	295.1	0.86	71.7
95	Retractable soot blower #1	400	1.1	1.5	295	0.79	71.8
96	Retractable soot blower #2	400	1.1	1.5	295	0.79	71.8
97	Retractable soot blower #3	400	1.1	1.5	295	0.79	71.8
98	Retractable soot blower #4	400	1.1	1.5	295	0.79	71.8
99	Primary super heater outlet to PRDS	400	0.18	0.24	295	0.13	72.2
100	Water drum to MBD boiler #1	400	0.18	0.24	295	0.13	72.2
101	Water drum to MBD boiler #1	400	0.18	0.24	295	0.13	72.2
102	Steam drum air ventilation	400	0.045	0.060	295	0.032	71.1
103	Steam drum outlet for CBD	400	0.045	0.060	295	0.032	71.1
104	Boiler#1 Vent silencer	400	0.72	0.97	295	0.53	73.6
105	Hydraulic power pack_1	400	3.7	5.0	295.8	2.7	73.0
106	Hydraulic power pack_2	400	3.7	5.0	295.8	2.7	73.0
107	RAV For air heater-1	400	3.7	5.0	295.8	2.7	73.0
108	RAV For air heater-2	400	3.7	5.0	295.8	2.7	73.0
109	RAV For air heater-3	400	3.7	5.0	295.8	2.7	73.0
110	RAV For air heater-4	400	3.7	5.0	295.8	2.7	73.0
111	H.P Dosing pump #1	400	1.5	2.0	295.1	1.1	73.3
112	H.P Dosing pump #2	400	1.5	2.0	295.1	1.1	73.3
113	H.P Dosing tank stirrer	400	0.37	0.50	295.0	0.26	70.3
114	Rotary soot blower #1	400	0.37	0.50	295.0	0.26	70.3
115	Rotary soot blower #2	400	0.37	0.50	295.0	0.26	70.3
116	Rotary soot blower #3	400	0.37	0.50	295.0	0.26	70.3
117	Rotary soot blower #4	400	0.37	0.50	295.0	0.26	70.3
118	Rotary soot blower #5	400	0.37	0.50	295.0	0.26	70.3

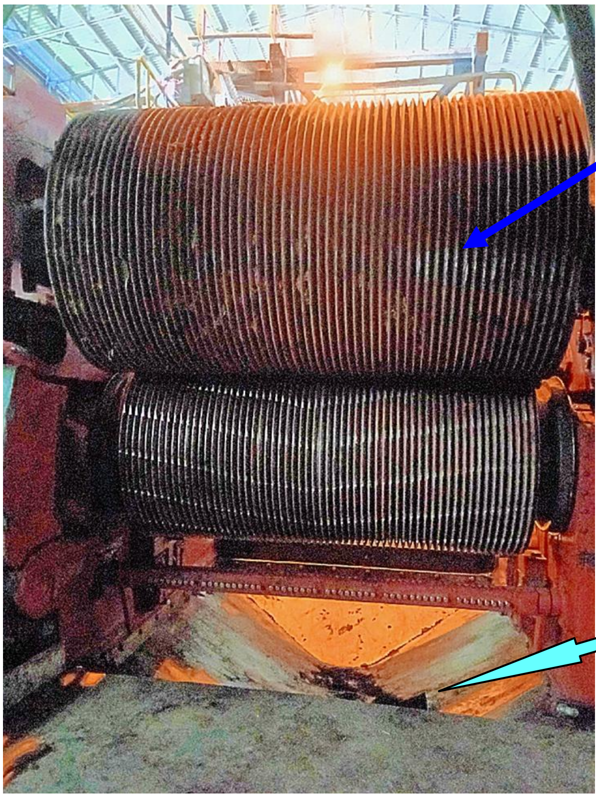
119	Rotary soot blower #6	400	0.37	0.50	295.0	0.26	70.3
120	Rotary soot blower #7	400	0.37	0.50	295.0	0.26	70.3
121	Rotary soot blower #8	400	0.37	0.50	295.0	0.26	70.3
122	Rotary soot blower #9	400	0.37	0.50	295.0	0.26	70.3
123	Rotary soot blower #10	400	0.37	0.50	295.0	0.26	70.3
124	Rotary soot blower #11	400	0.37	0.50	295.0	0.26	70.3
125	Rotary soot blower #12	400	0.37	0.50	295.0	0.26	70.3
126	Rotary soot blower #13	400	0.37	0.50	295.0	0.26	70.3
127	Rotary soot blower #14	400	0.37	0.50	295.0	0.26	70.3
128	Rotary soot blower #15	400	0.37	0.50	295.0	0.26	70.3
129	Rotary soot blower #16	400	0.37	0.50	295.0	0.26	70.3
130	Rotary soot blower #17	400	0.37	0.50	295.0	0.26	70.3
131	Rotary soot blower #18	400	0.37	0.50	295.0	0.26	70.3
132	Rotary soot blower #19	400	0.37	0.50	295.0	0.26	70.3
133	Telescopic chute-1	400	2.2	2.95	296	1.6	72.7
134	Telescopic chute-2	400	2.2	2.95	296	1.6	72.7
135	Dmerter Be-04 outlet	400	2.2	2.95	296	1.6	72.7
136	Tripper on BC-06	400	7.5	10.1	297	5.4	73.3
137	MSSV-Boiler	400	7.5	10.1	297	5.4	73.3
138	Steam inlet from boiler	400	7.5	10.1	297	5.4	73.3
139	Outlet from CSDH To TG	400	7.5	10.1	297	5.4	73.3
140	Steam stop valve for 50 TPH/1.5 bar PRDS	400	1.2	1.6	296	0.85	70.8
141	Feed water pump discharge	400	1.2	1.6	296	0.85	70.8
142	CSDH Outlet 70 TPH PRDS	400	3.7	5.0	296.5	2.7	73.0
143	LP Dosing pump	400	0.37	0.50	295.0	0.26	70.3
144	LP Dosing tank stirrer	400	0.37	0.50	295.0	0.26	70.3
145	Oil tank heater #1	400	5	6.70	296.2	3.6	72.0
146	Oil tank heater #2	400	5	6.70	296.2	3.6	72.0
147	Oil tank heater #3	400	5	6.70	296.2	3.6	72.0
148	Oil tank heater #4	400	5	6.70	296.2	3.6	72.0
149	Control Oil pump	400	5.5	7.37	296.8	4	72.7
150	Gland steam Blower	400	1.5	2.0	295.5	1.1	73.3
151	Oil vapor extraction fan	400	1.5	2.0	295.5	1.1	73.3
152	Jacking oil pump	400	3.7	5.0	296	2.7	73.0
153	Main steam stop valve	400	7.5	10.1	297	5.5	73.3
154	Condensate extraction pump	400	18.5	24.8	298.8	14	75.7
155	Main steam bypass valve	400	0.112 5	0.045	295	0.080 0	71.1
156	Bagasse belt conveyor #1	400	5.5	7.4	296	4	72.7
157	Condensate extraction pump	400	18.5	24.8	298.8	14	75.7
158	Bagasse belt conveyor #3	400	18.5	24.8	298.8	14	75.7
159	Bagasse belt conveyor #7	400	7.5	10.1	297	5.5	73.3
160	Bagasse belt conveyor #11	400	7.5	10.1	297	5.5	73.3
161	First MGF backwash pump	400	18.5	24.8	298.8	14	75.7
162	Second MGF Feed Pump	400	9.3	12.5	197.7	6.9	74.2

163	Overhead clarified water makeup water pump	400	5.5	11.6	296.0	4	72.7
164	Sodium hypochlorite dosing pump	400	0.37	0.50	295.0	0.26	70.3
165	Aluminum oxide dosing pump	400	0.37	0.50	295.0	0.26	70.3
166	Aluminum oxide stirrer	400	0.37	0.50	295.0	0.26	70.3
167	Polymer dosing pump	400	0.37	0.50	295.0	0.26	70.3
168	DM water pump	400	15	20.1	298.2	11.2	74.7
169	Auxiliary oil pump in boiler	400	18.5	24.8	298.8	14	75.7

Appendix 4 Flow charts of cane preparation unit of WSSF



Appendix 4.1 Extraction unit of Wonji/shoa sugar factory



Appendix 4.2 Roller mill of WSS

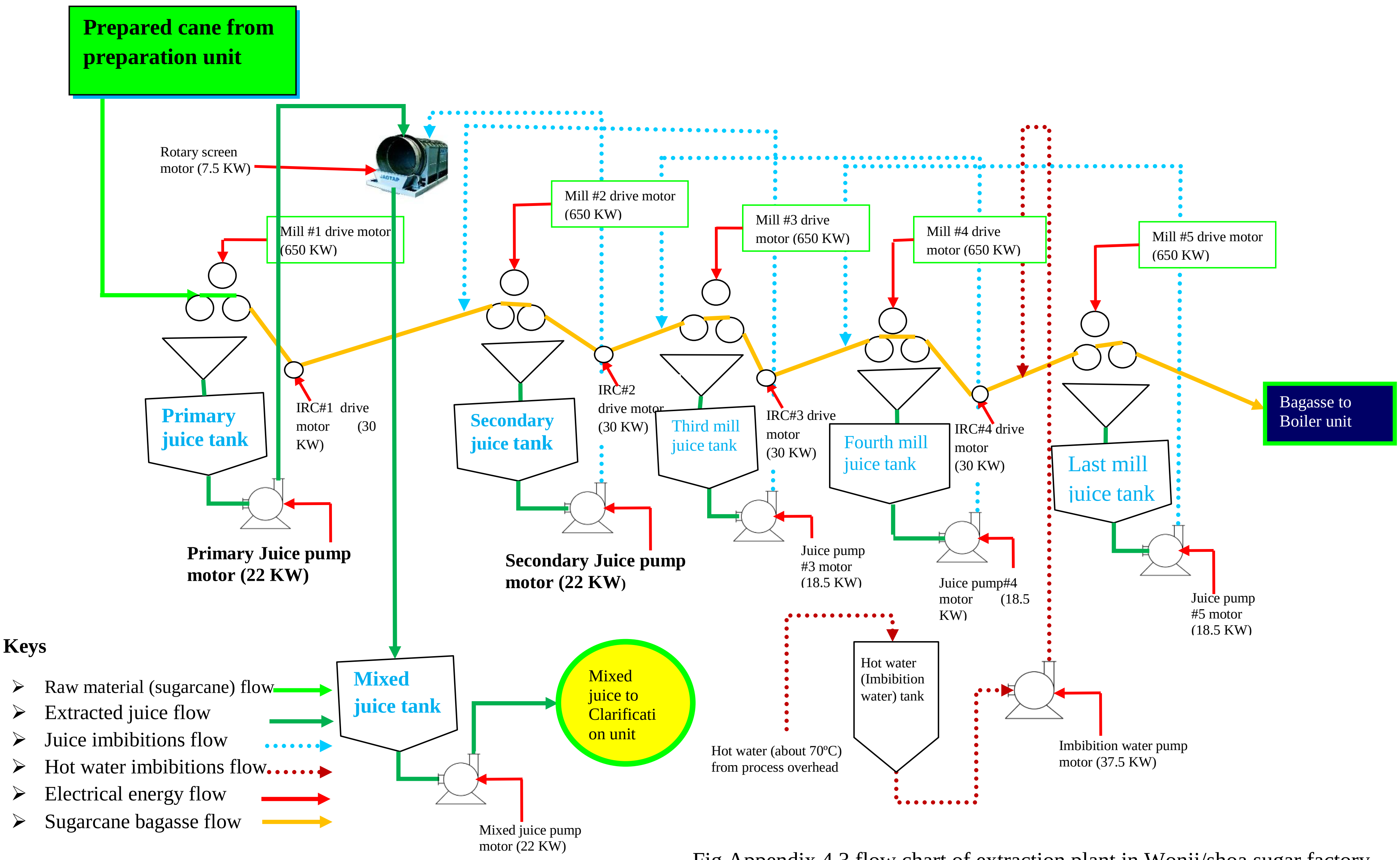
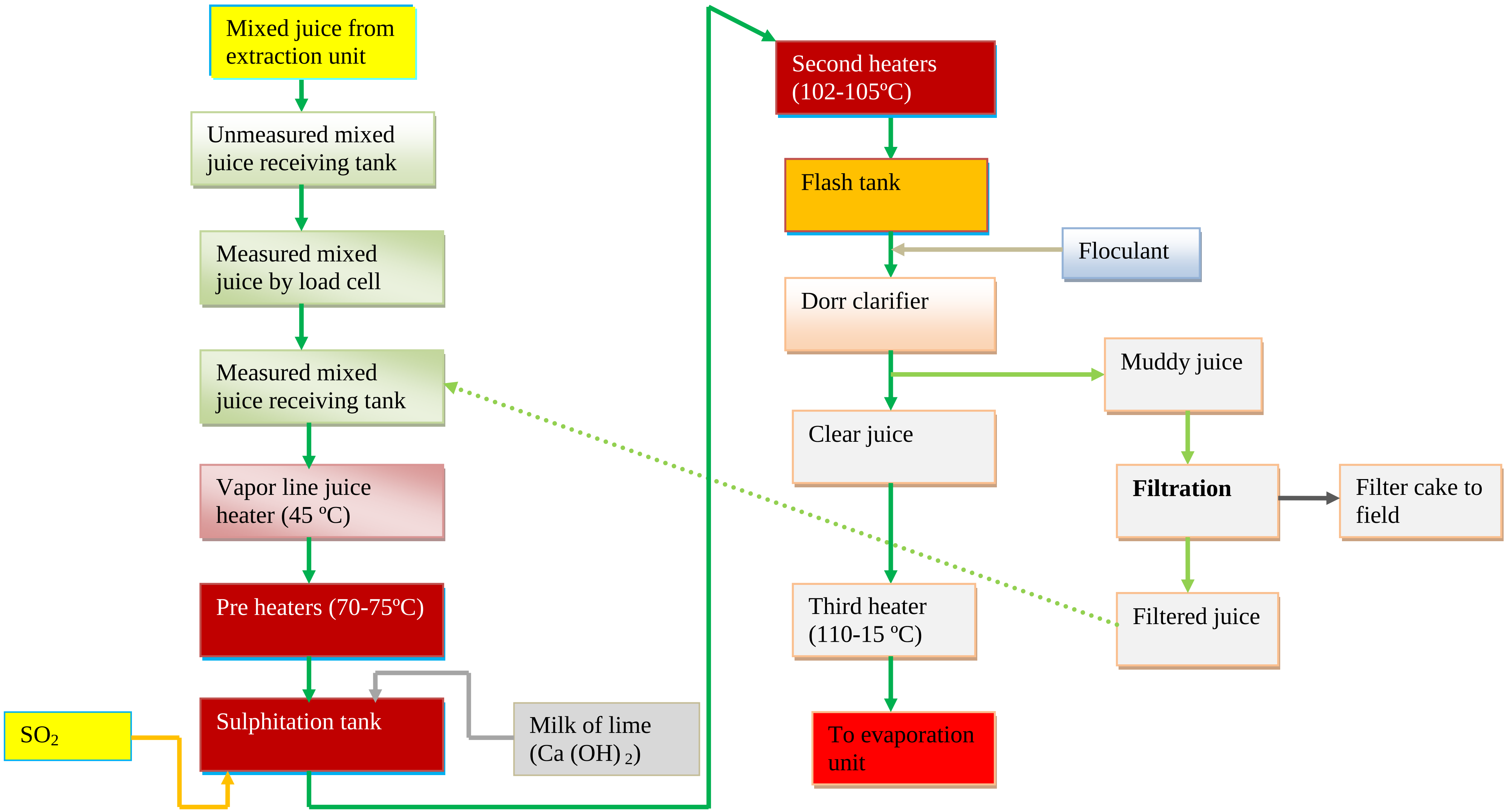
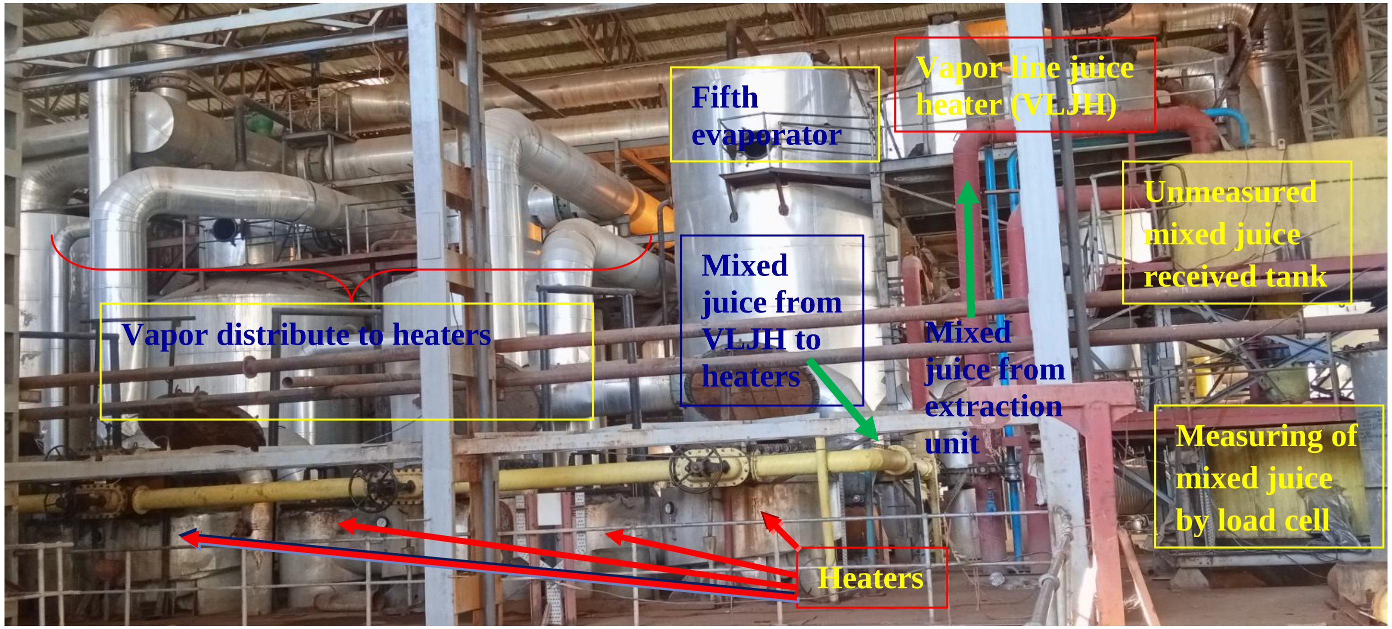
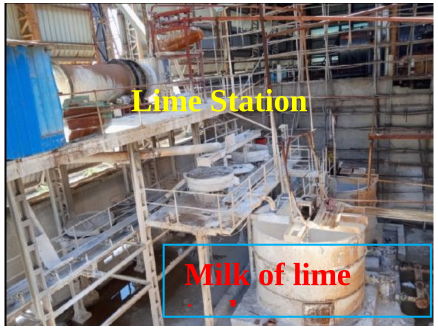


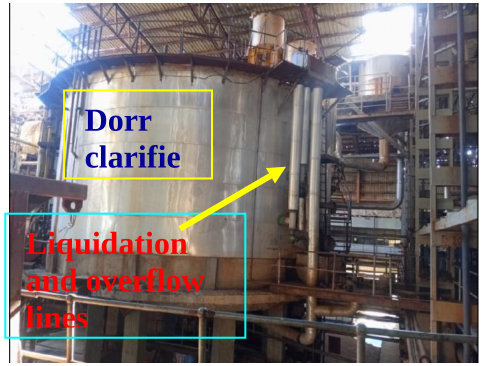
Fig Appendix 4.3 flow chart of extraction plant in Wonji/shoa sugar factory



Appendix 4.4 Flow chart of clarification unit of wonji/shoa sugar factory

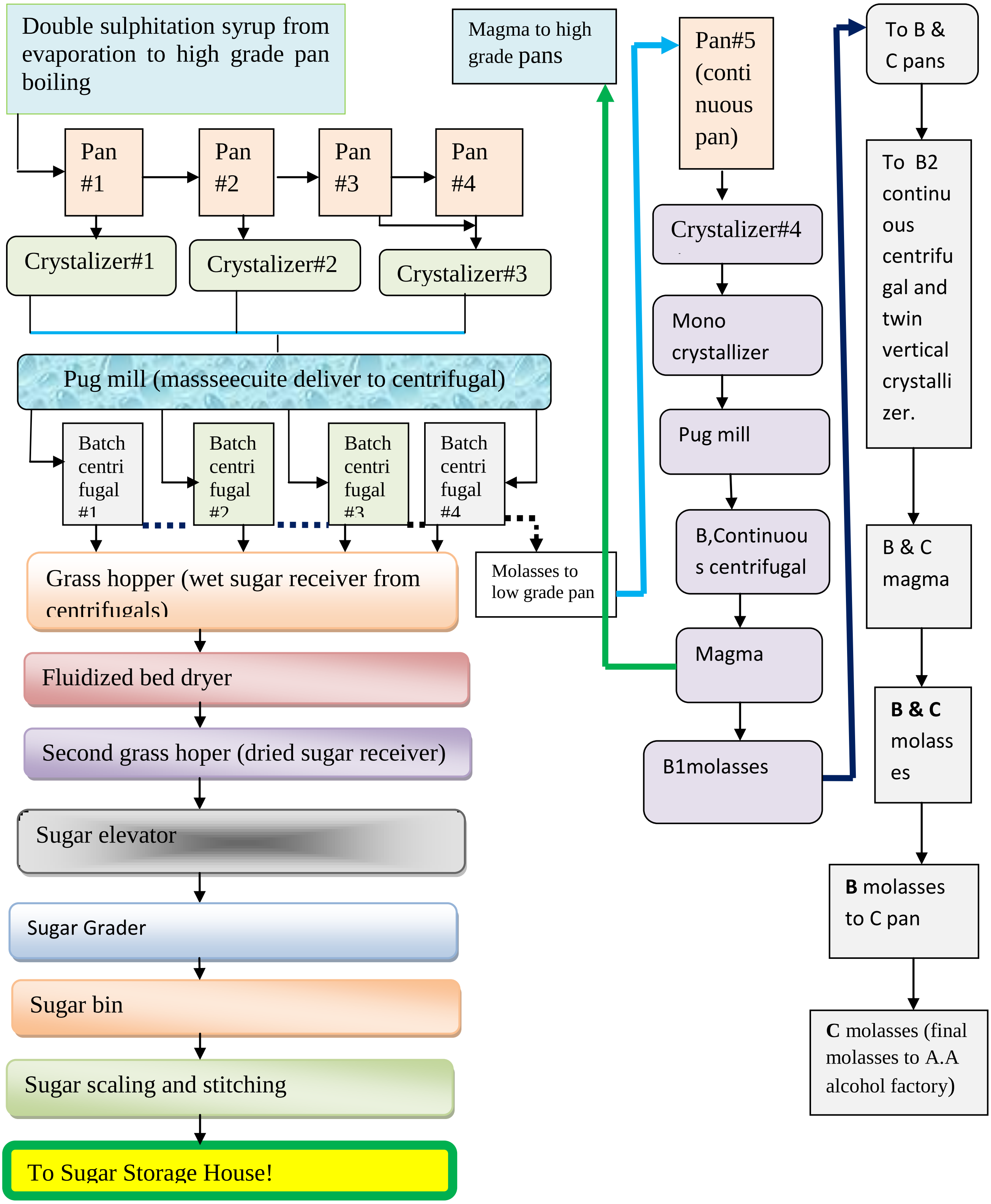




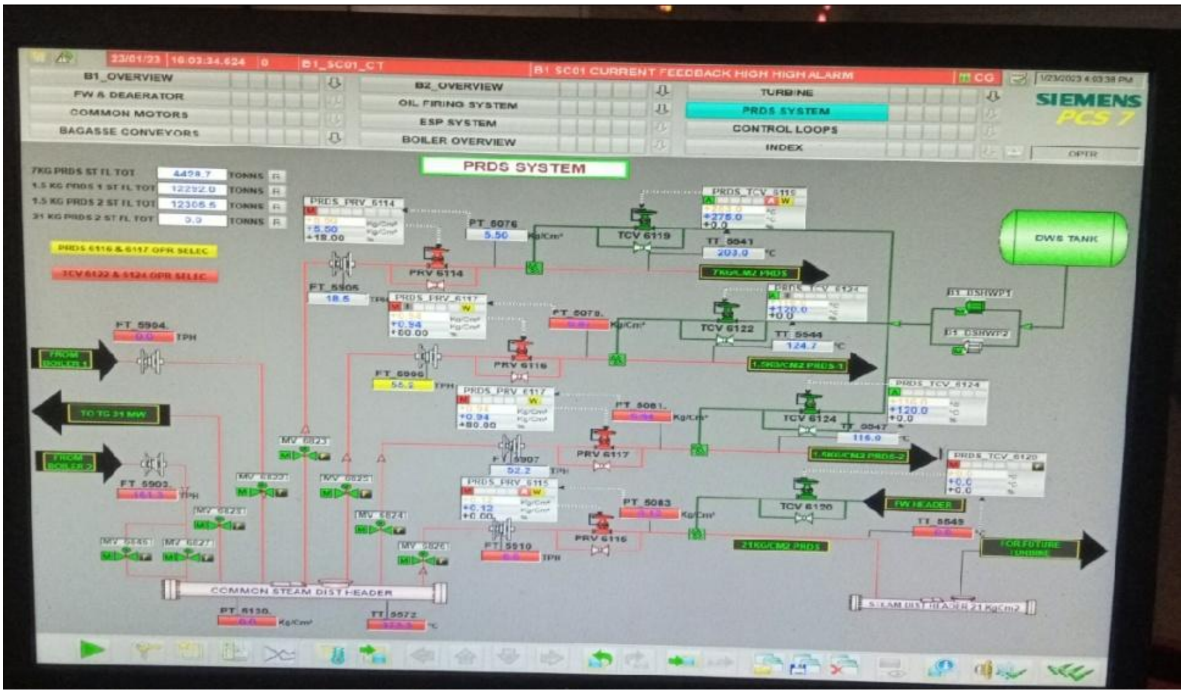


Appendix 4.5 Image of clarification & partial evaporation unit of wonji/shoa sugar factory

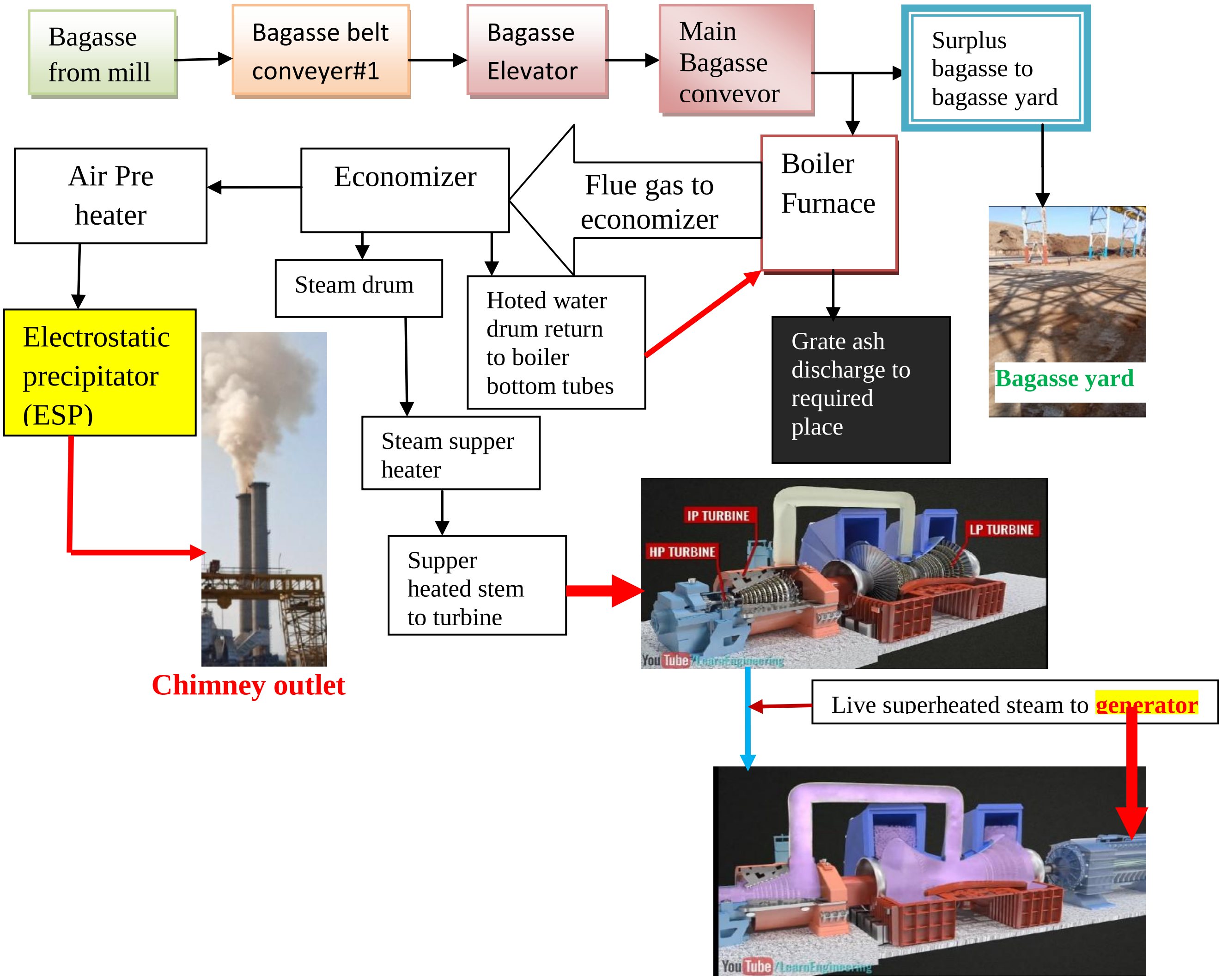
Appendix 4.6 Image of evaporation unit of wonji/shoa sugar factory



Appendix 4.7 Flow chart of crystallization unit of WSSF



Appendix 4.8 Boiler Pressure retarded and De-supper heater system (PRDS) of WSSF



Appendix 4.8 Flow chart and image of boiler unit of WSSF

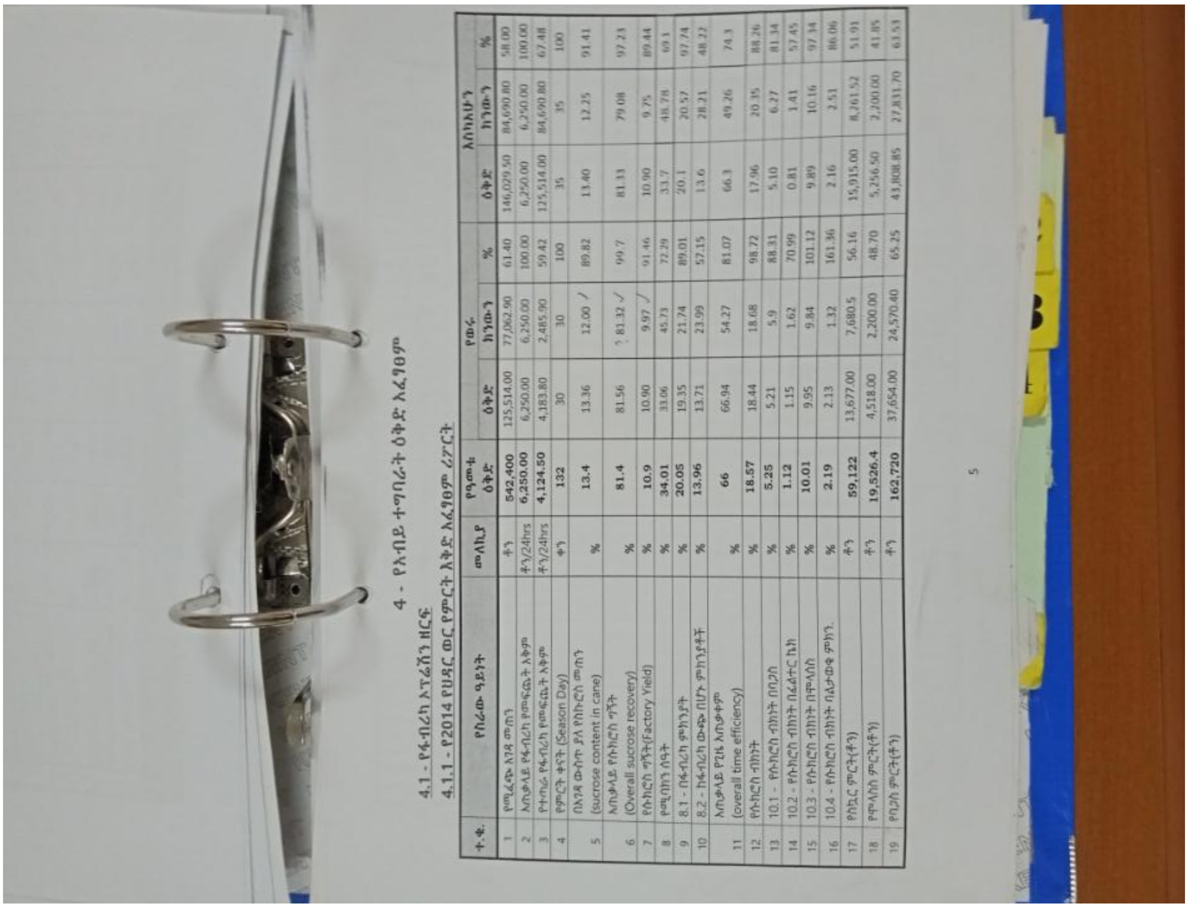
Filtration of Sugar solution by filter paper

Titration and reagent preparation lab room of WSSF

Bagasse and massecuite analysis lab room of WSSF

Spectrophotometer, Refractometer, polarimeter and refrigerator lab room of WSSF

PH and Conductivity meter lab room of WSSF



4 - የአብይ ተግባራት ዕቅድ አፈፃፀም

4.1 - የፋብሪካ ኦፕሬሽን ዘርፍ

4.1.1 - የ2014 የህዳር ወር የምርት እቅድ አፈፃፀም ሪፖርት

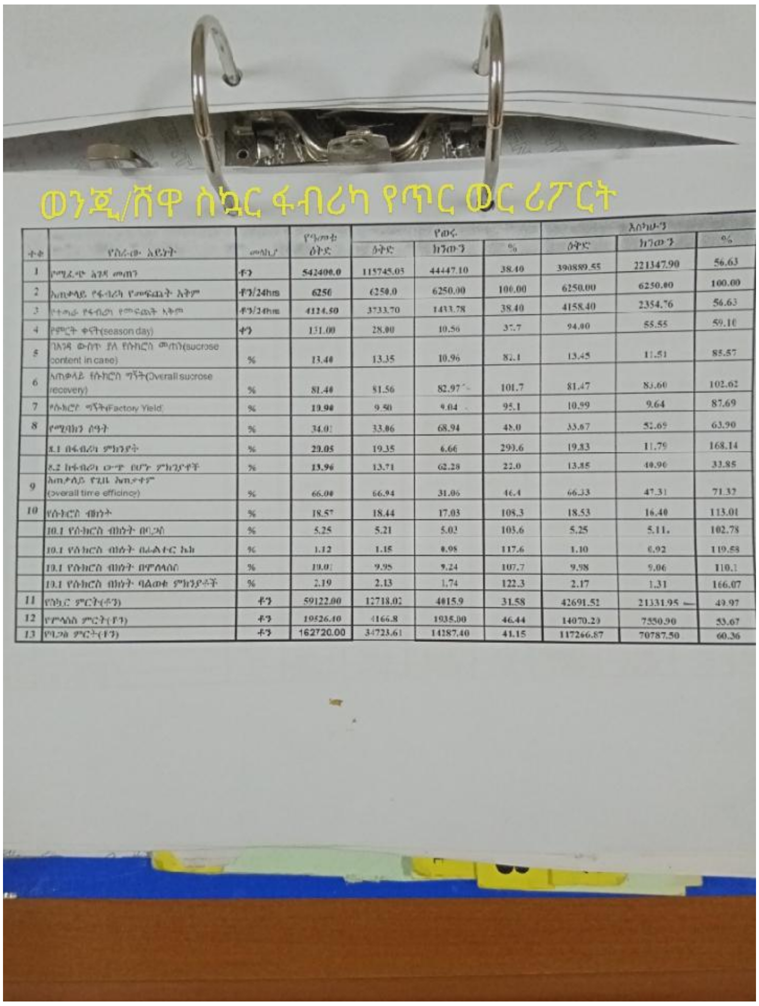
ተ.ቁ.	የስራው ዓይነት	መለኪያ	የዓመቱ ዕቅድ	የወሩ ዕቅድ	የወሩ ክንውን	የወሩ %	እስካሁን ዕቅድ	እስካሁን ክንውን	እስካሁን %
1	የሚፈጭ አገዳ መጠን	ቶን	542,400	125,514.00	77,062.90	61.40	146,029.50	84,690.80	58.00
2	አጠቃላይ የፋብሪካ የመፍጨት አቅም	ቶን/24hrs	6,250.00	6,250.00	6,250.00	100.00	6,250.00	6,250.00	100.00
3	የተጣራ የፋብሪካ የመፍጨት አቅም	ቶን/24hrs	4,124.50	4,183.80	2,485.90	59.42	125,514.00	84,690.80	67.48
4	የምርት ቀናት (Season Day)	ቀን	132	30	30	100	35	35	100
5	በአገዳ ውስጥ ያለ የስኳር መጠን (sucrose content in cane)	%	13.4	13.36	12.00	89.82	13.40	12.25	91.41
6	አጠቃላይ የስኳር ግኝት (Overall sucrose recovery)	%	81.4	81.56	81.32	99.7	81.33	79.08	97.23
7	የስኳር ግኝት(Factory Yield)	%	10.9	10.90	9.97	91.46	10.90	9.75	89.44
8	የሚባክን ሰዓት	%	34.01	33.06	45.73	72.29	33.7	48.78	69.1
9	8.1 - በፋብሪካ ምክንያት	%	20.05	19.35	21.74	89.01	20.1	20.57	97.74
10	8.2 - ከፋብሪካ ውጭ በሆኑ ምክንያቶች	%	13.96	13.71	23.99	57.15	13.6	28.21	48.22
11	አጠቃላይ የጊዜ አጠቃቀም (overall time efficiency)	%	66	66.94	54.27	81.07	66.3	49.26	74.3
12	የስኳር ብክነት	%	18.57	18.44	18.68	98.72	17.96	20.35	88.26
13	10.1 - የስኳር ብክነት በባጋስ	%	5.25	5.21	5.9	88.31	5.10	6.27	81.34
14	10.2 - የስኳር ብክነት በፊልተር ኬክ	%	1.12	1.15	1.62	70.99	0.81	1.41	57.45
15	10.3 - የስኳር ብክነት በሞላሰስ	%	10.01	9.95	9.84	101.12	9.89	10.16	97.34
16	10.4 - የስኳር ብክነት ባልታወቁ ምክን.	%	2.19	2.13	1.32	161.36	2.16	2.51	86.06
17	የስኳር ምርት(ቶን)	ቶን	59,122	13,677.00	7,680.5	56.16	15,915.00	8,261.52	51.91
18	የሞላሰስ ምርት(ቶን)	ቶን	19,526.4	4,518.00	2,200.00	48.70	5,256.50	2,200.00	41.85
19	የባጋስ ምርት(ቶን)	ቶን	162,720	37,654.00	24,570.40	65.25	43,808.85	27,831.70	63.53

5

ወንጂ/ሸዋ ስኳር ፋብሪካ ታህሳስ ወር ሪፖርት 01/12/2021 እስከ31/12/2021

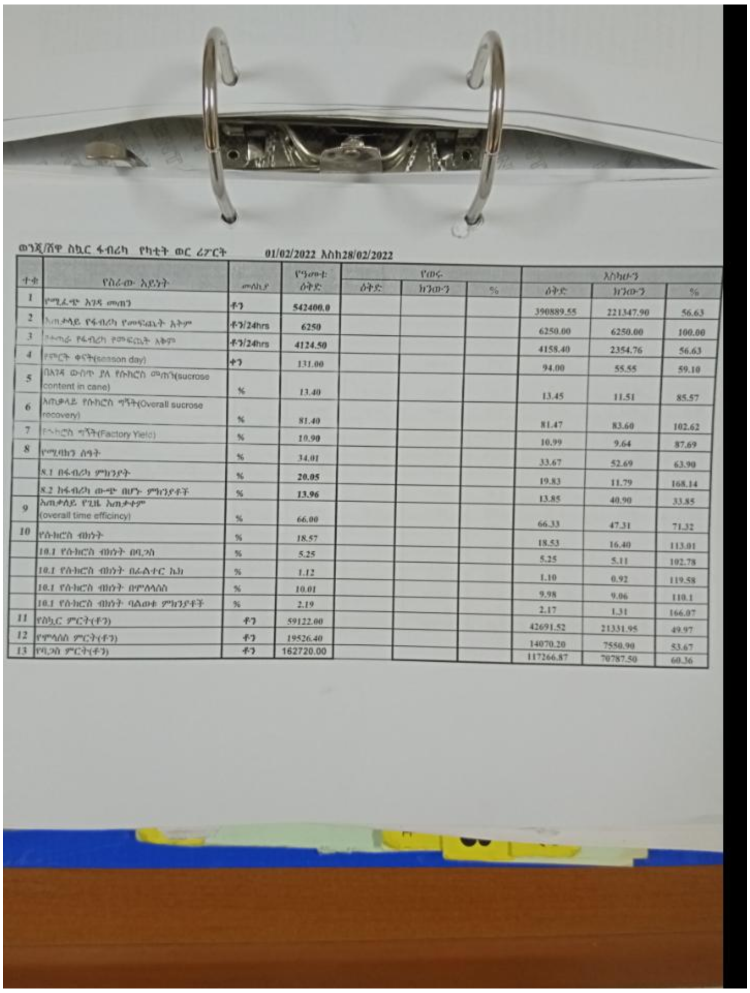
ተ.ቁ	የስራው አይነት	መለኪያ	የዓመቱ ዕቅድ	የወሩ ዕቅድ	የወሩ ክንውን	የወሩ %	እስካሁን ዕቅድ	እስካሁን ክንውን	እስካሁን %
1	የሚፈጭ አገዳ መጠን	ቶን	542400.0	129115.0	92210.00	71.42	275144.50	176900.80	64.29
2	አጠቃላይ የፋብሪካ የመፍጨት አቅም	ቶን/24hrs	6250	6250.0	6250.00	100.00	6250.00	6250.00	100.00
3	የተጣራ የፋብሪካ የመፍጨት አቅም	ቶን/24hrs	4124.50	4165.0	2974.52	71.42	4168.86	2680.32	64.29
4	የምርት ቀናት(season day)	ቀን	131.00	31.00	13.25	42.7	66.00	35.00	53.03
5	በአገዳ ውስጥ ያለ የስኳር መጠን(sucrose content in cane)	%	13.40	13.35	11.9	88.8	13.69	11.65	85.12
6	አጠቃላይ የስኳር ግኝት(Overall sucrose recovery)	%	81.40	81.56	82.68	101.4	81.41	80.57	98.97
7	የስኳር ግኝት(Factory Yield)	%	10.90	10.89	10.73	98.5	10.89	9.69	88.98
	የሚባክን ሰዓት	%	34.01	33.36	34.85	104.5	34.07	40.80	119.74
	8.1 በፋብሪካ ምክንያት	%	20.05	19.55	6.04	30.9	20.30	9.20	45.33
	8.2 ከፋብሪካ ውጭ በሆኑ ምክንያቶች	%	13.96	13.81	28.81	208.6	13.77	31.60	229.42
9	አጠቃላይ የጊዜ አጠቃቀም (overall time efficincy)	%	66.00	66.64	65.15	97.8	65.93	59.20	89.80
10	የስኳር ብክነት	%	18.57	18.44	17.32	106.4	18.59	19.43	95.68
	10.1 የስኳር ብክነት በባጋስ	%	5.25	5.21	4.29	121.6	5.10	4.79	93.88
	10.1 የስኳር ብክነት በፊልተር ኬክ	%	1.12	1.09	1.72	63.5	1.16	2.23	52.05
	10.1 የስኳር ብክነት በሞላሰስ	%	10.01	9.97	9.97	100.0	10.01	9.75	97.4
	10.1 የስኳር ብክነት ባልወቁ ምክንያቶች	%	2.19	2.17	1.35	160.7	2.17	2.67	81.34
11	የስኳር ምርት(ቶን)	ቶን	59122.00	14059.79	9890.4	70.34	29973.50	17865.98	59.61
12	የሞላሰስ ምርት(ቶን)	ቶን	19526.40	4648.14	3989.50	85.83	9903.40	5615.90	56.71
13	የባጋስ ምርት(ቶን)	ቶን	162720.00	38735	39395.00	101.70	82543.35	56500.10	68.45

November and December monthly production report at laboratory log book of WSSF



ወንጂ/ሸዋ ስኳር ፋብሪካ የጥር ወር ሪፖርት

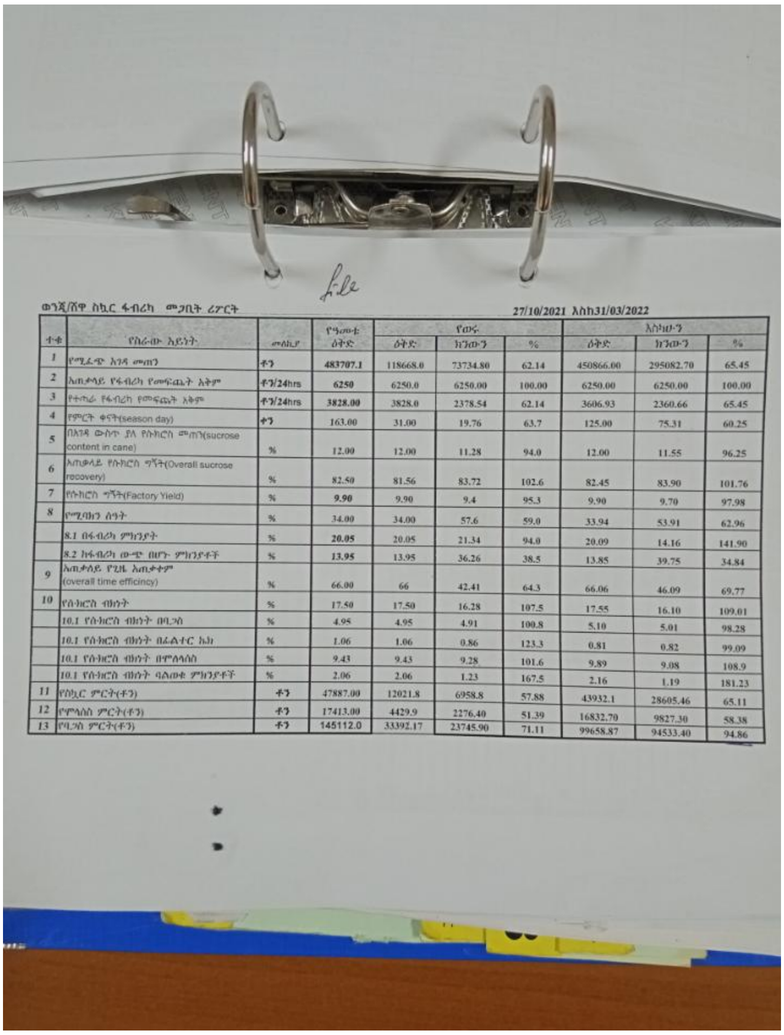
ተቁ	የስራው አይነት	መለኪያ	የዓመቱ ዕቅድ	የወሩ			እስካሁን		
				ዕቅድ	ክንውን	%	ዕቅድ	ክንውን	%
1	የሚፈጭ አገዳ መጠን	ቶን	542400.0	115745.05	44447.10	38.40	390889.55	221347.90	56.63
2	አጠቃላይ የፋብሪካ የመፍጨት አቅም	ቶን/24hrs	6250	6250.0	6250.00	100.00	6250.00	6250.00	100.00
3	የተጣራ የፋብሪካ የመፍጨት አቅም	ቶን/24hrs	4124.50	3733.70	1433.78	38.40	4158.40	2354.76	56.63
4	የምርት ቀናት(season day)	ቀን	131.00	28.00	10.56	37.7	94.00	55.55	59.10
5	በአገዳ ውስጥ ያለ የሱክሮስ መጠን(sucrose content in cane)	%	13.40	13.35	10.96	82.1	13.45	11.51	85.57
6	አጠቃላይ የሱክሮስ ግኝት(Overall sucrose recovery)	%	81.40	81.56	82.97	101.7	81.47	83.60	102.62
7	የሱክሮስ ግኝት(Factory Yield)	%	10.90	9.50	9.04	95.1	10.99	9.64	87.69
8	የሚባክን ሰዓት	%	34.01	33.06	68.94	48.0	33.67	52.69	63.90
	8.1 በፋብሪካ ምክንያት	%	20.05	19.35	6.66	290.6	19.83	11.79	168.14
	8.2 ከፋብሪካ ውጭ በሆኑ ምክንያቶች	%	13.96	13.71	62.28	22.0	13.85	40.90	33.85
9	አጠቃላይ የጊዜ አጠቃቀም (overall time efficincy)	%	66.00	66.94	31.06	46.4	66.33	47.31	71.32
10	የሱክሮስ ብክነት	%	18.57	18.44	17.03	108.3	18.53	16.40	113.01
	10.1 የሱክሮስ ብክነት በባጋስ	%	5.25	5.21	5.03	103.6	5.25	5.11	102.78
	10.1 የሱክሮስ ብክነት በፊልተር ኬክ	%	1.12	1.15	0.98	117.6	1.10	0.92	119.58
	10.1 የሱክሮስ ብክነት በሞላሰስ	%	10.01	9.95	9.24	107.7	9.98	9.06	110.1
	10.1 የሱክሮስ ብክነት ባልወቀ ምክንያቶች	%	2.19	2.13	1.74	122.3	2.17	1.31	166.07
11	የስኳር ምርት(ቶን)	ቶን	59122.00	12718.02	4015.9	31.58	42691.52	21331.95	49.97
12	የሞላሰስ ምርት(ቶን)	ቶን	19526.40	4166.8	1935.00	46.44	14070.20	7550.90	53.67
13	የባጋስ ምርት(ቶን)	ቶን	162720.00	34723.61	14287.40	41.15	117266.87	70787.50	60.36



ወንጂ/ሸዋ ስኳር ፋብሪካ የካቲት ወር ሪፖርት 01/02/2022 እስከ28/02/2022

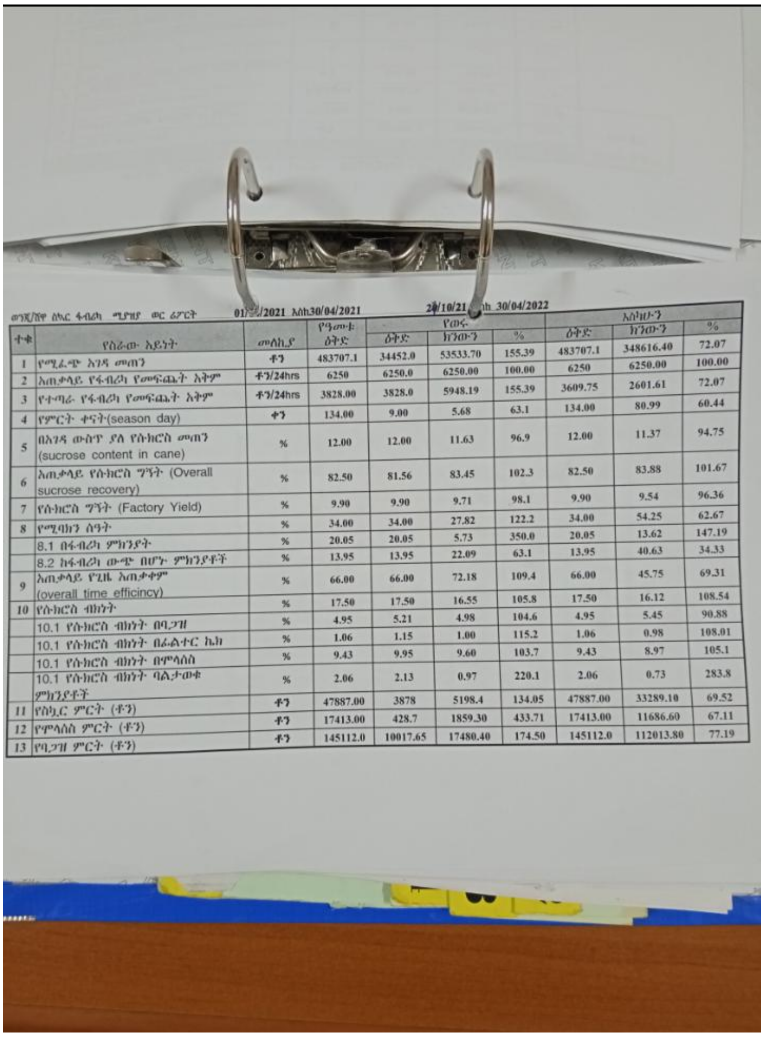
ተቁ	የስራው አይነት	መለኪያ	የዓመቱ ዕቅድ	የወሩ			እስካሁን		
				ዕቅድ	ክንውን	%	ዕቅድ	ክንውን	%
1	የሚፈጭ አገዳ መጠን	ቶን	542400.0				390889.55	221347.90	56.63
2	አጠቃላይ የፋብሪካ የመፍጨት አቅም	ቶን/24hrs	6250				6250.00	6250.00	100.00
3	የተጣራ የፋብሪካ የመፍጨት አቅም	ቶን/24hrs	4124.50				4158.40	2354.76	56.63
4	የምርት ቀናት(season day)	ቀን	131.00				94.00	55.55	59.10
5	በአገዳ ውስጥ ያለ የሱክሮስ መጠን(sucrose content in cane)	%	13.40				13.45	11.51	85.57
6	አጠቃላይ የሱክሮስ ግኝት(Overall sucrose recovery)	%	81.40				81.47	83.60	102.62
7	የሱክሮስ ግኝት(Factory Yield)	%	10.90				10.99	9.64	87.69
8	የሚባክን ሰዓት	%	34.01				33.67	52.69	63.90
	8.1 በፋብሪካ ምክንያት	%	20.05				19.83	11.79	168.14
	8.2 ከፋብሪካ ውጭ በሆኑ ምክንያቶች	%	13.96				13.85	40.90	33.85
9	አጠቃላይ የጊዜ አጠቃቀም (overall time efficincy)	%	66.00				66.33	47.31	71.32
10	የሱክሮስ ብክነት	%	18.57				18.53	16.40	113.01
	10.1 የሱክሮስ ብክነት በባጋስ	%	5.25				5.25	5.11	102.78
	10.1 የሱክሮስ ብክነት በፊልተር ኬክ	%	1.12				1.10	0.92	119.58
	10.1 የሱክሮስ ብክነት በሞላሰስ	%	10.01				9.98	9.06	110.1
	10.1 የሱክሮስ ብክነት ባልወቀ ምክንያቶች	%	2.19				2.17	1.31	166.07
11	የስኳር ምርት(ቶን)	ቶን	59122.00				42691.52	21331.95	49.97
12	የሞላሰስ ምርት(ቶን)	ቶን	19526.40				14070.20	7550.90	53.67
13	የባጋስ ምርት(ቶን)	ቶን	162720.00				117266.87	70787.50	60.36

January and February monthly production report at laboratory log book of WSSF



ወንጂ/ሸዋ ስኳር ፋብሪካ መጋቢት ሪፖርት 27/10/2021 እስከ31/03/2022

ተቁ	የስራው አይነት	መለኪያ	የዓመቱ ዕቅድ	የወሩ ዕቅድ	የወሩ ክንውን	የወሩ %	እስካሁን ዕቅድ	እስካሁን ክንውን	እስካሁን %
1	የሚፈጭ አገዳ መጠን	ቶን	483707.1	118668.0	73734.80	62.14	450866.00	295082.70	65.45
2	አጠቃላይ የፋብሪካ የመፍጨት አቅም	ቶን/24hrs	6250	6250.0	6250.00	100.00	6250.00	6250.00	100.00
3	የተጣራ የፋብሪካ የመፍጨት አቅም	ቶን/24hrs	3828.00	3828.0	2378.54	62.14	3606.93	2360.66	65.45
4	የምርት ቀናት(season day)	ቀን	163.00	31.00	19.76	63.7	125.00	75.31	60.25
5	በአገዳ ውስጥ ያለ የስኩሮስ መጠን(sucrose content in cane)	%	12.00	12.00	11.28	94.0	12.00	11.55	96.25
6	አጠቃላይ የስኩሮስ ግኝት(Overall sucrose recovery)	%	82.50	81.56	83.72	102.6	82.45	83.90	101.76
7	የስኩሮስ ግኝት(Factory Yield)	%	9.90	9.90	9.4	95.3	9.90	9.70	97.98
8	የሚባክን ሰዓት	%	34.00	34.00	57.6	59.0	33.94	53.91	62.96
	8.1 በፋብሪካ ምክንያት	%	20.05	20.05	21.34	94.0	20.09	14.16	141.90
	8.2 ከፋብሪካ ውጭ በሆኑ ምክንያቶች	%	13.95	13.95	36.26	38.5	13.85	39.75	34.84
9	አጠቃላይ የጊዜ አጠቃቀም (overall time efficincy)	%	66.00	66	42.41	64.3	66.06	46.09	69.77
10	የስኩሮስ ብክነት	%	17.50	17.50	16.28	107.5	17.55	16.10	109.01
	10.1 የስኩሮስ ብክነት በባጋስ	%	4.95	4.95	4.91	100.8	5.10	5.01	98.28
	10.1 የስኩሮስ ብክነት በፊልተር ኬክ	%	1.06	1.06	0.86	123.3	0.81	0.82	99.09
	10.1 የስኩሮስ ብክነት በሞላሰስ	%	9.43	9.43	9.28	101.6	9.89	9.08	108.9
	10.1 የስኩሮስ ብክነት ባልታወቁ ምክንያቶች	%	2.06	2.06	1.23	167.5	2.16	1.19	181.23
11	የስኳር ምርት(ቶን)	ቶን	47887.00	12021.8	6958.8	57.88	43932.1	28605.46	65.11
12	የሞላሰስ ምርት(ቶን)	ቶን	17413.00	4429.9	2276.40	51.39	16832.70	9827.30	58.38
13	የባጋስ ምርት(ቶን)	ቶን	145112.0	33392.17	23745.90	71.11	99658.87	94533.40	94.86



ወንጂ/ሸዋ ስኳር ፋብሪካ ሚያዝያ ወር ሪፖርት 01/[illegible]/2021 እስከ30/04/2021 2[illegible]/10/21 [illegible] 30/04/2022

ተቁ	የስራው አይነት	መለኪያ	የዓመቱ ዕቅድ	የወሩ ዕቅድ	የወሩ ክንውን	የወሩ %	እስካሁን ዕቅድ	እስካሁን ክንውን	እስካሁን %
1	የሚፈጭ አገዳ መጠን	ቶን	483707.1	34452.0	53533.70	155.39	483707.1	348616.40	72.07
2	አጠቃላይ የፋብሪካ የመፍጨት አቅም	ቶን/24hrs	6250	6250.0	6250.00	100.00	6250	6250.00	100.00
3	የተጣራ የፋብሪካ የመፍጨት አቅም	ቶን/24hrs	3828.00	3828.0	5948.19	155.39	3609.75	2601.61	72.07
4	የምርት ቀናት(season day)	ቀን	134.00	9.00	5.68	63.1	134.00	80.99	60.44
5	በአገዳ ውስጥ ያለ የስኩሮስ መጠን (sucrose content in cane)	%	12.00	12.00	11.63	96.9	12.00	11.37	94.75
6	አጠቃላይ የስኩሮስ ግኝት (Overall sucrose recovery)	%	82.50	81.56	83.45	102.3	82.50	83.88	101.67
7	የስኩሮስ ግኝት (Factory Yield)	%	9.90	9.90	9.71	98.1	9.90	9.54	96.36
8	የሚባክን ሰዓት	%	34.00	34.00	27.82	122.2	34.00	54.25	62.67
	8.1 በፋብሪካ ምክንያት	%	20.05	20.05	5.73	350.0	20.05	13.62	147.19
	8.2 ከፋብሪካ ውጭ በሆኑ ምክንያቶች	%	13.95	13.95	22.09	63.1	13.95	40.63	34.33
9	አጠቃላይ የጊዜ አጠቃቀም (overall time efficincy)	%	66.00	66.00	72.18	109.4	66.00	45.75	69.31
10	የስኩሮስ ብክነት	%	17.50	17.50	16.55	105.8	17.50	16.12	108.54
	10.1 የስኩሮስ ብክነት በባጋዝ	%	4.95	5.21	4.98	104.6	4.95	5.45	90.88
	10.1 የስኩሮስ ብክነት በፊልተር ኬክ	%	1.06	1.15	1.00	115.2	1.06	0.98	108.01
	10.1 የስኩሮስ ብክነት በሞላሰስ	%	9.43	9.95	9.60	103.7	9.43	8.97	105.1
	10.1 የስኩሮስ ብክነት ባልታወቁ ምክንያቶች	%	2.06	2.13	0.97	220.1	2.06	0.73	283.8
11	የስኳር ምርት (ቶን)	ቶን	47887.00	3878	5198.4	134.05	47887.00	33289.10	69.52
12	የሞላሰስ ምርት (ቶን)	ቶን	17413.00	428.7	1859.30	433.71	17413.00	11686.60	67.11
13	የባጋዝ ምርት (ቶን)	ቶን	145112.0	10017.65	17480.40	174.50	145112.0	112013.80	77.19

March and April monthly production report at laboratory log book of WSSF