A

Project Report

On

"EXERGY ANALYSIS OF ENERGY CONSUMING DEVICES AT SUGAR INDUSTRY"

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Under the guidance of

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CERTIFICATE

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Studying in B. Tech. Mechanical Engineering have successfully completed the projectentitled **"Exergy Analysis of Energy Consuming Devices at Sugar Industry"** under the guidance and supervision of Prof. K. S. Gharge during the academic year 2022-23.

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We take this opportunity to thank all our lecturers who have directly or indirectly helped our project. We pay our respects and love to our parents and all other family members and friends for their love and encouragement throughout our career.

ABSTRACT

This project aims to conduct an exergy analysis of energy consuming devices, namely a boiler and a pump, at a sugar factory. The purpose of this study is to identify the sources of energy inefficiencies in these devices and propose possible solutions for energy saving. The exergy analysis will be based on the input and output data of the devices, which will be obtained through measurements and data logging. The analysis will include the calculation of energy and exergy efficiencies, as well as the identification of the sources of exergy destruction. The results of the analysis will provide insights into the performance of the devices and the potential for energy savings. The proposed solutions will involve improvements in the design and operation of the devices, as well as the use of more efficient components. This study will contribute to the efforts of the sugar factory in reducing its energy consumption and improving its sustainability.

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ABBREVIATION AND NOMENCLATURE

Nomenclature:

$\dot{m}$	Mass flow rate
e	Specific exergy rate
$\dot{E}$	Total exergy rate
h	Enthalpy
s	Entropy
T	Temperature
P	Pressure
$\dot{I}$	Exergy destruction rate
$\dot{W}$	Work rate
NCV	Net calorific value
$\emptyset$	Mass fraction

Greek symbols:

η_{ex}	Exergetic efficiency

Subscripts:

o	Dead state conditions
b/B	Boiler
p/P	Pump
f	Fuel
fp	Feed water pump
sp	Sulphited juice pump
cp	Clear juice pump

CHAPTER 1
INTRODUCTION

1.1. Background

The energy crisis of the 1970s and the increasing emphasis on the conservation of fuel resources (i.e., efficiency) have led to a complete over haul of how power systems are analyzed and improved thermodynamically. Thermodynamics is a credible method of performing analysis of technical systems efficiently by finding the most economical solution within the limits of the technical possibilities. Thus, thermodynamics laws play an important role in performing the energy and exergy analysis of industrial systems.

The sugar industry is a vital sector in the global economy and is a major consumer of energy. The sugar industry is a big business in India. Sugarcane is planted in India on three occasions annually, in October, March, and July, depending on the region and the most effective habitat. India is now a structurally sugar-surplus country and is also exporting sugar to other countries. India's cooperative local sugar mills are where the majority of the country's sugar is produced. Around mills produced more than 288 Lakh tonne of sugar in the last crushing season, which lasted from October 2022 to March 2023. Sugarcane cultivation and extraction employs about 50 million farmers and thousands of additional industry workers. The largest consumer of sugar worldwide is India.

During the last sugar season 2021-22, India exported around 110 LMT of sugar. In the current sugar season 2022-23, the Government of India has allocated a quantity of 60 LMT of sugar for export to sugar mills across the country.

Sugar production requires numerous energy-intensive processes, including the boiling of juice, evaporation of water, and crystallization of sugar. The boiler and pump systems used in a sugar factory are critical components that consume a significant amount of energy for steam generation as well as the flow of fluid throughout the factory. The method for clearly distinguishing between energy losses to the environment and internal irreversibilities in the process is exergetic analysis. The exergy analysis methodology involves assessing the exergy at various points in a series or process of energy-conversion steps and serves as an aid forassessingtheperformanceofthedevicesaswellasprocesses.Withthisinformation,efficiencies can be evaluated, and the steps of a process having the largest losses (i.e. in turnhavingthegreatestmarginforimprovement)canbeidentified.Forthesereasons,thecontemporary approach to procedure analysis uses exergy analysis, which provides a more realistic view of the process and is a useful tool for engineering evaluation.

The exergy analysis applied can be obtained to reduce the use of natural resources for energy generation and, as a result, to decrease the pollution of the environment. Therefore, analysis of these systems can provide valuable insights into their performance and efficiency.

1.2 Objective:

The aim of this project is to perform exergy analysis of energy consuming devices.

i. Analyze the performance of efficiency of energy consuming devices i.e. Boiler and pumps.

ii. The exergy analysis will be conducted using thermodynamic principles, with a focus on calculating the exergy of the input and output streams, as well as the exergy destruction within the systems.

iii. To evaluate the exergy destruction rate and efficiency of these systems.

iv. To identify areas of improvement in these systems.

v. Find feasible solutions for significant energy savings.

1.3 Exergy:

An opportunity for doing work exists whenever two systems at different states are placed in contact, as work can be developed when the two are allowed to come into equilibrium. Exergy is the greatest theoretical shaft work or electrical work that can be obtained as the two systems interact to reach equilibrium, with heat transfer occurring exclusively with the environment when one of the two systems is a sufficiently idealized system known as the environment and the other is a system of interest

Exergy, on the other hand, is the minimal amount of theoretical electrical or shaft labor needed to create a certain amount of material from elements found in the environment and get it to a specific state. Exergy is typically destroyed rather than conserved. When energy would be lost, that would be a limiting circumstance. as would happen if a system were to naturally reach equilibrium with the environment without any means of obtaining work. The opportunity to develop work that exists initially would be completely wasted in the spontaneous process. Moreover, since no work needs to be done to effect such a spontaneous change, we may conclude that the value of exergy (the maximum theoretical work obtainable) is at least zero and therefore cannot be negative.

1.3.1 Exergy analysis:

The exergy analysis is based on the first and second laws of thermodynamics and Exergy is defined as the maximum amount of work potential of a material or an energy stream concerning the surrounding environment.

In addition, a feature of the exergy concept permits quantitative evaluation of energy degradation.

The first law of thermodynamics indicates that,

- The energy content of the universe and its masses are constant.
- Neither energy nor matter can be produced, destroyed, or consumed.
- Energy is never lost in quantitative terms; it only gets degraded in quality as the degradation of quality makes it less useful.

The concept of the destruction of something can be considered useful. But, energy cannot be considered, however, but there exists another term: exergy.

The second law of thermodynamics indicates that the quality of energy is degraded every time energy is used in any process. The energy quality has been named the exergy law or the second law. Exergy can be destroyed or consumed, but not conserved and created.

- Exergy is defined as the maximum amount of work that can be produced by a stream of matter, heat, or work, as it comes to equilibrium with a reference environment.
- Exergy is the useful work potential of the energy; it can never be recovered.
- The entropy of a system increases when the exergy is lost.
- The kinetic and potential energies of the system contribute their full magnitudes to the exergy magnitude when measured relative to the environment because each is fully convertible to work as the system approaches the dead state.
- Exergy can be expressed as the sum of the chemical exergy and the thermo-mechanical exergy. Thermo-mechanical exergy can be further classified as physical, kinetic, and potential exergy.
- Energy conservation does not apply to exergy; instead, it is used or destroyed as a result of irreversibilities in all procedures.

1.3.2 Exergy analysis application:

Thermal systems are supplied with exergy inputs derived directly or indirectly from the consumption of resources such as oil, natural gas, coal, and other resources. Accordingly, avoidable destructions and losses of exergy represent the waste of these resources. By devising ways to reduce such sources of inefficiency, better use can be made of fuels.

The exergy balance can be used to determine the location, type, and true magnitude of the waste of energy resources, and thus can play an important part in developing strategies for more effective fuel use. Exergy analysis can help locate system non-idealities that either are not identified or misevaluated by energy analysis, for example, the combustion irreversibility. Accordingly, exergy analysis can be used as a tool to devise better processes or design better components. Exergy analysis also can be used to assess the real effect of off-design conditions on individual components or overall plants. Ultimately, exergy analysis can be applied globally to the industrial sector, the agricultural sector, or an entire nation to develop insights concerning the location and relative significance of key non-idealities. Such insights can be used to guide measures for improving the sector's overall conversion efficiency in turn reducing thereby resource waste attributable to that sector.

1.4 Maintenance and advancement in system components:

1.4.1 Numerous measures related to maintenance and controls are possible to reduce losses. These include,

i. Minimizing gas, air, steam, and other substance leaks in pipes, valves, couplings, and equipment.

ii. Utilizing improved and more automated controllers, both to ensure design specifications are adhered to and to detect parameter variations that may indicate future problems.

iii. Improved maintenance to ensure minor breaks and actual operating parameters match design specifications, for example, minor modifications to reheat steam rising temperature in the boiler can be implemented to improve overall efficiency.

iv. Periodic overhauls of devices.

1.4.2 Exergy-related techniques for analyzing energy-consuming devices at sugar production factory:

To assist in improving the efficiencies of bagasse to electricity technologies, their thermodynamic performances are usually investigated. Energy analysis is typically used to analyze energy technology. A more comprehensive thermodynamic viewpoint, which makes use of the second rule of thermodynamics along with energy analysis via exergy methods, leads to a better understanding.

Exergy is more freely regarded as a measure of the quality or usefulness (in addition to the quantity) of an energy flow or quantity. Exergy analysis is a technique for evaluating the efficiencies of processes and devices and identifying the locations and causes/sources of major inefficiencies, where actual performance exhibits the largest deviations from ideal performance. Unlike energy efficiencies, exergy efficiencies always provide a measure of the approach to the ideal. Through the better understanding developed with exergy analysis, the efficiencies of devices and processes can usually be improved, often in a cost-effective manner.

Exergy analysis is therefore particularly beneficial for

i. Designing better new facilities, and

ii. Modifying existing facilities to improve them.

Exergy approaches may provide important insights that assist in improving productivity and achieving ideal designs.

CHAPTER 2

LITERATURE REVIEW

2.1 Review of literature:

I. Energy and exergy analysis conducted at sugar factory:

- **H. M. Sahin et al [2010]** - In this paper, the energy and exergy analysis of sugar production processes were presented using operational system data from a sugar plant in Turkey. The results showed that the best values of the energy and exergy efficiencies were obtained in the juice production process and juice concentration process, respectively. The authors also identified the location of energy degradation and irreversibility in the sugar production processes, and suggested that improving these rates could lead to increased energy and exergy efficiencies.
- **Sibo Dennis [2019]** - In his study, Sibo Dennis observed the energy losses of three power plants in a sugar refinery and used exergy and energy data to provide a technological solution for energy cost reduction and stability. The goals included developing a cutting-edge system for increasing revenue while reducing energy use, utilizing energy data to develop strategies for managing and reducing energy costs, and promoting efficient energy management systems.
- **Tolga Taner et al [2015]** - Sugar manufacturing in the food business uses a significant amount of energy, primarily from the usage of steam and the strength of the turbine power plant. Energy and exergy analyses are therefore vital in sugar mills. The input and output data necessary for energy and exergy analysis of sugar factories were the subject of a different study. According to the analysis, the plant had an overall energy efficiency and exergy efficiency of 72.2% and 37.4%, respectively, with an overall energy quality of 0.64.

II. Exergy analysis of energy-consuming devices (Boiler based):

- **Neetu Singh et al** [**2019]** - The paper identifies the reactions having max energy losses. The heat losses through the boiler and condenser are considered here and the energy balance and exergy destruction are performed around the different equipment of the plant. The major source of exergy loss is the boiler where around 77% of the fuel exergy was destroyed, in the turbine it is 13% of the total fuel exergy was destroyed. It shows that the boiler is the major source of the irreversibility in the plant. Exergy analyses are the first step in understanding where the weak points of the processes are. In this case study, energy and exergy analysis of a power plant is done with a varying reference temperature.

- **Yusuf Parvez et al [2019]** - In the present scenario, the energy crisis and its demand have become global problems that restrict sustainable development. To overcome this problem, one needs to develop an advanced technological system that not only improves the system's performance but also reduces the environmental effects. Yusuf Parvez and M M Hasan conducted an energy and exergy analysis of a sugarcane bagasse boiler and found that the energy efficiency of the boiler was high, but the second law efficiency was relatively low due to significant irreversibility rates associated with the combustion chamber and heat exchangers. The authors suggested that improving the performance of the combustion chamber and heat exchangers could lead to improved overall performance of the plant.
- **S. Jayakumar et al [2008]** - In this study, the authors performed an exergy analysis of boilers in the sugar industry, which are used to generate steam for various processes. The authors found that the combustion chamber had the highest exergy destruction, and suggested improvements in the combustion process to improve the overall efficiency of the boilers.
- **Hemanta kumar Panda et al [2018]** - The primary objective of the work is to analyze the system components separately to identify the parts responsible for the loss of energy at large. The conclusion of the research can enable the configuration of suitable modifications to improve the efficiency of the system components and minimize the energy loss of the power plant. Based on a study of energy destruction, the boiler system has a maximum of 64.04% energy loss. The energy efficiency of the power plant is 50.41%, which is low as compared to modern power plants. According to analysis, it is found that the boiler is the major source of irreversibility in the power plant, but the energy destruction rate in the boiler can be reduced by introducing a reheating system. It is an effective method for reducing boiler irreversibility. In this research, the effect of reheating on enhancing overall performance is contrasted with the actual state of the power plant. The impact of reheating to reduce energy destruction has also been studied, with no change in fuel use. It has been discovered that the introduction of the reheating technology boosted overall plant efficiency and increased power generation, in addition to minimizing boiler energy destruction.
- **PeriyasamyK et al [2018]** -The project's goals are to increase boiler efficiency and eliminate moisture from biogas. Bagasse is a byproduct of the sugar milling process that is used as a fuel resource. It is a low-density, fibrous material that has a very wide variety of particle sizes and a high moisture content. Its chemical characteristics are comparable to those of fiber from hardwoods. The physical characteristics of bagasse particles are challenging to describe using conventional metrics (such as particle density, size, drag coefficient, etc.). To use standard design practices, these characteristics are required. As an illustration, consider pneumatic conveyance, fluidization, drying, burning, etc. The

gravimetric method is typically used to determine moisture content. After milling, the moisture content is typically up to 50%.Moisture content has an impact on calorific value. Therefore, burning bagasse at the proper degree of moisture is crucial for the efficiency of the furnace. Here, both direct and indirect techniques are used to eliminate the moisture. the technique for altering the processes of conduction, convection, and radiation. by using exhaust flue gas as a source to drain bagasse of moisture.

- **R. Saidur et al [2010]** - This essay analyses and applies the practical idea of energy and energy utilization to the boiler system. In this study, the energy and exergy flows in a boiler are illustrated. Additionally, energy and exercise efficiencies have been established. Energy and exergy efficiencies in a boiler were discovered to be 72.46% and 24.89%, respectively. The energy and energy efficiency of a boiler are also evaluated in comparison to other works. It has been discovered that a boiler system's heat exchanger and combustion chamber are the two main contributors to energy destruction. Additionally, a number of energy-saving techniques are used to lessen a boiler's energy consumption, such as the use of variable-speed drives in the fan and heat recovery from flue gas. According to research, the payback period for heat recovery from boiler flue gas is roughly one year. The payback period for using a 19 kW motor with a VSD was found to be economically feasible for boiler fan energy reductions.

III. Exergy analysis of various components carried out at sugar industries:

- **M. Narayanan et al [2006]** - In this study, the authors performed an exergy analysis of a cogeneration system in a sugar industry, which produces both electricity and steam for the industry's use. The authors found that the boiler and the steam turbine had the highest exergy destruction, and suggested improvements in these devices to improve the overall efficiency of the system.
- **N. W. Kimari et al [2017]** -The authors performed an exergy analysis of a sugar industry process that incorporates a partial condensing turbo-generator. The authors found that the evaporator and the condenser had the highest exergy destruction, and suggested improvements in the heat transfer process to improve the overall efficiency of the system.

- **Necmettin Sahin et al [2015]** - A study was conducted at the Eregli Sugar Factory to analyze the energy and exergy used in sugar production processes. The study found that the factory needs to implement energy-saving innovations to prevent energy losses. To achieve this, the study recommended that the factory's systems be maintained, repaired, and renovated to save energy.
- **Muhammad Faisal Hasan et al [2018]** - Exergy analysis is a valuable tool for evaluating the performance and efficiency of various systems, including those related to

solar energy, sugar production, and cogeneration. In the study by Muhammad Faisal Hasan et al., the authors conducted a thermodynamic analysis on a serpentine-type thermosyphon flat-plate solar heater using the Second Law of thermodynamics. The results showed that most exergy destruction occurs due to the high-temperature difference between the sun and the absorber plate, and utilizing solar energy for water heating can greatly reduce energy costs.

- **Hector Velasquez et al [2010]** - In the study by Hector Velasquez et al., the authors aimed to determine how energy resources are used in the production of unrefined sugar in Colombia. The results showed that technological improvements can increase energy efficiency to acceptable levels, but implementing cogeneration systems in large-scale production processes may be necessary for further improvements in second-law efficiency.

IV. Thermal power plant’s analysis:

- **Isam H. Aljundi [2009]** – It is studied that the energy and exergy analysis of Al-Hussein power plant (396MW) in Jordan. The performance of the plant was estimated by a component wise modeling and a detailed break-up of energy and exergy losses for the considered plant has been presented. It was found that the exergy destruction rate of the boiler is dominant over all other irreversibility in the cycle. It counts alone for 77% of losses in the plant, while the exergy destruction rate of the condenser is only 9%. The real loss is primarily back in the boiler where entropy was produced. Contrary to the first law analysis, this demonstrates that significant improvements exist in the boiler system rather than in the condenser.
- **Sandhya Hasti et al [2013]** - In this study, exergy analysis was performed for ultra super-critical power plant. The analysis was carried out by means of process simulation using a computer model developed in Microsoft Excel The model was based on the concepts of coal combustion, energy balances, enthalpy balances, entropy changes and heat transfer of the steam power cycle. After development, the validated model was used to simulate the hypothetical power plant combusting lignite coal with the net output of 422 MW. The exergy loss indicates that the highest concentration of losses appears to be the furnace followed by the turbine.
- **Mohammadreza BabaeiJamnani et al [2020] -** The gas-fired combined-cycle power station that will be built in Kuantan and Kapar on the Malay Peninsula in 2020 is the subject of this study's energy-exergy analysis. The main goals of the current study are the evaluation of the gas turbine unit, condenser, heat recovery steam generator, and triple-pressure steam turbines as first- and second-law systems. Energy-exergy analysis allows us to analyze the major or minor effects of changes in environmental conditions on plant components in addition to determining the precise amount of energy destruction and

efficiency in each component independently. When the pressure ratio, reference temperature, HPT and condenser pressure, reheating, and stack temperature change, performance effects are also identified. With regard to the current analysis, the gas turbine cycle accounts for approximately 83.79% of all exergy destruction, followed by HRSG (11.3%), steam turbines (around 2.58%), and condenser (2.54%). The average molar percentages of nitrogen, oxygen, carbon dioxide, and water vapour are calculated to be 76.42%, 17.57%, 1.37%, and 4.64%, respectively, in the exhaust gas portions from the gas turbine across the combustor. In light of the findings, various positive prospects for the growth of CCPP's performance are introduced. Energy-exergy assessment and optimization advice may be beneficial for this project's construction in 2020 in order to improve some operating conditions and simultaneously take advantage of the low destruction rate.

2.2 Concluding remark:

i. It was found that the exergy destruction rate of the boiler is dominant over all other irreversibilities in the cycle and followed by the turbine of the plant closely followed by a condenser.

ii. The cost of exergy destruction in the boiler and turbine is higher in comparison to the other components' cost.

iii. Through exergy analysis, the most sensitive mechanisms associated with heat loss is the exergy lost by heat transfer and thermal irreversibilities.

iv. Exergy analysis results can aid efforts to improvement, design, and optimization efforts are likely to be more rational and comprehensive if exergy is one of the factors considered.

2.3 Methodology:

i. Detailed Literature survey regarding experimental performance of sugar production factory and performance analyze of it for enhancing performance.

ii. Literature survey gap analysis is carried out and gaps are identified.

iii. Data is collected from the actual workings of the sugar production factory.

iv. Energy-consuming components such as boilers and plant pumps are thoroughly examined.

v. To determine the exergy generated and the exergy destroyed at each component of the plant

vi. A conclusion is drawn from the discussion, and the scope of the work is decided.

CHAPTER 3
PLANT LAYOUT AND COMPONENTS

3.1 Theory:

The exergy analysis is conducted at Jaywant Sugars Ltd. (JSL) is located in Satara, Maharashtra, near post Dhawarwadi, Tal. Karad.

Corporation for agriculture and bio-energy, Jaywant Sugars Ltd. JSL is the outcome of an inspirational business concept and a compelling mission to become the most effective sugar processor. The company is founded by Dr. Suresh Jaywantrao Bhosale and his son Dr. Atul Suresh Bhosale in 2006, not just dreamers but doers in their own right.

JSL has installed capacity of 2500 Tonne per Day and 10 MW co-generation. JSL produce white crystal fine sugar of M & S grade with double sulphation process. Where clarified sugar cane juice treated and mixed with sulphur di-oxide and outcome is known as sulphured syrup, which is sent for pan boiling for crystallization process and then final free flow sugar crystal forms with by products such as bagasse and molasse.

With an added distillery producing Ethanol, rectified spirit, neutral alcohol and hand sanitizer.

3.2 Plant Layout:

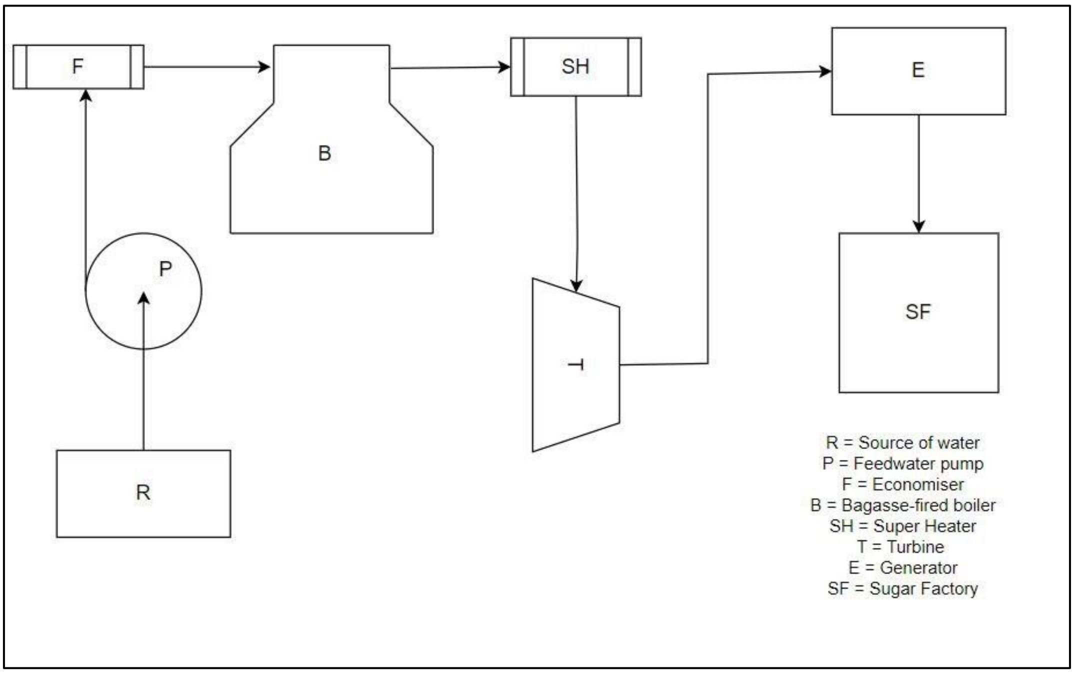

Figure 3.1 Plant Layout

Turbine:

The plant uses Triveni Eng. & Ind. Ltd. Multistage impulse type turbine. The turbine has a capacity of 10MW and temperature up to 510 ^{o}C. With generator of 10 MW and voltage-11000V and 656 A.

3.3 Component specifications:

The following data gives specifications about boiler and pumps used in the sugar factory:

I) Boiler

Figure 3.2 Water-tube boiler

Boiler is used for steam power production. It is fueled by burning bagasse.

Make	S. S. Eng. Ltd.
Type	Water tube – Bagasse fueled
Design and working parameter	45 kg/cm^2
Hydraulic test pressure	67.5 kg/cm^2
Boiler Capacity	70 Ton/hr.
Total heating capacity	3749sq.m.

II) Pump Specifications

All the mentioned pumps used are centrifugal-type pumps.

i. Feed water pump

The feed water pump is used to feed the water to the boiler for heating.

No. of pump	3
Make	KSB

Type	HAD-65/12
Capacity	45 m^3/hr
Head	650 m
Motor	Kiloskar make 225HP – 2900rpm

ii. Sulphited juice pump

A sulphited juice pump is used to mix the clear juice obtained from the sugarcane with sulphur dioxide.

Type	CPHM – 125/45
Head	70 m
Capacity	200 m^3/hr
Motor	75 kW/100 HP – 1470 rpm

iii. Clear juice pump

A clear juice pump is used to pump out the clear juice.

No. of pump	5
Type	GK/00/40B
Head	50 m
Capacity	200 m^3/hr
Motor	30 kW – 1460 rpm

3.4 Software Detail:

For numerical calculation, data analysis, and visualization, many different fields employ the high-level programming language and environment known as MATLAB. It offers a variety of tools and features that make it appropriate for utilization in engineering and scientific applications.

MATLAB was used for the validation of calculated data total exergy flow and exergy destruction rate of selected components. For the same MATLAB R2023a was utilized. Program was generated and ran for the computation of the exergy destruction rate along with determination of specific entropy, enthalpy and thermodynamical properties required in the calculations.

CHAPTER 4
EXERGY ANALYSIS CALCULATIONS

4.1 Exergy analysis procedure:

To carry out exergy analysis the following assumptions are considered:

i. The process is carried out at steady state.
ii. Changes in potential and kinetic energies are neglected
iii. There are no heat losses over the surface of the components.
iv. Cycle and cooling water are treated as pure
v. There are no changes of the specific chemical energies in the cycle.

a. Exergy can be transferred by heat, work and mass flow. The general equation of the total exergy for the all steps, considered as an open steady state thermodynamics system or a steady flow process, is calculated as :

$$Ex_{total} = Ex_{heat} + Ex_{work} + Ex_{mass}$$

- The total exergy of a system (E) can be divided into four components: physical exergy (E_{PH}) kinetic exergy (E_{KN}), potential exergy (E_{PT}), and chemical exergy (E_{CH}).

$$\dot{E} = \dot{E}_{PH} + \dot{E}_{KN} + \dot{E}_{PT} + \dot{E}_{CH}$$

- If the kinetic, potential and chemical exergy are considered to be negligible the specific exergy is defined as by equation.

$$e = (h-h_o) - T_o (s-s_o)$$

- The total exergy rate of the system is given by the equation.

$$\dot{E} = \dot{m} [(h - h_o) - T_o(s - s_o)]$$

Where 'h' and 's' are specific enthalpy and specific entropy at a particular point in a system a cycle at a particular pressure and temperature. T_o and P_o are the temperature and pressure at a or in reference environment considered for the analysis (P =101.325 KPa and T=298.15 K)

4.1.1 Exergy destruction rate

Irreversibilities such as friction, mixing, chemical reactions, heat transfer through a finite temperature difference, unrestrained expansion, non quasi-equilibrium compression or expansion always generate entropy, and anything that generates entropy always destroys exergy. The exergy destroyed is proportional to the entropy generated.

Note that exergy destroyed is a positive quantity for any actual process and becomes zero for a reversible process. Exergy destroyed represents the lost work potential and is also called the irreversibility or lost work. Since any system and its surroundings can be enclosed by a sufficiently large arbitrary boundary across which there is no heat, work, or mass transfer, any system, and its surroundings constitute an isolated system, the decrease of exergy and the exergy destruction are applicable to any kind of system undergoing any kind of process. Since no real process is fully reversible, energy is lost as a result of processes. As a result, the exergy of the universe, which may be thought of as a standalone system, is always declining. The amount of energy lost during a process increases in proportion to how irreversible it is.

A reversible process doesn't waste any energy. The decline of the exergy principle does not necessarily mean that a system's exergy is reduced.

To find out the exergy destruction rate the following equations can be used.

- Boiler,

Exergy destruction rate

$$\dot{I}_b = \dot{E}_f + \dot{E}_{in} - \dot{E}_{out}$$

Where, E_{fuel} is total exergy of fuel, E_{in} is total exergy at inlet, E_{out} is total exergy at outlet.

- Pump,

Exergy destruction rate

$$\dot{I}_{pump} = \dot{E}_{in} - \dot{E}_{out} + \dot{W}_P$$

Where, W_p is work rate by pump, E_{in} is total exergy at inlet, E_{out} is total exergy at outlet.

Work rate,

$$W = \frac{Q \times H \times \rho \times g}{\eta \times 1000} kJ/s$$

Where, Q is mass flow rate, H is head, η is efficiency of pump and ρ is density of fluid.

4.1.2 Efficiency

The ratio between the exergy used or gained and consumptive exergy is defined as exergy analysis of the system.

Efficiency of boiler:

$$\eta_{exB} = \frac{\dot{E}_{out} - \dot{E}_{in}}{\dot{E}_f}$$

Efficiency of pump:

$$\eta_{exP} = 1 - \frac{\dot{I}_{pump}}{\dot{W}_p}$$

4.2 Exergy of fuel (sugarcane bagasse)

The ratio of chemical exergy (e) of dry solid fuels to the net calorific value of fuel (NCV), with mass ratio of oxygen to carbon (O/C) varies from 0.667 to 2.67 in general and in particular for bagasse is given by Kotas,

$$\emptyset_{dry} = \frac{1.0438 + 1.0882\left({}^{h}/_{c}\right) - 0.2509[1 + 0.7256\left({}^{h}/_{c}\right) + 0.0383({}^{n}/_{c})]}{1 - 0.3035({}^{o}/_{c})}$$

$$= 1.2744$$

Where c, h, o and n are the mass fractions of carbon, hydrogen, oxygen and nitrogen respectively.

- Taking moisture of the fuel into consideration the chemical energy E of the wet bagasse is given by:

$$\dot{E} = \left[NCV + W * h_{fg}\right]\emptyset_{dry}$$

From the steam table, at T_o = 298.15 K the value of h_{fg} = 2442 kJ/kg is found.

W (water content of wet bagasse in percentage) = 0.5

NCV = 7130 kJ/kg c = 22.04 h = 2.72

n = 0.15 S = 0.02 o = 21.07

$$\dot{E}_{fuel} = [7130 + 0.5 * 2442] * 1.2744 = 10642.515\ KJ/kg$$

$$\dot{E}_{fuel} = 9.37 * 10642.515 = 103551.671\ kJ/s$$

$$\dot{E}_{f} = 103.5517\ MW$$

4.3 Observations

At the sugar factory, it was observed that, automation of most of the components is done to collect data regularly.

From such regular data collection, the following material was collected over a period of a month.

i. Boiler

The water tube boiler with a capacity of 70 TPH undergoes maintenance every six months during the off season of the sugar cane crop. With the average turbine load being 9400 kW.

Some of the observations are given below,

Sr. No.	Temperature (°C)	Pressure (bar)	ṁ (kg/s)
1	104	47	20.572
2	500	45	18.628
3	102.35	47	20.209
4	495.75	45	18.637

Table 4.1 Observation data of Boiler

ii. Feed Water Pump

Average pressure in feed water pump is about 1.5 kg/cm^2.

Some of the observations are given below,

Sr. No.	Temperature (°C)	ṁ (kg/s)
1	65.1	21
2	65.1	19.04
3	65.1	23.8
4	65.1	18.76

Table 4.2 Observation data of Feed water pump

iii. Sulphited Juice Pump

The pressure head is 70 m. Average pressure in sulphited juice pump is about 1 kg/cm^2 at inlet and at outlet 3.2 kg/cm^2.

Some of the observations are given below,

Sr. No.	Temperature (°C)	ṁ (kg/s)
1	65.1	62.1355
2	65.3	61.2885
3	65.4	61.3
4	65.7	64.46

Table 4.3 Observation data of Sulphited juice pump

iv. Clear Juice Pump

The pressure head is 40 m. Average pressure in clear juice pump is about 0.5 kg/cm^2 at inlet and at outlet 0.7 kg/cm^2.

Some of the observations are given below,

Sr. No.	**Temperature (°C)**	**ṁ (kg/s)**
1	65.1	21
2	65.1	19.04
3	65.1	23.8
4	65.1	18.76

Table 4.4 Observation data of clear juice pump

4.4 Sample Calculation

For boiler,

I. At inlet,

$$T_{in} = 104^oC = 377.15K \qquad \dot{m}_{ai} = 74\,TPH = 20.572\ kg/s$$

$$h_{in} = 436.04 \qquad s_{in} = 1.352$$

The specific exergy

e = (436.04 − 104.89) – [298.15 (1.352 − 0.3674)] = 37.592

The total exergy rate

$$\dot{E}_{in} = 20.572 * 37.592 = 423.207\,kJ/s$$

$$\dot{E}_{in} = 0.423\ MW$$

At outlet,

$$T_{out} = 500^oC = 778.15K \qquad \dot{m}_{ao} = 767\,TPH = 18.628\ kg/s$$

$$h_{out} = 3440.01 \qquad s_{out} = 2.312$$

The specific exergy

e = (3440.01 − 104.89) – [298.15 (2.312 − 0.3674)] = 2755.338

The total exergy rate

$$\dot{E}_{out} = 18.628 * 2755.338 = 51326.436\,kJ/s$$

$$\dot{E}_{out} = 51.326\ MW$$

Exergy destruction rate

$$\dot{I}_b = 103.5517 + 0.423 - 51.326$$

$$\dot{I}_b = 52.64\ MW$$

Efficiency:

$$\eta_{exB} = \frac{\dot{E}_{out} - \dot{E}_{in}}{\dot{E}_f}$$

$$= \frac{49725.94 - 700.2914}{103.5517}$$

$$= 0.47344$$

For pump,

II. Feed water pump,

At inlet,

$$T_{in} = 65.1^oC = 338.25K \qquad \dot{m}_{ai} = 75\,TPH = 21\ kg/s$$

$$h_{in} = 272.42 \qquad s_{in} = 0.895$$

The specific exergy

e = (272.42 − 104.89) – [298.15 (0.895 − 0.3674)] = 10.0968

The total exergy rate

$$\dot{E}_{in} = 212.0328\,kJ/s$$

$$\dot{E}_{in} = 0.212\ MW$$

At outlet,

$$T_{out} = 59.6^oC = 332.75K \qquad \dot{m}_{ao} = 75\,TPH$$

$$h_{out} = 249.42 \qquad s_{out} = 0.8260$$

The specific exergy

e = (249.42 − 104.89) – [298.15 (0.8260− 0.3674)] = 7.66915

The total exergy rate

$$\dot{E}_{out} = 21 * 7.669 = 161.05215\,kJ/s$$

$$\dot{E}_{out} = 0.161\ MW$$

Work done,

$$W_{fp} = 93.772\ kJ/s$$

Exergy destruction rate

$$\dot{I}_{fp} = 212.033 - 161.052 + 93.772$$

$$\dot{I}_{fp} = 144.753 \text{ kJ/s}$$

$$= 0.145\ MW$$

III. Sulphited juice pump

- $\dot{E}_{in} = 631.918\,kJ/s$

  $\dot{E}_{in} = 0.632\ MW$
- $\dot{E}_{out} = 705.2379\,kJ/s$

$\dot{E}_{out} = 0.705\ MW$

- $W_{sp} = 53.919\ kJ/s$
- $\dot{I}_{sp} = 127.239\ \text{kJ/s} = 0.127\ MW$

IV. Clear juice pump

- $\dot{E}_{in} = 1017.60\ kJ/s$

  $\dot{E}_{in} = 1.018\ MW$
- $\dot{E}_{out} = 779.229\ kJ/s$

  $\dot{E}_{out} = 0.779\ MW$
- $W_{cp} = 37.932\ kJ/s$
- $\dot{I}_{cp} = 276.303\ \text{kJ/s} = 0.276\ MW$

4.5 Software validation

MATLAB software is used for validation or comparison of derived data. The total exergy rate is computed with MATLAB values of specific enthalpy, specific entropy, and specific entropy. The graph in fig. 4.1 depicts a comparison of total exergy rate values generated with MATLAB and utilizing the exergy analysis process. The graph shows that there is no significant difference between actual and theoretical values (calculated using MATLAB); these two values are remarkably similar to each other.

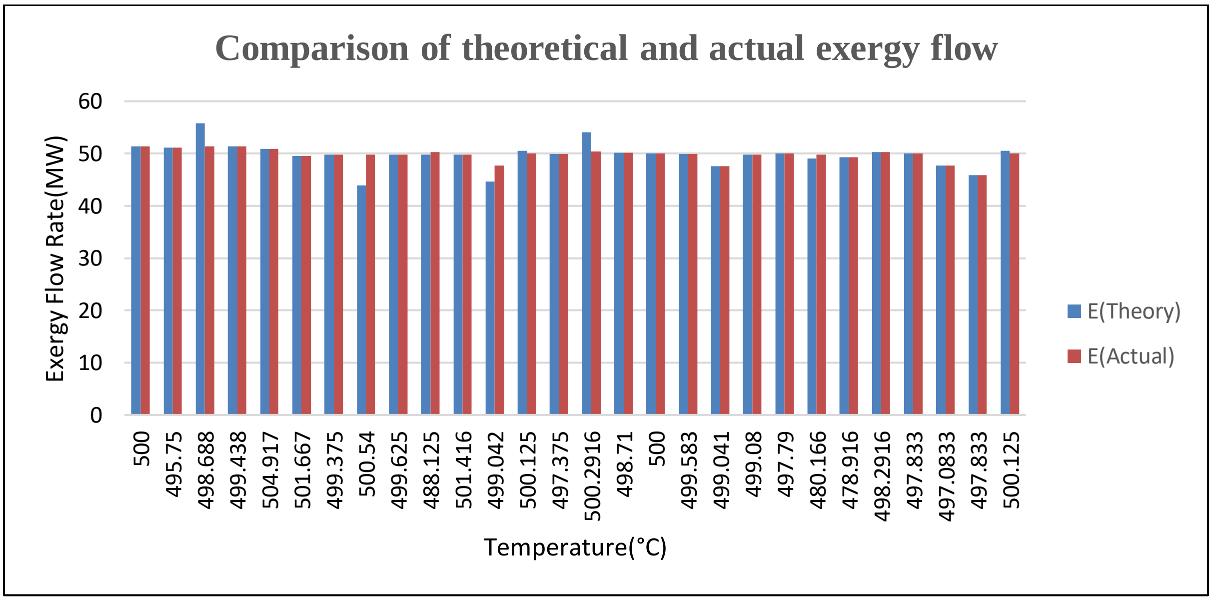

Figure 4.1 Comparison of theoretical and actual exergy flow

CHAPTER 5

RESULT AND DISCUSSION

5.1 Result

5.1.1 Total exergy flow of boiler:

The total exergy flow rate in boiler is depicted in the following graph. The total exergy rate is shown in MW on the ordinate. The graph contrasts how much exergy is provided by the fuel and how much of this exergy is used by the boiler to produce steam out of the water. Only a portion of the exergy produced by burning fuel is used by a boiler.

Significant quantities of exergy are destroyed in boilers, as shown by the significant distinction between these two things. This is primarily because of the irreversibility a boiler produces. The primary cause of irreversibility is a chemical process that takes place during fuel burning. This is known as uncontrolled combustion.

Total Exergy Flow in Boiler (MW)	
Fuel	103.5517
Boiler	49.725

Table 5.1 Total Exergy flow in Boiler

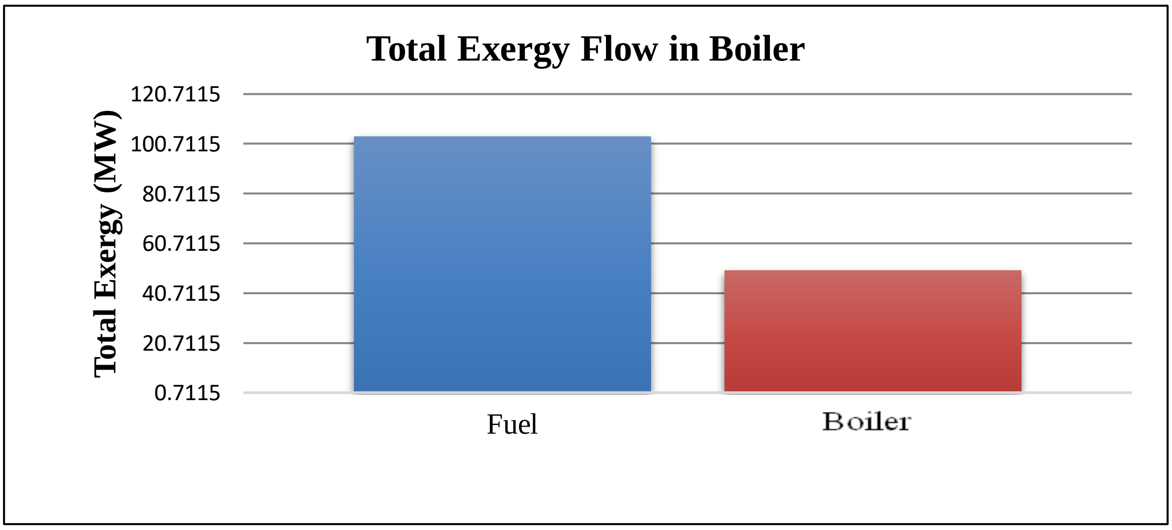

Figure 5.1 Total Exergy Flow in Boiler

5.1.2 Total exergy flow of pump

The irreversibility that occur throughout the pumping process, such as frictional losses, mechanical losses, and thermodynamic losses, are mostly accountable for the exergy destroyed in a pump.

The following graphs represent the flow of exergy from pump inlet to pump outlet.

5.1.2.1 Feed Water Pump:

Total Exergy Flow in Feed water pump (MW)	
Inlet	0.228
Outlet	0.1654

Table 5.2 Total Exergy flow in Feed Water Pump

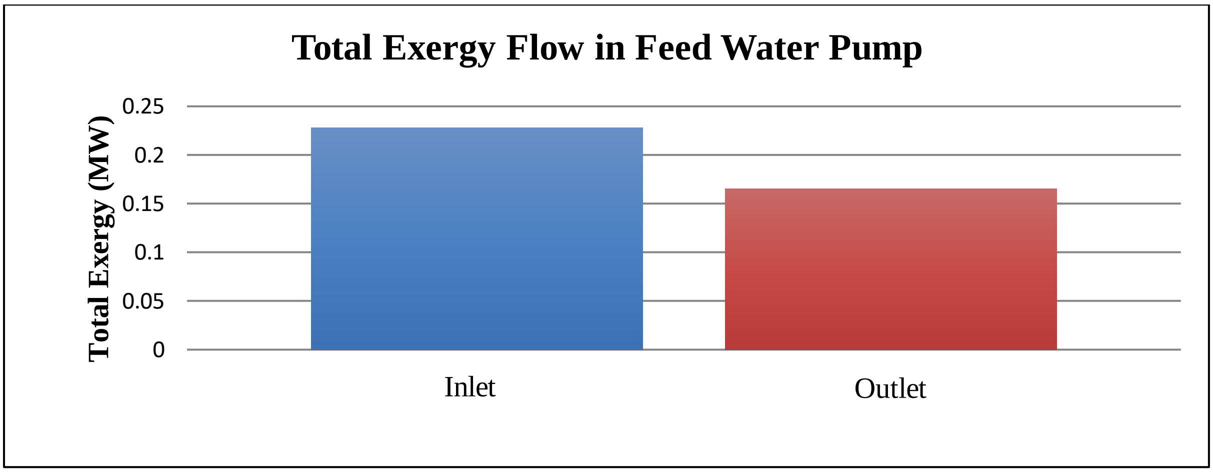

Figure 5.2 Total Exergy Flow in Feed Water Pump

5.1.2.2 Sulphited Juice Pump:

Total Exergy Flow in Sulphited Juice pump (MW)	
Inlet	0.7123
Outlet	0.7118

Table 5.3 Total Exergy flow in Sulphited Juice Pump

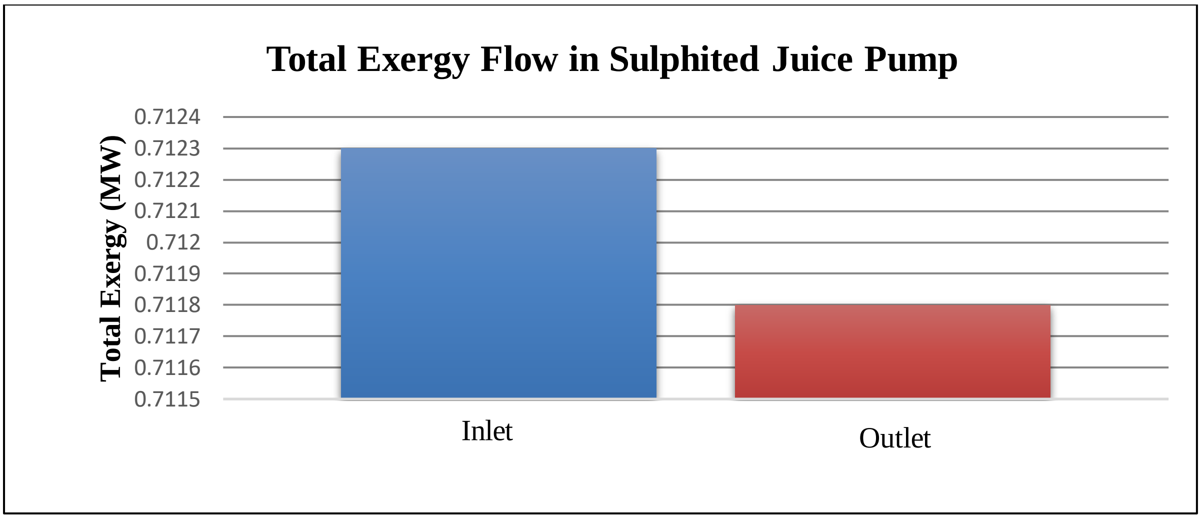

Figure 5.3 Total Exergy Flow in Sulphited Juice Pump

5.1.2.3 Clear Juice Pump:

Total Exergy Flow in Clear Juice pump (MW)	
Inlet	1.113
Outlet	1.094

Table 5.4 Total Exergy flow in Clear Juice Pump

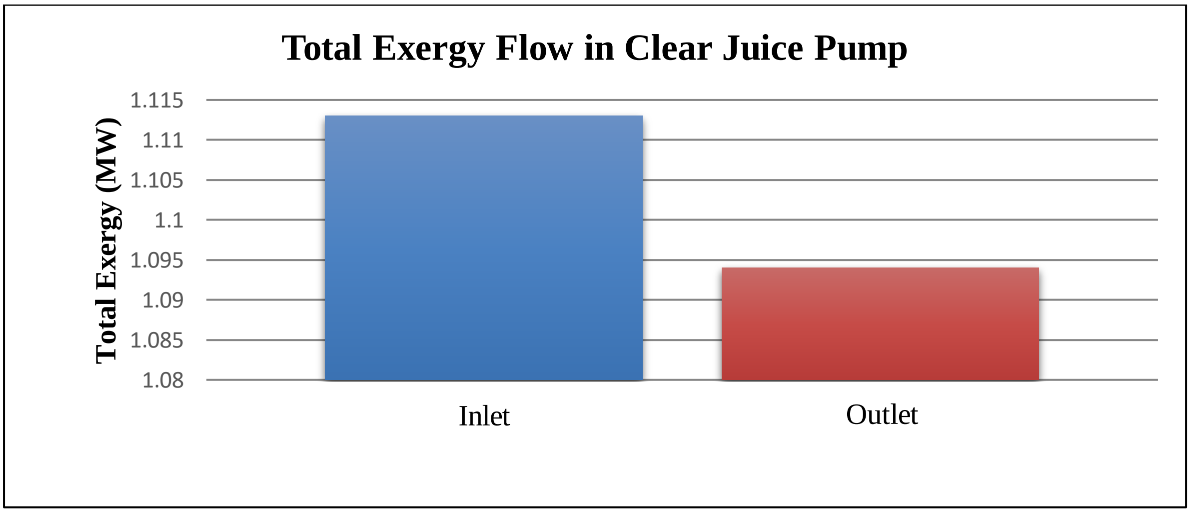

Figure 5.4 Total Exergy flow in Clear Juice Pump

5.1.3 Exergy Destruction Rate of Energy-consuming devices:

The following graph depicts the rate of exergy destruction of energy-consuming devices. The X-axis displays some of the components of a sugar factory, including the boiler, and pumps. The graph shows that the boiler consumes a significant amount of exergy. In comparison to the boiler, the exergy destruction rate of the pumps is low. The destruction of exergy is mostly caused by irreversibilities in the process.

Exergy Destruction Rate		
Sr. No.	**Components**	**Exergy Destruction Rate (MW)**
1	Boiler	54.524
2	Feed Water Pump	0.1565
	Sulphited Juice Pump	0.054
	Clear Juice Pump	0.0596
	Pumps	= 0.2701

Table 5.5 Exergy Destruction Rate of Energy-consuming devices

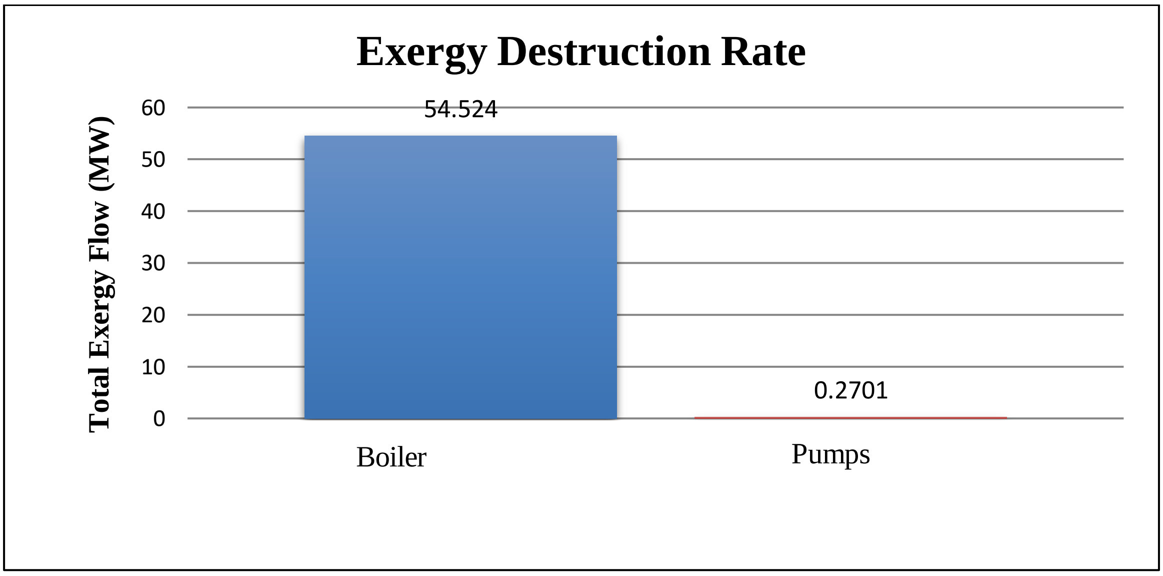

Figure 5.5 Exergy Destruction Rate of Energy-consuming devices

CHAPTER 6

CONCLUSION AND SUGGESTIONS

6.1 Conclusion:

In this study, an exergy analysis of energy-consuming devices in sugar industry has been presented. In terms of exergy destruction, the major loss was found in the boiler system.Theexergyanalysisrevealedthatthelostexergyinthepumpisthermodynamicallyin significant. The exergy destruction rate in boilers is about 54.524 MW. As for the pumps 0.2701 MW of exergy was destroyed. Where, the exergy destruction rate for the feed water pump, sulphited juice pump, and clear juice pump is 0.1565 MW, 0.054 MW, and 0.0596 MW, respectively.

6.2 Suggestions to reduce exergy destruction rate:

i. As concluded, boiler is a major source of exergy destruction. The most popular method for decreasing their reversibility of the boiler is to reheat steam. Reheating often involves using the boiler's combustion by-product. Combustible gas warms the steam after performing its primary heating function and before venting into the atmosphere.

ii. In a combustion chamber, the major source of exergy destruction is chemical reactions. Exergy destruction in the combustion chamber is primarily influenced by the excess air proportions and the inlet air temperature. By providing the needed air-fuel ratio, the thermodynamic inefficiencies of combustion can be decreased. To reduce unwanted exergy destruction, it is recommended that the combustion chamber be analyzed for varied air and bagasse mass fractions.

iii. An efficient technique to conserve exergy in a boiler is the method of heat recovery from flue gas.

iv. Reduction of moisture content of bagasse can reduce exergy destruction occurred due to chemical reactions. Moisture content of the bagasse can be reduced from 50 % to30-40%. The use of dryers helps to lower the moisture content before burning it. The waste heat from the boiler flue gases can also be used by this bagasse drying system to meet its partial heat needs.

v. The transport of heat across a limited temperature difference is one of the crucial variables in plants for the destruction of exergy. Losses increase as heat is carried far from a boiler, and the opposite is also true. Therefore, transferring heat over a short distance is effective. For minimum heat loss, the optimal distance for energy transfer optimal distance should be found.

vi. Minimize friction losses in the pump system by carefully selecting pipe materials, using smooth and corrosion-resistant surfaces, and employing proper pipe sizing to avoid excessive pressure drop. Additionally, ensure that the system is free from leaks and unnecessary fittings.

vii. Improving pump design can aid in reducing internal losses and increasing overall efficiency. Consider the shape, size, and material of the impeller, as well as optimize the volute or casing design. Simulations of Computational Fluid Dynamics (CFD) can help in evaluating various design possibilities.

6.3 Discussion:

The selected energy consuming devices was analyzed using the above relations noting that the environment reference temperature and pressure are 298.15 K and 1013 kPa, respectively. Exergy-based efficiencies and losses provide measurements of proximity to or deviation from ideality. Specific exergy and total exergy rate are summarized in appendix A for boiler, feed water pump, sulphited juice pump, and clear juice pump. It was found that the exergy destruction rate of the boiler dominant compared other components' irreversibilities. According to the second law analyze the values demonstrates that significant improvements exist in the boiler system rather than in the pump. However, due to physical, technological, and economic constraints, some of this irreversibility cannot be prevented.

To quantify a system's exergy, we must characterize both the system and its surroundings. It is assumed that no process alters the intense features of the environment appreciably. A system's dead state is one in which it is in balance with its surroundings. When a system is at the same temperature, pressure, elevation, velocity, and chemical composition as its surroundings, there are no potential differences that would allow usable work to be extracted. The reference environment state is irrelevant for calculating a change in a thermodynamic property (first law analysis) However, it is expected that the dead state will have some effects on the results of exergy (second law) analysis Although, some researchers assumed that small and reasonable changes in dead-state properties have little effect on the performance of a given system.

For evaluating a change in a thermodynamic characteristic (first law analysis), the reference environment state is unimportant. However, the dead condition is predicted to have some impact on the outcomes of the exergy (second law) analysis. However, other researchers assumed that tiny and reasonable changes in dead-state features have little effect on system performance.

REFERENCES

1. H. M. Sahin, A. Acir, T. Altunok, E. Baysal, and E. Kocyigit. "Analysis of exergy and energy of sugar production process in sugar plant." Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, vol. 32, no. 15, pp. 1414-1423, 2010.

2. Dennis Sibo. "Energy and Exergy Analysis of Vallumbra Sugar Mill." Department of Mechanical Marine Engineering, Niger Delta University, Nigeria, 2019.

3. Taner, Tolga and Sivrioglu, Mecit. "Data on energy, exergy analysis and optimisation for a sugar factory." Data in Brief, vol. 3, pp. 127-132, 2015.

4. Gaurav, Gajendra Kumar, Singh, Neetu, and Francis, Bijo. "Exergy Analysis of a Thermal Power Plant." International Journal of Engineering Research and Technology, vol. 12, no. 8, pp. 1367-1371, 2019.

5. Parvez, Yusuf, and Hasan, M. M. "Exergy Analysis and Performance Optimization of Bagasse Fired Boiler." Energy Procedia, vol. 157, pp. 37-44, 2019.

6. Jayakumar, S., & Senthil Kumar, R. "Exergy analysis of sugar industry boilers." Applied Thermal Engineering, 28(14-15), 1704-1714, 2008.

7. Hemanta kumar Panda and Dr. Alok Chaube. "Exergy Analysis of a Thermal Power Plant."International Journal of Engineering Research & Technology, Vol. 7 Issue 06, June-2018.

8. PeriyasamyK, Karthickannan V, R Karthikeyan, Gokulnath A and Gopinath R N. "Improve the Efficiency of Boiler by Reduce the Moisture in Bagasse." International Journal of Mechanical and Production Engineering Research and Development, vol. 8, no. 6, 2018.

9. R. Saidur, J.U. Ahamed, and H.H. Masjuki. "Energy, exergy and economic analysis of industrial boilers." Energy Policy, vol. 38, no. 5, pp. 2188-2197, 2010.

10. M. Narayanan and R. Senthil Kumar. "Exergy analysis of a cogeneration system in a sugar industry", Renewable Energy, 2006.

11. Kimari, N. W., Said, M. Y., & Makau, A. J. "Exergy analysis of a sugar industry process with partial condensing turbo-generator." Energy Conversion and Management, 149, 401-413, 2017.

12. Sahin, N., Kaplan, E., Bayrak, M., Yaka, F., & Gungor, A. "Exergy analysis of Eregli sugar factory." Journal of Cleaner Production, 107, 664-674, 2015.

13. Muhammad Faisal Hasan, Md. Sayeed Ur Rahim Mahadi , Takahiko Miyazaki, Shigeru Koyama and Kyaw Thu. "Exergy analysis of serpentine thermosyphon solar water heater." Energy Procedia, 153, 269-274, 2018.

14. Velasquez, H., Gudelo, A., & Chejne, F. "Energy use in the production of unrefined sugar in Colombia: Exergy analysis." Energy, 35(2), 963-969, 2010.

15. Isam H. Aljundi, “Energy and exergy analysis of a steam power plant in Jordan.” Applied thermal Engineering 29, 2009

16. Sandhya Hasti, Adisorn Aroonwils and Amornvadee Veawab. "Exergy analysis of Ultra Super-critical power plant." Energy procedia 37, 2013.

17. Mohammadreza Babaei Jamnani and Amin Kardgar. "Energy-exergy performance assessment with optimization guidance for the components of the 396-MW combined-cycle power plant." Energy Science & Engineering, 2020.

18. Cortez, L.A.B., Gomez, E.O., “A Method for exergy analysis of sugarcane bagasse boilers.” Brazillian Journal of Chemical Engineering Vl 1, 15. 1998.

19. Oladiran, M.T., Meyer, J.P., “Energy and exergy analyses of energy consumptions in the industrial sector in South Africa.” Applied Energy 84, 1056–1067, 2007.

20. tlu, Z., Hepbasli, A, A review and assessment of the energy utilization efficiency in the Turkish industrial sector using energy and exergy analysis method. Renewable and Sustainable Energy Reviews 11, 1438–1459, 2007.

21. Dincer I and Rosen M A “Exergy: energy, environment and sustainable development” Elsevier, 2012.

22. Ali Basem , Mohammed Moawed , Mohammed H. Abbood , Wael M. El-Maghlany, “The energy and exergy analysis of a combined parabolic solar dish – steam power plant”, Elsevier, Renewable Energy Focus 41 55–68, 2022.

23. Sairam Adibhatla SC. Kaushik, “Energy and exergy analysis of a super critical thermal Power plant at various operation load conditions under constant and pore sliding pressure operate”, Applied Thermal Engmeering 73, 2014.

24. Ravinder kumar “A critical review on energy exergy excroeconomic and economy analysis of thermal power plants.” Engineering Science and Technology, an Internationallemal 20, 283-297, 2017.

25. Abuelnuor A. A. Abuelnuor, Mohammednour Gibreel, Mohamed Ali Abuelnour, Obai Younis, Siddig Abuelgasim & Elshahat F. Mohmed, "Study of Energy and Exergy of Elgunied Sugar Company Plant in Sudan." Sugar Tech, Springer, 2023.

APPENDIX

Result table 1:

This result table represents the values of specific exergy, total exergy flow, enthalpy, entropy, at specific temperature and pressure for boiler. These values are calculated by following exergy analysis procedure.

Sr. No.	Temperature (°C)	Pressure (bar)	$\dot{m}$ (kg/s)	h (kJ/kg)	s (kJ/kg°C)	e (kJ/kg)	$\dot{E}$ (MW)
1	104	47	20.572	436.04	1.352	37.592	0.423
2	500	45	18.628	3440.01	2.312	2755.338	51.326
3	102.35	47	20.209	429.111	1.334	36.028	0.728
4	495.75	45	18.637	3430.19	2.313	2745.219	51.163
5	103.375	47	18.626	433.415	1.345	37.059	0.69
6	498.688	45	20.294	3435.99	2.3158	275.125	55.811
7	103.625	47	20.213	432.465	1.348	37.214	0.752
8	499.438	45	18.684	3437.72	2.316	2751.855	51.416
9	103.938	47	19.726	435.78	1.3514	37.332	0.736
10	504.917	45	18.418	3450.41	2.3138	2765.141	50.928
11	102.667	47	19.495	430.422	1.337	36.464	0.7109
12	501.667	45	17.978	3442.88	2.3148	2757.313	49.571
13	103	47	19.32	431.84	1.34	36.84	0.711
14	499.375	45	18.08	3438.57	2.3168	2752.337	49.762
15	103.41	47	19.519	433.545	1.3455	36.905	0.72
16	500.54	45	18.048	3441.26	2.311	2429.72	43.852
17	103.29	47	19.565	433.048	1.344	36.84	0.72127
18	499.625	45	18.08	3439.15	2.3116	2754.46	49.8
19	102.95	47	19.46	431.63	1.34	36.69	0.71398
20	488.125	45	18.25	341.54	2.3157	2726.623	49.76
21	102.65	47	19.5066	430.7	1.3369	36.624	0.7144
22	501.416	45	18.025	3443.29	2.31106	3338.39	49.7268
23	101.9583	47	19.3783	427.378	1.329	35.5929	0.6897
24	499.042	45	17.325	3437.8	2.31178	2574.1738	44.5975
25	101.5	47	19.506	425.423	1.3239	35.2232	0.687
26	500.125	45	18.1533	3440.3	2.31145	2755.62	50.504
27	103	47	19.565	431.512	1.361	30.2509	0.5918
28	497.375	45	18.165	3433.95	2.312	2749.148	49.938
29	103.375	47	19.616	433.4149	1.3408	38.1645	0.7484
30	500.2916	45	18.305	3440.69	2.3113	2756.067	54.05
31	102.66	47	19.79	430.412	1.3372	36.25487	0.7174
32	498.71	45	18.22	3437.22	2.3118	2752.459	50.1498
33	103.375	47	19.5	434.94	1.3493	37.1672	0.7247
34	500	45	18.14	3440.01	2.3114	2755.36	49.982
35	103.08	47	19.67	432.1	1.341	36.8019	0.72389
36	499.583	45	18.13	3439.05	2.31161	2754.364	49.936

37	103.666	47	19.3325	434.6397	1.9783	3729	0.72
38	499.041	45	17.3168	3436.8	2.3156	2751.1126	47.64
39	103.16	47	19.52	432.512	298.15	36.866	0.71962
40	499.08	45	18.11	3436.86	2.3156	2751.144	49.823
41	103.2	47	19.561	432.68	1.343	36.915	0.722
42	497.79	45	18.1973	3434.91	2.312	2750.238	50.047
43	103.75	47	21.069	434.99	1.349	37.436	0.788
44	480.166	45	18.116	3394.1	2.19	2707.34	49.046
45	103.45	47	19.599	433.73	1.346	37.07	0.727
46	478.916	45	18.209	3391.2	2.319	2704.44	49.245
47	104.04	47	19.564	436.21	1.353	37.463	0.733
48	498.2916	45	18.255	3436.06	2.312	2751.43	50.227
49	101.125	47	19.492	423.79	1.319	35.18046	0.6858
50	497.833	45	18.185	3435	2.312	2750.32	50.0147
51	101.66	47	19.5758	426.12	1.326	35.4234	0.6934
52	497.0833	45	17.34	3433.27	2.313	2750.5975	47.695
53	101.0833	47	18.255	423.611	1.319	35.001	0.6389
54	497.833	45	16.6568	3435	2.312	2750.3275	45.8116
55	101.5	47	19.506	425.423	1.3239	35.2232	0.687
56	500.125	45	18.1533	3440.3	2.31145	2755.62	50.504

Result table 2:

This result table represents the values of specific exergy, total exergy flow, enthalpy, entropy, at specific temperature and pressure for boiler. These values are calculated by MATLAB program.

Sr. No	Temperature (°C)	Pressure (bar)	$\dot{m}$ (kg/s)	h (kJ/kg)	s (kJ/kg°C)	e (kJ/kg)	$\dot{E}$ (MW)
1	500	45	18.628	3440.01	2.312	2755.34	51.33
2	495.75	45	18.637	3430.19	2.313	2745.22	51.16
3	498.688	45	20.294	3435.99	2.3158	2750.18	51.38
4	499.438	45	18.684	3437.72	2.316	2751.85	51.42
5	504.917	45	18.418	3450.41	2.3138	2765.2	50.93
6	501.667	45	17.978	3442.88	2.3148	2757.37	49.57
7	499.375	45	18.08	3438.57	2.3168	2752.47	49.76
8	500.54	45	18.048	3441.26	2.311	2756.93	49.76
9	499.625	45	18.08	3439.15	2.3116	2754.48	49.8
10	488.125	45	18.25	3441.54	2.3157	2755.76	50.29
11	501.416	45	18.025	3443.29	2.31106	2759.03	49.73
12	499.042	45	17.325	3437.8	2.31178	2753.19	47.7
13	500.125	45	18.1533	3440.3	2.31145	2755.79	50.03
14	497.375	45	18.165	3433.95	2.312	2749.28	49.94
15	500.2916	45	18.305	3440.69	2.3113	2756.23	50.45
16	498.71	45	18.22	3437.22	2.3118	2752.61	50.15
17	500	45	18.14	3440.01	2.3114	2755.52	49.99
18	499.583	45	18.13	3439.05	2.31161	2754.49	49.94
19	499.041	45	17.3168	3436.8	2.3156	2751.05	47.64
20	499.08	45	18.11	3436.86	2.3156	2751.11	49.82
21	497.79	45	18.1973	3434.91	2.312	2750.24	50.05
22	480.166	45	18.116	3394.1	2.19	2745.8	49.74
23	478.916	45	18.209	3391.2	2.319	2704.44	49.25
24	498.2916	45	18.255	3436.06	2.312	2751.39	50.23
25	497.833	45	18.185	3435	2.312	2750.33	50.01
26	497.0833	45	17.34	3433.27	2.313	2748.3	47.66
27	497.833	45	16.6568	3435	2.312	2750.33	45.81
28	500.125	45	18.1533	3440.3	2.31145	2755.79	50.03

Result table 3:

This result table represents the values of specific exergy, total exergy flow, enthalpy, entropy, at specific temperature for clear juice pump. These values are calculated by following exergy analysis procedure.

Sr. No.	Temperature (°C)	ṁ (kg/s)	h (kJ/kg)	s (kJ/kg°C)	e (kJ/kg)	$\dot{E}$ (MW)
1	79.9	50.93	334.48	1.07	19.9805	1.0176
2	81.8	57.44	342.4	1.0966	19.96	1.1465
3	79.53	58.81	332.92	1.0693	18.62	1.09504
4	81.83	58.7	342.586	1.0969	20.067	1.177932
5	78.69	59.32	329.394	1.0592	18.11	1.07428
6	77.2	59.55	323.14	1.0413	17.19	1.023665
7	79.32	60.82	332.004	1.0668	18.45	1.12213
8	81.15	60.76	339.73	1.088	20.28	1.232213
9	77.5	61.52	330.741	1.045	17.35	1.067372
10	81.7	61.67	342.04	1.095	20.08	1.238333
11	80.85	61.94	338.469	1.0851	19.467	1.205785
12	78.2	60.74	327.34	1.0534	17.789	1.0805
13	80.9	60.149	338.68	1.0858	19.468	1.170807
14	77.39	59.95	323.938	1.0436	17.38	1.041931
15	78.28	50.33	327.676	1.0548	20.33	1.023089
16	80.54	57.44	337.168	1.0814	19.26	1.10694
17	77.13	58.5	322.84	1.04	17.28	1.01088
18	78.26	57.02	327.5	1.054	17.77	1.013454
19	80.73	59.29	337.93	1.088	18.06	1.07774
20	81.18	59.65	339.86	1.089	19.697	1.17492
21	80.9	59.81	338.68	1.0858	19.469	1.1644
22	77.08	62.93	322.63	1.039	17.3732	1.09295
23	78.89	62.28	330.23	1.06	18.712	1.16538
24	80.62	58.62	337.504	1.082	19.426	1.13879
25	77.99	60.15	326.457	1.05	17.92	1.07788
26	78.7	61.85	329.42	1.059	18.2	1.12567
27	80.68	61.06	337.75	1.083	19.354	1.18155
28	77.2	63.03	323.14	1.04	17.58	1.10867
29	78.28	59.55	327.67	1.054	17.94	1.06827
30	81.83	57.44	342.58	1.096	20.32	1.16718
31	80.7	50.93	310.54	1.0054	15.3	0.77929
32	76.35	57.44	342.29	1.09612	20	1.1488
33	74.18	58.81	310.457	1.00516	15.28	0.896168
34	82.41	58.7	345.02	1.1039	20.41	1.19867
35	75.26	59.32	314.99	1.1018	15.99	0.948268
36	81.38	59.55	340.68	1.09156	19.75	1.17125
37	75.88	60.82	317.59	1.0225	16.35	0.99407
38	80.15	60.76	335.53	1.0767	19.03	1.156628

39	79.01	61.52	330.741	1.0631	18.29	1.12008
40	76.34	61.67	319.52	1.031	16.648	1.02682
41	79.83	61.94	334.86	1.0729	18.82	1.16508
42	76.67	60.74	320.914	1.035	16.84	1.022616
43	81.2	60.149	339.94	1.083	19.77	1.189457
44	77.66	59.95	325.07	1.046	17.726	1.066737
45	80.77	50.33	338.134	1.084	19.46	0.979422
46	77.36	57.44	323.812	1.043	17.36	0.99784
47	75.11	58.5	314.33	1.016	17.28	1.0188
48	78.5	57.02	328.6	1.057	17.97	1.02464
49	74.11	59.29	310.16	1	16.53	0.980637
50	78.15	59.65	327.13	1.05	18.593	1.109245
51	79.56	59.81	333.05	1.0667	18.639	1.1149
52	77.58	62.93	324.736	1.045	17.69	1.1135
53	79.87	62.28	334.35	1.073	18.956	1.18065
54	80.7	58.62	337.84	1.083	19.9696	1.14114
55	80.7	60.15	337.84	1.0834	19.345	1.16317
56	76.35	61.85	319.57	1.0312	16.638	1.0293
57	80.01	61.06	339.949	1.075	18.75	1.15787
58	74.25	63.03	310.75	1.006	15.33	1.6987
59	81.87	59.55	342.75	1.097	20.2	1.20291
60	75.52	57.44	316.08	1.02	16.48	0.94661

Result table 4:

This result table represents the values of specific exergy, total exergy flow, enthalpy, entropy, at specific temperature for sulphited juice pump. These values are calculated by following exergy analysis procedure.

Sr. No.	Temperature (°C)	$\dot{m}$ (kg/s)	h (kJ/kg)	s (kJ/kg°C)	e (KJ/kg)	$\dot{E}$ (MW)
1	65.1	62.1355	272.419	0.8947	10.17	0.631918
2	65.3	61.2885	273.2	0.897	10.2	0.625143
3	65.4	61.3	273.68	0.8985	10.31	0.632
4	65.7	64.46	274.93	0.9022	10.46	0.674251
5	69.1	64.603	289.22	0.9437	12.37	0.799578
6	69.04	64.043	288.96	0.943	12.333	0.78988
7	66.72	64.544	283.42	0.9264	11.667	0.753035
8	67.32	64.051	281.74	0.9218	11.418	0.731334
9	66.32	61.209	277.54	0.9098	10.8	0.661057
10	68.24	63.88	285.6	0.933	12.18	0.778584
11	66.4	49.449	277.88	0.9108	10.84	0.536027
12	69.4	60.16	290.52	0.9476	12.51	0.7526
13	68.8	61.32	287.96	0.94	9.22	0.565456
14	66.19	60.49	276.99	0.9082	10.739	0.649602
15	69.65	61.743	299.5311	0.95	12.8	0.790314
16	67.2	60.82	281.14	0.92	10.8	0.657072
17	66.76	65.84	287.79	0.9394	12.22	0.804565
18	65.07	63.8	272.29	0.849	15.06	0.960828
19	67.52	62.983	282.58	0.924	11.61	0.731233
20	65.52	60.358	274.09	0.9	10.27	0.619877
21	69.82	64.475	292.24	0.9527	12.71	0.81948
22	70.28	65.7	294.16	0.95836	12.94	0.850158
23	65.64	62.28	274.68	0.901	10.57	0.6583
24	66.23	62.57	287.79	0.908	10.96	0.68576
25	67.32	55.87	281.71	0.9218	11.3	0.631331
26	69.68	50.19	291.65	0.951	12.63	0.63389
27	67.82	63.518	283.84	0.9278	11.73	0.745066
28	68.88	65.127	288.29	0.941	12.25	0.797805
29	69.35	61.739	290.14	0.9464	12.495	0.771429
30	65.1	62.135	272.41	0.894	10.17	0.631918
31	68.43	62.1355	286.406	0.9377	11.35	0.705238
32	67.74	61.2885	283.58	0.9268	11.67	0.715237
33	68.84	61.3	288.12	0.9405	12.32	0.755261
34	69.49	64.46	290.15	0.9486	12.59	0.808838
35	70.31	64.603	294.28	0.9587	12.97	0.838
36	69.83	64.043	292.28	0.9528	12.72	0.815248

37	70.51	64.544	295.11	0.9611	13.05	0.843539
38	69.5	64.051	281.74	0.9487	12.55	0.80384
39	67.59	61.209	282.87	0.92502	11.61	0.710636
40	67.82	63.88	283.84	0.9278	11.73	0.749312
41	62.9	49.449	263.23	0.8676	9.2	0.454931
42	66.74	60.16	279.308	0.9148	11.08	0.666572
43	67.99	61.32	284.55	0.9298	11.85	0.726572
44	65.31	60.49	273.3	0.89	12.46	0.75424
45	66.62	61.743	278.84	0.9134	11.11	0.685968
46	65.98	60.82	276.11	0.905	11.46	0.697226
47	66.64	65.84	278.88	0.9136	11.01	0.724898
48	68.78	63.8	287.8	0.9397	12.14	0.774532
49	66.96	62.983	280.23	0.917	11.36	0.715487
50	65.86	60.358	275.612	0.907	10.6	0.639798
51	69.43	64.475	290.6	0.9478	12.54	0.808537
52	67.6	65.7	286.28	0.93	13.52	0.888264
53	70.28	62.28	284.97	9311	11.89	0.740509
54	68.09	62.57	287.79	0.9311	6.355	0.397633
55	68.76	55.87	268.97	0.8845	9.78	0.54648
56	64.28	50.19	267.36	0.8997	9.62	0.482828
57	63.89	63.518	290.22	0.9407	14.27	0.906402
58	69.34	65.127	294.66	0.9598	13.01	0.847302
59	70.4	61.739	286.95	0.937	12.1	0.447491
60	68.56	62.135	286.406	0.9377	11.35	0.705238

Result table 5:

This result table represents the values of specific exergy, total exergy flow, enthalpy, entropy, at specific temperature for feed water pump. These values are calculated by following exergy analysis procedure.

Sr. No.	Temperature (°C)	ṁ (kg/s)	h (kJ/kg)	s (kJ/kg°C)	e (kJ/kg)	$\dot{E}$ (MW)
1	65.1	21	272.42	0.895	10.0968	0.212328
2	65.1	19.04	272.42	0.895	10.0968	0.192243
3	65.1	23.8	272.42	0.895	10.0968	0.243038
4	65.1	18.76	272.42	0.895	10.0968	0.189415
5	65.1	23.52	272.42	0.895	10.0968	0.553902
6	65.1	19.18	272.42	0.895	10.0968	0.193566
7	65.1	22.4	272.42	0.895	10.0968	0.226683
8	65.1	19.32	272.42	0.895	10.0968	0.1957017
9	65.1	22.68	272.42	0.895	10.0968	0.228422
10	65.1	19.88	272.42	0.895	10.0968	0.20072438
11	65.1	22.96	272.42	0.895	10.0968	0.231225
12	65.1	20.44	272.42	0.895	10.0968	0.206378
13	65.1	23.24	272.42	0.895	10.0968	0.234494
14	65.1	23.8	272.42	0.895	10.0968	0.2400384
15	65.1	21.56	272.42	0.895	10.0968	0.217687
16	65.1	22.12	272.42	0.895	10.0968	0.22334
17	65.1	22.12	272.42	0.895	10.0968	0.22341216
18	65.1	23.66	272.42	0.895	10.0968	0.2390288
19	65.1	23.1	272.42	0.895	10.0968	0.2333608
20	65.1	19.544	272.42	0.895	10.0968	0.1973185
21	65.1	20.02	272.42	0.895	10.0968	0.202936
22	65.1	20.72	272.42	0.895	10.0968	0.2092
23	65.1	20.24	272.42	0.895	10.0968	0.20492
24	65.1	22.82	272.42	0.895	10.0968	0.234089
25	65.1	20.328	272.42	0.895	10.0968	0.2024775
26	65.1	22.4	272.42	0.895	10.0968	0.226832
27	65.1	18.76	272.42	0.895	10.0968	0.189159
28	65.1	23.8	272.42	0.895	10.0968	0.2403033
29	65.1	22.96	272.42	0.895	10.0968	0.231225
30	65.1	22.4	272.42	0.895	10.0968	0.22668
31	59.6	21	272.42	0.826	7.66915	0.1615215
32	56.6	19.04	238.24	0.7885	7.669775	0.146325
33	62.6	23.8	261.99	0.8635	9.058525	0.215529
34	55.7	18.76	233.14	0.7771	5.968685	0.1119725
35	62	23.52	259.95	0.856	8.80465	0.2070853
36	57	19.18	238.55	0.7985	4.9983	0.09566
37	61	22.4	255.33	0.84349	8.3345065	0.1866929
38	57.5	19.32	243.99	0.7997	10.0894	0.194929

39	61.3	22.68	256.56	0.84725	8.47346	0.192178
40	59	19.88	246.89	0.8185	7.384275	0.146799
41	61.9	22.96	259.08	0.854749	8.75	0.2009
42	59.5	20.44	249	0.82475	7.621	0.15577
43	62	23.24	261.99	0.8635	9.05588	0.210263
44	62.6	23.8	256.99	0.8485	8.52	0.202776
45	60	21.56	251.1	0.831	7.48584	0.169427104
46	59.5	22.12	249	0.82475	7.62	0.1685544
47	60.1	22.12	251.52	0.832249	7.98	0.1765176
48	62.8	23.66	262.82	0.86599	9.1461	0.2163967
49	61	23.1	255.3	0.84349	10.0968	0.092526
50	58	19.54	242.7	0.806	6.91	0.13504904
51	59.2	20.02	247.74	0.821	7.4799	0.15109398
52	60	20.72	251.1	0.831	7.8584	0.16282604
53	59.8	20.24	250.26	0.8284	7.764	0.15714336
54	61.6	22.82	257.82	0.851	8.6154	0.196603
55	60	20.32	251.1	0.831	7.8584	0.197455
56	61	22.4	255.3	0.84349	8.3345	0.1866928
57	55.7	18.76	233.14	0.7771	5.9686	0.1119709
58	62.6	23.8	256.98	0.8484	8.52	0.202776
59	61.9	22.96	259.08	0.85749	8.75	0.2009
60	61	22.4	255.3	0.84349	8.3345	0.1866928

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