TEMPERATURE DISTRIBUTION FOR PALM OIL MILL USING IR THERMAL IMAGING
(FELCRA NASARUDDIN PALM OIL MILL, BOTA, PERAK)

BY

NUR ZAIHASRA ZAHARI

Dissertation submitted in partial fulfillment of
the requirements for the
Bachelor of Engineering (Hons)
(Mechanical Engineering)

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Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved by,

____
(Name of Main Supervisor)

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK
MAY 2012

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

NUR ZAIHASRA ZAHARI

Abstract

This report is an energy audit in an oil palm mill by using the IR (infrared) Thermal Imaging system. The energy audit is to evaluate the energy consumption of the plant (oil palm mill) and management of energy. The efficiency of the energy usage can be evaluated and possible recommendation can be proposed to improve the energy consumption of the plant.

This energy audit starts with preliminary research to investigate the main factor of the energy consumption by the plant by doing a walk through energy audit. During this visit to the plant, data is gathered and collected. Using the data obtained the recommendation will be proposed according to the result.

The methodology that being used in this project can be classify to four main processes. The first processes are the Building and Utility Data Analysis; Walk through Survey, Baseline for Building Energy Use and Evaluation of Energy Saving Measures. This energy audit is done at FELCRA Nasaruddin Palm Oil Mill, Bota, Perak. This energy audit will focus on two main parts of the plant which are the boiler and the turbine (steam generation) that being used to generate the power needed for the plant operation.

Acknowledgement

It is such a great pleasure and gratitude to acknowledge people whose knowledge, guidance and encouragement contributed tremendously towards the completion of my final year project. During these periods, vast opportunities were provided for me to learn and gather as much knowledge as I can.

First and foremost, a huge thanks you to my supervisor, Mr. Mohd Faizairi Mohd Nor for being supportive in coaching and sharing knowledge with me, guiding me throughout the project.

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Thank you very much to my family and friends who never fail to support and motivate me. Finally, I wish to thank all of the people who have contributed directly or indirectly in helping me to complete the final year project.

Table of content

List of Figures

List of Tables

CHAPTER 1

Introduction

a) Background Study

An energy audit can be define as a process to evaluate, assess and estimate the use of energy and identify opportunities to reduce energy consumption in a building or a system. The scope for energy auditing may be differing according to the complexity of calculations and also the level of economic evaluation. It should be defined prior before beginning of any audits activities.

b) Problem statement

Currently, there is no standard energy audit for oil palm mill in Malaysia. By introducing IR Thermal Imaging is to investigate and evaluate capability of the system and identify possible improvement by using the method.

Using this energy audit, the efficiency of the main parts of the plant which are the boiler and the turbine will be evaluate. Therefore, the efficiency of the system can be improved and the cost of production can be reduced.

In addition, using the infrared thermal imaging technology, the major loses of the energy can be identify and improvement can be made.

c) Objective

1. To study the fundamental of energy auditing for the industrial plant (oil Palm Mill) using IR Thermal Imaging.
2. To adapt the application of IR Thermal Imaging inspection for potential usage in Palm Oil Mill plant energy audit.

c. **Scope of the study**

The project starts with the pre site works on palm oil mill processing and also the power generation of the plant. In the power generation processes, the steam generation which is the boiler and the turbine will plays a major role in producing the electricity for the plant to operates.

The project starts with understanding the overall set up and system of palm oil mill processes. Identify the energy generation and usage of the equipment in the system. Based on the energy usage, the potential energy saving will be proposed.

The applications of IR Thermal Imaging being used to identify the potential improvement at the palm oil mill plant. Understand of the limitation and potential of IR Thermal Imaging in the plant.

The project will continued by the site visit at Felcra Nassaruddin Palm Oil Mill, Bota. This plant will be the datum or the main reference in this project. This plant generates its own electricity by using the steam generation plant.

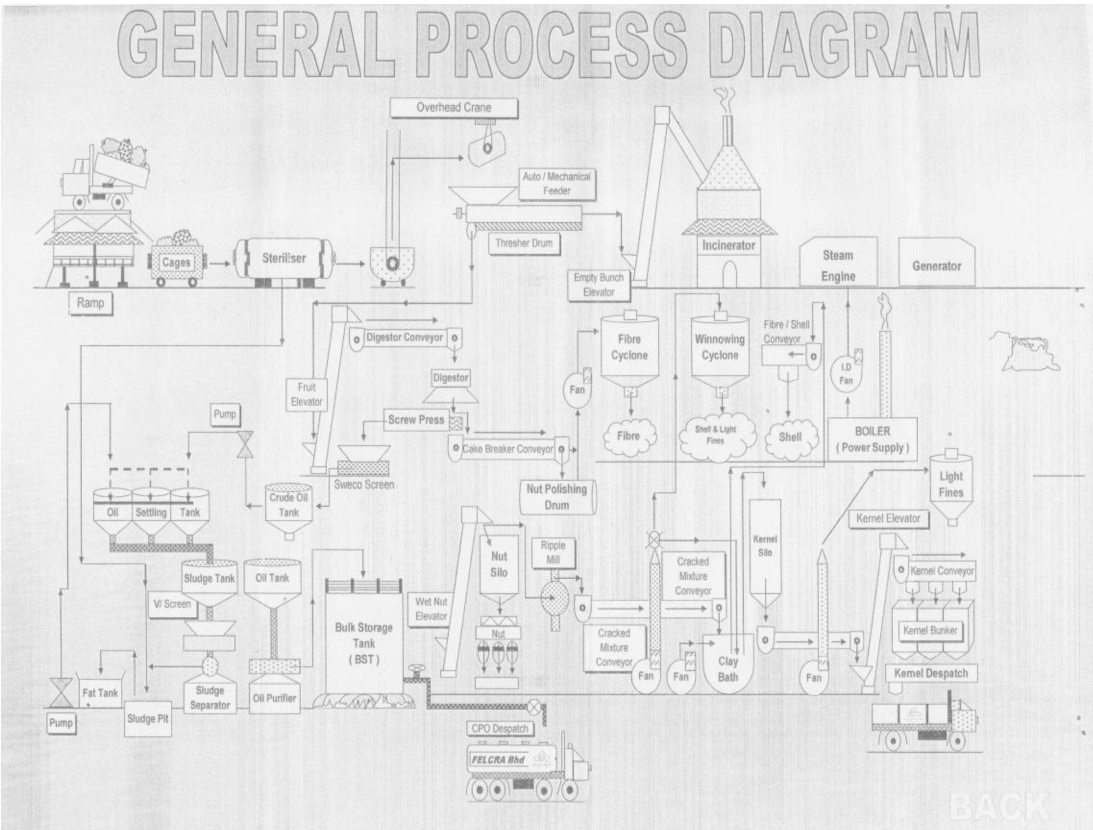


Figure 1: General Process Diagram of a Palm Oil Mill Plant

CHAPTER 2

Literature review

Energy audit is a process to evaluate where a building, plant or even a system uses or consume energy efficiently and also to identify the opportunity to reduce energy consumptions in the buildings or plants. By reducing energy consumption, the buildings or plants will save money and good for our environment. By using energy audit, we can checks the way energy is used and also checks for areas of inefficiency or that less energy can be used and identifies improvement that can be used to increase the efficiency of the energy usage. Based on ASME standard, there are a few types and steps for energy auditing.

a) Types of energy audit

There are 3 types of energy audit. The 1st type is the walk through audit. This type of audit is a tour of the facility to visually inspect each of the system or processes that uses energy. The evaluation usually used to analyze the quantity and the patterns of energy usage in the facility. Then, the comparison can be made between the average industry energy consumption and as benchmarks for the similar facilities. A preliminary estimate of saving potential will be produced and a list of low-cost savings opportunities will be yield.

The 2nd type is the standard audit which is the most common audit being done. This audit will quantify energy uses and losses through more detailed review and analysis of equipment, system and operational characteristics. There are on site measurement and testing to quantify the energy usage and also the efficiency of the systems in the facility. Certain standard engineering calculations will be needed to analyze the system efficiency and also to calculate energy and cost savings and also on the improvements on the systems required.

The 3rd type is the computer simulation. This computer simulation required using certain energy audit software such as TRANSYS. This energy audit need detail information on energy usage by function and more comprehensive evaluation of energy usage patterns. This computer simulation is the most expensive types of energy auditing because of the time involved in collecting detailed equipment information, operational data, setting up an accurate computer model an also warranted if the facility or systems are complex in nature.

b) Energy audit process

Based on the Handbook of Energy Audits by Albert Thumann, seventh edition, there are a few main processes for energy auditing to be performed. These processes will make the auditing organized. An organized approach to collect data is by splitting the audit into three main components:

i. Pre site work

It is important in getting to know basic aspect of the plant by doing several preparations before the site visit. This preparation will help to ensure the most effective use of our onsite time and also will minimize disruptions to plant personnel. A thorough pre site review will also reduce the time required to complete the onsite audit.

ii. The site visit

During the site visit, all the important information and data will be collected. The time required for this visit will depend on the completeness of the pre site information collected and also the complexity of the plant and system. Besides that, the need for testing the equipment also plays a major role.

iii. Post site work

Post site work is a necessary and important to ensure the audit will be useful planning tool. The information gathered during the site visit will be evaluated. All possible opportunity to conserve will be research and the audit will be organized into a comprehensive report and the recommendation will be made on mechanical, structural, operational and the maintenance improvements.

c) IR thermal imaging

The IR Thermal Imaging system is a closed circuit TV unit that is sensitive to the infrared light that the human eye cannot see. All objects emit infrared radiation proportional to their temperature and variation in surface temperature. Every object that made from different materials emits different infrared radiation rates. This property is called emissivity. Every infrared light can be reflected off a surface. The degree to which a surface will reflect light is call reflectance.

Object emissivity and reflectance must both be accounted for when interpreting information obtained using IR Thermal Imaging device. Any areas that are warmer than their surroundings stand out plainly. For example, any place that warm air is leaking to the outside can be detected.

Thermal imaging is a technology that creates picture from heat rather that light. IR thermal imaging is a device that measure radiated infrared (IR) energy and converts the data to corresponding maps of temperatures. IR thermal imaging is used widely in industry by providing real time data to determine defect that can lead to equipment failures, energy loss or environmental impacts.

By depending on the temperature measurement capability of the imaging equipment, it helps produce significant cost savings and cost avoidances. Thermal imagers with temperature measurement capability, called sometimes "Radiometric Imagers" and Quantitative Thermal Imagers" are used also in many Non-destructive testing situations and some of the professional societies for non-destructive testing around the world, such as the American Society for Non-destructive Testing (ASNT) in the USA, have adopted Infrared Testing as a sanctioned testing method.

By using IR Thermal Imaging may suggest a refinement in a building's operation and maintenance program that will result in energy savings. Operation and maintenance procedures can usually be implemented with greater ease and lower cost compared to the retrofit measures.

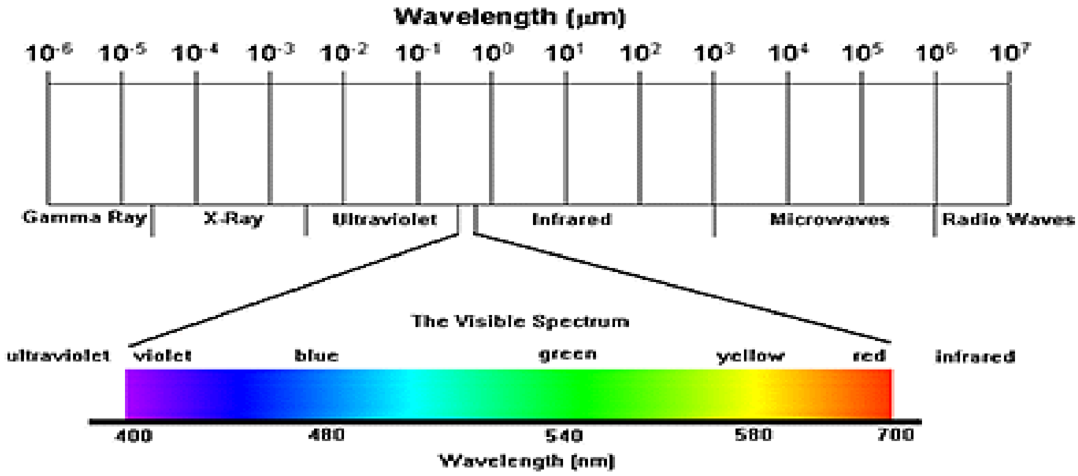


Figure 2: The electromagnetic spectrum

d) Advantages of using IR Thermal Imaging

i. Thermal imaging surveys are non-invasive and non-destructive allowing the thermal imaging survey to be completed whilst plant and equipment is running, in production and on load.

ii. Thermal imaging surveys are real time and produce fast, accurate and immediate temperature measurement and fault detection.

iii. It shows a visual picture so temperatures over a large area can be compared

iv. It can be used to measure or observe in areas inaccessible or hazardous for other methods

v. It can be used to find defects in shafts, pipes, and other metal or plastic parts

e) Applications of IR Thermal Imaging

i. Inspection of power transmission equipment.

ii. Water leakage into building roof insulation.

iii. Checking for poor building insulation.

iv. Detection of thermal pollution in rivers and lakes.

v. Inspecting cooling coils for plugged tubes.

vi. Spotting plugs and air locks in condenser tubes.

vii. Studying the behavior of thermal sealing equipment.

viii. Studying the behavior of heating and cooling devices.

ix. Detection of plugged furnace tubes.

x. Spotting defects in laminated materials.

xi. Finding leaks in buried steam line.

xii. Inspection of heavy machinery bearing.

xiii. Study of stresses due to thermal gradients in a component.

xiv. Detection of defects such as volds and inclusions in castings.

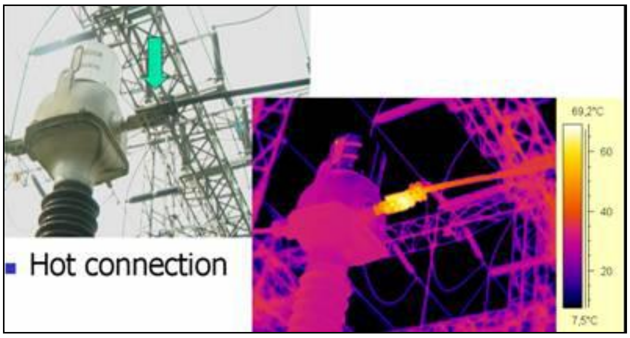


Figure 3: High voltage substation

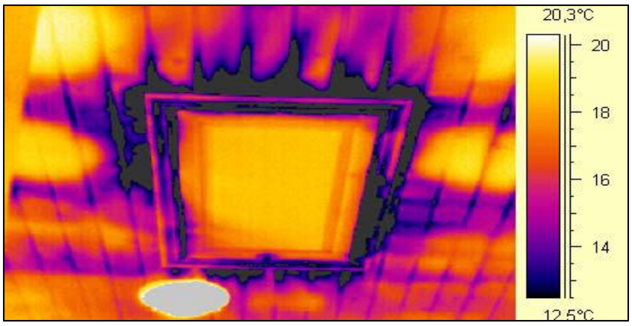


Figure 4: Building air leakage

Figure 5: Building insulation

f) Power generation plant

Power generation is the process of generating electricity from other forms of energy (heat). Electricity often generated at a power station by electromechanical generators, primarily driven by heat engines fueled by chemical combustion or nuclear fission but also by other means such as the kinetic energy of flowing water and wind. The most important equipment in power generation is the boilers to provide the heat and the turbine to converts the energy from kinetics energy to electricity.

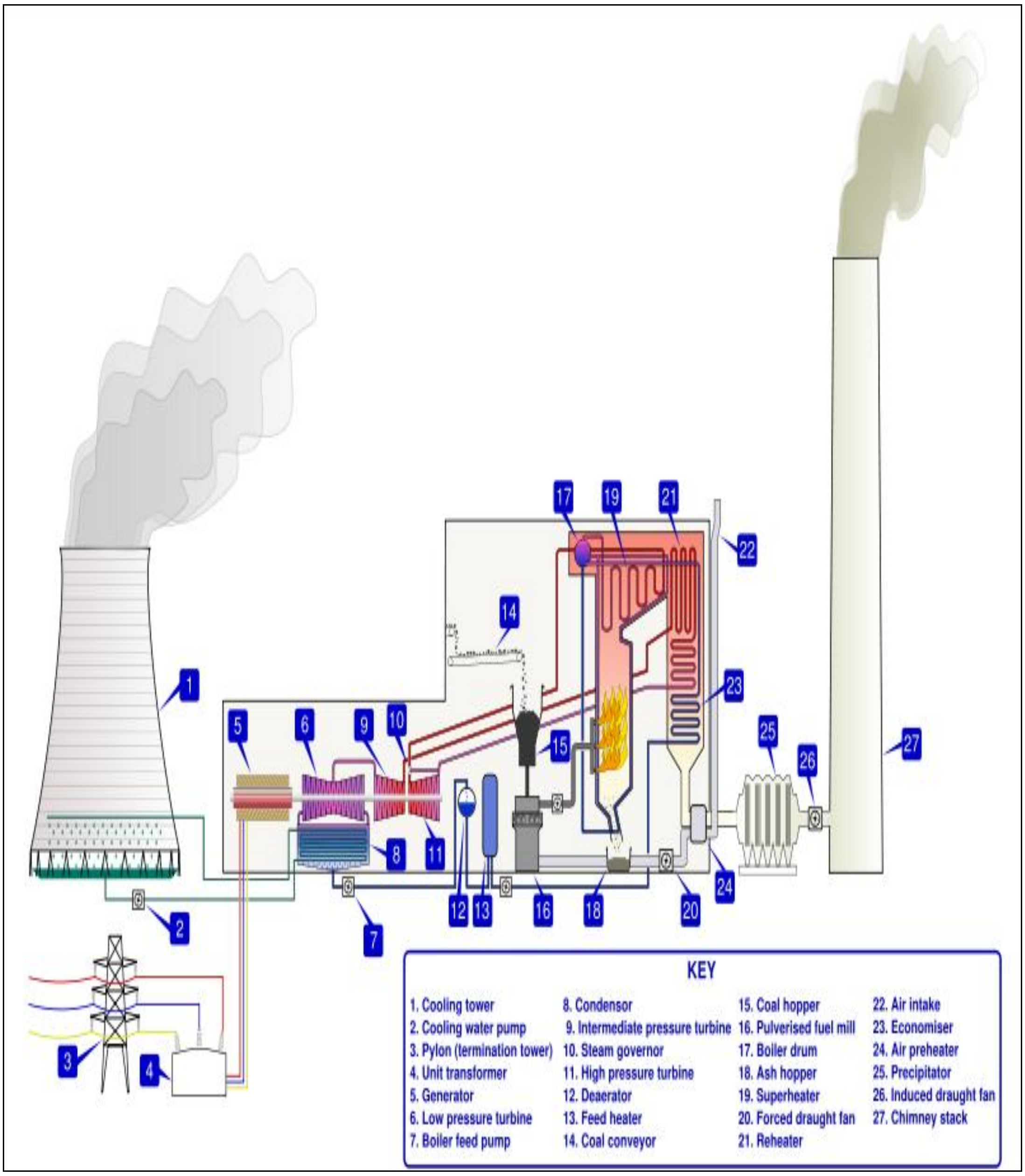


Figure 6: Thermal power plant Diagram

i. Combine Heat and Power (CHP)

Cogeneration (combined heat and power) is the use of a heat engine or a power station to simultaneously generate both electricity and useful heat. All thermal power plants emit a certain amount of heat during electricity generation.

Engines dedicated to electric power and heat production can be used for continuous energy production at remote settlements, for emergency power for hospitals, in mobile power packs, for peak production of electric power and etc.

Electric generator systems use an alternator to produce electric power at an efficiency approaching 40% without heat recovery. Cogeneration plants improve their total efficiency, and therefore their operating costs, with highly efficient heat exchange solutions that utilize more of the available high-grade heat.

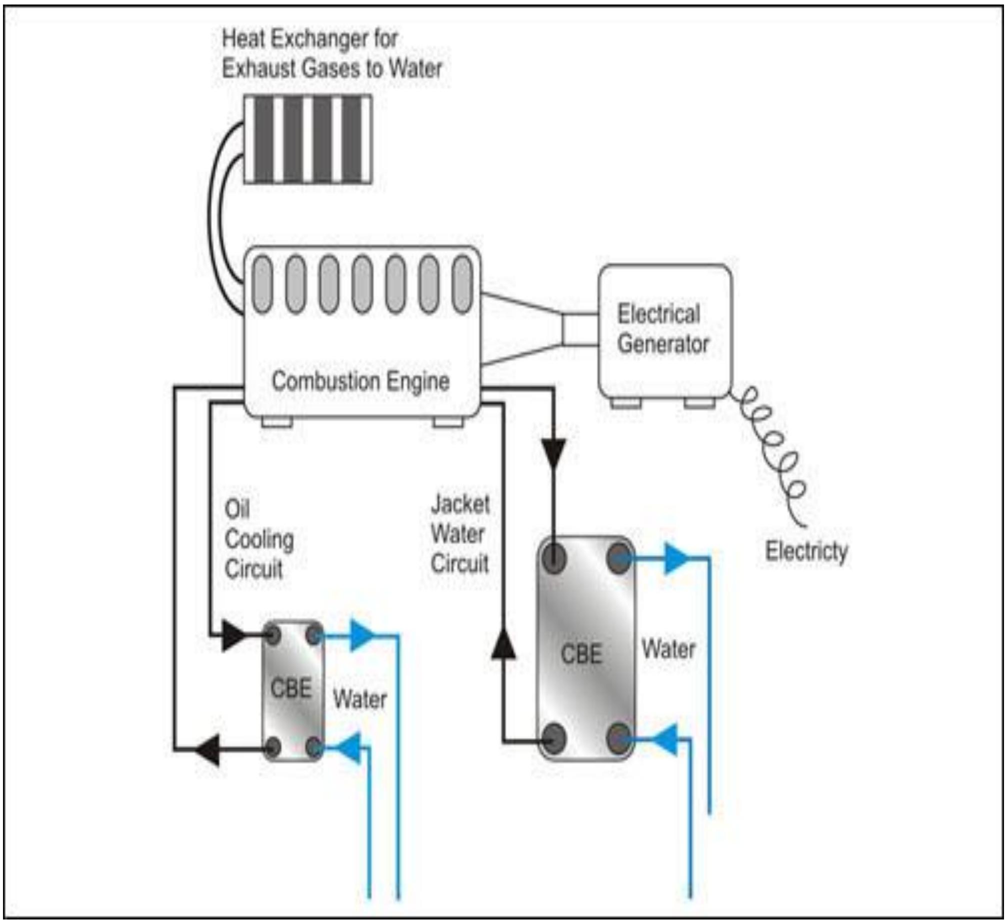


Figure 7: Combine Heat and Power Diagram

ii. Steam and Power Generation

Optimum utilization of energy resource in palm oil mills is required in production process which is pre-condition for a ‘combined heat and power (CHP) scheme or commonly known as Co-Generation System.

Solid waste from the oil palm plant such as shell, fiber and empty fruit bunch being utilized as fuel for the boiler. For processing approximately 500kg per hour per ton FFB, steam is required in the process. Steam is generated from water tube boiler to produce power. Power is required at the approximate rate of 15 to 25 kW per ton FFB. (Noel Wambeck, 1999)

A system has been introduced for the treatment and disposal of empty bunches and recovery of palm oil and at the same instances reduces the moisture contents of the empty fruit bunches to approximately 45% so they can be used as solid waste fuel for the boiler and production of additional steam and electrical power. (Noel Wambeck, 1999)

iii. Conversion to Steam

Steam is an ideal of source of heat for power generation. The boiling point of water at atmospheric pressure is 100^0C. The boiling point of the water increase as the pressure increase. Water phase will change from liquid to gaseous when the water boils. As a gas, it is commonly known as steam. In order to heat the water, energy is required. It takes 1 BTU (British Thermal Unit) to raise the temperature of 1 lb. of water 1 ^{0}F. Additionally, it takes 970 BTU to change 1 lb. of water at boiling point to steam. Thus, it takes total of 1082 BTU in process of boiling and conversion of 1 lb. of water to steam. This heat is released when the steam recondenses at the point of usage.

g) Boilers

A boiler is a device that converts the chemical energy fuel into heat output. Typical heat outputs are steams (saturated or superheated), hot water or thermal fluids like mineral oils. There are many types of boiler, but they can be classified into two basic group:

i. Water tube boiler

ii. Fire tube boiler

Most boilers have furnace chamber where the heat is transferred directly from the flame by radiation. After the furnace chamber, the flue gas goes through passage where the heat is transferred by convection. Two-third of heat transfer take place in the furnace and the remaining in the flue gas passages.

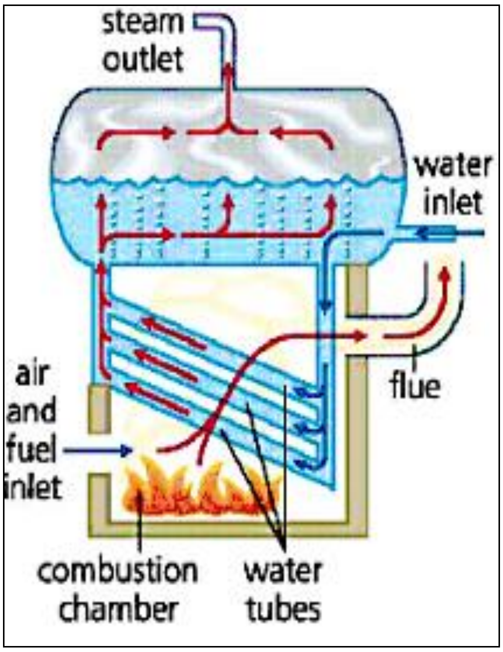


Figure 8: Water tube boiler

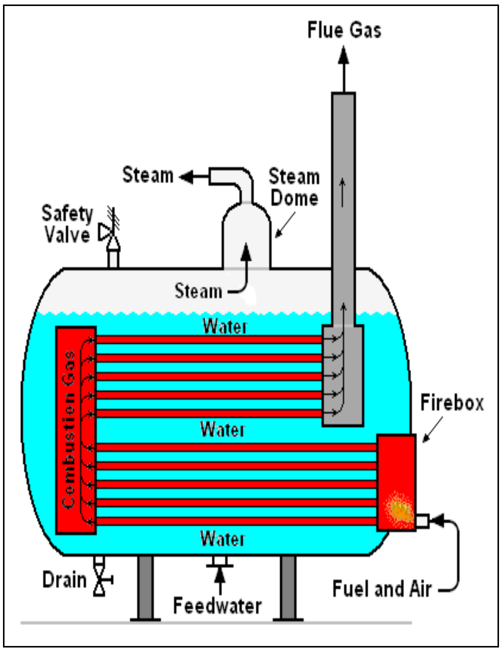


Figure 9: Fire tube boiler

h) Boiler Constructions and Characteristics

The most critical equipment in Felcra Nasaruddin Palm Oil Mill in Bota needs to be audited is the Water Tube Boiler. It is a Yoshimie Water Tube Boiler Type H-525 made in 1982 by Yoshimie Boiler Industry Co. Ltd., Osaka in Japan.

The performance of the boiler at any moment is recorded by the pressure gauge and the steam flow meter. The boiler pressure and the steam flow will be taken hourly by boiler man and filled into the boiler log sheet.

From the boiler data log sheet, the boiler pressure did not exceed 21 bar either in the steam drum or in super heater. The boiler pressure still under its maximum designated allowable pressure range. The water level in steam drum is maintained at safety level (central level) which is at ½ levels. Water is blown down every hour while the soot blow is at every 5 hours.

There are thirteen main components in water tube boiler need to be inspected and checked regularly during operation. The components are:

- i. Boiler fittings
- ii. Two units of water pumps
- iii. Two units of gauge glass
- iv. Two units of pressure gauge
- v. High and low water alarm
- vi. Main stop valve
- vii. Non return check valve
- viii. Feed check valve
- ix. Blow down valve
- x. Machinery test gauge
- xi. Two units of safety valve
- xii. Tin plate
- xiii. Manufacture plate

Specifications and particulars of water tube boiler	
Boiler :	
No of boiler	: PMD 2417
Type of boiler	: H-525
Manufacturer	: Yoshimine Boiler Industry Co. Ltd. Osaka Japan
Year of manufacture	: 1982
Capacity	: 18 mT/hr
Heating surface	: 527 m^2
Maximum allowable working pressure	: 21 bar
Water tube :	
Total No. of tube	: 530 tubes
Overall diameter	: 2’’
Allowable Inclined Angel	: 30^0
Furnace :	
Type of grate	: Fixed grate
Grate dimension	: 7000 mm (H) 9850 mm (W) 10500 mm (L)
Fuel :	
Class of fuel	: Oil Palm Fiber & Kernel
Calorific value of fuel	: 2191.334 kcal/kg
Moisture of fiber	: 0.65
Fuel consumption per hour	: 7.5 mT/hr (approx. 25% from FFB)
Gas and air :	
Average temp. at superheater	: 220 – 300 ^{0}C
Average temp. at turbine	: 260 – 280 ^{0}C
Flue gas temp.	: 230 – 250 ^{0}C
Feed water :	
Feed water temp.	: 60 – 70 ^{0}C

Table 1: General specification of water tube boiler in Felcra Nasaruddin Bota Palm Oil Mill

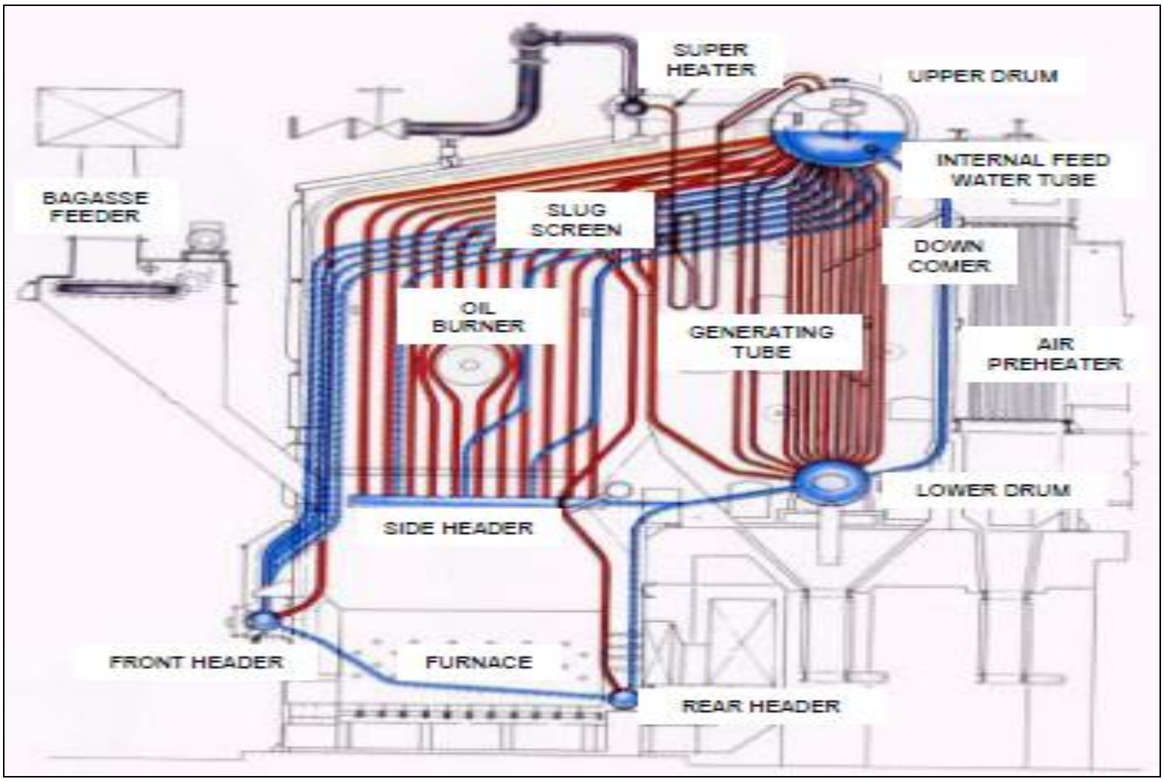


Figure 10: Schematic Diagram of High Efficiency Biomass Firing Boiler

Figure 11: Yoshimine Water Tube Boiler

i) Turbines

A turbine is a device that uses flowing fluids (liquids or gases) to produce electrical energy. Fluid is forced across blades mounted on a shaft, which causes the shaft to turn. The energy produced from the shaft rotation is collected by a generator which converts the motion to electrical energy.

Most power plants use turbines to produce energy by burning coal or natural gas. The heat produced from combustion is used to heat water in boiler. The liquid water is converted to steam and is exhausted through a pipe which feeds the steam to the turbine. The pressurized steam flow imparts energy on the blades and shaft of the turbine causing it to rotate. The rotational mechanical energy is then converted to electrical energy using a generator.

Turbines can be classified into two main groups, the steam turbine and the gas turbine. Steam turbine is a very satisfactory and dependable prime over for many process machines such as pumps fans, blowers and also compressors. It is used as a driver for electric generator to provide main power to the process plant motor drives. Steam turbines are axial-flow turbo machines in which steam flows parallel to the shaft axis.

Gas turbines are self-contained power plants that use gas as the fuel which burns with the compressed air in the combustor and is expanded through the turbine which drives the air compressor and delivers the excess of power generated as output. The products of combustion are exhausted to the atmosphere.

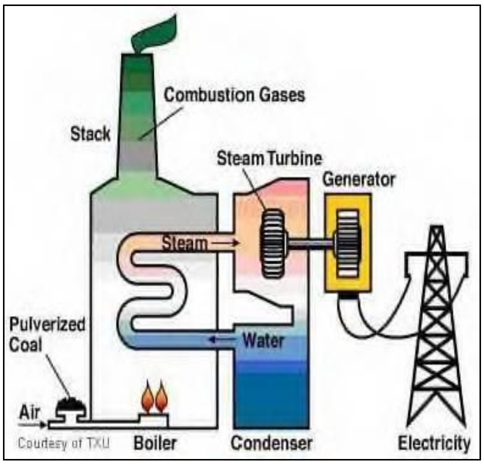


Figure 12: Steam turbine

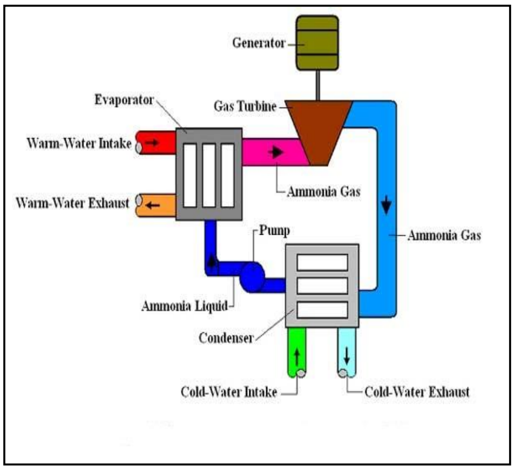


Figure 13: Gas turbine

j) Boiler Operation

i. Boiler Feed Water Purity

Feed water is needed in steam production. Most of the steam is used in the power generation process but some of it will return to the boiler after condensation process as part of the feed water. To supplement for the return condensate, make up water is fed in using electric pump.

The purity of the feed water depends on the type and design of the boiler. For fire tube boiler which is operating at low pressure can use feed water og high hardness whereas for the high pressure water tube boiler will require all impurities to be removed from the feed water.

The feed water is treated externally to remove impurities from the water. Softening and daeration are the common type of external treatment applied. The impurities after entering the boiler can be internally treated using chemicals to prevent scalling and corrosion.

ii. Boiler Maintenance

Water treatment is required to provide the physical plant with properly treated water in sufficient quantities to meet plant needs. Water treatment is required in all system by using special chemicals for corrosion and scale inhibitors. For palm oil mill, water treatment for boiler requires advanced water technologies which will treat the water by external approach or by chemical conditioning.

iii. Steam Generation

Empty fruit bunches in the form of solid waste fuel which is by- products of the process are used as the fuel for the boiler. Steam generated by water-tube boiler is required for processing at the approximate of 660 kg per hour per ton FFB. The power required to be generated is approximately 17 KW per ton FFB.

Steam is generated from the boiler at a pressure of 20 – 21 bar and being transferred to the steam turbo alternator at 17 – 18 bar (260^0C) with back pressure of 3.0 bar for the mill process which is convenient and effective for heating process.

Steam is produces and being expanded in steam turbines and led into the process where the latent heat contained in the exhaust steam is 41 psi being used for sterilization of FFB and heating systems in the process.

Based on energy indicators of income and products of the palm oil mill, every 1 mT of FFB supplied required 0.666 ton of steam to process and power of 17 kW of power.

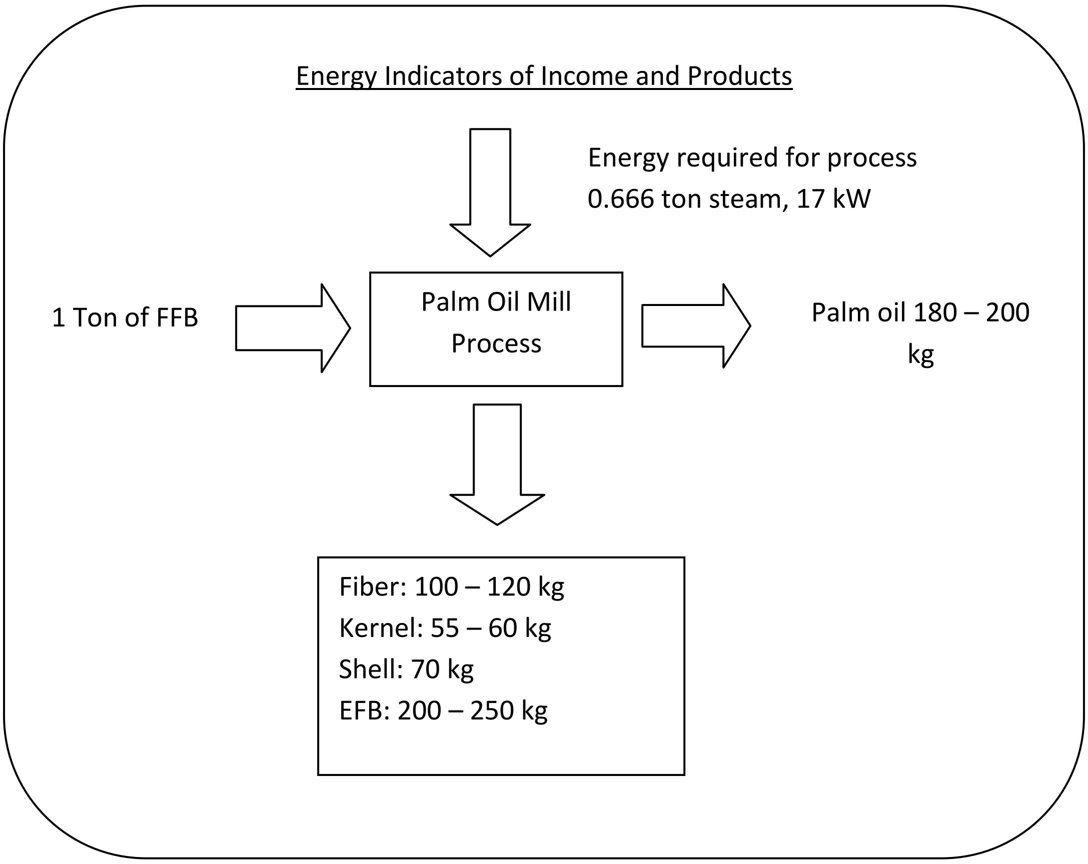


Figure 14: The Energy Indicators of Income and Products of Palm Oil Mill

iv. Power Distribution

Steam turbine is used to generate power in the mill where high pressure steam from the boiler outlet passes through the turbine and exhaust to the back pressure vessel at low pressure. There are two units of steam turbines being used in the mill but only one is operating at one time while the other one being kept available or standing by to avoid any power generation interruption during mill operation.

The turbine used in the mill is an impulse type back pressure turbine and gear coupled to a generator set. The turbine runs at 1500 rpm. The designated output of the turbine is 500 kW (normal) and 672 kW (maximum) with input steam pressure 14 bar and 3 bar of back pressure.

The power generation and consumption for all process station in the palm oil mill is recorded. The running kilowatt-hours power meter shows the amount of overall power consumption. The steam pressure input of the turbine is recorded at high pressure receiver while back pressure is recorded at back pressure receiver.

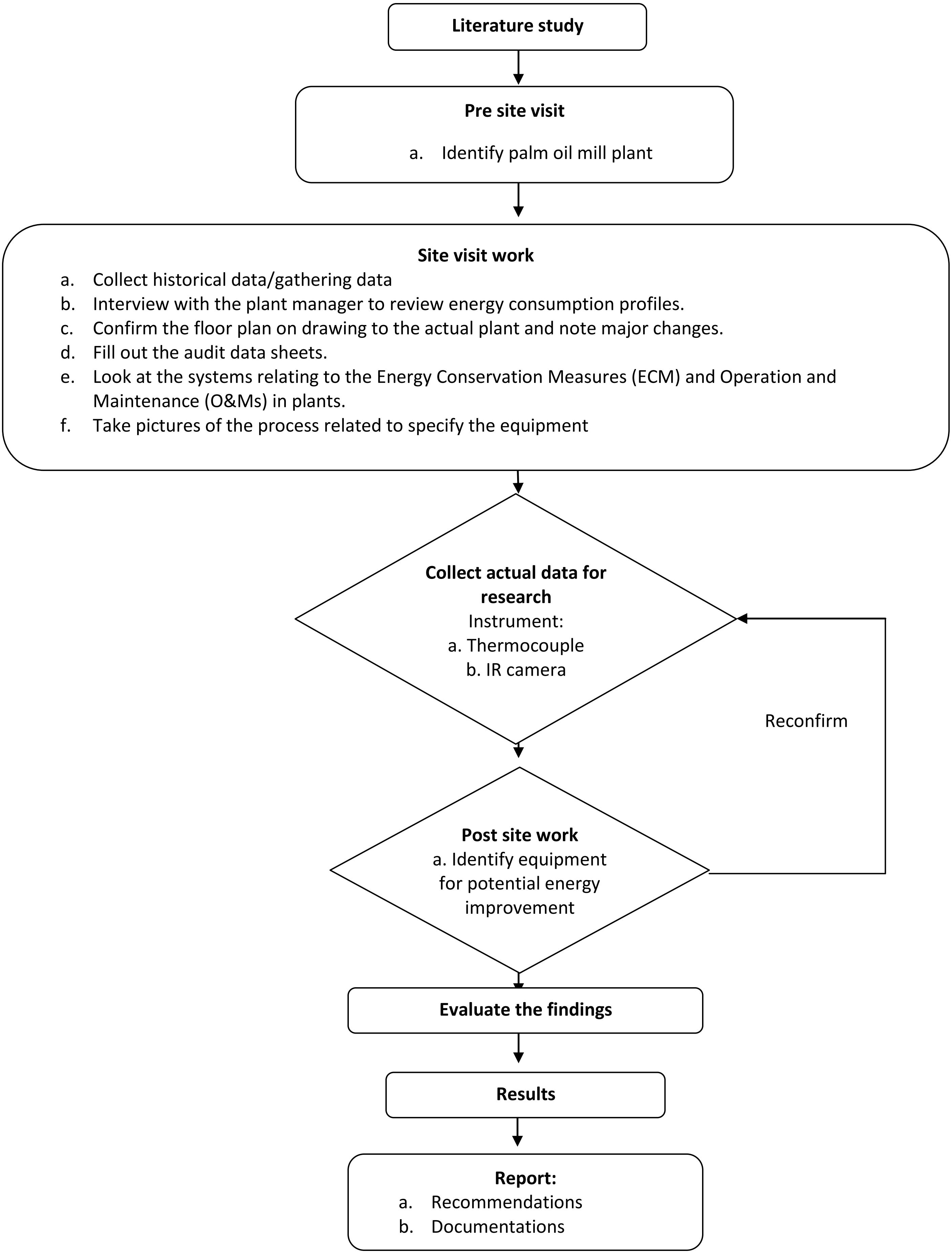
The power generated by turbine at the range of 500 kW to 672 kW. The power distributed to several process stations involved in the palm oil mill.

Felcra Nasaruddin Palm Oil Mill, Bota Turbine No 1 : 500 – 520 kW	
Station	Power (kW)
FFB Loading Ramp & Hoppers	50
FFB Pressing & Threshing Station	200
Boiler Station	17
Kernel Recovery Station	100
Oil Clarifying Station	60
Sterilization Station	55
Wastewater Plant	6
Workshop	5
Office and Canteens	4
Others	3

Table 2: Average Power Distribution in Daily Process in Palm Oil Mill

CHAPTER 3

Methodology



CHAPTER 4

Results and Discussion

During this energy auditing for palm oil mill at Felcra Nassaruddin, there are two major equipments that being consider as main equipment being used in power generation system which are the boiler and the turbine. There are 3 main systems that being inspected during this energy auditing which are the pipe insulation system, the hull insulation system and the rotating system. From IR thermal imaging, the hot spot of each of the system can be detected and defects of the system can be recognized.

a. Pipe insulation

Pipe insulation system plays a major role in maintaining the efficiency of the boiler. The steam pipe insulation from the boiler drum until it reaches the turbine is very important. The temperature of the steam needed to be maintaining in order to achieve desire energy output from the turbine. The temperature of the steam needed to be maintained in the range of 160 ^{0}C until 180^{0}C.

The furnace generates the heat to heat up the water that generates the steam. From the boiler drum the steam being transferred through the steam pipe line directly to the deaerator before it reaches the turbine to generate power. There are two valves that being used to control the steam flow which is the check valve and also the emergency stop valve.

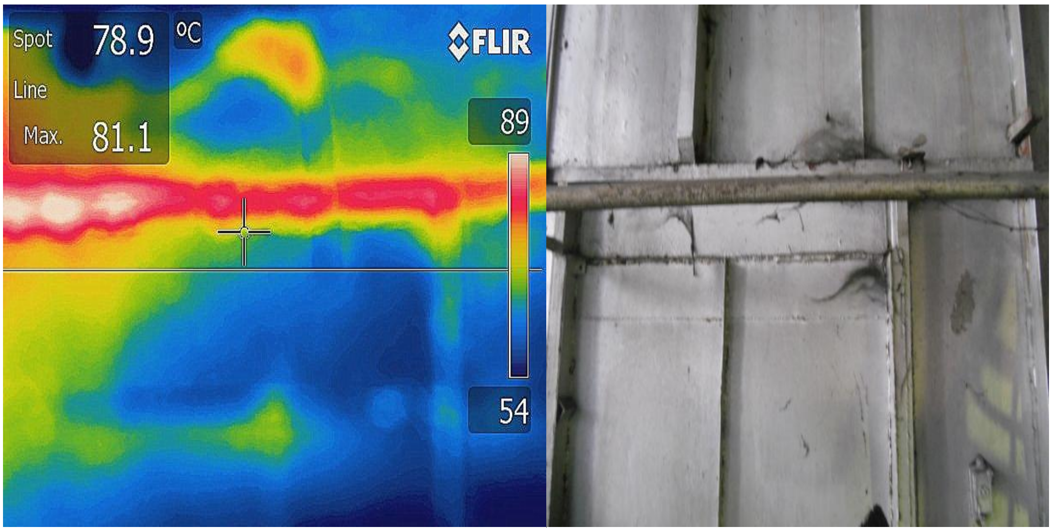


Figure 15: Feed Water Pipe

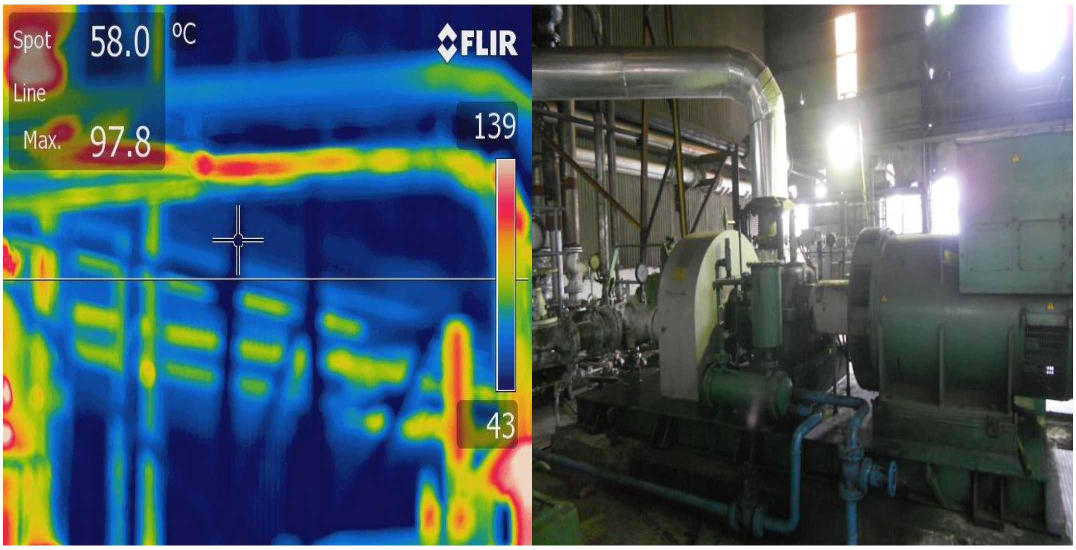


Figure 16: Steam Pipe

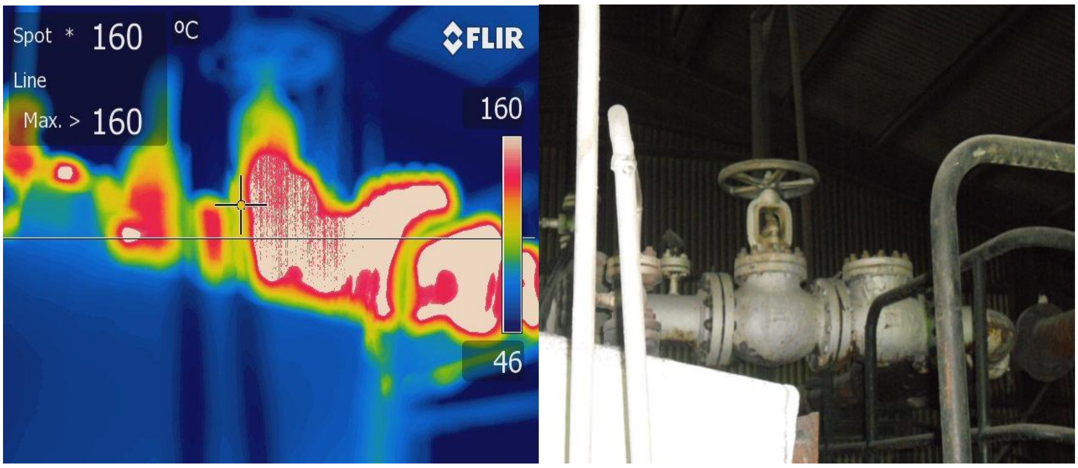


Figure 17: Emergency Check Valve

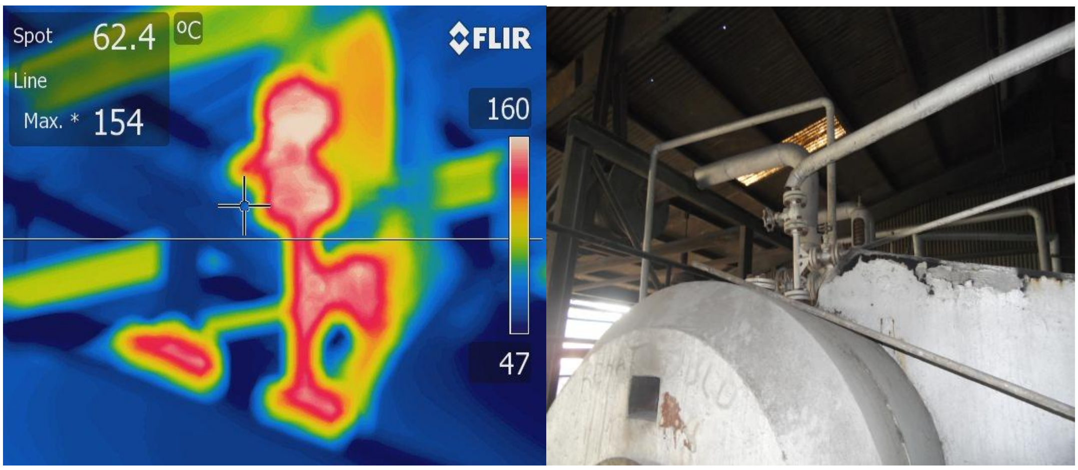


Figure 18: Check Valve

From Figure 15, the figure show the feed water pipe which is connected from the feed water pump to the boiler drum. The temperature of the feed water is in the range of 70^0C to 89^0C. By using IR thermal imaging device (FLIR camera) the insulation of the pipe can be inspect. There is defect within the insulation of the pipe which can cause decreasing in the overall efficiency of the system.

The steam pipe (Figure 16), emergency check valve (Figure 17) and the check valve (Figure 18) contains defect within the insulation system. The equipments are very important in controlling the power output of the system. The steam flows from the boiler drum through the check valve and the emergency check valve before enter the turbine to generate power. The temperature of the steam is in the range of 170^0C to 180^0C. The temperature and the pressure of the steam needed to be maintaining in order to get desire power output. Based from the figures, there are hot spots at the pipe and also the valve. The temperature of the steam pipe is only 139^0C while the required temperature is 170^0C to 180^0C. There is heat lost within the pipe.

b. Hull insulation

A deaerator removes dissolved oxygen from boiler make-up water. Oxygen removal is accomplished by heating the make-up water to its boiling temperature. Dissolved oxygen gets freed then and escapes to the atmosphere. Steam is taken from the boiler and is piped to the deaerator to heat the make-up water.

An existing boiler plant is fed with feed water at a temperature of 85°C. Due to the rising cost of chemical treatment, it is proposed that a pressurized deaerator be installed, operating at 0.2 bar g to raise the feed water temperature to 105°C, reducing the solubility of oxygen to quantities typically measured in parts per billion. Steam, produced in the boiler at 10 bar g, is to be used as the heating agent.

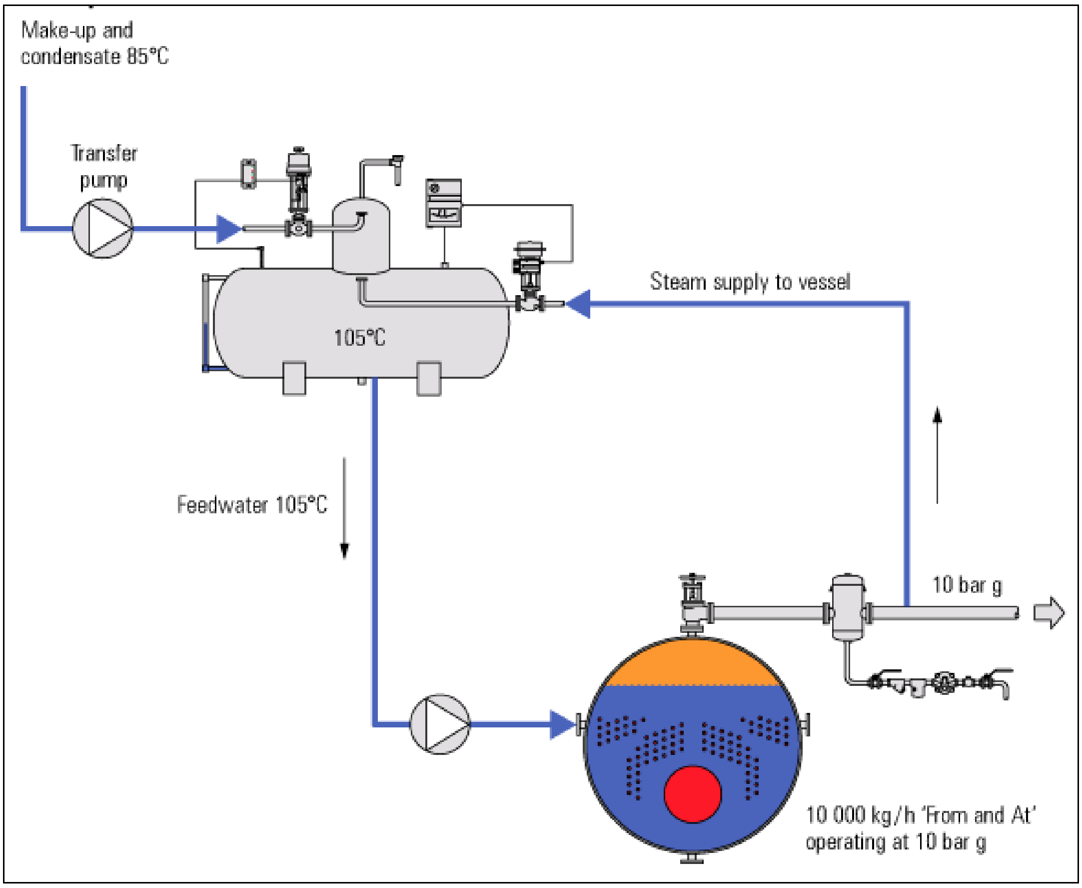


Figure 19: Working Principle of Deaerator

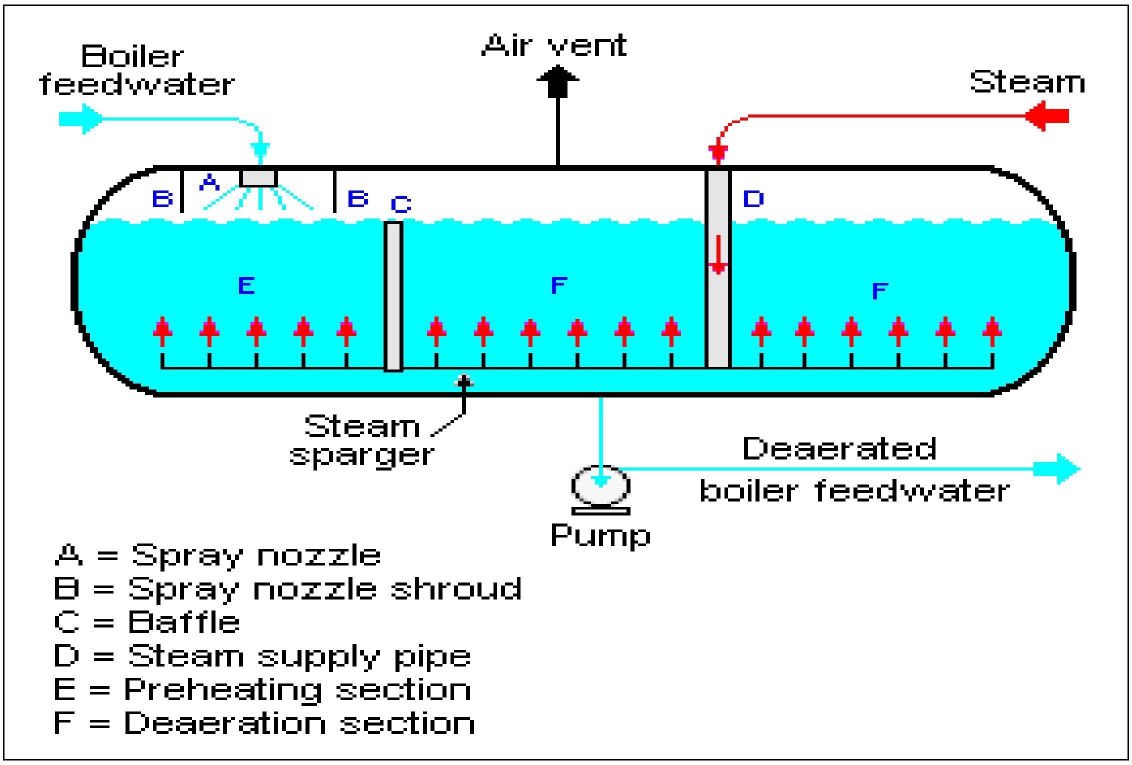


Figure 20: Schematic Diagram of A Typical Spray-Type Deaerator

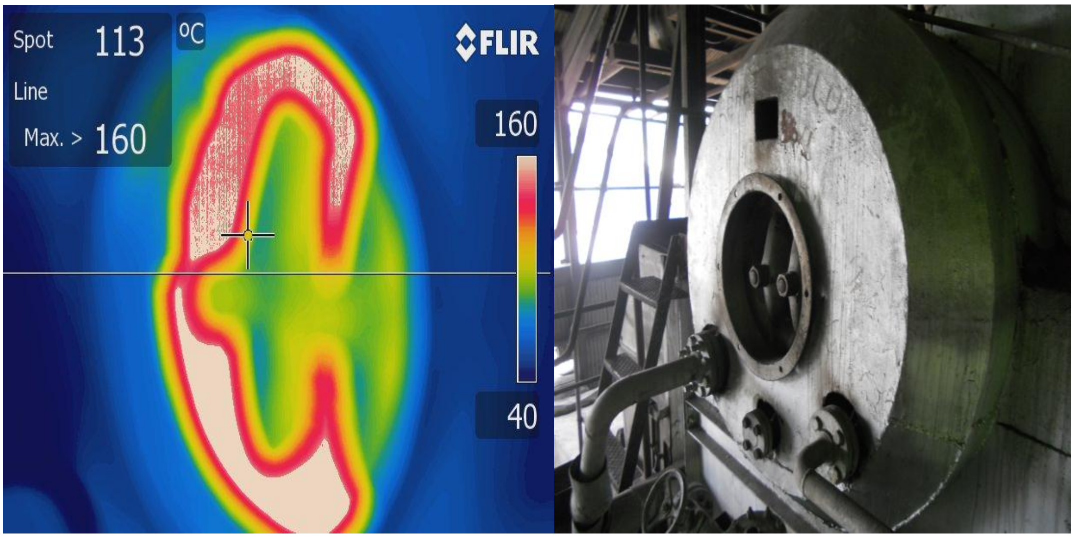


Figure 21: Boiler Drum

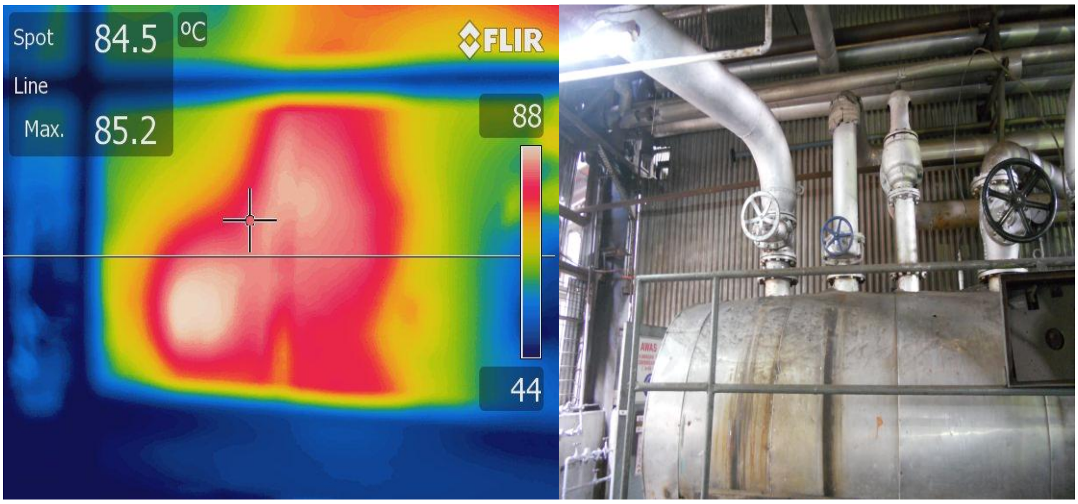


Figure 22: Deaerator

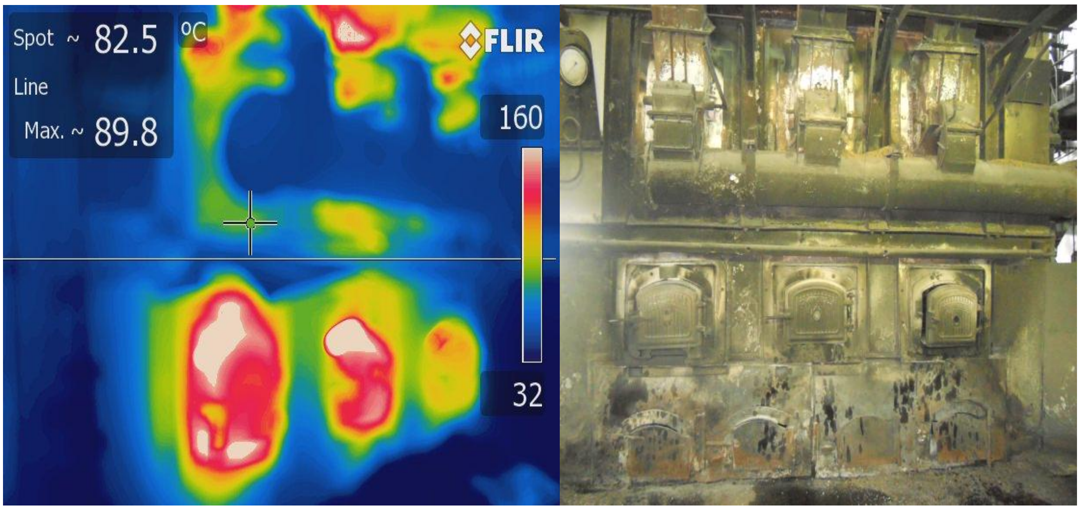


Figure 23: Boiler Furnace

The boiler drum (Figure 21) shows increasing in temperature within the door of the boiler drum. There is leakage within the insulation of the boiler drum's door. When there is leakage within the insulation of the door, the temperature of the steam will be effected. There will be decreasing in temperature of the steam.

There is leakage within the deaerator hull (Figure 22) and boiler furnace (Figure 23) insulation that may effect the efficiency of the system. The leakage cause decreasing in temperature of the steam before it enters the turbine.

c. Rotary Equipment

When considering electric motors and turbines, operating temperatures and thermal patterns can be a valuable key in a predictive maintenance program. All motors have a normal thermal pattern as well as given maximum operating temperature.

Steam turbine operation and performance require the correct steam pressure and temperature at the turbine inlet and high steam quality (steam without condensate entrapment) to ensure high turbine reliability.

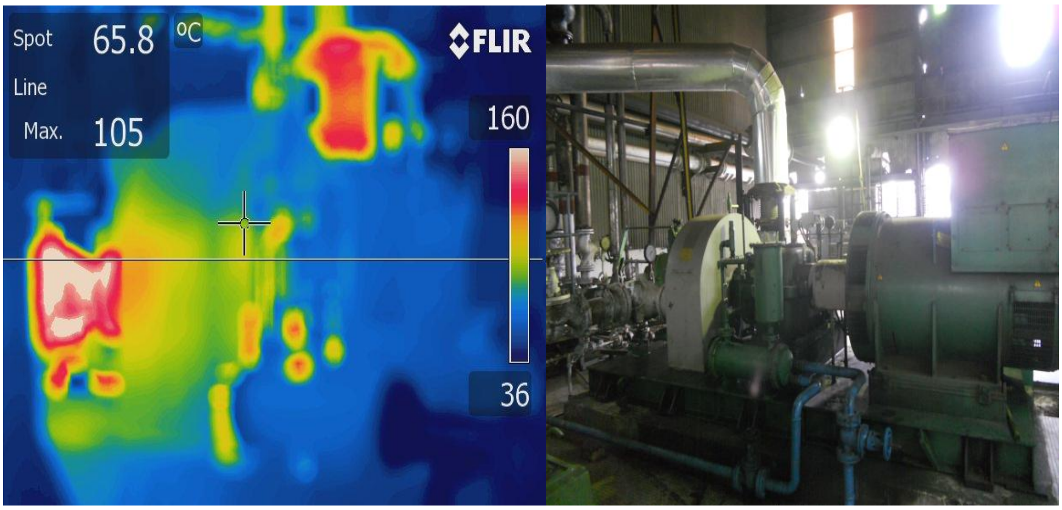


Figure 24: Turbine

Based on the turbine (Figure 24) infrared temperature profile, there are several hot spot at the turbine. The hot spot shows defect within the turbine that may effect the overall efficiency of the system and also the power output.

d. Energy Input and Output of Boiler

Energy input of the boiler mainly comes from the fuel burnt to generate heat for the feed water to circulate in the boiler which will then turn into steam. Steam that is generated will flow to the turbine with certain pressure and temperature to produce required amount of power. Energy output of a boiler is measured based on the percentage ratio of the energy output to energy input.

In order to determine and calculate the energy input, energy output and also the boiler efficiency, there are some parameters and data has been collected during the site visit.

Steam Produces per Boiler: 18 Mton/hr

Boiler Pressure: 20 bar

Feed Water Temperature: 70 ^{0}C

FFB Consumption: 30 mT/hr = 720 mT/day

Fiber Consumption: 7.5 mT/hr = 180 mT/day

Calorific Value of Fuel: 2191.334 kcal/kg

Assumption: only 1% of fuel escapes unburnt

Conversion: 1kcal = 4.1868kj

1 kcal = 10^3 kg

Figure 25: Boiler Parameters

e. Heat required to raise 1 ton of steam

Enthalpy of dry, saturated steam at 20 bar, h_2 = 668.6491 kcal/kg

Enthalpy of water at 70 ^{0}C, h_1 = 69.997 kcal/kg

Therefore,

Heat required to raise 1 ton of steam = $10^3(h_2 - h_1)$

= 103(668.6491 – 69.997) kcal/ton

= **<u>598.671 x 10^3 kcal/ton</u>**

f. Equivalent evaporation

Fiber consumption = 7.5 mT/hr

Steam generated per ton of fuel $= \dfrac{\text{steam generated/hr}}{\text{FFB consumption/hr}}$

$= \dfrac{18 \text{ ton/hr}}{7.5 \text{ ton/hr}} = 2.4$

Therefore,

Equivalent evaporation $= \dfrac{2.4(598.6714 \times 10^3)}{539 \times 10^3}$

= **<u>2.666 ton of steam per ton fiber</u>**

g. Equivalent steam generation

FFB consumption = 30 mT/hr

Steam generated per ton of fuel $= \dfrac{\text{steam generated/hr}}{\text{FFB consumption/hr}}$

$= \dfrac{18 \text{ ton/hr}}{30 \text{ ton/hr}} = 0.6$

Therefore,

Equivalent evaporation $= \dfrac{0.6\,(598.6714 \times 10^3)}{539 \times 10^3}$

= **<u>0.666 ton of steam per ton FFB</u>**

h. Boiler efficiency

Energy output = (steam generated per hour) x (heat required)

$= 18\,(598.671 \times 10^3)$ kcal/h

Fiber consumption = 7.5 mT/hr

Actual Fiber burnt = 7.5(1 – 1/100) = 7.425 ton/hr

Energy input = (Actual fiber burnt) x (calorific value of fuel)

$= 7.425 \times 10^3\,(2191.334)$ kcal/h

ηboiler = energy output/energy input

$$= \frac{18\,(598.671 \times 10^3)\ \text{kcal/h}}{7.425 \times 10^3\,(2191.334)\ \text{kcal/h}} \times 100$$

= **66.23%**

i. Overall efficiency

ηboiler (overall) = energy output/energy input

$$= \frac{18\,(598.671 \times 10^3)\ \text{kcal/h}}{30 \times 10^3\,(2191.334)\ \text{kcal/h}} \times 100$$

= **16.39%**

j. Thermal efficiency

Energy to steam = (Equivalent steam generation) x (heat required) x 4.1868

$= 0.666(598.671 \times 10^3) \times 4.1868$

= 1669.28 kJ/kg

Energy from fuel = 1 ton FFB x Calorific value x 4.1868

= (1 X 2191.334 x 4.1868) kJ/kg

= 9174.68 kJ/kg

ηthermal = **18.20%**

CHAPTER 5

Conclusion and Recommendation

a. Conclusion

In conclusion, energy audits for palm oil plant has covered a wide variety of task and techniques which requires knowledge and understanding in data collecting and handling, mechanical designing, steam generation and heat transfer.

In order to achieve optimum results, four major steps in energy auditing has been taken in this project. Through the system characteristics and the equipment involved in crude palm oil process, energy system and energy usage can be defined.

By using IR thermal imaging, this energy auditing became easier. Using the FLIR camera, direct contact with the equipment can be avoided. This device can capture temperature profile of each of the equipment by just capturing the surface area of the equipment interested.

From the results, we can conclude that the boilers and the turbine play a major role in power generation of the plant. By inspecting the boiler and the turbine, all the defects and failure of the system can be detected easily.

Based from the results, there are several parts of the equipment from the boiler and the turbine needed urgent attention. Mostly for the insulation part for the steam pipe, emergency check valve, check valve, boiler drum's door, deaerator and the boiler furnace. As for the rotating mechanism, the turbine system needed regular maintenance to avoid any faulty and accident.

b. Recommendation

i. Boiler thermal insulation

Boilers require thermal insulation techniques and materials to control heat radiation and conduction. The heat loss due to radiation and conduction will reduces the performance of the boilers over a period of time. Boilers have huge heating surfaces which results in equally huge loss of heat through radiation and conduction.

Insulating boilers has the following purposes:

- Reduces heat losses and increases the efficiency of the boiler
- Guarantees protection against contact by minimizing the surface temperature
- Prevents heating of the compartment air in the boiler house, which guarantees an acceptable working.

ii. Regular maintenance

Boiler and turbine operation and maintenance are closely tied together. Good operation includes performing necessary daily and periodic maintenance. Low maintenance cost depends on good daily operating control, given that the system and fuel are compatible.

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APPENDIXES

Timelines for FYP 1

No.	Detail/week	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1	Selection of project topic														
2	Preliminary research work														
	a. Collecting relevant information about:														
	Energy audit														
	IR thermal imaging														
3	Submission of Extended Proposal Defence														
4	Proposal Defence														
5	Project work continues														
	a. collect and review the previous utility energy data														
	b. Obtain technical drawings														
	c. Draw simple floor plan														
	d. Determine important equipments and systems														
6	Submission of Interim Draft Report														
7	Submission of Interim Report														

Timelines for FYP 2

No.	Detail/week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Project work continues															
	a. Site visit															
	b. post site work															
2	Submission of Progress Report															
3	Project work Continues															
	a. Calculation															
	b. Results															
	c. Discussion and recommendations															
4	Pre- EDX															
5	Submission of Draft Report															
6	Submission of Dissertation(soft bound)															
7	Submission of Technical Paper															
8	Oral Presentation															
9	Submission of Project Dissertation (Hard Bound)															