The Optimization of Capacity Boiler Efficiency 26 Tons/Hours with Fuel Alumination and Statistical Product and Service Solutions (Spss) Analysis

Istianto Budhi Rahardja¹, Ahmad Mahfud², Arif Muhammad³, Masnia⁴
Plantation Products Processing Technology, Citra Widya Education Palm Oil Polytechnic¹²³
Nusantara Citra Media College of Education, Mathematics Education⁴
em-a: istianto.rahardja@gmail.com or, m_nia83@yahoo.com

To cite this document:
Rahardja, I., & Masnia, M. (2020). THE OPTIMIZATION OF CAPACITY BOILER EFFICIENCY 26 TONS/HOURS WITH FUEL ALUMINATION AND STATISTICAL PRODUCT AND SERVICE SOLUTIONS (SPSS) ANALYSIS. ADI Journal on Recent Innovation (AJRI), 2(2), 304-364.
DOI : https://doi.org/10.34306/ajri.v2i2.70
Hash : xWkaMtYrX6b4y3t6kETql-FYaWw4td8FUxcvNF_hQQ8=

Abstract

The boiler is a steam-producing installation that is used to drive steam turbines as power plants in palm oil mills. It is working to remove the heat generated by fuel into the form of steam containing enthalpy, which is used to drive a steam turbine. This study was conducted for 15 days started from May 27, 2017, until June 15, 2017. The location of the study was conducted at PMKS South Sumatra Province. The average boiler efficiency is 81% with a heating value of 2117.6717 kcal/kg compared to other dates that have a higher heating value but efficiency is below 80%. This shows the success of the boiler's performance is not only determined by the heating value contained in the fuel but also determined by the temperature of the feedwater entering the boiler, the amount of fuel in the boiler and the condition of the fuel in the boiler combustion chamber.

Keywords: Boiler, Boiler Fuel, Calorific Value, Efficiency
I. INTRODUCTION

Palm Oil Mill (PMKS) is a factory that processes palm Fresh Fruit Bunches (FFB) into Crude Palm Oil (CPO) and kernel products. As well as other products such as fibers and shells that are used as boiler fuel. In addition to fiber and palm oil mill shells, it also produces liquid and solid waste such as empty bunch and ash boiler that can be used as fertilizer. The processing in the palm oil mill consists of the main station and the supporting station. The main stations consist of a reception station, a sterile station, a thresher station, a digester and press station, a palm oil purification station, a clarification station and a nut and kernel station. While the supporting stations consist of the boiler, powerhouse, water treatment plant, workshop, warehouse, laboratories, and waste treatment. (Setiyani, 2015). According to Naibaho (1998), a boiler is a steam-producing installation that is used to drive a steam turbine as a power plant in a palm oil mill. It works to convert the heat generated by fuel into the form of steam containing enthalpy, which is used to drive a steam turbine. The process of entering fuel manually causes a fluctuating supply of fuel. Fluctuating feed causes fuel to build upon one door and a lack of fuel on another door, so it needs to be smoothing the fuel on the excess fuel door in a certain time. The efficiency needed by PMKS to process the processing of oil palm, we want to do an analysis of the causes of boiler capacity not being achieved.

II. HEATING VALUE

According to Pardamean (2011), the success of plant operation can be known by the following matters:

- The efficiency of oil and core extraction
- Effective processing capacity, a minimum of 85% of installed capacity
- Low processing/processing costs
- Production quality in accordance with standards
- Work calm in PKS
- The engineering life of the tool and the installation is longer than previously specified.

2.1 Boiler

According to Syafriuddin (2012), oil palm fiber as an alternative fuel is one of the solid wastes produced from a palm oil mill which is the fiber pulp (fiber) produced from the cyclone fiber station after passing through the extraction process through the screw press unit. Palm kernel shell as an alternative fuel, palm shell is the hardest part of the components found in oil palm. As for the way to calculate the heating value of fiber (PT. Super Andalas Steel) with the following formula:

\[ N.O = \frac{(\sum \text{mlh.} \text{Oil} \times \text{NO Oil}) + (\sum \text{mlh.} \text{Water} \times \text{NO Water}) - (\sum \text{mlh.} \text{NO. S})}{\sum \text{bb}} \]

Which:

- N.O = Calorific Value (kcal/kg)
- GB = Weight of fuel produced (kg)
N.O NOS = Heat value of NOS (kcal/kg)

N.O Oil = heating value of oil (kcal/kg)

N.O water = heating value of water (kcal/kg)

The heating value can be seen in the table below:

Table 1. The heating value contained in boiler fuel

| Name          | Number of heat (kcal/kg) |
|---------------|--------------------------|
| N.O NOS Fiber | 3850 kcal/kg             |
| N.O NOS Shell | 4200 kcal/kg             |
| N.O Oil       | 8800 kcal/kg             |
| N.O Water     | 600 kcal/kg              |

To find out the efficiency of the boiler can use the "Rankine" cycle. The Rankine cycle is a thermodynamic cycle that converts heat into work. The heat is supplied externally in a closed flow, which usually uses water as a moving fluid. Different types of liquids can be used in this cycle, but water is chosen because of various physical and chemical characteristics, such as non-toxic, large quantities, and inexpensive. (Canada, 2004). The "Rankine" cycle can be seen in the following image:

Figure 1. Rankine Cycle
1- 2: Pumping water from the tower tank to the feed water tank
2- 3: Heating water in the steam pipes
3- 4: Process water to steam inside the boiler
4- 5: Advanced heating process
5- 6: Steam enters the turbine
6- 1: Condensation process
The efficiency of the boiler can be known by the following formula (Kristono, 2016):

\[ \eta = \frac{Q(\Delta \text{Enthalpy})}{GB \times N.O} \]

Which are:

- \( \eta \) = Boiler efficiency (%)
- GB = Weight of fuel produced (kg/hour)
- \( \Delta \text{Enthalpy} \) = Difference between steam enthalpy and water enthalpy (kcal/kg)
- N.O = heating value of fuel (kCal/kg)
- Q = boiler capacity (kg/hour)

2.2 Radiant heat transfer or radiation

Radiant heat transfer or radiation is heat transfer between an object to another object by means of an electromagnetic wave without depending on the presence or absence of media or substances between the objects receiving the radiant heat. Radiation heat transfer can be imagined to take place through the media in the form of aether, a type of weightless shadow material, which fills the entire space between the molecules of certain substances, or even in a vacuum. The amount of heat received by emission or \( Q_r \) is based on the formula of Stephan-Boltzmann. (Setyardjo, 1999).

\[ Q_r = C_\varepsilon F \cdot \left[ (T_{\text{api}}/100)^4 - (T_{\text{enda}}/100)^4 \right] \]

Which are:

- \( Q_r \) = Amount of heat received by transmission (KJ / m2.hour.K2)
- \( C_\varepsilon \) = emission constant from Stephan - Boltzmann stated in (Kilojoule / m2.hour.K4)
- F = Area of heated area (m2)
- T = Temperature (K)

2.3 Stream or Convection Heat Transfer

Convection heat transfer is heat transfer carried out by the molecules of a fluid (liquid or gas). The fluid molecules in their movements hover carrying a certain amount of heat each \( q \) Joule. Molecules that hover are caused by differences in temperature within the fluid itself, so the heat transfer is called free convection (natural convection). If the movement of these molecules as a result of mechanical forces, the heat transfer is called forced convection. The amount of heat delivered by convection can be calculated using the following equation. (Setyardjo, 1999).

\[ Q_K = \alpha F (T_{\text{api}} - T_{\text{enda}}) \]

Which are:

- \( Q_K \) = Amount of heat delivered by convection (KJ/hour)
α = Heat transfer rate from fire to boiler wall (KJ/m²)

F = Area of heated area (m²)

T = Temperature (K)

2.4 Propagation or conduction heat transfer

Heat transfer by condensation is the transfer of heat from one part of a solid object to another part of the same solid object, or from one solid object to another solid object related to free contact to be discussed with molecules from the solid body itself. In the boiler wall, the heat will be propagated by the molecules of the outer boiler wall bordering the fire, leading to the molecules of the inner boiler wall bordering the air, good air vapor. The amount of heat that can be calculated using the following equation. (Setyandjo, 1999).

\[ Q_R = \frac{\lambda}{s} F (T_{d1} - T_{d2}) \]

Which are:

Q_R = Amount of heat propagated (KJ / m.hour. °C)

λ = Heat propagation rate inside the boiler wall (KJ/m.hour.K)

s = Wall thickness (m)

F = area of boiler wall which propagates heat (m²)

T_{d1} = Boiler wall temperature bordering fire (°C)

T_{d2} = Boiler wall temperature bordering water, steam or air (°C)

III. METHOD

In this paper, researchers apply the following methodology:
The observations made at PMKS show that steam produced after each leveling of the fuel obtained can be seen in table 2.

Table 2. Flattened Fuel Observation Results Data

| Date        | Time     | T in (°C) | T out (°C) | Gbb fiber (kg/jam) | Q (kg/hours) |
|-------------|----------|-----------|------------|--------------------|--------------|
| May 30 2017 | 11.34-11.47 | 14 | 90 | 23 0 | 6,525 | 19,014 |
|             | 11.49-12.02 | 14 | 90 | 23 0 | 6,525 | 18,628 |
|             | 12.04-12.35 | 32 | 90 | 23 0 | 6,525 | 18,387 |
|             | 12.39-12.58 | 20 | 90 | 23 0 | 6,525 | 18,625 |
|             | 13.02-13.25 | 24 | 90 | 23 0 | 6,525 | 18,633 |
|             | 13.28-13.38 | 11 | 90 | 23 0 | 6,525 | 19,036 |
|             | 13.40-13.42 | 3  | 90 | 23 0 | 6,525 | 18,800 |
|             | 13.44-14.36 | 53 | 95.9| 23 0 | 6,525 | 18,988 |
| Time Range          | Count | Fuel | Energy | Total  | Cost   |
|---------------------|-------|------|--------|--------|--------|
| 13.28-15.00         | 23    | 98   | 23     | 6,525  | 19,252 |
| 15.06               | 1     | 98   | 23     | 6,525  | 19,012 |
| 15.24-15.26         | 33    | 98   | 23     | 6,525  | 16,066 |
| 15.58-16.00         | 3     | 98.7 | 23     | 6,525  | 19,284 |
| 07.58-08.22         | 25    | 97.2 | 23     | 6,525  | 18,654 |
| 08.24-08.34         | 11    | 97   | 23     | 6,525  | 18,831 |
| 08.36-08.51         | 16    | 96.3 | 23     | 6,525  | 19,350 |
| 08.55-09.02         | 8     | 95   | 23     | 6,525  | 19,337 |
| 09.06-09.21         | 16    | 95   | 23     | 6,525  | 18,766 |
| 09.23-09.31         | 9     | 96   | 23     | 6,525  | 19,095 |
| 09.33-09.52         | 20    | 95   | 23     | 6,525  | 19,119 |
| 09.54-10.14         | 21    | 95.6 | 23     | 6,525  | 19,413 |
| 10.48-11.17         | 30    | 96   | 23     | 6,525  | 19,226 |

*The Optimization Of Capacity Boiler*
The Optimization Of Capacity Boiler ..
| Time       | Valve Open | Valves | Flow Rate | Flow Duration | Total Flow |
|------------|------------|--------|-----------|---------------|------------|
| 14.51-14.49 | 9          | 10     | 23        | 0             | 6,525      | 17,720     |
| 15.32-15.36 | 5          | 95     | 23        | 0             | 6,525      | 18,551     |
| 15.40-16.10 | 31         | 95     | 23        | 0             | 6,525      | 19,015     |

| Time       | Valve Open | Valves | Flow Rate | Flow Duration | Total Flow |
|------------|------------|--------|-----------|---------------|------------|
| June 3 2017 | 08.44-09.03 | 20    | 95        | 23            | 0          | 6,525      | 18,730     |
|            | 09.05-19.17 | 13    | 95        | 23            | 0          | 6,525      | 18,540     |
|            | 09.30-09.39 | 10    | 95        | 23            | 0          | 6,525      | 18,012     |
|            | 09.43-09.50 | 8     | 95        | 23            | 0          | 6,525      | 18,991     |
|            | 09.52-10.03 | 12    | 95        | 23            | 0          | 6,525      | 18,850     |
|            | 10.07-10.18 | 12    | 95        | 23            | 0          | 6,525      | 18,600     |
|            | 10.21-10.24 | 4     | 95        | 23            | 0          | 6,525      | 18,620     |
|            | 10.56-11.00 | 5     | 95        | 23            | 0          | 6,525      | 16,950     |
| June 5 2017 | 07.45-07.46 | 2     | 80        | 23            | 0          | 6,525      | 17,820     |
|            | 07.48-07.57 | 10    | 80        | 23            | 0          | 6,525      | 18,880     |

The Optimization Of Capacity Boiler ..
### Table: Gbb fiber (kg/jam) and Q (kg/hours)

| Date       | Time       | T in (°C) | T out (°C) | Gbb fiber (kg/jam) | Q (kg/hours) |
|------------|------------|-----------|------------|--------------------|--------------|
| May 30 2017 | 11.34-11.47 | 14        | 90         | 23                 | 6,525         | 19,014       |
|            | 11.49-12.02 | 14        | 90         | 23                 | 6,525         | 18,628       |
|            | 12.04-12.35 | 32        | 90         | 23                 | 6,525         | 18,387       |
|            | 12.39-12.58 | 20        | 90         | 23                 | 6,525         | 18,625       |
|            | 13.02-13.25 | 24        | 90         | 23                 | 6,525         | 18,633       |
|            | 13.28-13.38 | 11        | 90         | 23                 | 6,525         | 19,036       |
|            | 13.40-13.42 | 3         | 90         | 23                 | 6,525         | 18,800       |
|            | 13.44-14.36 | 53        | 95         | 23                 | 6,525         | 18,988       |

The Optimization Of Capacity Boiler
The Optimization Of Capacity Boiler ..
| Date       | Time   | Available | Power | Price  | Total   |
|------------|--------|-----------|-------|--------|---------|
| June 2 2017| 09.28-09.28 | 11    | 90     | 23 0   | 6,525   | 18,880  |
|            | 10.13-10.22 | 10    | 95     | 23 0   | 6,525   | 18,376  |
|            | 10.24-10.44 | 21    | 94 8   | 23 0   | 6,525   | 18,416  |
|            | 10.49-11.00 | 12    | 94     | 23 0   | 6,525   | 19,490  |
|            | 13.41-13.50 | 10    | 94 6   | 23 0   | 6,525   | 19,411  |
|            | 13.52-14.00 | 9     | 99     | 23 0   | 6,525   | 19,241  |
|            | 14.03-14.14 | 12    | 99     | 23 0   | 6,525   | 19,093  |
|            | 14.30-14.45 | 16    | 99     | 23 0   | 6,525   | 18,333  |
|            | 14.47-14.49 | 3     | 99     | 23 0   | 6,525   | 19,133  |

The Optimization Of Capacity Boiler ..
| Time Interval | Cycle | Efficiency | Power | Cost | Total Cost |
|--------------|-------|------------|-------|------|------------|
| 14.51-14.49  | 9     | 0.90       | 6,525 | 17,720 |
| 15.32-15.36  | 5     | 0.95       | 6,525 | 18,551 |
| 15.40-16.10  | 31    | 0.95       | 6,525 | 19,015 |
| June 3 2017  | 08.44-09.03 | 20      | 0.95 | 6,525 | 18,730 |
| 09.05-19.17  | 13    | 0.95       | 6,525 | 18,540 |
| 09.30-09.39  | 10    | 0.95       | 6,525 | 18,012 |
| 09.43-09.50  | 8     | 0.95       | 6,525 | 18,991 |
| 09.52-10.03  | 12    | 0.95       | 6,525 | 18,850 |
| 10.07-10.18  | 12    | 0.95       | 6,525 | 18,600 |
| 10.21-10.24  | 4     | 0.95       | 6,525 | 18,620 |
| 10.56-11.00  | 5     | 0.95       | 6,525 | 16,950 |
| June 5 2017  | 07.45-07.46 | 2       | 80   | 6,525 | 17,820 |
| 07.48-07.57  | 10    | 80         | 6,525 | 18,880 |

The Optimization Of Capacity Boiler ..
Data from the analysis of the percentage of oil, moisture and NOS content contained in fiber fuel can be seen in table 3.

Table 3. Laboratory Data of PT. PMKS (2017)

| Date       | Press | % Oil(Wet) | % Moisture | % NOS |
|------------|-------|------------|------------|-------|
| 05/30/2017 | 1     | 4.58       | 34.47      | 61.95 |
|            | 3     | 3.73       | 33.42      | 62.83 |
|            | 4     | 4.08       | 30.96      | 64.96 |
| **Average**|       | 4.13       | 32.95      | 63.25 |
| 05/31/2017 | 1     | 3.47       | 34.36      | 62.17 |
|            | 3     | 3.58       | 58.68      | 37.74 |
|            | 4     | 4.02       | 36.06      | 59.92 |
| **Average**|       | 3.69       | 43.03      | 53.28 |
| 05/02/2017 | 1     | 3.51       | 42.38      | 54.11 |
|            | 3     | 3.11       | 40.4       | 56.86 |
|       |  4     | 2.82  | 40.85 | 56.01 |
|-------|--------|-------|-------|-------|
| **Average** |       | 3.15  | 41.21 | 55.66 |
| **6/3/2017** | 1     | 2.74  | 32.17 | 65.09 |
|         | 3     | 2.3   | 30.94 | 66.76 |
|         | 4     | 3     | 27.81 | 69.19 |
Data from observations of PAF / FDF, SDF / SAF, IDF and combustion chamber vacuum conditions can be seen in table 4.

Table 4. PAF / FDF, SDF / SAF, IDF and Combustion Chamber Conditions

| Date   | Hour | Ampere Meter (A) | Combustion Pressure (mmag) |
|--------|------|------------------|-----------------------------|
|        |      | ID F | PAF/FDF F | SDF/SA F |                          |
| May 30, 2017 | 11   | 18   | 32   | - | -6.6 |
|         | 12   | 18   | 32   | - | -6.6 |
|         | 13   | 18   | 32   | - | -6.6 |
|         | 14   | 18   | 32   | - | -6.6 |
|         | 15   | 18   | 32   | - | -6.6 |
The Optimization Of Capacity Boiler ..

| 16 | 18 | 32 | -  | -6.6 |
|----|----|----|----|------|
|      | 31, 2017 | 7 | 18 | 0 | 32 | - | -6.6 |
|------|----------|---|----|---|----|---|------|
|      | 8        | 18| 0  | 32| -  | -6.6|
|      | 9        | 18| 0  | 32| -  | -6.6|
|      | 10       | 18| 0  | 32| -  | -6.6|
|      | 11       | 18| 0  | 32| -  | -6.6|
|      | 12       | 18| 0  | 32| -  | -6.6|
|      | June 2, 2017 | 9 | 18 | 0 | 32 | - | -6.6 |
|      | 10       | 18| 0  | 32| -  | -6.6|
|      | 11       | 18| 0  | 32| -  | -6.6|
|      | 13       | 18| 0  | 32| -  | -6.6|
|      | 14       | 18| 0  | 32| -  | -6.6|
|      | 15       | 18| 0  | 32| -  | -6.6|
|   | 16 | 18 0 | 32 | - | -6.6 |
|---|----|-----|----|---|------|

The Optimization Of Capacity Boiler ..
### 4.1 Fuel Efficiency

Based on the data above, the percentage (%) of boiler efficiency, GBB fiber, heating value, requirement of heating value to convert full steam to further heated steam and enthalpy can be calculated using the formula:

Which are:

\[
\eta = \frac{Q(\Delta \text{Enthalpy})}{Gbb \times N. O}
\]

\[
N. O = \frac{\text{(amount of NOS x N0 NOS) + (amount of Oil x N0 Oil) - (amount of water x N0 Water)}}{Gbb}
\]

- \(Gbb\) = factory capacity × material balance fiber
- \(\Delta \text{Enthalpy} = h_{uup} - h_{ctb}\)
- \(Q_u = Q \times C_p \times \Delta \text{Enthalpy}\)

\(\eta\) = Boiler efficiency (%)
\(Q\) = Boiler capacity (kg/hour)

| June 3, 2017 | 8  | 18  | 32  | -    | -6.6 |
|--------------|----|-----|-----|------|------|
|              | 9  | 18  | 32  | -    | -6.6 |
|              | 10 | 18  | 32  | -    | -6.6 |
|              | 11 | 18  | 32  | -    | -6.6 |
| June 5, 2017 | 2  | 18  | 32  | -    | -6.6 |
|              | 10 | 18  | 32  | -    | -6.6 |
|              | 15 | 18  | 32  | -    | -6.6 |
|              | 12 | 18  | 32  | -    | -6.6 |
ΔEnthalpy = Difference between steam enthalpy and water enthalpy (kcal/kg)

N.O = Heating value of fuel (kcal/kg)

Qc = The heat needed to convert full steam to further heated steam (kcal/kg)

Cp = Steam specific heat at constant pressure (kcal/kg)

4.2 Calculation of the amount of fuel

Based on the data above, the amount of fuel entering the boiler can be determined using the following equation:

\[
G_{bb} = \text{Factory capacity} \times \text{material balance factor} \\
G_{bb} = 45 \frac{\text{ton}}{\text{hour}} \times 14.5\% \\
G_{bb} = 45,000 \frac{\text{kg}}{\text{hour}} \times 0.145 \\
G_{bb} = 6,525 \frac{\text{kg}}{\text{hour}}
\]

The amount of fuel that enters the boiler is 6525 kg/hour. This value can be calculated using the above equation.

4.3 Calculation of heating value of fuel

The heating value on May 30 can be calculated as follows:

\[
N.O = \frac{(\text{amount of NOS} \times \text{NOS}) + (\text{amount of Oil} \times \text{Oil}) - (\text{amount of water} \times \text{Water})}{G_{bb}} \\
N.O = \frac{(4,110.75 \frac{\text{kg} \times \text{kcal}}{\text{kg}}) + (269.91 \frac{\text{kg} \times \text{kcal}}{\text{kg}} - 2,149.99 \frac{\text{kg} \times \text{kcal}}{\text{kg}})}{6,525 \frac{\text{kg}}{\text{hour}}} \\
N.O = \frac{15,883,353.25 \frac{\text{kcal}}{\text{kg}} + 2,375,274 \frac{\text{kcal}}{\text{kg}} - 128,999.2 \frac{\text{kcal}}{\text{kg}}}{6,525 \frac{\text{kg}}{\text{hour}}} \\
N.O = 2,601.32 \frac{\text{kcal}}{\text{kg}}
\]

By doing the calculations as above, then the heating value will be obtained on a different date.

| Date | N.O Fiber (kkal/kg) |
|------|---------------------|
|      | (kcal/kg)           |

The Optimization Of Capacity Boiler ..
The heating value produced in fiber fuel is influenced by the percentage of oil, moisture, NOS. The value on June 5, 2017 the highest percentage of heating value was 2,686.3 kcal/kg with the highest heating value of oil being 2,296,800 kcal/kg, moisture was 1,096,200 kcal/kg, and the NOS was 16,328,812.5 kcal/kg, while on May 31, 2017 lower heating value percentage was is 2,117.67 kcal/kg with the calorific value of oil is 2,118,798 kcal/kg, moisture is 1,684,755 kcal/kg, and NOS is 13,383,764.63 kcal/kg. The calculation results above show that there are differences in the amount of heat in each fiber fuel content. June 5, the heating value of oil and NOS is greater than May 31, while the heating value of moisture on May 31 is greater than June 5, causing the amount of heating value of fiber fuel on May 31 is smaller compared to other dates.

### 4.4 Enthalpy $\Delta$ Calculation

The heating value of enthalpy of water on May 30 at 11.34-11.47 $900^\circ C$ and $2300^\circ C$ steam can be seen in the steam table, for $\Delta$ enthalpy can be calculated as follows:

$$\Delta \text{Enthalpy} = h_{\text{steam}} - h_{\text{water}}$$

$$\Delta \text{Enthalpy} = \frac{683.7936 \text{ kcal}}{\text{kg}} - \frac{90.46 \text{ kcal}}{\text{kg}}$$

$$\Delta \text{Enthalpy} = 593.3136 \text{ kcal/kg}$$

The calculation results above will get results for each different date.

Table 6. Calculation Results $\Delta$ Enthalpy
| Date            | Time       | Leveling up time interval (minute) | $T_{in}$ (°C) | $T_{out}$ (°C) | Enthalpy $T_{in}$ (kcal/kg) | Enthalpy $T_{out}$ (kcal/kg) | $\Delta$ Enthalpy (kcal/kg) |
|-----------------|------------|-----------------------------------|---------------|---------------|-----------------------------|-----------------------------|-----------------------------|
| May 30, 2017    | 11.34-11.47 | 14                                | 90            | 230           | 90.48                       | 683.7936                    | 593.3136                    |
|                 | 11.49-12.02 | 14                                | 90            | 230           | 90.48                       | 683.7936                    | 593.3136                    |
|                 | 12.04-12.35 | 32                                | 90            | 230           | 90.48                       | 683.7936                    | 593.3136                    |
|                 | 12.39-12.58 | 20                                | 90            | 230           | 90.48                       | 683.7936                    | 593.3136                    |
|                 | 13.02-13.25 | 24                                | 90            | 230           | 90.48                       | 683.7936                    | 593.3136                    |
|                 | 13.28-13.38 | 11                                | 90            | 230           | 90.48                       | 683.7936                    | 593.3136                    |
|                 | 13.40-13.42 | 3                                 | 90            | 230           | 90.48                       | 683.7936                    | 593.3136                    |
|                 | 13.44-14.36 | 53                                | 95.86         | 230           | 96.34                       | 683.7936                    | 587.4587                    |
|                 | 13.28-15.00 | 23                                | 98            | 230           | 98.48                       | 683.7936                    | 585.3168                    |
|                 | 15.06       | 1                                 | 98            | 230           | 98.48                       | 683.7936                    | 585.3168                    |
|                 | 15.24-15.26 | 33                                | 98            | 230           | 98.48                       | 683.7936                    | 585.3168                    |
|                 | 15.58-16.00 | 3                                 | 98.67         | 230           | 99.15                       | 683.7936                    | 584.6469                    |
| May 31, 2017    | 07.58-08.22 | 25                                | 97.24         | 230           | 97.72                       | 683.7936                    | 586.0736                    |
|                 | 08.24-08.34 | 11                                | 97            | 230           | 97.48                       | 683.7936                    | 586.3136                    |
| Time Period           | Value 1 | Value 2 | Value 3 | Value 4 | Value 5 |
|----------------------|---------|---------|---------|---------|---------|
| 08.36-08.51          | 16      | 96.25   | 230     | 96.73   | 683.7936|
| 08.55-09.02          | 8       | 95      | 230     | 95.48   | 683.7936|
| 09.06-09.21          | 16      | 95      | 230     | 95.48   | 683.7936|
| 09.23-09.31          | 9       | 96      | 230     | 96.48   | 683.7936|
| 09.33-09.52          | 20      | 95      | 230     | 95.48   | 683.7936|
| 09.54-10.14          | 21      | 95.6    | 230     | 96.08   | 683.7936|
| 10.48-11.17          | 30      | 96      | 230     | 96.48   | 683.7936|
| 11.21-11.35          | 15      | 96      | 230     | 96.48   | 683.7936|
| 11.37-11.46          | 10      | 96      | 230     | 96.48   | 683.7936|
| 11.48-11.55          | 8       | 96      | 230     | 96.48   | 683.7936|
| 11.57-12.00          | 4       | 96.75   | 230     | 97.23   | 683.7936|
| June 2, 2017         |         |         |         |         |         |
| 09.28-09.28          | 11      | 90      | 230     | 90.48   | 683.7936|
| 10.13-10.22          | 10      | 95      | 230     | 95.48   | 683.7936|
| 10.24-10.44          | 21      | 94.75   | 230     | 95.23   | 683.7936|
| 10.49-11.00          | 12      | 94      | 230     | 94.48   | 683.7936|
| 13.41-13.50          | 10      | 94.56   | 230     | 95.04   | 683.7936|
| 13.52-14.00          | 9       | 99      | 230     | 99.48   | 683.7936|

The Optimization Of Capacity Boiler..
14.03- 14.14 & 12 & 99 & 230 & 99.48 & 683.7936 & 584.3136 \\
14.30- 14.45 & 16 & 99 & 230 & 99.48 & 683.7936 & 584.3136 \\
14.47- 14.49 & 3 & 99 & 230 & 99.48 & 683.7936 & 584.3136 \\
14.51- 14.49 & 9 & 100 & 230 & 100.48 & 683.7936 & 583.3123 \\
15.32- 15.36 & 5 & 95 & 230 & 95.48 & 683.7936 & 588.3136 \\
15.40- 16.10 & 31 & 95 & 230 & 95.48 & 683.7936 & 588.3136 \\
June 3, 2017 & 08.44- 09.03 & 20 & 95 & 230 & 95.48 & 683.7936 & 588.3136 \\
 & 09.05- 19.17 & 13 & 95 & 230 & 95.48 & 683.7936 & 588.3136 \\
 & 09.30- 09.39 & 10 & 95 & 230 & 95.48 & 683.7936 & 588.3136 \\
 & 09.43- 09.50 & 8 & 95 & 230 & 95.48 & 683.7936 & 588.3136 \\
 & 09.52- 10.03 & 12 & 95 & 230 & 95.48 & 683.7936 & 588.3136 \\
 & 10.07- 10.18 & 12 & 95 & 230 & 95.48 & 683.7936 & 588.3136 \\
 & 10.21- 10.24 & 4 & 95 & 230 & 95.48 & 683.7936 & 588.3136 \\
 & 10.56- 11.00 & 5 & 95 & 230 & 95.48 & 683.7936 & 588.3136 \\
June 5, 2017 & 07.45- 07.46 & 2 & 80 & 230 & 118.59 & 683.7936 & 565.1987 \\
 & 07.48- 07.57 & 10 & 80 & 230 & 118.59 & 683.7936 & 565.1987 \\
 & 08.32- 08.46 & 15 & 90 & 230 & 90.48 & 683.7936 & 593.3136 \\

The Optimization Of Capacity Boiler ..
Enthalpy produced boiler feed water on 3 June 2017 95°C with enthalpy 588.31 kcal/kg, while on 5 June 2017 boiler feed water 80°C with Δ enthalpy 565.19 kcal/kg. The low temperature of feed water will require a more heat value. If a low heating value is fed, it will take longer to become steam.

4.5 The Calculation of amount of heat

The heating value required by the kettle on May 30 to change 19,014 kg of full steam to the incoming air temperature of 363 K and steam that has been heated to 503 K can be calculated as follows:

\[
Q_u = Q \times C_p \times \Delta \text{ Enthalpy} \\
Q_u = 19,014 \text{ kg} \times 0.48 \frac{kcal}{kg} \times 593.31 \frac{kcal}{kg} \\
Q_u = 5.39 \times 10^5 \frac{kcal}{kg}
\]

Based on the calculation above, a heating value is needed to convert air to steam at different date and time.

Table 7. Data on Calculation Results of Need for Calorific Value

| Date       | Time     | T_{in} (K) | T_{out} (K) | Q (kg/hour) | Δ Entalpi (kcal/kg) | C_p (kcal/kg.K) | Q_u (kcal/kg.K) |
|------------|----------|------------|-------------|-------------|---------------------|-----------------|-----------------|
| May 30, 2017 | 11.34-11.47 | 363        | 503         | 19,014      | 593.31              | 0.48            | 5,396,055       |
|            | 11.49-12.02 | 363        | 503         | 18,628      | 593.31              | 0.48            | 5,286,510       |
|            | 12.04-12.35 | 363        | 503         | 18,387      | 593.31              | 0.48            | 5,218,116       |
|            | 12.39-12.58 | 363        | 503         | 18,625      | 593.31              | 0.48            | 5,285,659       |
|            | 13.02-     | 363        | 503         | 18,633      | 593.31              |                 |                 |
| Date       | Type | Value1 | Value2 | Value3 | Value4 | Value5 | Value6 |
|------------|------|--------|--------|--------|--------|--------|--------|
| 13.25      |      | 24     | 363    | 503    | 0.48   | 5,287,929 |
| 13.28-13.38| 11   | 363    | 503    | 19,036 | 593.31 | 0.48   | 5,402,298 |
| 13.40-13.42| 3    | 363    | 503    | 18,800 | 593.31 | 0.48   | 5,335,323 |
| 13.44-14.36| 53   | 368.8  | 503    | 18,988 | 587.46 | 0.48   | 5,390,166 |
| 13.28-15.00| 23   | 371    | 503    | 19,252 | 585.32 | 0.49   | 5,466,764 |
| 15.06      | 1    | 371    | 503    | 19,012 | 585.32 | 0.49   | 5,398,614 |
| 15.24-15.26| 33   | 371    | 503    | 16,066 | 585.32 | 0.49   | 4,562,073 |
| 15.58-16.00| 3    | 371.6  | 503    | 19,284 | 585.32 | 0.49   | 5,483,057 |
| May 31, 2017| 07.58-08.22| 25 | 370.2 | 503 | 18,654 | 585.32 | 0.48 | 5,289,389 |
| 08.24-08.34| 11   | 370    | 503    | 18,831 | 586.31 | 0.48   | 5,346,255 |
| 08.36-08.51| 16   | 369.2  | 503    | 19,350 | 587.06 | 0.48   | 5,492,860 |
| 08.55-09.02| 8    | 368    | 503    | 19,337 | 588.31 | 0.48   | 5,487,889 |
| 09.06-09.21| 16   | 368    | 503    | 18,766 | 588.31 | 0.48   | 5,325,837 |
| 09.23-      |      | 19,095 | 587.31 |        |        |        |        |
|   |   |   |   |   |   |
|---|---|---|---|---|---|
|   |   |   |   |   |   |
| 09.31 | 9 | 369 | 503 |  0.48 | 5,420,225 |
|   |   |   |   |   |   |
| 09.33-09.52 | 20 | 368 | 503 | 19,119 | 588.31 | 0.48 | 5,426,020 |
|   |   |   |   |   |   |
| 09.54-10.14 | 21 | 368.6 | 503 | 19,413 | 587.71 | 0.48 | 5,510,082 |
|   |   |   |   |   |   |
| 10.48-11.17 | 30 | 369 | 503 | 19,226 | 587.31 | 0.48 | 5,457,410 |
|   |   |   |   |   |   |
| 11.21-11.35 | 15 | 369 | 503 | 19,380 | 587.31 | 0.48 | 5,501,124 |
|   |   |   |   |   |   |
| 11.37-11.46 | 10 | 369 | 503 | 19,287 | 587.31 | 0.48 | 5,474,725 |
|   |   |   |   |   |   |
| 11.48-11.55 | 8 | 369 | 503 | 19,750 | 587.31 | 0.48 | 5,606,150 |
|   |   |   |   |   |   |
| 11.57-12.00 | 4 | 369.7 | 5 | 503 | 18,872 | 586.56 | 0.48 | 5,357,656 |
|   |   |   |   |   |   |
| June 2, 2017 | 09.28-09.28 | 11 | 363 | 503 | 18,880 | 593.31 | 0.48 | 5,358,026 |
|   |   |   |   |   |   |
| 10.13-10.22 | 10 | 368 | 503 | 18,376 | 588.31 | 0.48 | 5,215,154 |
|   |   |   |   |   |   |
| 10.24-10.44 | 21 | 367.7 | 5 | 503 | 18,416 | 588.56 | 0.48 | 5,226,516 |
|   |   |   |   |   |   |
| 10.49-11.00 | 12 | 367 | 503 | 19,490 | 589.31 | 0.48 | 5,531,340 |
|   |   |   |   |   |   |
| 13.41-13.50 | 10 | 367.5 | 6 | 503 | 19,411 | 588.76 | 0.48 | 5,509,321 |

*The Optimization Of Capacity Boiler*
| Time                  | Start | End | Temperature | Capacity | Efficiency | Load  |
|-----------------------|-------|-----|-------------|----------|------------|-------|
| 13.52-14.00           | 9     | 72  | 503         | 19,241   | 584.31     | 0.49  |
| 14.03-14.14           | 12    | 72  | 503         | 19,093   | 584.31     | 0.49  |
| 14.30-14.45           | 16    | 72  | 503         | 18,333   | 584.31     | 0.49  |
| 14.47-14.49           | 3     | 72  | 503         | 19,133   | 584.31     | 0.49  |
| 14.51-14.49           | 9     | 73  | 503         | 17,720   | 583.31     | 0.49  |
| 15.32-15.36           | 5     | 72  | 503         | 18,551   | 588.31     | 0.48  |
| 15.40-16.10           | 31    | 72  | 503         | 19,015   | 588.31     | 0.48  |
| June 3, 2017          | 08.44 | 09.03| 72          | 18,730   | 588.31     | 0.48  |
| 09.05-19.17           | 13    | 72  | 503         | 18,540   | 588.31     | 0.48  |
| 09.30-09.39           | 10    | 72  | 503         | 18,012   | 588.31     | 0.48  |
| 09.43-09.50           | 8     | 72  | 503         | 18,991   | 588.31     | 0.48  |
| 09.52-10.03           | 12    | 72  | 503         | 18,850   | 588.31     | 0.48  |
| 10.07-10.18           | 12    | 72  | 503         | 18,600   | 588.31     | 0.48  |

*The Optimization Of Capacity Boiler*..
The heating value needed by the boiler to convert 19,014 kg of temperature water 303 K into a temperature of 363 K is:

$$Q_u = 19,014 \text{ kg} \times 1 \frac{\text{kcal}}{\text{kg}} \times 60.24 \frac{\text{kcal}}{\text{kg}}$$

$$Q_u = 1.14 \times 10^8 \frac{\text{kcal}}{\text{kg}}$$

Based on the above calculation results, the heating value needs to increase the temperature of the water at different dates and times.

Table 8. Data for the calculation of the need for heat value

| Date         | Time   | in (minute) | T<sub>in</sub> (K) | T<sub>out</sub> (K) | nthalpy (cal/kg) | C<sub>p</sub> (cal/kg·K) | Q<sub>g</sub> (g/hour) | Q<sub>u</sub> (cal/kg·K) |
|--------------|--------|-------------|---------------------|---------------------|-------------------|-----------------------|------------------------|------------------------|
| June 5, 2017 | 07.45-07.46 | 2           | 353                 | 503                 | 17,820            | 565.20                | 0.47                   | 4,742,628              |
|              | 07.48-07.57 | 10          | 353                 | 503                 | 18,880            | 565.20                | 0.47                   | 5,024,738              |
|              | 08.32-08.46 | 15          | 363                 | 503                 | 19,050            | 593.31                | 0.48                   | 5,406,271              |
|              | 08.48-08.59 | 12          | 363                 | 503                 | 19,220            | 593.31                | 0.48                   | 5,454,516              |
The Optimization Of Capacity Boiler

| Day | Hour | Value | Formula | Sum | Unit |
|-----|------|-------|---------|-----|------|
| 08/31/2017 | 08:22 | 70.24 | 67.48 | 1.00 | 18,654,261,289 |
| 04/08/2017 | 08:34 | 370 | 67.24 | 1.00 | 18,831,268,729 |
| 06/08/2017 | 08:51 | 69.25 | 66.49 | 1.00 | 19,350,289,155 |
| 05/09/2017 | 09:02 | 368 | 65.24 | 1.00 | 19,337,264,069 |
| 06/09/2017 | 09:21 | 368 | 65.24 | 1.00 | 18,766,226,742 |
| 03/09/2017 | 09:31 | 369 | 66.24 | 1.00 | 19,095,267,383 |
|    |    |    |    |    |    |    |    |    |    |
|----|----|----|----|----|----|----|----|----|----|
| 3- | 09.52 | 20 | 368 | 65.24 | 1.00 | 19,119 | 249,818 |
| 4- | 10.14 | 21 | 68.6 | 65.84 | 1.00 | 19,413 | 280,708 |
| 8- | 11.17 | 30 | 369 | 66.24 | 1.00 | 19,226 | 276,077 |
| 1- | 11.35 | 15 | 369 | 66.24 | 1.00 | 19,380 | 286,299 |
| 7- | 11.46 | 10 | 369 | 66.24 | 1.00 | 19,287 | 280,126 |
| 8- | 11.55 | 8  | 369 | 66.24 | 1.00 | 19,750 | 310,856 |
| 7- | 12.00 | 4  | 69.75| 66.99 | 1.00 | 18,872 | 266,764 |
| 2, 2017 | 8- | 09.28 | 11 | 363 | 60.24 | 1.00 | 18,880 | 139,606 |
| 3- | 10.22 | 10 | 368 | 65.24 | 1.00 | 18,376 | 201,248 |
| 4- | 10.44 | 21 | 67.75| 64.99 | 1.00 | 18,416 | 199,250 |
| 9- | 11.00 | 12 | 367 | 64.24 | 1.00 | 19,490 | 254,542 |
| 1- | 13.50 | 10 | 67.56| 64.78 | 1.00 | 19,411 | 260,262 |
| 2- | 14.00 | 9  | 372 | 69.24 | 1.00 | 19,241 | 334,911 |
| 3- | 14.14 | 12 | 372 | 69.24 | 1.00 | 19,093 | 324,643 |
| 0- | 14.45 | 16 | 372 | 69.24 | 1.00 | 18,333 | 271,916 |
| 7- | 14.49 | 3  | 372 | 69.24 | 1.00 | 19,133 | 327,418 |
| 1- | 14.49 | 9  | 373 | 70.24 | 1.00 | 17,720 | 247,165 |

The Optimization Of Capacity Boiler ..
The Optimization Of Capacity Boiler ..

| Date   | Time | Value | Type | Unit | Value | Unit   |
|--------|------|-------|------|------|-------|--------|
| 2- 15.36 | 5 | 368 | 65.24 | 1.00 | 18,551 | .212,688 |
| 0- 16.10 | 31 | 368 | 65.24 | 1.00 | 19,015 | .243,020 |
| 3, 2017 | 4- 09.03 | 20 | 368 | 65.24 | 1.00 | 18,730 | .224,389 |
| 5- 19.17 | 13 | 368 | 65.24 | 1.00 | 18,540 | .211,969 |
| 0- 09.39 | 10 | 368 | 65.24 | 1.00 | 18,012 | .177,453 |
| 3- 09.50 | 8 | 368 | 65.24 | 1.00 | 18,991 | .241,451 |
| 2- 10.03 | 12 | 368 | 65.24 | 1.00 | 18,850 | .232,234 |
| 7- 10.18 | 12 | 368 | 65.24 | 1.00 | 18,600 | .215,891 |
| 1- 10.24 | 4 | 368 | 65.24 | 1.00 | 18,620 | .217,198 |
| 6- 11.00 | 5 | 368 | 65.24 | 1.00 | 16,950 | .108,030 |
| 5, 2017 | 5- 07.46 | 2 | 353 | 88.35 | 1.00 | 17,820 | .577,633 |
| 8- 07.57 | 10 | 353 | 88.35 | 1.00 | 18,880 | .671,477 |
| 2- 08.46 | 15 | 363 | 60.24 | 1.00 | 19,050 | .149,867 |
| 8- 08.59 | 12 | 363 | 60.24 | 1.00 | 19,220 | .160,128 |
May 30, 2017 the required heating value of 303 K temperature to be heated to 363 K requires a heating value of $1.14 \times 10^6$ kcal / kg.K, whereas on May 30 2017 to heat the 303 K temperature to 369.25 K requires the heating value of $1.29 \times 10^6$ kcal/kg.K. The low temperature of feed water will require a more heat value. If a low heating value is fed, it will take longer to become steam. The data above shows the lower the temperature of the feed entering the feed water tank, the higher the heating value needed to raise the water temperature. This affects when the water enters the upper drum and will be converted into steam, so more heat is needed.

### 4.6 Amount of Burning Air

If the composition of the fuel is known, then the amount of fuel needed for complete combustion can be calculated.

#### Table 9. Fuel Composition

| No. | Name   | Percentage |
|-----|--------|------------|
| 1   | Carbon | 49%        |
| 2   | Hydrogen | 6%        |
| 3   | Oxygen | 44%        |
| 4   | Nitrogen | -        |
| 5   | Ash    | 0.1%       |
| 6   | Sulfur | 0.1%       |
Per 6,525 kg of fiber fuel contains 3,179.25 kg C, 391.5 kg H, 6,525 kg S so the amount of oxygen needed:

\[ O_2 = (3,179.25 \times 2.67 \text{ kg } O_2) + (391.5 \times 8 \text{ kg } O) + (6,525 \times 1 \text{ kg } O_2) \]

\[ O_2 = 11,675.2 \text{ kg } O_2 \]

The oxygen content in the fuel is 44% so that in 6,526 kg of fuel there are 2.871 kg O\(_2\). Thus oxygen is needed only:

\[ 11,675 - 2,871 = 8,804.2 \]

1 kg of air contains 21% oxygen (0.21 kg O\(_2\)), so the theoretical air needed is:

\[ U_o = 8,804.2 / 0.21 \text{ kg } O_2 \]

\[ U_o = 41,924 \text{ kg } O_2 \]

So 6,525 kg of fiber requires 41,924 kg of O\(_2\).

4.7 Heat Transfer in Boiler Combustion Chambers

The heat generated by burning fuel, which is in the form of fire.

1. Radiant heat transfer

Radiation heat transfer can be calculated by doing the following equation:

\[ Q_p = C_2 \cdot F \cdot \left[ (T_{\text{fire}}/100)^4 - (T_{\text{object}}/100)^4 \right] \]

1 kg of air contains 21% oxygen (0.21 kg O\(_2\)), so the theoretical air needed is:

\[ U_o = 8,804.2 / 0.21 \text{ kg } O_2 \]

\[ U_o = 41,924 \text{ kg } O_2 \]

So 6,525 kg of fiber requires 41,924 kg of O\(_2\).

Table 10. Radiation Displacement

| Date       | Time     | CZ (KJ/m\(^2\). hour. K\(^4\)) | F (m\(^2\)) | T\(_{\text{api}}\) (K) | T\(_{\text{fire}}\) (K) | T\(_{\text{benda}}\) (K) | Q\(_p\) (KJ/m\(^2\). hour. K\(^4\)) |
|------------|----------|---------------------------------|-------------|-------------------------|-------------------------|-------------------------|----------------------------------|
| May 30, 2017 | 11.34- 11.47 | 14                              | 5,569       | 18                      | 503                     | 363                      | 46,763,379                      |
| Time Frame     | Value1 | Value2 | Value3 | Value4 | Value5 | Value6 |
|---------------|--------|--------|--------|--------|--------|--------|
| 11.49-12.02   | 14     | 5,569  | 18     | 503    | 363    | 46,763,379 |
| 12.04-12.35   | 32     | 5,569  | 18     | 503    | 363    | 46,763,379 |
| 12.39-12.58   | 20     | 5,569  | 18     | 503    | 363    | 46,763,379 |
| 13.02-13.25   | 24     | 5,569  | 18     | 503    | 363    | 46,763,379 |
| 13.28-13.38   | 11     | 5,569  | 18     | 503    | 363    | 46,763,379 |
| 13.40-13.42   | 3      | 5,569  | 18     | 503    | 363    | 46,763,379 |
| 13.44-14.36   | 53     | 5,569  | 18     | 503    | 368.85 | 45,612,996 |
| 13.28-15.00   | 23     | 5,569  | 18     | 503    | 371    | 45,177,575 |
| 15.06         | 1      | 5,569  | 18     | 503    | 371    | 45,177,575 |
| 15.24-15.26   | 33     | 5,569  | 18     | 503    | 371    | 45,177,575 |
| 15.58-16.00   | 3      | 5,569  | 18     | 503    | 371.67 | 45,040,704 |
| May 31, 2017  |        |        |        |        |        |        |
| 07.58-08.22   | 25     | 5,569  | 18     | 503    | 370.24 | 45,332,710 |
| 08.24-08.34   | 11     | 5,569  | 18     | 503    | 370    | 45,381,502 |
| 08.36-08.51   | 16     | 5,569  | 18     | 503    | 369.25 | 45,533,366 |
| 08.55-09.02   | 8      | 5,569  | 18     | 503    | 368    | 45,784,425 |
| 09.06-09.21   | 16     | 5,569  | 18     | 503    | 368    | 45,784,425 |
| 09.23-09.31   | 9      | 5,569  | 18     | 503    | 369    | 45,583,783 |

_The Optimization Of Capacity Boiler_ ..
| Time          | Price | Type | Volume | Depth | Capacity |
|--------------|-------|------|--------|-------|----------|
| 09.33-09.52  | 20    | 5,569| 18     | 503   | 368      | 45,784,425 |
| 09.54-10.14  | 21    | 5,569| 18     | 503   | 368.6    | 45,664,236  |
| 10.48-11.17  | 30    | 5,569| 18     | 503   | 369      | 45,583,783  |
| 11.21-11.35  | 15    | 5,569| 18     | 503   | 369      | 45,583,783  |
| 11.37-11.46  | 10    | 5,569| 18     | 503   | 369      | 45,583,783  |
| 11.48-11.55  | 8     | 5,569| 18     | 503   | 369      | 45,583,783  |
| 11.57-12.00  | 4     | 5,569| 18     | 503   | 369.75   | 45,432,226  |
| June 2, 2017 |       |      |        |       |          |             |
| 09.28-09.28  | 11    | 5,569| 18     | 503   | 363      | 46,763,379  |
| 10.13-10.22  | 10    | 5,569| 18     | 503   | 368      | 45,784,425  |
| 10.24-10.44  | 21    | 5,569| 18     | 503   | 367.75   | 45,834,331  |
| 10.49-11.00  | 12    | 5,569| 18     | 503   | 367      | 45,983,439  |
| 13.41-13.50  | 10    | 5,569| 18     | 503   | 367.56   | 45,873,076  |
| 13.52-14.00  | 9     | 5,569| 18     | 503   | 372      | 44,971,992  |
| 14.03-14.14  | 12    | 5,569| 18     | 503   | 372      | 44,971,992  |
| 14.30-14.45  | 16    | 5,569| 18     | 503   | 372      | 44,971,992  |
| 14.47-14.49  | 3     | 5,569| 18     | 503   | 372      | 44,971,992  |
| 14.51-14.49  | 9     | 5,569| 18     | 503   | 373      | 44,764,745  |

The Optimization Of Capacity Boiler..
An object temperature of 363 K and a fire temperature of 503 K produce a radiant heat transfer value of $46.76 \times 10^6$ if an object temperature of 368 K and a fire temperature of 503 K produce a radiant heat transfer value of $45.78 \times 10^6$.

1. Conduction heat transfer

Conduction heat transfer can be calculated by doing the following equation:

$$Q_K = \frac{\lambda}{\delta} \cdot F \cdot (T_{a1} - T_{a2})$$

$$Q_K = 2.58 \cdot 0.003 \cdot 18 \cdot (230 - 90)$$

$$Q_K = 2.16 \times 10^8 \frac{KJ}{m} \cdot J \cdot ^oC$$
| Date          | Time       | Leveling up interval (minute) | Λ (KJ/m.hour.°C) | S (m) | F (m²) | T d1 (°C) | T d2 (°C) | Qr (KJ/m².hour.°C) |
|--------------|------------|-------------------------------|------------------|-------|--------|----------|----------|-----------------|
| May 30, 2017 | 11.34-11.47| 14                            | 2.58             | 0.003 | 18     | 230      | 90       | 2,167,200       |
|              | 11.49-12.02| 14                            | 2.58             | 0.003 | 18     | 230      | 90       | 2,167,200       |
|              | 12.04-12.35| 32                            | 2.58             | 0.003 | 18     | 230      | 90       | 2,167,200       |
|              | 12.39-12.58| 20                            | 2.58             | 0.003 | 18     | 230      | 90       | 2,167,200       |
|              | 13.02-13.25| 24                            | 2.58             | 0.003 | 18     | 230      | 90       | 2,167,200       |
|              | 13.28-13.38| 11                            | 2.58             | 0.003 | 18     | 230      | 90       | 2,167,200       |
|              | 13.40-13.42| 3                             | 2.58             | 0.003 | 18     | 230      | 90       | 2,167,200       |
|              | 13.44-14.36| 53                            | 2.58             | 0.003 | 18     | 230      | 95.85    | 2,076,566       |
|              | 13.28-15.00| 23                            | 2.58             | 0.003 | 18     | 230      | 98       | 2,043,360       |
| Date       | No. | 2.58 | 0.003 | 18  | 230 | 98  | 2,043,360 |
|------------|-----|------|-------|-----|-----|-----|-----------|
| May 07.58- | 16  | 2.58 | 0.003 | 18  | 230 | 96.25 | 2,070,450 |
| 08.34      |     |      |       |     |     |      |           |
| May 08.24- | 11  | 2.58 | 0.003 | 18  | 230 | 97   | 2,058,840 |
| 08.34      |     |      |       |     |     |      |           |
| May 08.55- | 23  | 2.58 | 0.003 | 18  | 230 | 95   | 2,089,800 |
| 09.31      |     |      |       |     |     |      |           |
| May 09.06- | 16  | 2.58 | 0.003 | 18  | 230 | 95   | 2,089,800 |
| 09.31      |     |      |       |     |     |      |           |
| May 09.23- | 9   | 2.58 | 0.003 | 18  | 230 | 96   | 2,074,320 |
| 09.52      |     |      |       |     |     |      |           |
| May 09.33- | 20  | 2.58 | 0.003 | 18  | 230 | 95   | 2,089,800 |
| 09.52      |     |      |       |     |     |      |           |
| May 09.54- | 21  | 2.58 | 0.003 | 18  | 230 | 95.6 | 2,080,512 |
| 10.14      |     |      |       |     |     |      |           |
| May 10.48- | 30  | 2.58 | 0.003 | 18  | 230 | 96   | 2,074,320 |
| 11.17      |     |      |       |     |     |      |           |
| May 11.21- | 15  | 2.58 | 0.003 | 18  | 230 | 96   | 2,074,320 |
| 11.35      |     |      |       |     |     |      |           |
| Time           | Value | Slope | Intercept | Temperature | Energy (kWh) |
|---------------|-------|-------|-----------|-------------|--------------|
| 11.37-11.46   | 10    | 2.58  | 0.003     | 18          | 230, 96      | 2,074,320    |
| 11.48-11.55   | 8     | 2.58  | 0.003     | 18          | 230, 96      | 2,074,320    |
| 11.57-12.00   | 4     | 2.58  | 0.003     | 18          | 230, 96.75   | 2,062,710    |
| **June 2, 2017** |      |       |           |             |              |              |
| 09.28-09.28   | 11    | 2.58  | 0.003     | 18          | 230, 90      | 2,167,200    |
| 10.13-10.22   | 10    | 2.58  | 0.003     | 18          | 230, 95      | 2,089,800    |
| 10.24-10.44   | 21    | 2.58  | 0.003     | 18          | 230, 94.75   | 2,093,670    |
| 10.49-11.00   | 12    | 2.58  | 0.003     | 18          | 230, 94      | 2,105,280    |
| 13.41-13.50   | 10    | 2.58  | 0.003     | 18          | 230, 94.56   | 2,096,680    |
| 13.52-14.00   | 9     | 2.58  | 0.003     | 18          | 230, 99      | 2,027,880    |
| 14.03-14.14   | 12    | 2.58  | 0.003     | 18          | 230, 99      | 2,027,880    |
| 14.30-14.45   | 16    | 2.58  | 0.003     | 18          | 230, 99      | 2,027,880    |
| 14.47-14.49   | 3     | 2.58  | 0.003     | 18          | 230, 99      | 2,027,880    |
| 14.51-14.49   | 9     | 2.58  | 0.003     | 18          | 230, 99      | 2,012,400    |
| Time       | Value | 2.58 | 0.003 | 18 | 230 | 95 | 2,089,800 |
|------------|-------|------|-------|----|-----|----|-----------|
| 15.32-15.36| 5     |      |       | 18 | 230 | 95 | 2,089,800 |
| 15.40-16.10| 31    | 2.58 | 0.003 | 18 | 230 | 95 | 2,089,800 |
| June 3, 2017| 08.44-09.03 | 20 | 2.58 | 0.003 | 18 | 230 | 95 | 2,089,800 |
| 09.05-19.17 | 13    | 2.58 | 0.003 | 18 | 230 | 95 | 2,089,800 |
| 09.30-09.39 | 10    | 2.58 | 0.003 | 18 | 230 | 95 | 2,089,800 |
| Date          | Time     | Leveling up time interval (minute) | A (KJ/m.hour.°C) | S (m) | F (m²) | T<sub>d1</sub> (°C) | T<sub>d2</sub> (°C) | Q<sub>r</sub> (KJ/m².hour.°C) |
|--------------|----------|----------------------------------|------------------|-------|--------|----------------|----------------|-------------------|
| June 5, 2017 | 07.45-07.46 | 2                                | 2.58             | 0.003 | 18     | 230            | 80             | 2,322,000         |
|              | 07.48-07.57 | 10                               | 2.58             | 0.003 | 18     | 230            | 80             | 2,322,000         |
|              | 08.32-08.46 | 15                               | 2.58             | 0.003 | 18     | 230            | 90             | 2,167,200         |
|              | 08.48-08.59 | 12                               | 2.58             | 0.003 | 18     | 230            | 90             | 2,167,200         |

The Optimization Of Capacity Boiler ..
| Date                        | A1   | A2   | A3   | A4   | A5   | A6   |
|-----------------------------|------|------|------|------|------|------|
| **May 30, 2017**            |      |      |      |      |      |      |
| 11.34-11.47                 | 14   | 2.58 | 0.003| 18   | 230  | 90   |
| 11.49-12.02                 | 14   | 2.58 | 0.003| 18   | 230  | 90   |
| 12.04-12.35                 | 32   | 2.58 | 0.003| 18   | 230  | 90   |
| 12.39-12.58                 | 20   | 2.58 | 0.003| 18   | 230  | 90   |
| 13.02-13.25                 | 24   | 2.58 | 0.003| 18   | 230  | 90   |
| 13.28-13.38                 | 11   | 2.58 | 0.003| 18   | 230  | 90   |
| 13.40-13.42                 | 3    | 2.58 | 0.003| 18   | 230  | 90   |
| 13.44-14.36                 | 53   | 2.58 | 0.003| 18   | 230  | 95.85|
| 13.28-15.00                 | 23   | 2.58 | 0.003| 18   | 230  | 98   |
| 15.06                       | 1    | 2.58 | 0.003| 18   | 230  | 98   |
| 15.24-15.26                 | 33   | 2.58 | 0.003| 18   | 230  | 98   |
| 15.58-16.00                 | 3    | 2.58 | 0.003| 18   | 230  | 98.67|
| **May 31, 2017**            |      |      |      |      |      |      |
| 07.58-08.22                 | 25   | 2.58 | 0.003| 18   | 230  | 97.24|
|                             |      |      |      |      |      |      |

The Optimization Of Capacity Boiler..

156
The Optimization Of Capacity Boiler..
| Period     | Value | 2.58 | 0.003 | 18 | 230 | 97  | 2,058,840 |
|------------|-------|------|-------|----|-----|-----|-----------|
| 08.24-08.34 | 11    | 2.58 | 0.003 | 18 | 230 | 97  | 2,058,840 |
| 08.36-08.51 | 16    | 2.58 | 0.003 | 18 | 230 | 96.25 | 2,070,450 |
| 08.55-09.02 | 8     | 2.58 | 0.003 | 18 | 230 | 95  | 2,089,800 |
| 09.06-09.21 | 16    | 2.58 | 0.003 | 18 | 230 | 95  | 2,089,800 |
| 09.23-09.31 | 9     | 2.58 | 0.003 | 18 | 230 | 96  | 2,074,320 |
| 09.33-09.52 | 20    | 2.58 | 0.003 | 18 | 230 | 95  | 2,089,800 |
| 09.54-10.14 | 21    | 2.58 | 0.003 | 18 | 230 | 95.6 | 2,080,512 |
| 10.48-11.17 | 30    | 2.58 | 0.003 | 18 | 230 | 96  | 2,074,320 |
| 11.21-11.35 | 15    | 2.58 | 0.003 | 18 | 230 | 96  | 2,074,320 |
| 11.37-11.46 | 10    | 2.58 | 0.003 | 18 | 230 | 96  | 2,074,320 |
| 11.48-11.55 | 8     | 2.58 | 0.003 | 18 | 230 | 96  | 2,074,320 |
| 11.57-12.00 | 4     | 2.58 | 0.003 | 18 | 230 | 96.75 | 2,062,710 |
| June 2, 2017 | 09.28-09.28 | 11 | 2.58 | 0.003 | 18 | 230 | 90 | 2,167,200 |

The Optimization Of Capacity Boiler ..
| Time   | Value | Error | Duration | Temperature | Capacity |
|--------|-------|-------|----------|-------------|----------|
| 10.13-10.22 | 10 | 2.58 | 0.003 | 18 | 230 | 95 | 2,089,800 |
| 10.24-10.44 | 21 | 2.58 | 0.003 | 18 | 230 | 94.75 | 2,093,670 |
| 10.49-11.00 | 12 | 2.58 | 0.003 | 18 | 230 | 94 | 2,105,280 |
| 13.41-13.50 | 10 | 2.58 | 0.003 | 18 | 230 | 94.56 | 2,096,680 |
| 13.52-14.00 | 9 | 2.58 | 0.003 | 18 | 230 | 99 | 2,027,880 |
| 14.03-14.14 | 12 | 2.58 | 0.003 | 18 | 230 | 99 | 2,027,880 |
| 14.30-14.45 | 16 | 2.58 | 0.003 | 18 | 230 | 99 | 2,027,880 |
| 14.47-14.49 | 3 | 2.58 | 0.003 | 18 | 230 | 99 | 2,027,880 |
| 14.51-14.49 | 9 | 2.58 | 0.003 | 18 | 230 | 100 | 2,012,400 |
| 15.32-15.36 | 5 | 2.58 | 0.003 | 18 | 230 | 95 | 2,089,800 |
| 15.40-16.10 | 31 | 2.58 | 0.003 | 18 | 230 | 95 | 2,089,800 |
| June 3, 2017 | 08.44-09.03 | 20 | 2.58 | 0.003 | 18 | 230 | 95 | 2,089,800 |
The Optimization Of Capacity Boiler ..
The pipe temperature is 90 °C and the fire temperature is 230 °C resulting in a radiation heat transfer value of $2.16 \times 10^6$ if the pipe temperature is 80 °C and the fire temperature is 203 °C produces a conduction heat transfer value of $2.32 \times 10^6$.

### 4.7 Calculation of boiler efficiency

The boiler efficiency on May 30 can be calculated as follows:
From the calculation results above, we will get results for each different date and time.

Table 12. Boiler Efficiency

\[ \eta = \frac{Q(\Delta \text{Enthalpy})}{G_{bb} \times N, O} \]
\[ \eta = \frac{19,014 \, \frac{kg}{\text{hour}} \times 593.3136 \, \frac{kcal}{kg}}{6,525 \, \frac{kg}{\text{hour}} \times 2,601.32 \, \frac{kcal}{kg}} \]
\[ \eta = 66.46\% \]
| Date       | Time  | T<sub>in</sub> | T<sub>out</sub> | \(\text{bb fiber}\) | N.O | Q  | Entalpi | H  |
|-----------|-------|----------------|----------------|----------------------|-----|----|---------|----|
| 4-11.47   | ay 30, 2017 | 14 | 90 | 30 | 6,525 | 601.32 | 19,014 | 93.31 | 6.46 |
| 9-12.02   | 14 | 90 | 30 | 6,525 | 601.32 | 18,628 | 93.31 | 5.11 |
| 4-12.35   | 32 | 90 | 30 | 6,525 | 601.32 | 18,387 | 93.31 | 4.27 |
| 9-12.58   | 20 | 90 | 30 | 6,525 | 601.32 | 18,625 | 93.31 | 5.10 |
| 2-13.25   | 24 | 90 | 30 | 6,525 | 601.32 | 18,633 | 93.31 | 5.13 |
| 8-13.38   | 11 | 90 | 30 | 6,525 | 601.32 | 19,036 | 93.31 | 6.54 |
| 0-13.42   | 3  | 90 | 30 | 6,525 | 601.32 | 18,800 | 93.31 | 5.72 |
| 4-14.36   | 53 | .85 | 30 | 6,525 | 601.32 | 18,988 | 87.46 | 5.72 |
| 8-15.00   | 23 | 98 | 30 | 6,525 | 601.32 | 19,252 | 85.32 | 6.39 |
| 15.06     | 1  | 98 | 30 | 6,525 | 601.32 | 19,012 | 85.32 | 5.56 |

The Optimization Of Capacity Boiler..
The Optimization Of Capacity Boiler..
| Time   | Hour | Minute | Power | Energy | Temperature | Efficiency | Pressure |
|--------|------|--------|-------|--------|-------------|------------|----------|
| 9-11.00 | 12   | 94     | 30    | 6,525  | 143.81      | 19,490     | 89.31    |
| 1-13.50 | 10   | .56    | 30    | 6,525  | 143.81      | 19,411     | 88.76    |
| 2-14.00 | 9    | 99     | 30    | 6,525  | 143.81      | 19,241     | 84.31    |
| 3-14.14 | 12   | 99     | 30    | 6,525  | 143.81      | 19,093     | 84.31    |
| 0-14.45 | 16   | 99     | 30    | 6,525  | 143.81      | 18,333     | 84.31    |
| 7-14.49 | 3    | 99     | 30    | 6,525  | 143.81      | 19,133     | 84.31    |
| 1-14.49 | 9    | 00     | 30    | 6,525  | 143.81      | 17,720     | 83.31    |
| 2-15.36 | 5    | 95     | 30    | 6,525  | 143.81      | 18,551     | 88.31    |
| 0-16.10 | 31   | 95     | 30    | 6,525  | 143.81      | 19,015     | 88.31    |

3, 2017

| Time   | Hour | Minute | Power | Energy | Temperature | Efficiency | Pressure |
|--------|------|--------|-------|--------|-------------|------------|----------|
| 4-09.03 | 20   | 95     | 30    | 6,525  | 663.50      | 18,730     | 88.31    |
| 5-19.17 | 13   | 95     | 30    | 6,525  | 663.50      | 18,540     | 88.31    |
| 0-09.39 | 10   | 95     | 30    | 6,525  | 663.50      | 18,012     | 88.31    |
| 3-09.50 | 8    | 95     | 30    | 6,525  | 663.50      | 18,991     | 88.31    |
| 2-10.03 | 12   | 95     | 30    | 6,525  | 663.50      | 18,850     | 88.31    |
| 7-10.18 | 12   | 95     | 30    | 6,525  | 663.50      | 18,600     | 88.31    |
| 1-10.24 | 4    | 95     | 30    | 6,525  | 663.50      | 18,620     | 88.31    |
| 6-11.00 | 5    | 95     | 30    | 6,525  | 663.50      | 16,950     | 88.31    |
|   |   |   |   |   |
|---|---|---|---|---|
| 8- 07.57 | 10 | 80 | 30 | 6,525 | 686.50 | 18,880 | 65.20 | 0.87 |
| 2- 08.46 | 15 | 90 | 30 | 6,525 | 686.50 | 19,050 | 93.31 | 4.48 |
| 8- 08.59 | 12 | 90 | 30 | 6,525 | 686.50 | 19,220 | 93.31 | 5.05 |

The Optimization Of Capacity Boiler.
| Date       | Time | T<sub>in</sub> | T<sub>out</sub> | b<sub>fiber</sub> | N.O | Q | Entalpi | H (%) |
|------------|------|----------------|----------------|------------------|-----|---|---------|-------|
| Day 30, 2017 | 4- 11.47 | 14 | 90 | 30 | 6,525 | 601.32 | 19,014 | 93.31 | 6.46 |
|            | 9- 12.02 | 14 | 90 | 30 | 6,525 | 601.32 | 18,628 | 93.31 | 5.11 |
|            | 4- 12.35 | 32 | 90 | 30 | 6,525 | 601.32 | 18,387 | 93.31 | 4.27 |
|            | 9- 12.58 | 20 | 90 | 30 | 6,525 | 601.32 | 18,625 | 93.31 | 5.10 |
|            | 2- 13.25 | 24 | 90 | 30 | 6,525 | 601.32 | 18,633 | 93.31 | 5.13 |
|            | 8- 13.38 | 11 | 90 | 30 | 6,525 | 601.32 | 19,036 | 93.31 | 6.54 |
|            | 0- 13.42 | 3  | 90 | 30 | 6,525 | 601.32 | 18,800 | 93.31 | 5.72 |
|            | 4- 14.36 | 53 | .85 | 30 | 6,525 | 601.32 | 18,988 | 87.46 | 5.72 |
|            | 8- 15.00 | 23 | 98 | 30 | 6,525 | 601.32 | 19,252 | 85.32 | 6.39 |
|            | 15.06 | 1  | 98 | 30 | 6,525 | 601.32 | 19,012 | 85.32 | 5.56 |
|            | 4- 15.26 | 33 | 98 | 30 | 6,525 | 601.32 | 16,066 | 85.32 | 5.40 |
The Optimization Of Capacity Boiler.
| Period | Time | Temperature | Pressure | Power | Efficiency | Cost 1 | Cost 2 | Cost 3 | Cost 4 | Cost 5 | Cost 6 |
|--------|------|-------------|----------|-------|------------|--------|--------|--------|--------|--------|--------|
| 3, 2017 | 4- 09.03 | 20 | 95 | 30 | 6,525 | 663.50 | 18,730 | 88.31 | 3.40 |
| 5- 19.17 | 13 | 95 | 30 | 6,525 | 663.50 | 18,540 | 88.31 | 2.76 |
| 0- 09.39 | 10 | 95 | 30 | 6,525 | 663.50 | 18,012 | 88.31 | 0.97 |
| 3- 09.50 | 8 | 95 | 30 | 6,525 | 663.50 | 18,991 | 88.31 | 4.29 |
| 2- 10.03 | 12 | 95 | 30 | 6,525 | 663.50 | 18,850 | 88.31 | 3.81 |
| 7- 10.18 | 12 | 95 | 30 | 6,525 | 663.50 | 18,600 | 88.31 | 2.96 |
| 1- 10.24 | 4 | 95 | 30 | 6,525 | 663.50 | 18,620 | 88.31 | 3.03 |
| 6- 11.00 | 5 | 95 | 30 | 6,525 | 663.50 | 16,950 | 88.31 | 7.38 |
| 5, 2017 | 5- 07.46 | 2 | 80 | 30 | 6,525 | 686.50 | 17,820 | 65.20 | 7.46 |

*The Optimization Of Capacity Boiler.*
| 8- 07:57 | 10 | 80 | 30 | 6,525 | 686.50 | 18,880 | 65.20 | 0.87 |
|----------|----|----|----|-------|--------|--------|-------|-----|

The Optimization Of Capacity Boiler ..
The data above shows the differences in boiler efficiency due to different heating and enthalpy values. May 31 has an average efficiency of 81% with a heating value of 2,117.7 kcal/kg and an average feed water temperature of 95°C. On May 30, the average efficiency was 64.83% with a heating value of 2,601.3 kcal/kg and the average feed water was 93.21°C. On June 2, the average efficiency was 78.9% with a heating value of 2,143.8 kcal/kg and the average feed water was 96.2°C. On June 3, the average efficiency was 61.9% with a heating value of 2,663.5 kcal/kg and average feed water with a temperature of 96°C.

On 5 June the average efficiency was 61.9% with a heating value of 2,686.5 kcal/kg and the average feed water with a temperature of 85°C. The efficiency of the boiler is affected by the temperature of the feed water, the heating value of the fuel and the amount of fuel entering the material. The heating value on May 31 is lower than the heating value on other dates and the feedwater temperature is lower than June 2 and June 3 but the steam produced on June 3 is greater. The amount of fuel smoothing done will increase efficiency so that the high heating value of the fuel does not guarantee high efficiency in the boiler.

From table 6 regarding the conditions of PAF, SDF, IDF, and combustion chamber vacuum show that there is no significant effect of oxygen availability on the combustion process due to combustion in the combustion chamber (fire grate) on different dates given the same treatment (oxygen availability).

4.8 Calculation of Opportunities for Flattening

The probability of occurrence of can be calculated with the following equation:

\[
\% \text{ Opportunities for leveling up} = \frac{A \text{ lot of leveling}}{\text{Boiling operational hours}} \times 100
\]

\[
\% \text{ Opportunities for leveling up} = \frac{12}{390 \text{ minute}} \times 100 = 3.1\%
\]

| Date | Hours | Leveling | Efficiency | Heating Value | Feed Water Temperature | Efficiency | Heating Value | Feed Water Temperature |
|------|-------|----------|------------|---------------|------------------------|------------|---------------|------------------------|
| 2-08.46 | 15 | 90 | 30 | 6,525 | 686.50 | 19,050 | 93.31 | 4.48 |
| 8-08.59 | 12 | 90 | 30 | 6,525 | 686.50 | 19,220 | 93.31 | 5.05 |
| 4-08.34 | 11 | 97 | 30 | 6,525 | 117.67 | 18,654 | 85.32 | 9.02 |
| 6-08.51 | 16 | .25 | 30 | 6,525 | 117.67 | 19,350 | 87.06 | 2.21 |
| 5-09.02 | 8 | 95 | 30 | 6,525 | 117.67 | 19,337 | 88.31 | 2.33 |

*The Optimization Of Capacity Boiler..*
| Date   | Time | Room | Temperature | Humidity | Current DC | Voltage DC | Efficiency |
|--------|------|------|-------------|----------|------------|------------|------------|
| 6- 09.21 | 16 95 | 30 | 6,525 | 117.67 | 18,766 | 88.31 | 9.90 |
| 3- 09.31 | 9 96 | 30 | 6,525 | 117.67 | 19,095 | 87.31 | 1.16 |
| 3- 09.52 | 20 95 | 30 | 6,525 | 117.67 | 19,119 | 88.31 | 1.40 |
| 4- 10.14 | 21 5.6 | 30 | 6,525 | 117.67 | 19,413 | 87.71 | 2.57 |
| 8- 11.17 | 30 96 | 30 | 6,525 | 117.67 | 19,226 | 87.31 | 1.72 |
| 1- 11.35 | 15 96 | 30 | 6,525 | 117.67 | 19,380 | 87.31 | 2.37 |
| 7- 11.46 | 10 96 | 30 | 6,525 | 117.67 | 19,287 | 87.31 | 1.98 |
| 8- 11.55 | 8 96 | 30 | 6,525 | 117.67 | 19,750 | 87.31 | 3.95 |
| 7- 12.00 | 4 .75 | 30 | 6,525 | 117.67 | 18,872 | 86.56 | 0.11 |
| 8- 09.28 | 11 90 | 30 | 6,525 | 143.81 | 18,880 | 93.31 | 0.08 |
| 3- 10.22 | 10 95 | 30 | 6,525 | 143.81 | 18,376 | 88.31 | 7.28 |
| 4- 10.44 | 21 .75 | 30 | 6,525 | 143.81 | 18,416 | 88.56 | 7.49 |
| 8- 08.22 | 25 .24 | 30 | 6,525 | 117.67 | 18,654 | 85.32 | 9.02 |
| 4- 08.34 | 11 97 | 30 | 6,525 | 117.67 | 18,831 | 86.31 | 9.90 |
| 6- 08.51 | 16 .25 | 30 | 6,525 | 117.67 | 19,350 | 87.06 | 2.21 |
| 5- 09.02 | 8 95 | 30 | 6,525 | 117.67 | 19,337 | 88.31 | 2.33 |
| 6- 09.21 | 16 95 | 30 | 6,525 | 117.67 | 18,766 | 88.31 | 9.90 |
| 3- 09.31 | 9 96 | 30 | 6,525 | 117.67 | 19,095 | 87.31 | 1.16 |

*The Optimization Of Capacity Boiler ..*
From the above calculation, the percentage of the amount of leveling can be seen in table 13.

Table 13. Opportunities for Flattening

| Date          | Boiler Operating Hours (Hours) | Boiler Operating Hours (Minutes) | Lots of Leveling | Chance for Flattening (%) |
|---------------|--------------------------------|---------------------------------|------------------|---------------------------|
| May 30, 2017  | 6.30                           | 390                             | 12               | 3.1                       |

The Optimization Of Capacity Boiler ..
The data above shows that there are differences in the percentage of opportunities for leveling. On May 30, there is a chance of a 3.1% leveling with an average efficiency value of 64.83%. On May 31, there is a chance of a 3.8% leveling with an average efficiency value of 81.43%. On June 2 there is a chance of a leveling of 2.4% with an average efficiency value of 78.93%. On June 3 the chance for a leveling is 3.6% with an average efficiency value of 63.22%. On June 5 the chance of leveling is 1.8% with an average efficiency value of 61.97%.

4.9 Analysis on Statistical Product And Service Solutions (SPSS)

Statistical Product and Service Solution (SPSS) analysis is a logarithmic system used to determine the effect of values with system validation. In carrying out the SPSS system, researchers conducted the value of the boiler passivity and the enthalpy value. The SPSS process is as follows:

DESCRIPTIVES VARIABLES

/STATISTICS=MEAN SUM STDDEV VARIANCE RANGE MIN MAX SEMEAN.
Based on the SPSS data output as many as 49 observations we can know that for Boiler Capacity the range is 3,684, the lowest Boiler Capacity is 16,066 and the highest is 19,750. In addition, the total boiler capacity of 49 observations is 920,727, the average is 18,790.35 and the standard deviation is 0.640488. Whereas for the enthalpy change of 49 observations the range is 28,1149, the lowest enthalpy change is 565.1987 the highest is 593.3136 and the number of enthalpy changes from 49 observations is 28785.4777 and the average is 587.458729 the standard deviation is 5.4642423.

EXAMINE VARIABLES

/ PLOT BOXPLOT STEMLEAF HISTOGRAM NPLOT

/COMPARE GROUPS

/STATISTICS DESCRIPTIVES

/CINTERVAL 95

/MISSING LISTWISE

/NOTOTAL.
### Explore

#### Statistic

| Boiler Capacity | Mean       | Std. Error |
|-----------------|------------|------------|
|                 | 18.79035   | .091498    |

| Boiler Capacity | 95% Confidence Interval for Mean |
|-----------------|---------------------------------|
|                 | Lower Bound                      |
|                 | 18.60638                         |
|                 | Upper Bound                       |
|                 | 18.97432                         |

| Boiler Capacity | 5% Trimmed Mean |
|-----------------|-----------------|
|                 | 18.86080        |

| Boiler Capacity | Median          |
|-----------------|-----------------|
|                 | 18.88000        |

| Boiler Capacity | Variance        |
|-----------------|-----------------|
|                 | .410            |

| Boiler Capacity | Std. Deviation  |
|-----------------|-----------------|
|                 | .640488         |

---

### Case Processing Summary

| Case            | Valid | Missing | Total |
|-----------------|-------|---------|-------|
| Boiler Capacity | 49    | 0       | 49    |

---

### Notes

- **Boiler Capacity**
- **Mean**
  - 18.79035
  - Std. Error: .091498
- **95% Confidence Interval for Mean**
  - Lower Bound: 18.60638
  - Upper Bound: 18.97432
- **5% Trimmed Mean**: 18.86080
- **Median**: 18.88000
- **Variance**: .410
- **Std. Deviation**: .640488

---

*The Optimization Of Capacity Boiler*
| Statistic           | Lower Bound | Upper Bound |
|--------------------|-------------|-------------|
| Minimum Enthalpy Change | 565.1987    | 593.3136    |
| Maximum Enthalpy Change | 585.889215  | 589.028242  |
| Mean Enthalpy Change | 587.458729  | 588.185294  |
| 95% Confidence Interval for Mean | 585.889215  | 589.028242  |
| Median Enthalpy Change | 588.313600  | 588.313600  |
| Variance Enthalpy Change | 29.858      | 29.858      |
| Std. Deviation Enthalpy Change | 5.4642423   | 5.4642423   |
| Minimum Enthalpy Change | 16.066      | 16.066      |
| Maximum Enthalpy Change | 19.750      | 19.750      |
| Range Enthalpy Change | 3.684       | 3.684       |
| Interquartile Range Enthalpy Change | 0.613       | 0.613       |
| Skewness Enthalpy Change | -2.178      | -2.178      |
| Kurtosis Enthalpy Change | 6.804       | 6.804       |

The Optimization Of Capacity Boiler ..
Tests of Normality

| Statistic | df | Sig. |
|-----------|----|------|
| .164      | 49 | .002 |
| .221      | 49 | .000 |

By looking at the Tests Normality table, it is obtained that the boiler capacity with a static number is 164 and the enthalpy change is 221 (Kolmogorov-Smirnov). Whereas at Shapiro-Wilk, the static value becomes 818 for boiler capacity and enthalpy change of 676. (there is a signal of 002 in boiler capacity).

a. Lilliefors Significance Correction

**Boiler Capacity**

Kapasitas Boiler Stem-and-Leaf Plot

| Frequency | Stem & Leaf |
|-----------|-------------|
| 3.00 Extremes | (=<17.7) |
| 1.00       | 17 . 8     |
| 5.00       | 18 . 03334 |

*The Optimization Of Capacity Boiler*
The boiler capacity shown in the Histogram graphic image shows some of the greatest frequency parameters being at the boiler capacity of 19,000. But in the beginning it only shows 16,000 and the last one is 20,000 (frequency 1).

In the normal graph, the boiler capacity that occurs is in the normal area of the normal observation value, then the value is considered still valid.

In the detrended normal graph, the boiler capacity occurs a value very far from the observation value. Then detrended from the boiler capacity that occurs is invalid.
Enthalpy Change

Perubahan grafik histogram menjadi sangat tinggi pada entalpi bernilai 590.000, namun pada nilai 595.00, 585.000 dan 565.000 menjadi lebih rendah.

Changes to the histogram graph are very high at 590,000 enthalpies, but at 595.00, 585,000 and 565,000 are lower.

Stem-and-Leaf Plot

Stem-and-Leaf Plot Enthalpy

| Change Frequency | Stem & Leaf |
|------------------|-------------|
| 2.00 Extremes    | (=<565.2)   |
|                  | 1.00  583 . 3 |
|                  | .00  583 .   |
|                  | 4.00  584 . 3333 |
|                  | 1.00  584 . 6 |
|                  | 3.00  585 . 333 |
|                  | .00  585 .   |
|                  | 2.00  586 . 03 |
|                  | 1.00  586 . 5 |
The enthalpy change on the normal graph changes enthalpy, almost close to the normal line. This means the enthalpy changes that occur towards the valid value.

On the detrended graph, the change in enthalpy of boiler capacity has a value far from observations made by SPSS. This value has no validation.
By looking at the value of the boiler capacity and the enthalpy value in the boiler combustion, the normal value that occurs is closer to the normal value of SPSS validation. However, when the graph detrended between the boiler capacity and the enthalpy value is further from the normal SPSS validation value.

V. CONCLUSION

The results of the study "Efforts to Increase Boiler Efficiency by 26 Tons / Hour by Performing Fuel Leveling" can be concluded that:

• Fuel leveling 13 times with boiler operating hours based on the entry of fiber fuel, which is 5.58 hours to produce steam an average of 19,160 kg/hour. Fuel leveling 12 times with boiler operating hours based on the entry of fiber fuel that is for 5.34 hours produces steam an average of 18,346.75 kg/hour. The average boiler efficiency is 81% with a heating value of 2,117.67 kcal/kg compared to others that have a higher heating value but efficiency is below 80%. This shows the success of the performance of the boiler is not only determined by the value contained in the fuel but also determined by the temperature of the feedwater entering the boiler, the amount of fuel in the boiler, the condition of the fuel in the boiler combustion chamber.

• By looking at the value of the boiler capacity and the enthalpy value inside the boiler combustion, the normal value that occurs is closer to the normal value of SPSS validation. However, when the graph detrended between the boiler capacity and the enthalpy value is further from the normal SPSS validation value.

REFERENCES

[1]. Canada, scott, dkk. 2004. Parabolic Trough Organic Rankine Cycle Solar Power Plant. DOE Solar Energy Technologies Denver, Colorado: US Department of Energy NREL.
[2]. Kristono, Stevanus Nugroho. 2016. Sistem Pembangkit Energi Uap. Politeknik Citra Widya Edukasi. Bekasi.
[3]. Mahfud, Ahmad. 2010. Modul Teknik Pengolahan I dan II. Politeknik Citra Widya Edukasi. Bekasi.
[4]. Naibaho, P. M. 1998. Teknologi Pengolahan Kelapa Sawit. Pusat Penelitian Kelapa Sawit. Medan.
[5]. Pardamean, M. 2011. Sukses Membuka Kebun Dan Pabrik Kelapa Sawit. Penebar Swadaya. Bogor.
[6]. Setiyani, Wardah Agus. 2015. Laporan Tugas Akhir : Pengaruh Kandungan Minyak Dan Moisture Pada Fiber & Shell Terhadap Pemakaian Bahan Bakar Boiler di PT Sabut

The Optimization Of Capacity Boiler ..

184
Mas Abadi, Medco Agro Group, Kalimantan Tengah. Politeknik Citra Widya Edukasi. Bekasi.

[7]. Zulfikar, Dafi dan Broto Wisnu. 2016. “Optimalisasi Pemanfaatan Energi Listrik Tenaga Surya Skala Rumah Tangga”. Jurnal. Prosiding Seminar Nasional Fisika (E-Journal) SNF2016. Vol. V, Oktober 2016. P-ISSN: 2339-0654

[8]. Syafriuddin. 2012. Perbandingan Penggunaan Energi Alternatif Bahan Bakar Serabut (Fiber) dan Cangkang Kelapa Sawit Terhadap Bahan Bakar Batubara Dan Solar Pada Pembangkit Listrik. Teknologi AKPRIND. Yogyakarta.

[9]. Statistical Product And Service Solution (SPSS), 2020, https://www.ibm.com/analytics/spss-statistics-software