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The Optimization Of Capacity Boiler Efficiency 26 Tons/Hours With Fuel Alumination And Statistical Product And Service Solutions (Spss) Analysis

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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 is 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:

$$N.O = \frac{(jumlh\ NOS\ x\ N.O\ NOS) + (jmlh.\ Oil\ x\ N.O\ Oil) - (jmlh Water\ x\ N.O\ Water)}{Gbb}$$

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:

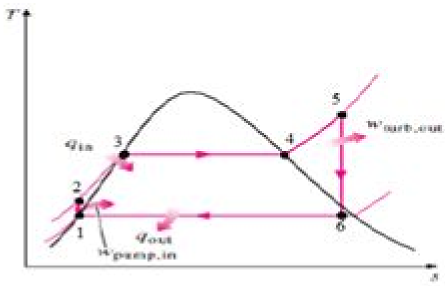

Figure 1. Rankine Cycle
1- 2: Pumping water from the tower tank to the feed water tank
2- 3: Heating water in the steam pipes
3- 4: Process water to steam inside the boiler
4- 5: Advanced heating process
5- 6: Steam enters the turbine
6- 1: Condensation process

The efficiency of the boiler can be known by the following formula (Kristono,2016):

$$\eta = \frac{Q(\Delta\ Entalpi)}{Gbb \times N.O}$$

Which are

η = Boiler efficiency (%)

GB = Weight of fuel produced (kg/hour)

Δ 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_P is based on the formula of Stephan-Boltzmann. (Setyardjo, 1999).

$$Q_P = C_Z.F.[(T_{api}/100)^4 - (T_{benda}/100)^4]$$

Which are:

Q_P = Amount of heat received by transmission (KJ / m2.hour.K2)

C_Z = 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).

Which are: $Q_K = \alpha . F(T_{api} - T_{benda})$

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. (Setyardjo, 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 (m^2)

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

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

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III. METHOD

In this paper, researchers apply the following methodology:

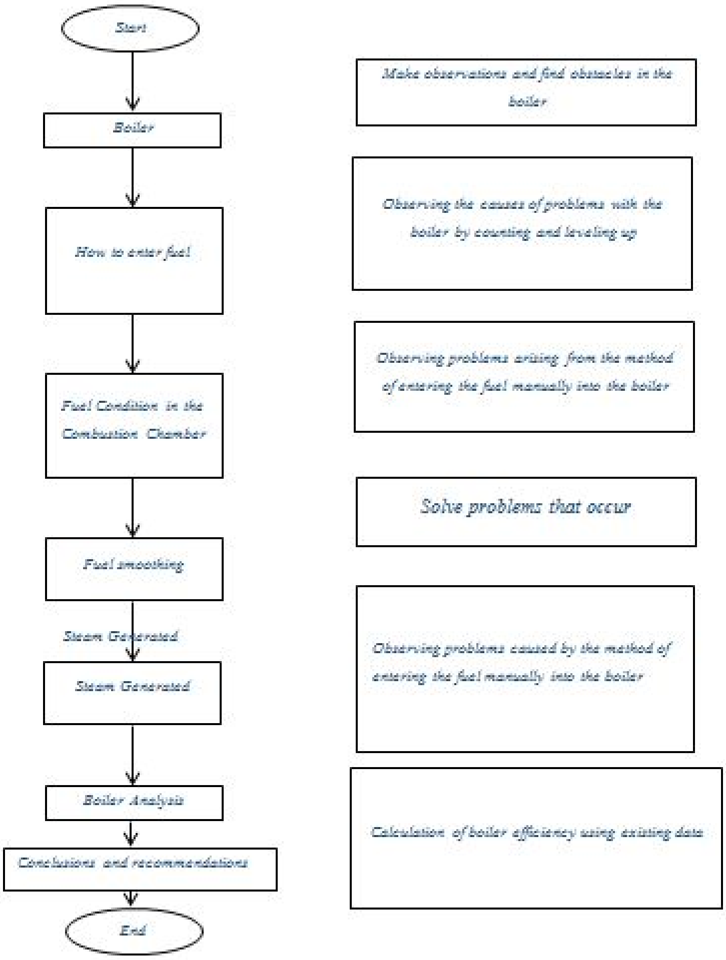

Figure 2. Research Methodology

IV. RESULT AND DISCUSSION

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***	*The interval of leveling out (minute)*	**T in (º C)**	**T ou t (º C)**	**Gbb fiber (kg/jam) (kg / hour)**	**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
	13.28- 15.00	23	98	23 0	6,525	19,252
	15.06	1	98	23 0	6,525	19,012
	15.24- 15.26	33	98	23 0	6,525	16,066

	15.58- 16.00	3	98. 7	23 0	6,525	19,284
May 31 2017	07.58- 08.22	25	97. 2	23 0	6,525	18,654
	08.24- 08.34	11	97	23 0	6,525	18,831
	08.36- 08.51	16	96. 3	23 0	6,525	19,350
	08.55- 09.02	8	95	23 0	6,525	19,337
	09.06- 09.21	16	95	23 0	6,525	18,766
	09.23- 09.31	9	96	23 0	6,525	19,095
	09.33- 09.52	20	95	23 0	6,525	19,119
	09.54- 10.14	21	95. 6	23 0	6,525	19,413
	10.48- 11.17	30	96	23 0	6,525	19,226
	11.21- 11.35	15	96	23 0	6,525	19,380
	11.37- 11.46	10	96	23 0	6,525	19,287
	11.48- 11.55	8	96	23 0	6,525	19,750

	11.57- 12.00	4	96.8	230	6,525	18,872
June 2 2017	09.28- 09.28	11	90	230	6,525	18,880
	10.13- 10.22	10	95	230	6,525	18,376
	10.24- 10.44	21	94.8	230	6,525	18,416
	10.49- 11.00	12	94	230	6,525	19,490
	13.41- 13.50	10	94.6	230	6,525	19,411
	13.52- 14.00	9	99	230	6,525	19,241
	14.03- 14.14	12	99	230	6,525	19,093
	14.30- 14.45	16	99	230	6,525	18,333
	14.47- 14.49	3	99	230	6,525	19,133
	14.51- 14.49	9	100	230	6,525	17,720
	15.32- 15.36	5	95	230	6,525	18,551
	15.40- 16.10	31	95	230	6,525	19,015

June 3 2017	08.44- 09.03	20	95	230	6,525	18,730
	09.05- 19.17	13	95	230	6,525	18,540
	09.30- 09.39	10	95	230	6,525	18,012
	09.43- 09.50	8	95	230	6,525	18,991
	09.52- 10.03	12	95	230	6,525	18,850
	10.07- 10.18	12	95	230	6,525	18,600
	10.21- 10.24	4	95	230	6,525	18,620
	10.56- 11.00	5	95	230	6,525	16,950
June 5 2017	07.45- 07.46	2	80	230	6,525	17,820
	07.48- 07.57	10	80	230	6,525	18,880
	08.32- 08.46	15	90	230	6,525	19,050
	08.48- 08.59	12	90	230	6,525	19,220

Date	***Time***		**T in**	**T out**	**Gbb fiber (kg/jam)**	**Q**

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		The interval of leveling out (minute)	(º C)	(º C)	(kg / hour)	*(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
	13.28- 15.00	23	98	23 0	6,525	19,252
	15.06	1	98	23 0	6,525	19,012
	15.24- 15.26	33	98	23 0	6,525	16,066
	15.58- 16.00	3	98. 7	23 0	6,525	19,284

May 31 2017	07.58- 08.22	25	97.2	230	6,525	18,654
	08.24- 08.34	11	97	230	6,525	18,831
	08.36- 08.51	16	96.3	230	6,525	19,350
	08.55- 09.02	8	95	230	6,525	19,337
	09.06- 09.21	16	95	230	6,525	18,766
	09.23- 09.31	9	96	230	6,525	19,095
	09.33- 09.52	20	95	230	6,525	19,119
	09.54- 10.14	21	95.6	230	6,525	19,413
	10.48- 11.17	30	96	230	6,525	19,226
	11.21- 11.35	15	96	230	6,525	19,380
	11.37- 11.46	10	96	230	6,525	19,287
	11.48- 11.55	8	96	230	6,525	19,750
	11.57- 12.00	4	96.8	230	6,525	18,872

June 2 2017	09.28- 09.28	11	90	230	6,525	18,880
	10.13- 10.22	10	95	230	6,525	18,376
	10.24- 10.44	21	94.8	230	6,525	18,416
	10.49- 11.00	12	94	230	6,525	19,490
	13.41- 13.50	10	94.6	230	6,525	19,411
	13.52- 14.00	9	99	230	6,525	19,241
	14.03- 14.14	12	99	230	6,525	19,093
	14.30- 14.45	16	99	230	6,525	18,333
	14.47- 14.49	3	99	230	6,525	19,133
	14.51- 14.49	9	100	230	6,525	17,720
	15.32- 15.36	5	95	230	6,525	18,551
	15.40- 16.10	31	95	230	6,525	19,015
June 3 2017	08.44- 09.03	20	95	230	6,525	18,730

	09.05- 19.17	13	95	230	6,525	18,540
	09.30- 09.39	10	95	230	6,525	18,012
	09.43- 09.50	8	95	230	6,525	18,991
	09.52- 10.03	12	95	230	6,525	18,850
	10.07- 10.18	12	95	230	6,525	18,600
	10.21- 10.24	4	95	230	6,525	18,620
	10.56- 11.00	5	95	230	6,525	16,950
June 5 2017	07.45- 07.46	2	80	230	6,525	17,820
	07.48- 07.57	10	80	230	6,525	18,880
	08.32- 08.46	15	90	230	6,525	19,050
	08.48- 08.59	12	90	230	6,525	19,220

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)

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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

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Average		2.68	30.31	67.01
6/5/2017	1	4.39	24.3	63.31
	3	2.31	28.56	67.11
	4	4.31	32.23	63.46
Average		3.67	28.36	64.63

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 (mmaq)*
		IDF	PAF/FDF	SDF/SAF	
May 30, 2017	11	180	32	-	-6.6
	12	180	32	-	-6.6
	13	180	32	-	-6.6
	14	180	32	-	-6.6
	15	180	32	-	-6.6
	16	180	32	-	-6.6

May 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

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June 3, 2017	8	18 0	32	-	-6.6
	9	18 0	32	-	-6.6
	10	18 0	32	-	-6.6
	11	18 0	32	-	-6.6
June 5, 2017	2	18 0	32	-	-6.6
	10	18 0	32	-	-6.6
	15	18 0	32	-	-6.6
	12	18 0	32	-	-6.6

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:

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

$$N.O = \frac{(amount\ of\ NOS\ x\ NO\ NOS) + (amount\ of\ Oil\ x\ NO\ Oil) - (amount\ of\ water\ x\ NO\ Water)}{Gbb}$$

$$Gbb = factory\ capacity \times material\ balance\ fiber$$

$$\Delta\ Enthalpy = h_{uap} - h_{air}$$

$$Q_u = Q \times C_p \times \Delta\ Enthalpy$$

η = Boiler efficiency (%)

Q = Boiler capacity (kg/hour)

ΔEnthalpy = Difference between steam enthalpy and water enthalpy (kcal/kg)

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

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

C_p = 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:

$$\text{Gbb} = Factory\ capacity \times material\ balance\ fiber$$
$$Gbb = 45\frac{ton}{hour} \times 14.5\%$$
$$Gbb = 45{,}000\frac{kg}{hour} \times 0.145$$
$$Gbb = 6{,}525\frac{kg}{hour}$$

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:

$$N.O = \frac{(amount\ of\ NOS\ x\ NO\ NOS) + (amount\ of\ Oil\ x\ NO\ Oil) - (amount\ of\ water\ x\ NO\ Water)}{Gbb}$$
$$N.O = \frac{\left(4{,}110.75\ kgx3{,}840\frac{kcal}{kg}\right) + \left(269.91\ kg\ x\ 8{,}800\frac{kcal}{kg}\right) - \left(2{,}149.99\ kgx600\frac{kcal}{kg}\right)}{6{,}525\frac{kg}{hour}}$$
$$N.O = \frac{15{,}888{,}353.25\frac{kcal}{kg} + 2{,}375{,}274\frac{kcal}{kg} - 128{,}999.2\frac{kcal}{kg}}{6{,}525\frac{kg}{hour}}$$
$$N.O = 2{,}601.32\frac{kcal}{kg}$$

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

.Table 5. Heating Value

Date	N.O Fiber (kkal/kg) *(kcal/kg)*
May 30, 2017	2,601.32
May 31, 2017	2,117.67
June 2, 2017	2,143.81
June 3, 2017	2,663.5
June 5, 2017	2,686.5

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 Δ Calculation

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

$$\Delta\, Enthalpy = h_{steam} - h_{water}$$
$$\Delta\, Enthalpy = 683.7936\,\frac{kcal}{kg} - 90.48\,\frac{kcal}{kg}$$
$$\Delta\, Enthalpy = 593.3136\,\frac{kcal}{kg}$$

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

Table 6. Calculation Results Δ Enthalpy

Date	***Time***	***Leveling up time interval (minute)***	T_{in} (ºC)	T_{out} (ºC)	*Enthalpy* T_{in} ***(kcal/kg)***	*Enthalpy* T_{out} ***(kcal/kg)***	**Δ** *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
	08.36- 08.51	16	96.25	230	96.73	683.7936	587.0636

	08.55- 09.02	8	95	230	95.48	683.7936	588.3136
	09.06- 09.21	16	95	230	95.48	683.7936	588.3136
	09.23- 09.31	9	96	230	96.48	683.7936	587.3136
	09.33- 09.52	20	95	230	95.48	683.7936	588.3136
	09.54- 10.14	21	95.6	230	96.08	683.7936	587.7136
	10.48- 11.17	30	96	230	96.48	683.7936	587.3136
	11.21- 11.35	15	96	230	96.48	683.7936	587.3136
	11.37- 11.46	10	96	230	96.48	683.7936	587.3136
	11.48- 11.55	8	96	230	96.48	683.7936	587.3136
	11.57- 12.00	4	96.75	230	97.23	683.7936	586.5636
June 2, 2017	09.28- 09.28	11	90	230	90.48	683.7936	593.3136
	10.13- 10.22	10	95	230	95.48	683.7936	588.3136
	10.24- 10.44	21	94.75	230	95.23	683.7936	588.5636
	10.49- 11.00	12	94	230	94.48	683.7936	589.3136
	13.41- 13.50	10	94.56	230	95.04	683.7936	588.758
	13.52- 14.00	9	99	230	99.48	683.7936	584.3136
	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
	08.48- 08.59	12	90	230	90.48	683.7936	593.3136

Enthalpy produced boiler feed water on 3 June 2017 95oC with enthalpy 588.31 kcal/kg, while on 5 June 2017 boiler feed water 80oC 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:

$$Q_u = Q \times C_p \times \Delta\ Enthalpy$$
$$Q_u = 19{,}014\ kg \times 0.48 \frac{kcal}{kg} \times 593.31 \frac{kcal}{kg}$$
$$Q_u = 5.39 \times 10^6\ \frac{kcal}{kg}$$

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*	*Leveling up time interval (minute)*	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	14	363	503	19,014	593.31	0.48	5,396,055
	11.49-12.02	14	363	503	18,628	593.31	0.48	5,286,510
	12.04-12.35	32	363	503	18,387	593.31	0.48	5,218,116
	12.39-12.58	20	363	503	18,625	593.31	0.48	5,285,659
	13.02-13.25	24	363	503	18,633	593.31	0.48	5,287,929

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	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	368.85	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	371.67	503	19,284	585.32	0.49	5,483,057
May 31, 2017	07.58-08.22	25	370.24	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	369.25	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
	09.23-09.31	9	369	503	19,095	587.31	0.48	5,420,225

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	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	369.75	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	367.75	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	367.56	503	19,411	588.76	0.48	5,509,321
	13.52-14.00	9	372	503	19,241	584.31	0.49	5,464,530

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	14.03-14.14	12	372	503	19,093	584.31	0.49	5,422,497
	14.30-14.45	16	372	503	18,333	584.31	0.49	5,206,654
	14.47-14.49	3	372	503	19,133	584.31	0.49	5,433,857
	14.51-14.49	9	373	503	17,720	583.31	0.49	5,033,362
	15.32-15.36	5	368	503	18,551	588.31	0.48	5,264,820
	15.40-16.10	31	368	503	19,015	588.31	0.48	5,396,504
June 3, 2017	08.44-09.03	20	368	503	18,730	588.31	0.48	5,315,620
	09.05-19.17	13	368	503	18,540	588.31	0.48	5,261,698
	09.30-09.39	10	368	503	18,012	588.31	0.48	5,111,850
	09.43-09.50	8	368	503	18,991	588.31	0.48	5,389,693
	09.52-10.03	12	368	503	18,850	588.31	0.48	5,349,677
	10.07-10.18	12	368	503	18,600	588.31	0.48	5,278,726
	10.21-10.24	4	368	503	18,620	588.31	0.48	5,284,402

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	10.56-11.00	5	368	503	16,950	588.31	0.48	4,810,452
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 heating value needed by the boiler to convert 19,014 kg of temperature water 303 K into a temperature of 363 K is:

$$Q_u = 19{,}014\ kg \times 1\,\frac{\text{kcal}}{\text{kg}} \times 60.24\,\frac{\text{kcal}}{\text{kg}}$$
$$Q_u = 1.14 \times 10^6\,\frac{\text{kcal}}{\text{kg}}$$

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***	***ing up time nterval minute)***	**$_{in}$ K)**	**T_{out} (K)**	***nthalpy cal/kg)***	**C_p T_{in} *cal/kg.K)***	**Q *g/hour)***	**Q_u *cal/kg.K)***
ay 30, 2017	4- 11.47	14	03	363	60.24	1.00	19,014	,147,694
	9- 12.02	14		363	60.24	1.00	18,628	,124,395
	4- 12.35	32		363	60.24	1.00	18,387	,109,848

	9- 12.58	20		363	60.24	1.00	18,625	,124,214
	2- 13.25	24		363	60.24	1.00	18,633	,124,697
	8- 13.38	11		363	60.24	1.00	19,036	,149,022
	0- 13.42	3		363	60.24	1.00	18,800	,134,777
	4- 14.36	53		68.85	66.09	1.00	18,988	,257,520
	8- 15.00	23		371	68.23	1.00	19,252	,316,322
	15.06	1		371	68.23	1.00	19,012	,299,913
	4- 15.26	33		371	68.23	1.00	16,066	,098,485
	8- 16.00	3		71.67	68.9	1.00	19,284	,331,454
ay 31 2017	8- 08.22	25		70.24	67.48	1.00	18,654	,261,289
	4- 08.34	11		370	67.24	1.00	18,831	,268,729
	6- 08.51	16		69.25	66.49	1.00	19,350	,289,155
	5- 09.02	8		368	65.24	1.00	19,337	,264,069
	6- 09.21	16		368	65.24	1.00	18,766	,226,742
	3- 09.31	9		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

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	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
	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

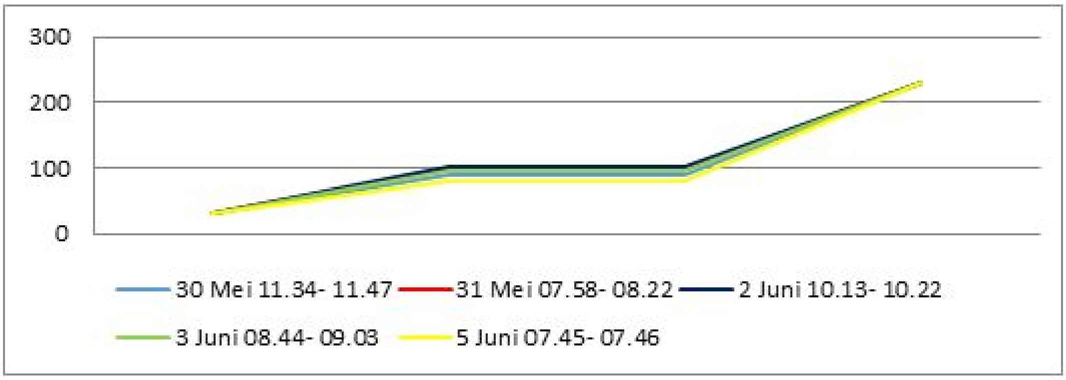

Figure 3. Graph of Temperature difference

May 30, 2017 the required heating value of 303 K temperature to be heated to 363 K requires a heating value of 1.14 × 106 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 × 106 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:

$$O_2 = (3{,}197.25 \times 2.67\ kg\ O_2 + (391.5 \times 8\ kg\ O) + (6.525 \times 1\ kg\ O_2\ )$$
$$O_2 = 11{,}675.2\ kg\ O_2$$

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 O2), so the theoretical air needed is:

U_{og} = 8,804.2 / 0.21 kg O_2

U_{og} = 41,924 kg O_2

So 6,525 kg of fiber requires 41,924 kg of O2.

4.7 Heat Transfer in Boiler Combustion Chambers

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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:

$$Q_P = C_Z.F.[(T_{fire}/100)^4 - (T_{object}/100)^4]$$
$$Q_P = 5{,}569.18.[(503/100)^4 - (363/100)^4]$$
$$Q_P = 46.76 \times 10^6\ KJ/m^2.hour.K^2$$

Table 10. Radiation Displacement

Date	*Time*	*Leveling up time interval (minute)*	CZ *(KJ/m².hour.K⁴)*	F (m^2)	T_{api} T_{fire} (K)	T_{benda} T_{object} (K)	Q_P ((KJ/m². hour. K⁴)
May 30, 2017	11.34- 11.47	14	5,569	18	503	363	46,763,379
	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

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	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
	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

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	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
	15.32- 15.36	5	5,569	18	503	368	45,784,425
	15.40- 16.10	31	5,569	18	503	368	45,784,425
June 3, 2017	08.44- 09.03	20	5,569	18	503	368	45,784,425
	09.05- 19.17	13	5,569	18	503	368	45,784,425
	09.30- 09.39	10	5,569	18	503	368	45,784,425
	09.43- 09.50	8	5,569	18	503	368	45,784,425
	09.52- 10.03	12	5,569	18	503	368	45,784,425
	10.07- 10.18	12	5,569	18	503	368	45,784,425
	10.21- 10.24	4	5,569	18	503	368	45,784,425
	10.56- 11.00	5	5,569	18	503	368	45,784,425

June 5, 2017	07.45- 07.46	2	5,569	18	503	353	48,603,488
	07.48- 07.57	10	5,569	18	503	353	48,603,488
	08.32- 08.46	15	5,569	18	503	363	46,763,379
	08.48- 08.59	12	5,569	18	503	363	46,763,379

An object temperature of 363 K and a fire temperature of 503 K produce a radiant heat transfer value of 46.76 × 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 × $10^{6.}$

1. Conduction heat transfer

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

$$Q_K = \frac{\lambda}{s}.F.(T_{d1} - T_{d2})$$
$$Q_K = \frac{2.58}{0.003}.18.(230 - 90)$$
$$Q_K = 2.16 \times 10^6 \frac{KJ}{m}.J.°C$$

Table 11. Heat transfer by conduction

Date	***Time***	***Leveling up time interval (minute)***	**Λ** *(KJ/m.hour.°C)*	**S** (m)	**F** (m^2)	**T_{d1}** (°C)	**T_{d2}** (°C)	**Q_R** *(KJ/m^2. hour. °C)*
May 30, 2017	11.34- 11.47	14	2.58	0.003	18	230	90	2,167,200

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	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
	15.06	1	2.58	0.003	18	230	98	2,043,360
	15.24-15.26	33	2.58	0.003	18	230	98	2,043,360
	15.58-16.00	3	2.58	0.003	18	230	98.67	2,033,040
May 31, 2017	07.58-08.22	25	2.58	0.003	18	230	97.24	2,055,125
	08.24-08.34	11	2.58	0.003	18	230	97	2,058,840

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	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
	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
	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

	09.43-09.50	8	2.58	0.003	18	230	95	2,089,800
	09.52-10.03	12	2.58	0.003	18	230	95	2,089,800
	10.07-10.18	12	2.58	0.003	18	230	95	2,089,800
	10.21-10.24	4	2.58	0.003	18	230	95	2,089,800
	10.56-11.00	5	2.58	0.003	18	230	95	2,089,800
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

Date	***Time***	***Leveling up time interval (minute)***	**Λ** *(KJ/m.hour.°C)*	**S** **(m)**	**F** **(m^2)**	**T_{d1}** **(°C)**	**T_{d2}** **(°C)**	**Q_R** *(KJ/m^2. 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
	15.06	1	2.58	0.003	18	230	98	2,043,360
	15.24-15.26	33	2.58	0.003	18	230	98	2,043,360
	15.58-16.00	3	2.58	0.003	18	230	98.67	2,033,040
May 31, 2017	07.58-08.22	25	2.58	0.003	18	230	97.24	2,055,125

	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

	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
	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
	09.43-09.50	8	2.58	0.003	18	230	95	2,089,800
	09.52-10.03	12	2.58	0.003	18	230	95	2,089,800
	10.07-10.18	12	2.58	0.003	18	230	95	2,089,800
	10.21-10.24	4	2.58	0.003	18	230	95	2,089,800
	10.56-11.00	5	2.58	0.003	18	230	95	2,089,800
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 pipe temperature is 90 oC and the fire temperature is 230 oC resulting in a radiation heat transfer value of 2.16 × 106 if the pipe temperature is 80 oC and the fire temperature is 203 oC produces a conduction heat transfer value of 2.32 × 106.

4.7 Calculation of boiler efficiency

The boiler efficiency on May 30 can be calculated as follows:

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$$\eta = \frac{Q(\Delta\, Enthalpy)}{Gbb \times N.O}$$

$$\eta = \frac{19{,}014 \frac{kg}{hour} \times 593.3136 \frac{kcal}{kg}}{6{,}525 \frac{kg}{hour} \times 2{,}601.32 \frac{kcal}{kg}}$$

η= 66.46%

From the calculation results above, we will get results for each different date and time.

Table 12. Boiler Efficiency

Date	*Time*	*eling up interval ninute)*	T_{in} °C)	$_{out}$ C)	bb *fiber* *g/hour)*	N.O *cal/kg)*	Q *g/hour)*	Entalpi *cal/kg)*	H %)
ay 30, 2017	4- 11.47	14	90	30	6,525	601.32	19,014	93.31	.46
	9- 12.02	14	90	30	6,525	601.32	18,628	93.31	.11
	4- 12.35	32	90	30	6,525	601.32	18,387	93.31	.27
	9- 12.58	20	90	30	6,525	601.32	18,625	93.31	.10
	2- 13.25	24	90	30	6,525	601.32	18,633	93.31	.13
	8- 13.38	11	90	30	6,525	601.32	19,036	93.31	.54
	0- 13.42	3	90	30	6,525	601.32	18,800	93.31	.72
	4- 14.36	53	.85	30	6,525	601.32	18,988	87.46	.72
	8- 15.00	23	98	30	6,525	601.32	19,252	85.32	.39
	15.06	1	98	30	6,525	601.32	19,012	85.32	.56

	4- 15.26	33	)8	30	6,525	601.32	16,066	;85.32	5.40
	8- 16.00	3	3.67	30	6,525	601.32	19,284	;85.32	5.50
ay 31, 2017	8- 08.22	25	7.24	30	6,525	117.67	18,654	;85.32	).02
	4- 08.34	11	)7	30	6,525	117.67	18,831	;86.31	).90
	6- 08.51	16	5.25	30	6,525	117.67	19,350	;87.06	2.21
	5- 09.02	8	)5	30	6,525	117.67	19,337	;88.31	2.33
	6- 09.21	16	)5	30	6,525	117.67	18,766	;88.31	).90
	3- 09.31	9	)6	30	6,525	117.67	19,095	;87.31	1.16
	3- 09.52	20	)5	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	)6	30	6,525	117.67	19,226	;87.31	1.72
	1- 11.35	15	)6	30	6,525	117.67	19,380	;87.31	2.37
	7- 11.46	10	)6	30	6,525	117.67	19,287	;87.31	1.98
	8- 11.55	8	)6	30	6,525	117.67	19,750	;87.31	3.95
	7- 12.00	4	5.75	30	6,525	117.67	18,872	;86.56	).11
: 2, 2017	8- 09.28	11	)0	30	6,525	143.81	18,880	;93.31	).08
	3- 10.22	10	)5	30	6,525	143.81	18,376	;88.31	7.28
	4- 10.44	21	4.75	30	6,525	143.81	18,416	;88.56	7.49

	9- 11.00	12	94	30	6,525	143.81	19,490	589.31	2.11
	1- 13.50	10	.56	30	6,525	143.81	19,411	588.76	1.70
	2- 14.00	9	99	30	6,525	143.81	19,241	584.31	0.37
	3- 14.14	12	99	30	6,525	143.81	19,093	584.31	9.75
	0- 14.45	16	99	30	6,525	143.81	18,333	584.31	6.58
	7- 14.49	3	99	30	6,525	143.81	19,133	584.31	9.92
	1- 14.49	9	00	30	6,525	143.81	17,720	583.31	3.89
	2- 15.36	5	95	30	6,525	143.81	18,551	588.31	8.02
	0- 16.10	31	95	30	6,525	143.81	19,015	588.31	9.97
e 3, 2017	4- 09.03	20	95	30	6,525	663.50	18,730	588.31	3.40
	5- 19.17	13	95	30	6,525	663.50	18,540	588.31	2.76
	0- 09.39	10	95	30	6,525	663.50	18,012	588.31	0.97
	3- 09.50	8	95	30	6,525	663.50	18,991	588.31	4.29
	2- 10.03	12	95	30	6,525	663.50	18,850	588.31	3.81
	7- 10.18	12	95	30	6,525	663.50	18,600	588.31	2.96
	1- 10.24	4	95	30	6,525	663.50	18,620	588.31	3.03
	6- 11.00	5	95	30	6,525	663.50	16,950	588.31	7.38
e 5, 2017	5- 07.46	2	80	30	6,525	686.50	17,820	565.20	7.46

	8- 07.57	10	80	30	6,525	686.50	18,880	565.20	).87
	2- 08.46	15	90	30	6,525	686.50	19,050	593.31	4.48
	8- 08.59	12	90	30	6,525	686.50	19,220	593.31	5.05

Date	*Time*	*eling up interval ninute)*	T in (°C)	out (C)	bb *fiber* (*g/hour)*	N.O (*cal/kg)*	Q (*g/hour)*	Entalpi (*cal/kg)*	H %)
ay 30, 2017	4- 11.47	14	90	30	6,525	601.32	19,014	593.31	6.46
	9- 12.02	14	90	30	6,525	601.32	18,628	593.31	5.11
	4- 12.35	32	90	30	6,525	601.32	18,387	593.31	4.27
	9- 12.58	20	90	30	6,525	601.32	18,625	593.31	5.10
	2- 13.25	24	90	30	6,525	601.32	18,633	593.31	5.13
	8- 13.38	11	90	30	6,525	601.32	19,036	593.31	6.54
	0- 13.42	3	90	30	6,525	601.32	18,800	593.31	5.72
	4- 14.36	53	5.85	30	6,525	601.32	18,988	587.46	5.72
	8- 15.00	23	98	30	6,525	601.32	19,252	585.32	6.39
	15.06	1	98	30	6,525	601.32	19,012	585.32	5.56
	4- 15.26	33	98	30	6,525	601.32	16,066	585.32	5.40

	8- 16.00	3	3.67	30	6,525	601.32	19,284	585.32	5.50
ay 31, 2017	8- 08.22	25	7.24	30	6,525	117.67	18,654	585.32	9.02
	4- 08.34	11	97	30	6,525	117.67	18,831	586.31	9.90
	6- 08.51	16	5.25	30	6,525	117.67	19,350	587.06	2.21
	5- 09.02	8	95	30	6,525	117.67	19,337	588.31	2.33
	6- 09.21	16	95	30	6,525	117.67	18,766	588.31	9.90
	3- 09.31	9	96	30	6,525	117.67	19,095	587.31	1.16
	3- 09.52	20	95	30	6,525	117.67	19,119	588.31	1.40
	4- 10.14	21	5.6	30	6,525	117.67	19,413	587.71	2.57
	8- 11.17	30	96	30	6,525	117.67	19,226	587.31	1.72
	1- 11.35	15	96	30	6,525	117.67	19,380	587.31	2.37
	7- 11.46	10	96	30	6,525	117.67	19,287	587.31	1.98
	8- 11.55	8	96	30	6,525	117.67	19,750	587.31	3.95
	7- 12.00	4	5.75	30	6,525	117.67	18,872	586.56	0.11
e 2, 2017	8- 09.28	11	90	30	6,525	143.81	18,880	593.31	0.08
	3- 10.22	10	95	30	6,525	143.81	18,376	588.31	7.28
	4- 10.44	21	4.75	30	6,525	143.81	18,416	588.56	7.49
	9- 11.00	12	94	30	6,525	143.81	19,490	589.31	2.11

	1- 13.50	10	.56	30	6,525	143.81	19,411	88.76	.70
	2- 14.00	9	99	30	6,525	143.81	19,241	84.31	.37
	3- 14.14	12	99	30	6,525	143.81	19,093	84.31	.75
	0- 14.45	16	99	30	6,525	143.81	18,333	84.31	.58
	7- 14.49	3	99	30	6,525	143.81	19,133	84.31	.92
	1- 14.49	9	00	30	6,525	143.81	17,720	83.31	.89
	2- 15.36	5	95	30	6,525	143.81	18,551	88.31	.02
	0- 16.10	31	95	30	6,525	143.81	19,015	88.31	.97
3, 2017	4- 09.03	20	95	30	6,525	663.50	18,730	88.31	.40
	5- 19.17	13	95	30	6,525	663.50	18,540	88.31	.76
	0- 09.39	10	95	30	6,525	663.50	18,012	88.31	.97
	3- 09.50	8	95	30	6,525	663.50	18,991	88.31	.29
	2- 10.03	12	95	30	6,525	663.50	18,850	88.31	.81
	7- 10.18	12	95	30	6,525	663.50	18,600	88.31	.96
	1- 10.24	4	95	30	6,525	663.50	18,620	88.31	.03
	6- 11.00	5	95	30	6,525	663.50	16,950	88.31	.38
5, 2017	5- 07.46	2	80	30	6,525	686.50	17,820	65.20	.46
	8- 07.57	10	80	30	6,525	686.50	18,880	65.20	.87

	2- 08.46	15	90	30	6,525	686.50	19,050	593.31	4.48
	8- 08.59	12	90	30	6,525	686.50	19,220	593.31	5.05

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 95oC. 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 93.21oC. 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 96.2oC. 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 96oC.

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 85oC. 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 31 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:

$$\%\,Opportunities\ for\ leveling\ up = \frac{A\ lot\ of\ leveling}{Boiling\ operational\ hours} \times 100$$

$$\%\,Opportunities\ for\ leveling\ up = \frac{12}{390\ minute} \times 100$$

$$\%\,Opportunities\ for\ leveling\ up = 3.1\%$$

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
May 31, 2017	5.45	345	13	3.8
June 2, 2017	8.12	492	12	2.4
June 3, 2017	3.43	223	8	3.6
June 5, 2017	3.45	225	4	1.8

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.

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Descriptives

Notes

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	Cases Used	All non-missing data are used.
Syntax		DESCRIPTIVES VARIABLES=Kapasitas_Boiler Perubahan_Entalpi /STATISTICS=MEAN SUM STDDEV VARIANCE RANGE MIN MAX SEMEAN.
Resources	Processor Time	00:00:00.02
	Elapsed Time	00:00:00.05

Descriptive Statistics

	N	Range	Minimum	Maximum	Sum	Mean		Std. Deviation	Variance
	Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Statistic
Boiler Capacity	49	3.684	16.066	19.750	920.727	18.79035	.091498	.640488	.410
Enthalpy Change	49	28.1149	565.1987	593.3136	28785.4777	587.458729	.7806060	5.4642423	29.858
Valid N (listwise)									

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 18.79035 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 NPPLOT

  /COMPARE GROUPS

  /STATISTICS DESCRIPTIVES

  /CINTERVAL 95

  /MISSING LISTWISE

  /NOTOTAL.
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Explore

Notes

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	N of Rows in Working Data File	49
Missing Value Handling	Definition of Missing	User-defined missing values for dependent variables are treated as missing.
	Cases Used	Statistics are based on cases with no missing values for any dependent variable or factor used.
Syntax		EXAMINE VARIABLES=Kapasitas_Boiler Perubahan_Entalpi /PLOT BOXPLOT STEMLEAF HISTOGRAM NPPLOT /COMPARE GROUPS /STATISTICS DESCRIPTIVES /CINTERVAL 95 /MISSING LISTWISE /NOTOTAL.
Resources	Processor Time	00:00:03.45
	Elapsed Time	00:00:04.72

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Boiler Capacity	49	100.0%	0	0.0%	49	100.0%
Enthalpy Change	49	100.0%	0	0.0%	49	100.0%

			Statistic	Std. Error
Boiler Capacity	Mean		18.79035	.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	

	Minimum		16.066	
	Maximum		19.750	
	Range		3.684	
	Interquartile Range		.613	
	Skewness		-2.178	.340
	Kurtosis		6.804	.668
Enthalpy Change	Mean		587.458729	.7806060
	95% Confidence Interval for Mean	Lower Bound	585.889215	
		Upper Bound	589.028242	
	5% Trimmed Mean		588.185294	
	Median		588.313600	
	Variance		29.858	
	Std. Deviation		5.4642423	
	Minimum		565.1987	
	Maximum		593.3136	
	Range		28.1149	
	Interquartile Range		2.4672	
	Skewness		-2.701	.340
	Kurtosis		10.141	.668

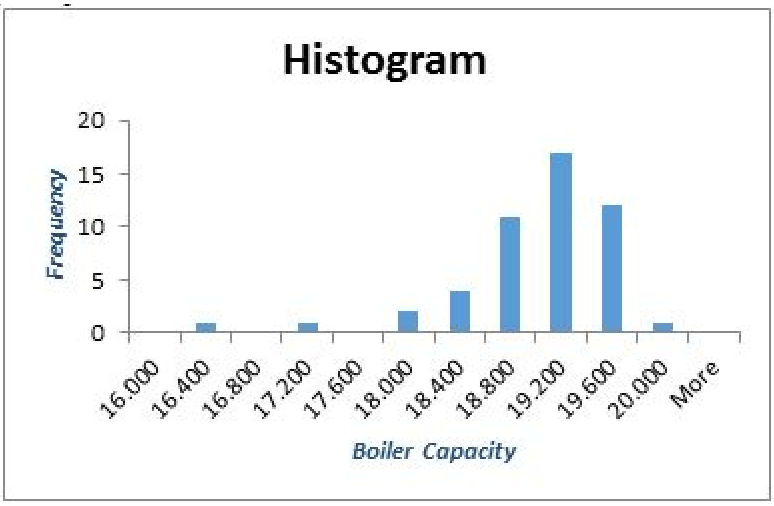
Tests of Normality

Kolmogorov-Smirnov[a]		
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 *Stem-and-Leaf Plot Boiler Capacity*

Frequency Stem & Leaf

3.00 Extremes (=<17.7)

1.00 17 . 8

5.00 18 . 03334

18.00 18 . 5566666677888888899

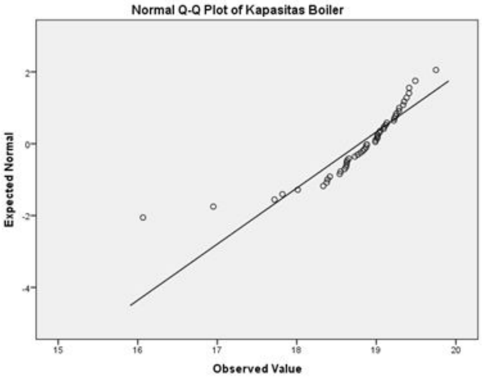
21.00 19 . 000000011222222333444

1.00 19 . 7

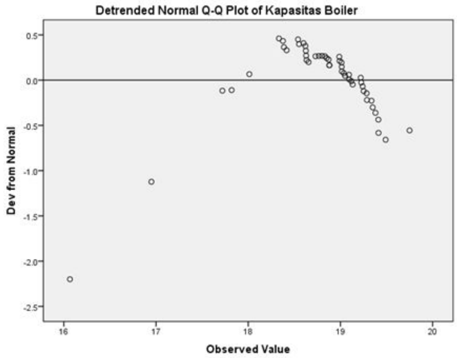
Stem width: 1.000

Each leaf: 1 case(s)

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.

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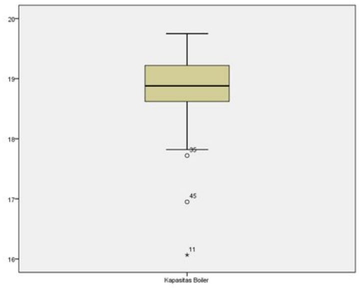
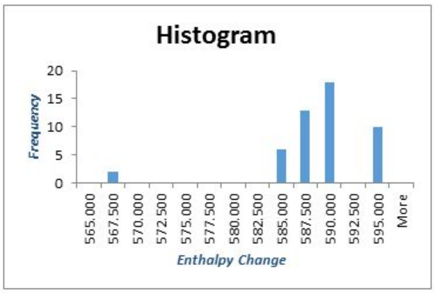


Enthalpy Change



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

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7.00 587 . 0333334

1.00 587 . 7

14.00 588 . 33333333333333

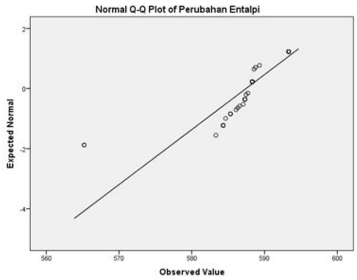
2.00 588 . 57

1.00 589 . 3

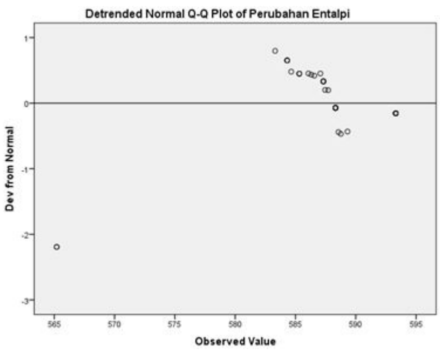
10.00 Extremes (>=593.3)

Stem width: 1.0000

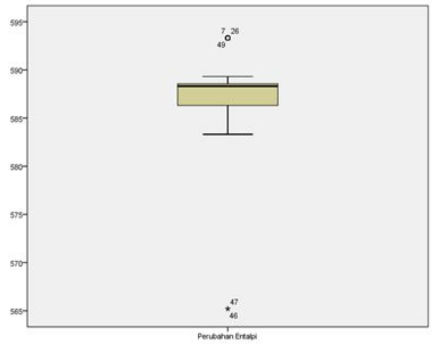
Each leaf: 1 case(s)



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