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The Analysis of Lignite Coal Combustion Process in the Steam Power Plant in Merauke

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ABSTRACT

This research is to analyze the combustion process of steam boiler (PLTU) 2 X 7 MW Merauke using Lignite coal as the fuel. The combustion process is how much input of heat energy into the steam boiler and how much the use of heat energy to change the phase and how much heat energy that released in the air. The process calculation of the steam boiler uses method of British Thermal Units (BTU). The BTU method is a method used to analyze the qualification of the cogeneration. The research is using the existing data of power plant on the qualification study and located in PLTD Kelapa Lima, Merauke. As for the data retrieved is data ultimate fuel, technique and design of PLTU 2 X 7 MW Merauke. From the calculation result of combustion process in the steam boiler of (PLTU) 2 X 7 MW Merauke. it shows that the low quality coal of Lignite analyzed using ultimate analysis as follows: Carbon (C) 54.03%, Hydrogen (H2) 3.83%, Sulfur (S) 0.33 %, Oxygen (O2) 17.06%, Nitrogen (N2) 1.35%, Water (H2O) 18.40%, Ash 5% and the heat value of 15080 Height Heating Value (HHV) 3800 kcal/kg = 15080 Btu/lb, low heating value (LHV) 1770 kcal/kg = 7024 Btu/lb, excess air 32.94% and fuel consumption of 16784 kg/hour. The mass flow rate vapor is 37 ton or 66150 lb/hr, the need of primary air is 3.4281 kg air and the secondary air is 2.2281 kg air , 93.34 x 106 BTU/hr or 27.35525369 MW, the heat used in the process of a change of phase liquid fluid in the water pipe along the steam boiler is 83.038 x 16 BTU/hr or 3.019218165 MW, so the result is above the energy balance occurs in the cycle of steam boiler.

KEYWORDS: steam boiler, coal, Lignite, BTU method

INTRODUCTION

The growth of electricity load for Papua region, especially Merauke, increases so the available electricity power is not enough. The need of electricity power in Merauke increases each year, and the capacity of PLN is limited. The PLN's power plant is not in good condition, and some of the power plant is damaged. To face the problem, PT PLN (persero) increases the electricity power by renting. The HSD diesel fuelled power plant and the private owned PLTD; that makes the cost of electricity power generation very expensive. The existing electricity power owned by PLN in Merauke is 10.8 MW, it is gained from the local electricity system and the rental PLTD; while the load is 10.2 MW and the average power is 5.6 MW, so the rental PLTD is disturbed and it will cause the blackout. The request of new electricity connection could not be provided yet because of the lack of power plant capacity. [1].

In order to supply the need of electricity in some area, PLN has a plan to buy the electricity from the new power plant of independent power producer (IPP). The new power plant of IPP is a small scale coal generated power plant spread all over Indonesia. So to reduce the deficit of electricity supply in Merauke, it needs the more reliable and cheap power plant system.

PT PLN (Persero) has a plan to build a coal steam power plant (PLTU) of 2 x 7 MW. The purpose of the research is to calculate the combustion process of coal used as a fuel of steam boiler for Merauke PLTU 2 x 7 MW, [2].

MATERIALS AND METHOD

Selection of Power Plant Location

The mapping study of PLTU Merauke 2x 7 MW location is an early study done by the consultant to examine the appropriateness of PLTU Merauke 2 x 7 MW located in Merauke, Papua Province. The study of location selection is done by PT Arkonin Engineering Manggala Pratama, [3]. The study is done systematically, based on the criteria established by PLN. The survey method is a direct survey to some alternative location and collecting the secondary data from the local institution. Data is analysed using weight method according to the each criterion. The result of the examination is multiplied by the value of each criterion, [4].

There are three alternative locations proposed by PLN:

1. Location I, Kuprik : located in Kuprik, near Maro river, Semangga District, Merauke

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2. Location II, Kelapa Lima : located in Kelapa Lima, near Maro river, Merauke District, Merauke
3. Location III, Gudang Arang: located in Gudang Arang, near Maro River, Merauke Distrcit, Merauke.

From the analysis result, the location III Gudang Arang is recommended as the location of PLTU 2 x 7 MW Merauke. The Kuprik and Kelapa Lima locations are near Maro River, so it makes the development access hard. The location of PLTU Merauke is Gudang Arang village, Merauke District, Papua province. The geographical location of Gudang Arang is 8^0 27' 22.20" LS and 140' 24' 12.66" BT in the UTM coordinate system.

Fuel Supply

The purpose of the fuel supply is to gain the coal supply for the need of PLTU Merauke 2 x 7 MW; it is decided by the following study:

1. The potential coal supplier and its deposits
2. The coal characteristic and the fitness for the PLTU fuel
3. The coal price of PLTU Merauke
4. The transportation of coal to PLTU

Coal used in PLTU Merauke is a low calorie coal that is 3,800 kcal/ kg HHV. The low calorie coal is used as the fuel because the supply is abundant and the price is low. The fuel consumption is 8107 kg/ day or 8.107 ton/ day and the output generator is 8.351,95 kW for 2 units. The net output generator is 7.368,63 kW. The coal requirement is 389.14 ton/day full load or 11,674.09 ton/ month. If the assumption of factor capacity is 80%, then the coal requirement is 112,071 23/ year or 3,362,136.78 ton for 30 years.

The availability of coal

There are 60 companies that explore East Kalimantan and take control of the land containing coal, and only 44 companies report their supply. The data of coal supply is also given by the exploration of Mineral Resources Inventory Directory. The region in Kalimantan that contains coal could be classified into 8 groups, based on its deposit location; they are, Group I Simenggaris, Group II Tanjung Redep, Group III Malinau, Group IV Sangatta, Group V Wahau, Group VI Delta Mahakam, Group VII South Kalimantan Border and Group VIII Pasir.

The calculation analysis and performance evaluation steam boiler

The performance parameter of steam boiler such as efficiency and evaporation ratio, decrease against time is caused by the bad combustion process, the dirty heat change surface and the bad operation and maintenance. Even for the new steam boiler, the bad quality of fuel and water could make the performance of steam boiler bad. The heat stability could help to identify the heat lost that could be prevented. The test of steam boiler efficiency could help to find the deviation of steam boiler efficiency and the problem target [5].

The combustion process in the boiler could be illustrated in the form of energy flow diagram. The diagram illustrates how energy of fuel change into energy for much usage, and into lost heat and energy. The arrow direction shows the energy contained in each current. The heat balance is the balance of total energy entering the steam boiler that leaves the steam boiler in the different form. The next picture illustrates many lost portraits in the steam power plant. [6].

Theoretical air required

One kg fuel consists of c kg Carbon, h kg Hydrogen, s kg Sulphur, and o kg Oxygen (the rest is non-flammable). The need of oxygen for the perfect combustion is Oxygen to burn c kg Carbon $\frac{8}{3}c$, oxygen to burn h kg Hydrogen 8 h, oxygen to burn S kg sulphur s kg, so the total required of oxygen is:

$$\left(\frac{8}{3}c + 8h + s\right) kg$$

The fuel contains o kg oxygen, it is considered to be used for combustion. Therefore, the theoretical air required for the perfect combustion of 1 kg fuel will be:

$$\left(\frac{8}{3}c + 8h + s - 0\right) kg$$

The need of oxygen for combustion is gained from the atmosphere containing 23% oxygen and the 77% remaining of nitrogen, because it ignores the quantity of other gas in the atmosphere.
The theoretical air required for each fuel could be determined by:

$$11.5 + 34.5\left(h - \frac{0}{8}\right) + 4.32 \times s\ (kg\ air)$$

From the equation above, the perfect combustion process consists of Carbon dioxide, sulphur dioxide and vapour. The performance calculation of steam kettle components is following, [2]:

1. Furnace

$$heat\ release\ rate = \frac{heat\ available\ \times gas\ mas\ flow\ rate}{flat\ projected\ area\ \times effectiveness\ factor}$$

2. The radiation energy leaving the combustion chamber

$$q = \sigma \times Fe \times (T_1^4 - T_2^4)$$

Where:
σ = Constant a Steffen Boltzmann, 1.71 x 10^{-9} Btu/h ft^2
Fe = effectiveness factor
T_1 = the gas temperature leaving the furnace
T_2 = the saturation temperature

3. To calculate the heat transfer in the surface using the below equation :

$$q = m_s \times \Delta H$$

Where:
q = heat transfer rate (BTU/h)
m_s = mass flow rate of steam (LB/h)
ΔH = enthalpy difference of vapor (BTU/h)

4. To calculate the rate of convection and radiation heat transfer inter tube using the equation below :
$q_{c1} = q - q_r$

5. To calculate the gas leaving the super heater using the equation below :

$$T_2 = T_1 - \left[\frac{q_{ci}}{m_g . Cp}\right]$$

where:
T_2 = the temperature of gas leaving super heater (F)
T_1 = the temperature of gas entering super heater (F)
m_g = mass flow rate of gas (LB /h)
Cp = average specific heat of gas (BTU/LB.F)

6. Super heater Log Mean Temperature Difference (LMTD)

$$LMTD = \frac{(T_1 - T_2') - (T_2 - T_1')}{In\left(\frac{T_1 - T_2'}{T_2 - T_1'}\right)}$$

The average temperature of film on the gas side:

$$T_f = \left[\frac{T_1 - T_2^1}{2}\right] + \left[\frac{LMTD}{2}\right]$$

The rate of vapor mass current:

$$G_2 = \frac{m_s}{A_g}$$

With:
A_g = the width of vapor current region
$A_g = N_{RW}$ x ¼ π (OD)
m_s = mass flow rate of vapor

7. To calculate the flux of air mass using the following equation :

$$G_a = \frac{m_a}{A_a}$$

8. To calculate the Reynolds number using the following equation :

$$R_e = \frac{G_a D_e}{\mu}$$

9. To calculate the air resistance from the wind box inlet to the air heater outlet using the following equation :

$$\Delta P = \left(\frac{fl}{D_e} + N\right)\left(\frac{30}{B}\right)\left(\frac{T + 460}{1.73 \times 10^3}\right)\left(\frac{G_a}{10^3}\right)^2$$

with :

$N = N_{bend} + N_{expansion}$

10. To calculate the volume of air loss from the air heater inlet to forced draft fan transition outlet using the following equation :

$$\Delta P = N\left(\frac{30}{B}\right)\left(\frac{T+460}{1.73 \times 10^3}\right)\left(\frac{G_a}{10^3}\right)^2$$

Research Design

The research uses the method of data gathering from the PLTD Merauke or the design data of the proper test of PLTU 2 x 7 MW Merauke. The data is taken from PT PLN Persero Merauke and PLTD Kelapa Lima Merauke.

1. Research procedure

The steps of the research are following:

1) Literature study
   Literature study is to study the secondary data of reference related to the research
2) Data collection
   The technical data is recorded in the form of analysis of fuel needs and composition, and also other data needed for the research.

2. Data processing

The data processing is a calculation using the following steps, [5]:

1. Calculation combustion rate of steam PLTU 2 x 7 MW Merauke and the rate of energy balance
2. Analysis by evaluating the estimation result in order to identify the boiler performance
3. Data survey
   The method is done by collecting data on PLTU 2 x 7 MW Merauke is:
   a) Technical data / boiler system design
      Technical data / boiler system design is based on the manual book and documents of used boiler system
   b) Operational data of steam boiler system
      The data retrieval is done based on the early design of low quality coal steam boiler
   c) Data collection Procedures
      Retrieval of data required to done by recording in the manual book and literature of steam kettle in PLTU 2 x 7 MW Merauke.
      Data of fuel is taken.
      The fuel used in PLTU 2 x 7 MW Merauke is low quality coal; as follows:
      1. Carbon (C) : 54.03%
      2. Hydrogen (H2) : 3.83%
      3. Sulfur (S) : 0.33%
      4. Oxygen (O2) : 17.06%
      5. Nitrogen (N2) : 1.35%
      6. Water (H2O) : 18.40%
      7. Ash : 5%
      8. Height Heating value (HHV) : 3800 kcal/kg = 15080 Btu/lb
      9. Low Heating Value (LHV)` : 1770 kcal/kg = 7024 Btu/lb
      10. Excess air : 32.94%

RESULTS AND DISCUSSION

Based on the fitness study of building PLTU Merauke 2 x 7 MW published by PT Arkonin Engineering MP and PT Catur KG as designer, the recommended characteristics of lignite coal is as on the fuel data above. There is also technical data of steam boiler recommended based on the fitness study published by PT Arkonin Engineering MP and PT Catur KG [3], as following:

1. Temperature of gas leaving the furnace : 1322^{0}C
2. Air temperature :28 - 30^{0}C
3. Temperature of gas entering the air heater : 186^{0}C
4. Temperature of gas leaving the air heater : 145^{0}C
5. Temperature of air entering the air heater : 30^{0}C
6. Temperature of air leaving the air heater : 159^{0}C

7. Temperature of steam entering super heater : 253^0C
8. Temperature of steam leaving super heater : 450^0C
9. Pressure of steam entering super heater : 4.250 MPa
10. Pressure of steam leaving super heater : 4.0 MPa
11. Temperature of gas entering super heater : 612^0C
12. Temperature of steam entering economizer : 368^0C
13. Temperature of steam leaving economizer : 252^0C
14. Temperature of air entering economizer : 202^0C
15. Temperature of air leaving economizer : 253^0C
16. Pressure of steam entering economizer : 0.1020 MPa
17. Exhaust gas temperature : 163^0C
18. Pressure of kettle drum : 4.250 MPa
19. Mass flow rate of steam : 37 ton/hour
20. Rate of containing water : 37 ton/hour
21. Consumption of lignite coal : 16,784 kg/hour
22. Heat entering the boiler : 30,806,615.96 kcal/hour
23. Generator load : 7 MW
24. Excess air : 15%

Combustion air requirements

1) The theoretical air required for combustion proses:

$$L_0 = \frac{100}{23}\left[\left(\frac{8}{3}C\right) + 8H + S - O_2\right]$$

$$L_0 = 11.5 \times C + 34.5\left(H - \frac{O_2}{8}\right) + 4.32 \times S\ (kg\ air)$$

$$L_0 = 11.5(0.5403) + 34.5\left(0.383 - \frac{0.1706}{8}\right) + 4.32(0.033)(kg\ air)$$

$$L_0 = 18.834\ (kg\ fuel)$$

The factor of excess air based on the data is 20%, so the real volume of air need is as follows:
L = n. Lo
L = 0.20 x 18.834
= 3.767 kg air

The AFR score could be identified from the test of combustion reaction. The score is actual AFR. The other AFR is stokio-metric AFR, that is, AFR obtained from the equation of combustion reaction.
So:

$$\lambda = \frac{(A/F)_{actual}}{\left(\frac{A}{F}\right)_{stokiometric}}$$

The value of λ is as follows:

a. If λ> 1, then the combustion reaction of fuel poor
b. If λ = 1, then the combustion reaction is perfect or stokhio-metric reaction
c. If λ< 1, then the combustion reaction is rich of fuel

The fuel is lignite coal ($C_{100}H_{85}$), the combustion reaction is:

$$C_nH_m\left(n + \frac{m}{4}\right)(O_2 + 3.76N_2) \rightarrow nCO_2 + \frac{m}{2}H_2O + \left(n + \frac{m}{4}\right)3.76N_2$$

$$C_{100}H_{85}\left(100 + \frac{84}{4}\right)(O_2 + 3.76N_2) \rightarrow 100CO_2 + \frac{85}{2}H_2O + \left(100 + \frac{84}{4}\right)3.76N_2$$

$$C_{100}H_{85} + 121.25(O_2 + 3.76N_2) \rightarrow 100CO_2 + 42.5H_2O + 182N_2$$

Then the baker fuel mass (F) is :
(12.01)100 + (1,008)85 = 1201 + 85,68 = 1286.68 kg
And the air mass (A) is:
121.25{(16 x 2) + 3.76 (14.01 x 2)} = 3880 + 1316.94 = 5196.94 kg
So the ratio of air and fuel required in the stokhio-metric condition is:

$$AFR_{stok} = \frac{mol\ air \times BM\ air}{mol\ fuel \times BM\ fuel}$$

$$AFR_{stok} = \frac{air\ mass}{fuel\ mass} = \frac{5196.94}{1286.68} = 4.0390\ kg\ air\ /\ kg\ fuel$$

The AFR value in the actual condition is obtained using the following equation:

$$\lambda = \frac{AFR_{act} - AFR_{theoritis}}{AFR_{theoritis}} \times 100\%$$

Where λ is the factor of air need (1, 2)

Then

$$AFR_{akt} = \frac{\lambda - AFR_{theoritis}}{100\%} + AFR_{theoritis}$$

$$AFR_{akt} = \frac{1.2 - 18.834}{100\%} + 18.834 = 19.060\ kg$$

Then, the total demand of primary air requirements (α_1) is

$$\alpha_1 = \frac{AFR_{akt}}{AFR_{stok}} = \frac{19.060}{4.0390} = 4.719\ kg$$

While, the amount of secondary air requirement (α_2) is :

$$\alpha_2 = \alpha_1 - \lambda = 4.719 - 1.2 = 3.519\ kg$$

Based on the feasibly study published by PT Arkonin Engineering MP and PT Catur KG, the design data is following [3]:

a. Furnace surface area : 394.831 ft^2
b. Excess air : 32.94%
c. The lost of non-flammable carbon (UBCL) : 0.40%
d. The lost of non-detectable material (ABMA curve) : 1.5%
e. The lost of radiation : 0.4%
f. The temperature of gas leaving furnace : 1490^0C = 2714^0F
g. Steam leaving super heater
   - Steam flow rate : 30.000 kg/hour → 66150 lb/hour
   - Temperature of steam : 932^0F
   - Pressure of steam : 21 kg/cm^2→ 298.6922 psig
   - Enthalpy of steam (H_2) : 1496.474 Btu/lb m
h. Water leaving economizer
   - Water flow rate : 66150 lb/hour
   - Temperature of water : 257^0F
   - Pressure of water : 28.40 kg/cm^2→ 403.943 psig
   - Enthalpy of water (H_1) : 235.177 Btu/lb m
i. Air heater
   - Inlet air temperature : 28^0C → 82.8^0F
   - Pressure of barometer : 30 in. Hg
   - Leaving the flue gas temperature : 150^0C → 365^0F

j. Output :
   Output = m ($H_2 - H_1$)
   Where:
   m: 66150 lb/h
   H_2: 1496.474 BTU/JB
   H_1 : 235.177 Btu/h
   So:
   Output = 66150 (1496.474 – 235.177)
   Output = 83.038 x 10^6 BTU/h → (Table BTU No 10)
k. Input heating fuel:

$$input = \frac{output}{efficiency}$$

   Where:
   Efficiency of kettle from the data is 88.964% → (Table BTU no 53)

$$input = \frac{83.038 \times 10^6}{88.964\%} = 93.34 \times 10^6 BTU/h$$

l. Mass flow rate of gas:
m_g = input x weight of wet gas
with:
weight of wet gas:6.277 x 10^{-4}→ (Table BTU, no 33)
$m_g = (93.34 \times 10^6) \times (6.277 \times 10^{-4})$
$m_g = 324.10 \times 10^3$ lb/h m_g→ (Table BTU no 56)

m. mass flow rate of air
dry air mass = 5.381 b/10000 Btu → (table BTU no 26)
correction moisture vapor = 1.01316 vapor/lb dry air
then:

$$m_a = (99.953 \times 10^6) \times 1.01316 \times (5.381 \times 10^{-3})$$

$$m_a = 52.73 \times \frac{10^3 lb}{h} \rightarrow (Table\ BTU, no\ 58)$$

n. Heat Release Rate

$$HRR = \frac{heat\ available \times rate\ of\ gas\ current}{flat\ projected\ area \times effectiviness\ factor}$$

Where:
Heat available = 285.64 Btu/lb (Table 4.1 BTU Method no 60)
Flat projected area = 2360.0805 ft^2
Effectiveness factor = 1.0 (STEAM, Babcock and Wilcox, Attachment 1A, picture 1)
So:

$$HRR = \frac{285.64 \times 106130.09}{2360.0805 \times 10} = 12.754 \times 10^3 \frac{BTU}{h.ft^2}$$

Temperature of gas leaving furnace is 2714^{0}F.
Table 1 presents the combustion calculation –BTU method.

Table 1 Combustion Calculation-BTU Method

Combustion Calculations - Btu Method

Bahan Bakar Lignite

	INPUT CONDITIONS - BY TEST OR SPECIFICATION		
1	Excess air at burner/leaving boiler/econ/entering AH, % by wt		20/20
2	Entering air temperature, F (tRA = 77 for PTC 4)		80
3	Reference temperature, F		80
4	Fuel temperature, F		80
5	Air temperature leaving air heater, F		318,2
6	Flue gas temperature leaving (excluding leakage), F		390
7	Moisture in air, lb/lb dry air		0,05
8	Additional moisture, lb/100 lb fuel		0
9	Residue leaving boiler/econ/entering AH, % Total		80
10	Output, 1,000,000 Btu/h		83,038
	Corrections for sorbent (if used)		
11	Sulfur capture, lbm/lbm sulfur	Table 16, item [24]	0
12	CO_2 from sorbent, lb/10,000 Btu	Table 14, item [19]	0
13	H_2O from sorbent, lb/10,000 Btu	Table 14, item [20]	0
14	Spent sorbent, lb/10,000 Btu	Table 14, item [24]	0

FUEL- *Coal Lignite*, PLTU 2 x 7 MW - MERAUKE

	15 Ultimate Analysis		16 Theo Air, lb/100 lb fuel		17 H_2O, lb/100 lb fuel	
	Constituent	% by weight	K1	[15] × K1	K2	[15] × K2
A	C	54,03	11,51	621,89		
B	S	0,33	4,32	1,43		
C	H_2	3,83	34,29	131,33	8,94	34,24
D	H_2O	18,4			1,00	18,4
E	N_2	1,35				
F	O_2	17,06	-4,32	-73,70		
G	Ash	5				
H	Total	100,00	Air	680,94	H_2O	52,64

18	Higher heating value (HHV), Btu/lb fuel		15.080,0
19	Unburned carbon loss, % fuel input		0,40
20	Theoretical air, lb/10,000 Btu	[16H] × 100 / [18]	4,516
21	Unburned carbon, % of fuel	[19] × [18] / 14,500	0,42

	COMBUSTION GAS CALCULATION, Quantity/10,000 Btu Fuel Input		
22	Theoretical air (corrected), lb/10,000 Btu	[20] − [21] × 1151 / [18] + [11]	4,484
23	Residue from fuel, lb/10,000 Btu	([15G] + [21]) × 100 / [18]	0,036
24	Total residue, lb/10,000 Btu	[23] + [14]	0,036

			A At Burners	B Infiltration	C Leaving Furnace		D Leaving Blr/Econ	
25	Excess air, % by weight		20,0	20,0		20,0		20,0
26	Dry air, lb/10,000 Btu	(1 + [25] / 100) × [22]				5,381		5,381
27	H_2O from air, lb/10,000 Btu	[26] × [7]			0,269	0,269	0,269	0,269
28	Additional moisture, lb/10,000 Btu	[8] × 100 / [18]			0,000	0,000	0,000	0,000
29	H_2O from fuel, lb/10,000 Btu	[17H] × 100 / [18]			0,349	0,349	0,349	0,349
30	Wet gas from fuel, lb/10,000 Btu	(100 − [15G] − [21]) × 100 / [18]				0,627		0,627
31	CO_2 from sorbent, lb/10,000 Btu	[12]				0,000		0,000
32	H_2O from sorbent, lb/10,000 Btu	[13]			0,000	0,000	0,000	0,000
33	Total wet gas, lb/10,000 Btu	Summation [26] through [32]				6,277		6,277
34	Water in wet gas, lb/10,000 Btu	Summation [27] + [28] + [29] + [32]			0,618	0,618	0,618	0,618
35	Dry gas, lb/10,000 Btu	[33] − [34]				5,659		5,659
36	H_2O in gas, % by weight	100 × [34] / [33]				9,847		9,847
37	Residue, % by weight (zero if < 0.15 lbm/10KB)	[9] × [24] / [33]				0,458		0,458

	EFFICIENCY CALCULATIONS, % Input from fuel				
	Losses				
38	Dry gas, %		0.0024 × [35D] × ([6] − [3])		4,210
39	Water from fuel, as fired %	Enthalpy of steam at 1 psi, T = [6]	$H_1 = (3.958 \times 10^{-5} \times T + 0.4329) \times T + 1062.2$	1237,051	
40		Enthalpy of water at T = [3]	H_2 = [3] − 32	48	
41			[29] × ([39] − [40]) / 100		4,151
42	Moisture in air, %		0.0045 × [27D] × ([6] − [3])		0,375
43	Unburned carbon, %		[19] or [21] × 14,500 / [18]		0,400
44	Radiation and convection, %		ABMA curve, Chapter 23		0,400
45	Unaccounted for and manufacturers margin, %				1,500
46	Sorbent net losses, % if sorbent is used		From Table 14 item [41]		0,000
47	Summation of losses, %		Summation [38] through [46]		11,036
	Credits				
48	Heat in dry air, %		0.0024 × [26D] × ([2] − [3])		0,000
49	Heat in moisture in air, %		0.0045 × [27D] × ([2] − [3])		0,000
50	Sensible heat in fuel, %		(H at T[4] − H at T[3]) × 100 / [18]	0,0	0,000
51	Other, %				0,000
52	Summation of credits, %		Summation [48] through [51]		0,000
53	Efficiency, %		100 − [47] + [52]		88,964

	KEY PERFORMANCE PARAMETERS		Leaving Furnace	Leaving Blr/Econ
54	Input from fuel, 1,000,000 Btu/h	100 × [10] / [53]		93,34
55	Fuel rate, 1000 lb/hr	1000 × [54] / [18]		6,19
56	Wet gas weight, 1000 lb/hr	[54] × [33] / 10	324,10	324,10
57	Air to burners (wet), lb/10,000 Btu	(1 + [7]) × (1 + [25A] / 100) × [22]	5,65	
58	Air to burners (wet), 1000 lb/h	[54] × [57] / 10	52,73	
59	Heat available, 1,000,000 Btu/h	[54] × {([18] − 10.30 × [17H]) / [18] − 0.005		
	H_a = 66 Btu/lb	× ([44] + [45]) + H_a at T[5] × [57] / 10,000}	92,58	
60	Heat available/lb wet gas, Btu/lb	1000 × [59] / [56]	285,64	
61	Adiabatic flame temperature, F	From ch. 10, Fig. 3 at H = [60], % H_2O = [36]	1075	

CONCLUSION

The conclusion of the research is that steam boiler in Merauke using Lignite coal has chemical contents as following : Carbon 54.03%, hydrogen 3.83%, sulphur 0.33%, Oxygen 17.06%, Nitrogen 1.35%, water 18.40%, Ash 5%, height heating value 3800 kcal/kg = 15080 Btu/lb, low heating value 1770 kcal/kg or 7024 Btu/lb, excess air 32.94%.

The power capacity of 2 x 7 MW power plant generated by Lignite coal will result steam rate of 37 ton/hour and the energy is 93.34 x 10^6 BTU/h or 27.35535369 MW at 1322^{0}C and the energy is 83.038 x 10^6 BTU/h or 24.33603552MW, the lost energy because of radiation is 10.302 x 10^6 BTU/h or 3.019218165 MW.

From the result above, there is balance energy in the steam boiler cycle, which is the energy volume in the cycle is as much as the energy volume used in the cycle plus the lost energy. Therefore, the efficiency of steam boiler is 88.964%; it means that 11.036% is lost, according to the law of Thermodynamics II.

The suggestion is that to produce the perfect combustion, it should pay attention the condition of component such as superheater, economizer, air heater and fan to air requirements for combustion in the boiler, then the routine maintenance could be done.

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