# EFFECT OF LOADING FLUCTUATION ON EFFICIENCY BOILER PLTU UNIT I SOUTH MINAHASA

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**ABSTRACT**: Many aspects affect the performance of a power plant . One of her in the form of fluctuations in load of Control Center Interkoneksi expenses electricity network , as that occurred at the power plant Unit 1 South Minahasa. It is the possibility of big will air an influence on the efficiency of boiler power plant , which is now a reference in the assessment *Performance Regulatory Base* a steam power plant. Through the analysis of the effect of fluctuations in the workload of the Efficiency Boiler power plant Amurang Unit 1 Unit 1, the expected performance of the existing power plant can be in the know , s ehingga *Performance Regulatory Base* him untracked . Thus the energy saving effort will be achieved and at the same time encourage environmental preservation efforts. Because the Amurang PLTU Unit 1 uses medium rank coal / LRC which is environmentally friendly (low sulfur and ash content).

**Keywords:** ***Workload , nett plant heat rate , efisiensi , energy, environment***

## 1. Introduction

Coal power plant is currently the main source of electricity in the world. More than 60% of the world's electricity depends on coal. Likewise in Indonesia, the choice of using a coal-fired power plant was felt appropriate, considering that Indonesia has substantial coal reserves of ± 32.38 billion tons. The largest coal reserves are medium rank coal or often called Low Rank Coal (LRC) with calorific values between 3400 - 4400 kCal / kg AR. Medium level coal reserves amount to 63% of the total coal reserves in Indonesia. This medium rank coal (LRC ) is an environmentally friendly coal (low sulfur and ash content) [4].

Many aspects affect the performance of a power plant . One of them is the condition of fluctuations in the load on the plant , due to changes in the level of demand load from the Load Control Center . Interconnection load regulation is very important in large-scale electricity network systems , so that optimal electrical system operation is achieved . The performance of the generator will affect the performance of the PLTU system. [6] states, Over the period of operation, estimated efficiency of the generator has decreased due to several factors such as derating (reduced load) or trip (unit shutdown) maintenance factors, factors operating errors and other factors.

In order to anticipate the effects of varying demand for supply loads from the load interconnection system, it is very important for the PLTU management to ensure the load limits have optimal efficiency values . Because this plays an important role in evaluating the *Performance Base Regulatory of* a steam power plant.

The current efficiency value plays an important role, as one of the evaluation parameters which is often called the Performance Base Regulatory. According to [1] from the linear regression tests that have been carried out, efficiency has a large or very significant effect on the performance of a power plant. The value of efficiency is very important to calculate the operating costs and profits for a plant [2]. When operating the plant carelessly without monitoring its efficiency or performance, the plant's performance will decrease [3].

## 2. PLTU Production Process

In a Steam Power Plant (PLTU), it takes several processes to run the electricity production process. This is because the steam used as a working fluid in turbines has a long process , because it requires several energy conversion processes from chemical energy contained in coal, to electricity that is generated by generators. Coal is used as fuel to heat feed water in the boiler , so that it becomes steam with a certain pressure and temperature that will drive the steam turbine, where the turbine is also coupled to the generator at the end of the shaft so that it can produce electrical energy.

A general power plant me make use of water as the working medium , which in the working process, in heat up to steam at high pressure and temperature to be able to drive the turbine. This water is generally obtained from sea water is converted into fresh water d eng 's through several processes in order to meet the quality standards of boiler feed water.

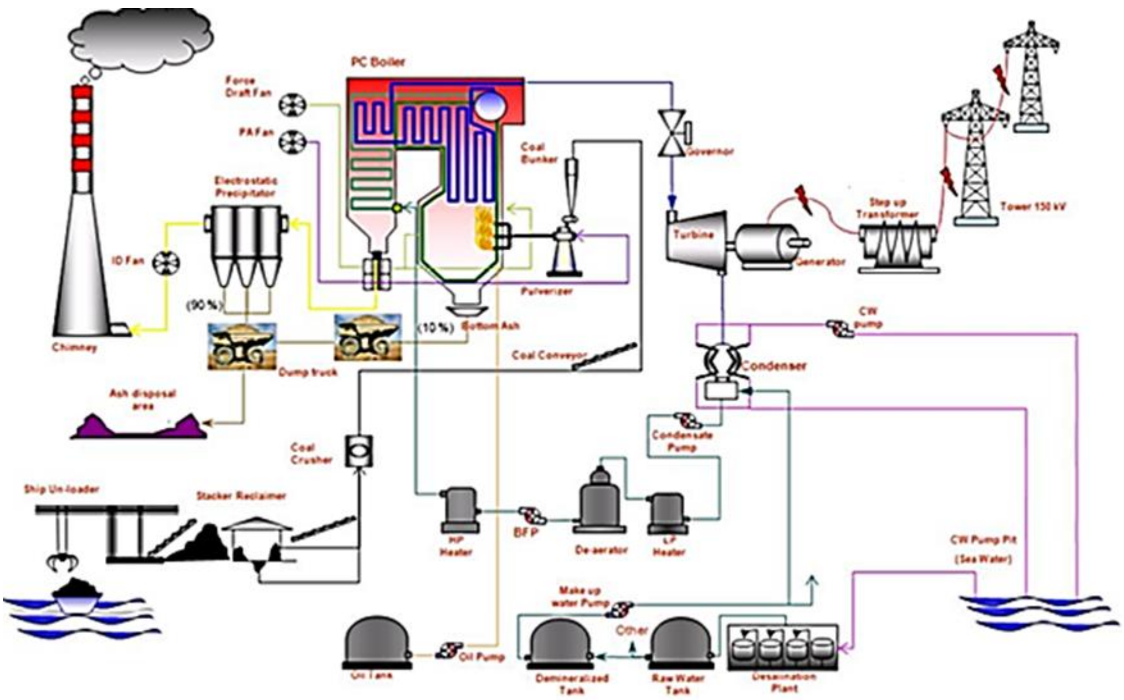


**Figure 1 Power Plant Production Process Flow (PLN Corporate University, 2014)**

Through the Boiler unit, water is converted into steam by heat generated from combustion in the Boiler combustion chamber, until it reaches the *superheat* vapor phase. Steam superheat then flowed through the turbine, so the turbine is able to rotate the generator for generate power electricity.

Amurang power plant is a power plant that uses a type of Circulating Fluidized Bed (CFB) boiler. The combustion concept of this CFB boiler is:

- CFB Boilers are able to burn with low emission levels (SOx and NOx are very low)
- Coal is burned in the floating "bed of material" and circulates in the furnace due to high air velocity, which causes fluidization of the bed material.
- Bed infentory consists of fuel, Sorbent, Inert sand, and reinjected coal from the cyclone.

The coal combustion process that occurs in the CFB Boiler, are:

- Coal and limestone are put into the Furnace, as well as fluidizing water / primary water from plenum water through the grate nozzle.
- Turbulent flow causes coal to quickly mix with limestone evenly on the bed material. Fluidizing water and bed temperatures causes the material to burn and circulation.
- Material that has been burnt rises to the top of the furnace for a long time because of its reduced mass then enters the cyclone separator through the transition piece, so that the flue gas and fly ash are separated from the material.
- The solid material rotates to the cyclone outlet cone with the help of air from the fluidizing air blower to the seal pot and is injected back into the furnace through the return pot duct seal.

## 3. Boiler Heat Rate and Efficiency

### 3.1 Corrected Net Power Output

$$P_{\text{Corrected Net}} = P_{\text{corrected Gross}} - P_{\text{Auxiliary}} + P_{\text{Common Aux (PT)}} - P_{\text{Common Aux (daily)}}$$

- $P_{\text{Corrected Net}}$ = Corrected Net Power Output, kW
- $P_{\text{Gross}}$ = Corrected Gross Power Output at Generator Terminal, kW
- $P_{\text{Auxiliary}}$ = Total Auxiliary Power, kW
- $P_{\text{Common Aux (PT)}}$ = Measured value for common Aux Consumption during performance test
- $P_{\text{Common Aux (PT) (daily)}}$ = Measured value for common Aux Consumption during 24 hr

### 3.2 Corrected Gross Power Output

$$P_{\text{Corrected Gross}} = P_{\text{Measured Gross}} + \Delta_1 + \Delta_2 + \Delta_3$$

- $P_{\text{corrected Gross}}$ = Measured Gross Power Output, kW
- $\Delta_1$ = Correction Factor for Power Factor
- $\Delta_2$ = Correction Factor for Process Steam Flow
- $\Delta_2$ = Correction Factor for Cooling Water Temperature

### 3.3 Corrected Plant Nett Heat Rate

$$\text{HR Corrected} = \frac{[(Msh\,x\,H_{SH} - Wfx H_{FW}) + W_{sh}\,x\,(H_{SH} - Hsf)]}{Eff_{\text{Corrected}}\,x\,P_{\text{corrected}}} \text{ kCal/kW}$$

- $HR_{Corrected}$ = Corrrected Plant Net Heat Rate, kCal/kW

- $Eff_{Corrected\ boiler}$ = Corrected Boiler Efficiency, (%)
- $P\ Corr$ = Corrected Net Electrical Power Output, (kW)
- $Wf$ = Final Feedwater Flow, ( kg/hr)
- $Msh$ = Main steam Flow (kg/hr)
- $W_{sh}$ = Superheater Spray Flow, [ kg/hr]
- $H_{SH}$ = Main steam Enthalpy lkCal/kg]
- $H_{FW}$ = Feed water Enthalpy, [ kCal/kg]
- $H_{shf}$ = Super heater Spray Enthalpy,[ kCal/kg]

### 3.4 Boiler Efficiency

$$\text{Eff. Boiler} = 100 - [\, L_1 + L_2 + L_3 + L_4 + L_5 + L_6 + L_7 + L_8 + L_9 \,]$$

- $L_1$ = Heat loss due to dry flue gas, %
- $L_2$ = Heat loss due to mosturein fuel, %
- $L_3$ = Heat loss due to moisture from the combustion of H2 in the fuel, %
- $L_4$ = Heat loss due to moisture in air, %
- $L_5$ = Heat loss due to Surface Radiation %

The radiation loss use in the calculation shall be in accordance with ASME PTC 4.2 ABMA chart. This could be agreed to be 0,3% based on HHV'

- $L_6$ = Heat loss due to Unburned carbon %
- $L_7$ = Heat loss due to Sensible heat in Bed Ash, %
- $L_8$ = Heat loss due to sensible heat in Flue dust, %
- $L_9$ = Heat loss due to unaccounted loss % [0,2% design value applied]
- $L_{10}$ = Heat loss due to formation carbon monoxide

### 3.5 Plant Heat Rate Input – Output Energy Metode

$$\text{Eff. Boiler} = 100 - [\, L_1 + L_2 + L_3 + L_4 + L_5 + L_6 + L_7 + L_8 + L_9 \,]$$

For the purpose of commercial electricity purchase transactions with normal operating conditions, the plant heat rate can be calculated using the following formula :

Gross Plant Heat Rate = Amount of Fuel x HHV/Generator Power Output

Nett Plant Heat Rate = Amount of Fuel x HHV/Power after main trafo

Dimana :

a. The amount of fuel is recorded from the coal flowmeter every 30 minutes for 1 hour.

b. HHV (High Heating Value) is the calorific value of coal as received (AR) obtained from coal laboratory analysis
c. Generator Power Output is electrical energy coming out of the generator.
d. Power after playing a transformer is electrical energy sent to the Java-Bali System.

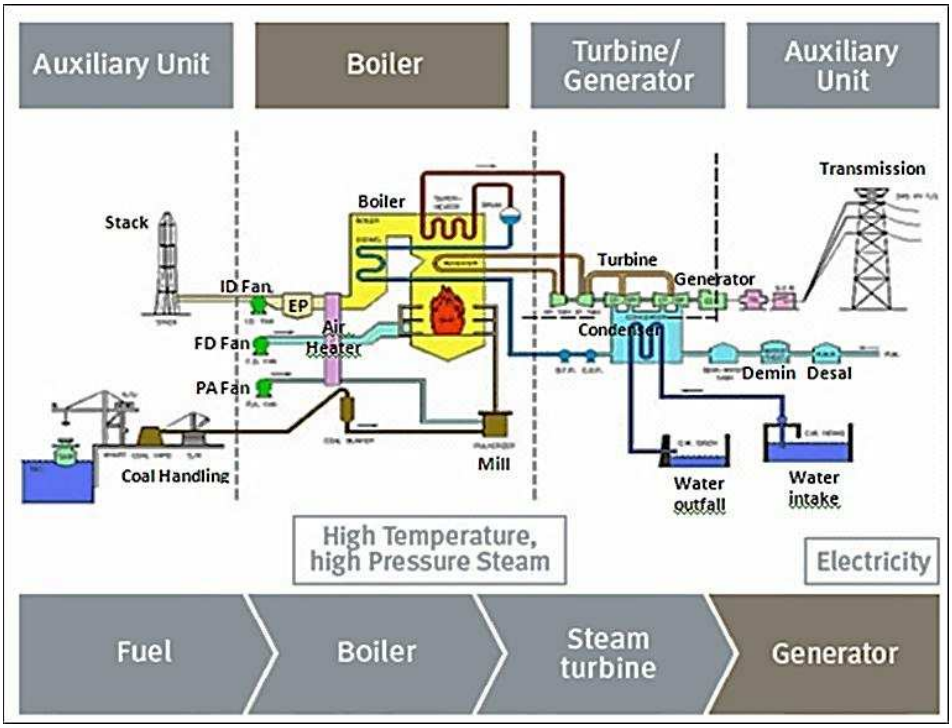


**Figure 2 Flow of energy conversion at PLTU (PLN Corporate University, 2014)**

## 3.6 Testing Procedure

[1] The heat rate testing time (data collection) is 60 minutes and 120 minutes for stabilization.
[2] Local data collection is carried out every 10 minutes
[3] DCS data collection is carried out every 10 minutes
[4] Coal and ash sampling is done every 30 minutes
[5] Coal and ash samples are divided into 3 (three) (1 Sucofindo sample, 1 Indonesia Power sample and 1 ireire sample)
[6] Flue gas sampling is carried out after ESP.

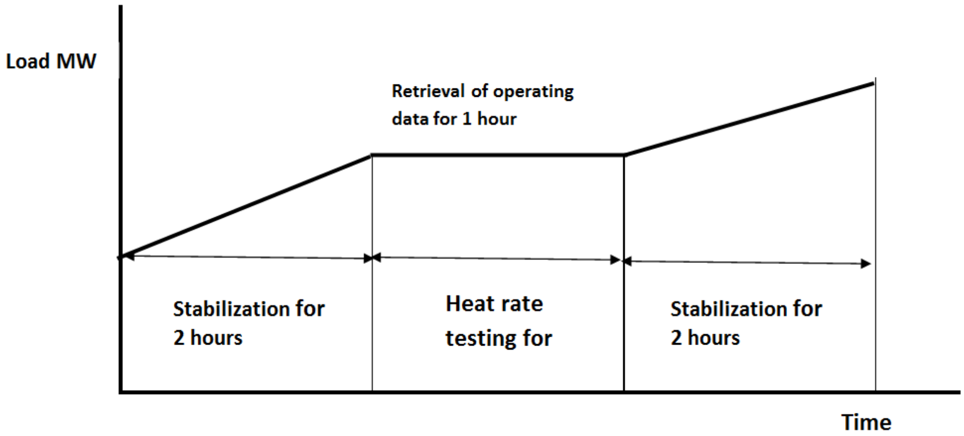


**Figure 3 Procedure for Loading the Performance Test**

## 4. Boiler Efficiency

### 4.1 Coal Analysis Results

**Table 1 Results of coal performance test analysis**

| PARAMETER | 50% | | | | 75% | | | | 85% | | | | 100% | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ar | ad | db | daf | ar | ad | db | daf | ar | ad | db | daf | ar | ad | db | daf |
| **Proximate Analysis (% as received)** | | | | | | | | | | | | | | | | |
| Total Moisture (TM) | 36.78 | | | | 34.07 | | | | 34.85 | | | | 36.05 | | | |
| Inherent Moisture (IM) | | 20.78 | | | | 17.64 | | | | 20.04 | | | | 21.46 | | |
| Ash | 3.58 | 4.48 | 5.66 | | 3.86 | 4.82 | 7.31 | | 3.77 | 4.63 | 5.79 | 0.00 | 3.44 | 4.22 | 5.37 | |
| Volatile Matter (VM) | 30.72 | 38.49 | 48.59 | 52.22 | 30.79 | 38.46 | 58.33 | 49.60 | 30.90 | 37.92 | 47.42 | 50.34 | 30.96 | 38.02 | 48.41 | 51.16 |
| Fixed Carbon (FC) | 28.93 | 36.25 | 45.76 | 47.78 | 31.28 | 39.08 | 59.27 | 50.40 | 30.48 | 37.41 | 46.79 | 49.66 | 29.56 | 36.30 | 46.22 | 48.84 |
| ***Total*** | | | | | | | | | | | | | | | | |
| **Specific Energy (as received)** | | | | | | | | | | | | | | | | |
| Higher Heating Value (kCal/kg) | 4,049 | 5,073.74 | 6,404.62 | 7,121 | 4,379 | 5,470 | 8,296.68 | 7,054.76 | 4,207 | 5,163 | 6,457 | 6,854.30 | 4,077 | 5,008 | 6,375 | 6,737 |
| **Ultimate Analysis (% dry ash free)** | | | | | | | | | | | | | | | | |
| Carbon (C) | 42.14 | 52.80 | 73.54 | 70.65 | 46.69 | 58.33 | 88.47 | 74.19 | 44.61 | 55.57 | 68.47 | 72.68 | 44.43 | 54.57 | 69.48 | 73.42 |
| Hydrogen (H) | 3.22 | 4.03 | 6.64 | 5.40 | 3.44 | 4.30 | 6.52 | 5.54 | 3.35 | 4.17 | 5.14 | 5.46 | 3.30 | 4.05 | 5.16 | 5.45 |
| Nitrogen (N) | 0.62 | 0.78 | 0.98 | 1.04 | 0.77 | 0.96 | 1.46 | 1.24 | 0.70 | 0.87 | 1.07 | 1.13 | 0.68 | 0.84 | 1.06 | 1.12 |
| Oxygen (O) | 13.53 | 16.95 | 12.22 | 22.68 | 11.63 | 14.53 | 22.04 | 18.74 | 12.55 | 15.74 | 19.26 | 20.41 | 11.96 | 14.69 | 18.70 | 19.76 |
| Sulphur (S) | 0.16 | 0.20 | 0.26 | 0.27 | 0.18 | 0.22 | 0.34 | 0.29 | 0.20 | 0.21 | 0.31 | 0.33 | 0.18 | 0.22 | 0.28 | 0.30 |
| ***Total*** | ***59.67*** | ***74.77*** | ***93.64*** | ***100.04*** | ***62.71*** | ***78.34*** | ***118.82*** | ***100.00*** | ***61.41*** | ***76.55*** | ***94.25*** | ***100.00*** | 61.94 | 71.16 | 91.00 | 100.00 |
| **FLY ASH** | | | | | | | | | | | | | | | | |
| Total Moisture(%) | 0.13 | | | | 0.18 | | | | 0.12 | | | | 0.16 | | | |
| Unburned carbon (%) | 0.48 | | | | 0.30 | | | | 0.40 | | | | 0.44 | | | |
| Gross CaloricValue (kCal/kg) | 0 | | | | 0 | | | | 0 | | | | | | | |
| **BOTTOM ASH** | | | | | | | | | | | | | | | | |
| Total Moisture(%) | 0.17 | | | | 0.11 | | | | 0.14 | | | | 0.10 | | | |
| Unburned carbon (%) | 0.09 | | | | 0.17 | | | | 0.22 | | | | 0.18 | | | |
| Gross CaloricValue (kCal/kg) | 5.00 | | | | 2.00 | | | | 3.50 | | | | | | | |

### 4.2 Results of Boiler Efficiency Calculations

**Table 2 Efficiency of Heat Loss Boilers and Input-Output**

| URAIAN | UNIT | 50 % MCR | 75 % MCR | 85%MCR | 100% MCR |
|---|---|---|---|---|---|
| Tanggal test | | 20-Feb-2018 | 20-Feb-2018 | 20-Feb-2018 | 20-Feb-2018 |
| EFISIENSI BOILER (Input -Output) | % | 74.06 | 72.24 | 76.58 | 80.55 |
| EFISIENSI BOILER (Heat Loss) | % | 83.61 | 84.03 | 83.51 | 82.84 |

From the boiler efficiency table above, the highest boiler efficiency is at 75% load, which is 84.03%

because the caloric quality is better at 4379 kcal / kg, then followed by 85% load efficiency 83.51%. At 50% load high efficiency due to lower heat loss flue gas compared to other generator loads [5].
While the efficiency of the boiler calculation of input output is lower than the heat loss method, this can occur in a combustion reaction when a Bouduard $CO2 + C = 2CO$ Δ H - 6,000 kCal / kg reaction occurs. So there is heat needed for the Bouduard reaction unit.

### 4.3 Heat Rate and Generating Efficiency

Calculation of plant heat input input method is lowest at 100% load, which is 3118.91 kCal / kWh. While the calculation with the lowest heat loss method at a load of 75%, this situation is caused by a 75% load high boiler efficiency (84,03%).

Calculation of net plant heat with the lowest input output method at a load of 100% is equal to 3682.10 kCal / kWh. Whereas if using the lowest heat loss heat rate method at 75% load, this is due to the relatively high boiler efficiency of 84.03%. At a 50% load, the heat rate is quite high because in addition to the low load the electricity usage is quite high, i.e.18,36%

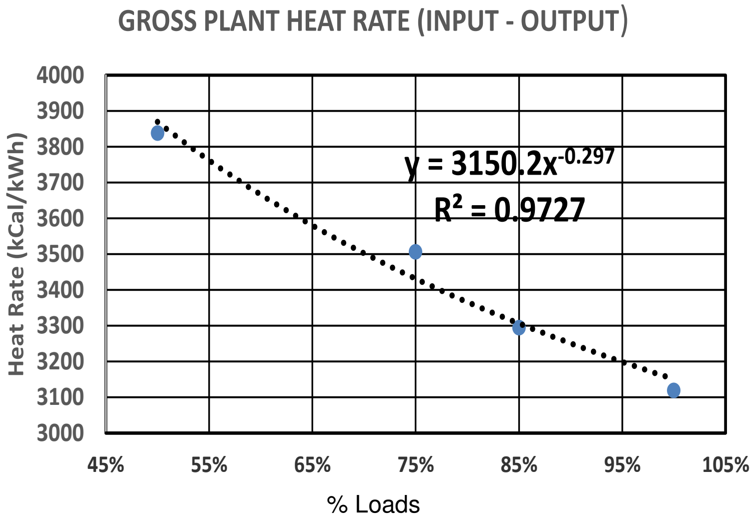


**Figure 4 Gross Plant Heat Rate Input – Output**

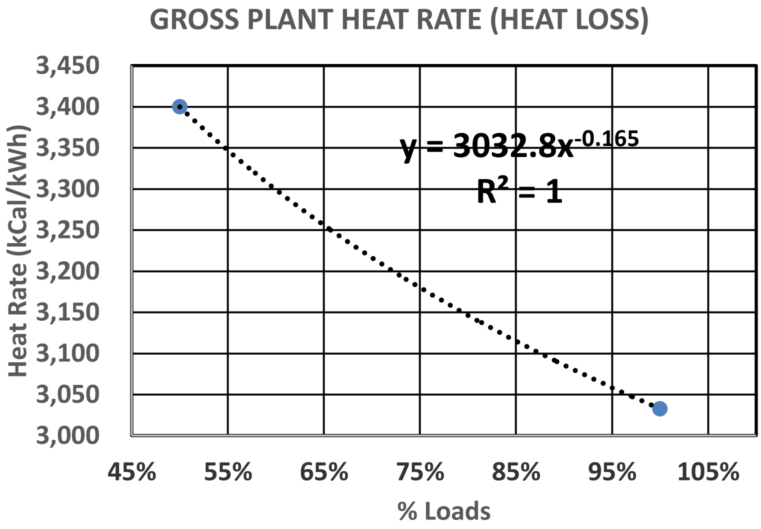


**Figure 5. Gross Plant Heat Rate (Heat loss)**

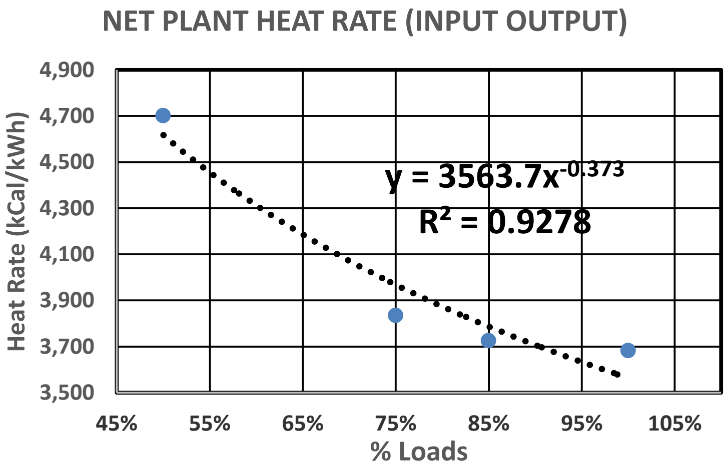


**Figure 5 Net Plant Heat Rate (Input Output)**

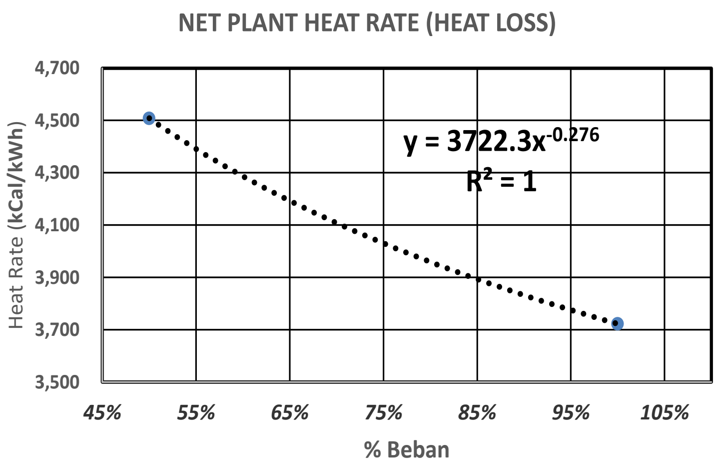


**Figure 6 Net Plant Heat Rate (Heat loss)**

## 4.4 Specific Fuel Consumption(SFC)

| URAIAN | UNIT | 50 % MCR | 75 % MCR | 85%MCR | 100% MCR |
|---|---|---|---|---|---|
| **Tanggal test** | | **20-Feb-2018** | **20-Feb-2018** | **20-Feb-2018** | **20-Feb-2018** |
| NILAI KALOR BATUBARA | kCal / kg | 4,049 | 4,379 | 4,207 | 4,077 |
| SFC heat loss | kg / kWh | 0.84 | 0.69 | 0.72 | 0.74 |
| SFC input output | kg / kWh | 0.95 | 0.80 | 0.78 | 0.77 |
| PEMAKAIAN BATUBARA | Ton / Jam | 14.20 | 17.98 | 19.85 | 22.95 |

SFC calculation for the lowest heat loss method at a load of 70% is 0.69 kg / kWh because the boiler efficiency is relatively high, whereas the SFC calculation of the lowest input output method at 100% load due to the higher load the generator is more efficient.

## 4.5 SO2 Emissions in Flue Gas

| URAIAN | UNIT | 50 % MCR | 75 % MCR | 85%MCR | 100% MCR |
|---|---|---|---|---|---|
| **Tanggal test** | | **20-Feb-2018** | **20-Feb-2018** | **20-Feb-2018** | **20-Feb-2018** |
| Emisi Sox | **mg/Nm3** | 322.00 | 401.00 | 504.00 | 495.00 |
| Emisi Sox | **ppm v/v** | 404 | 328.00 | 412.00 | 404.00 |
| Temperature stack gas buang | **oC** | 94.9 | 106.40 | 116.60 | 126.00 |
| Temperature dew point | **oC** | 113.40 | 116,4 | 119.00 | 118.00 |

The SO2 emissions table above shows that SO2 emissions are still below the LH quality standard standard of 750 mg / Nm3 (LH Regulation No.21 of 2008). But the dew point temperature is around 113 - 116 oC, still slightly higher than the stack temperature.

## 5. Conclusion

1. Efficiency Boiler power plant Amurang Unit I through energy method of energy input-output , the highest in the load of 100 %, ie 8 0 , 55 % and the lowest in the burden of 75 %, ie 72 , 24 %

2. Efficiency Amurang PLTU Boiler Unit I through the method of heat loss , the highest at a load of 75 %, namely 8 4 , 03 % while the lowest at a load of 100 %, namely 8 2 , 8 4 %

3. The efficiency of the boiler based on the calculation of input energy output is more h than the heat loss method . So that the optimal load limit that can be guided is at 75% loading

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