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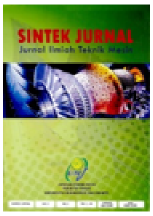

ANALYSIS OF BOILER EFFICIENCY AND NPHR WITH THE USE OF SOOT BLOWER IN A 315 MW COAL-FIRED POWER PLANT

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ABSTRACT

In the power generation sector, particularly in Indonesia, coal-fired power plants remain a key source of electricity. The Lontar Extension Coal-Fired Steam Power Plant (PLTU) (1x315 MW) is a significant facility that plays a critical role in ensuring a stable electricity supply to the Jakarta area and its surroundings. One of the major operational challenges faced by the plant is managing the ash produced during coal combustion, which leads to slagging and fouling on boiler tube surfaces. These phenomena impair heat transfer efficiency and increase fuel consumption. Given the growing emphasis on operational efficiency and sustainability in the power generation industry, addressing these challenges is of paramount importance. In this research, we conduct a comprehensive analysis of key performance parameters, such as Net Plant Heat Rate (NPHR) and boiler efficiency, at the Lontar Extension PLTU. A particular focus is placed on the use of soot blowers in the Heat Recovery Area (HRA) to mitigate slagging and fouling issues. This study offers unique insights by quantifying the benefits of soot blower operation, which resulted in a 0.71% increase in boiler efficiency and a 33.91 kcal/kWh decrease in NPHR at 100% load, and a 0.63% increase in boiler efficiency and 47.16 kcal/kWh reduction in NPHR at 50% load. Additionally, the soot blowers contributed to increased net power output and reduced coal consumption, highlighting the innovation in boiler cleaning techniques and their significant impact on fuel efficiency.

Keywords: boiler efficiency; Net Plant Heat Rate (NPHR); slagging; fouling; heat recovery area

ABSTRAK

Di sektor pembangkit listrik, khususnya di Indonesia, pembangkit listrik tenaga batu bara masih menjadi sumber utama listrik. Pembangkit Listrik Tenaga Uap (PLTU) Batubara Lontar Extension (1x315 MW) adalah fasilitas penting yang memainkan peran penting dalam memastikan pasokan listrik yang stabil ke wilayah Jakarta dan sekitarnya. Salah satu tantangan operasional utama yang dihadapi oleh PLTU ini adalah mengelola abu yang dihasilkan selama pembakaran batu bara, yang menyebabkan terjadinya slagging dan fouling pada permukaan tabung boiler. Fenomena ini mengganggu efisiensi perpindahan panas dan meningkatkan konsumsi bahan bakar. Dengan meningkatnya penekanan pada efisiensi operasional dan keberlanjutan dalam industri pembangkit listrik, mengatasi tantangan ini menjadi sangat penting. Dalam penelitian ini, kami melakukan analisis komprehensif terhadap parameter kinerja utama, seperti Net Plant Heat Rate (NPHR) dan efisiensi boiler, di PLTU Lontar Extension. Fokus khusus diberikan pada penggunaan soot blower di Heat Recovery Area (HRA) untuk mengurangi masalah slagging dan fouling. Studi ini menawarkan wawasan yang unik dengan mengkuantifikasi manfaat dari pengoperasian soot blower, yang menghasilkan peningkatan efisiensi boiler sebesar 0,71% dan penurunan NPHR sebesar 33,91 kkal/kWh pada beban 100%, serta peningkatan efisiensi boiler sebesar 0,63% dan penurunan NPHR sebesar 47,16 kkal/kWh pada beban 50%. Selain itu, blower jelaga berkontribusi pada peningkatan output daya bersih dan pengurangan konsumsi batubara, menyoroti inovasi dalam teknik pembersihan boiler dan dampaknya yang signifikan terhadap efisiensi bahan bakar.

***Kata Kunci**: efisiensi boiler; Net Plant Heat Rate (NPHR); slagging; fouling; area pemulihan panas*

1. Introduction

Amid global climate change and the drive for environmental sustainability, the power generation sector faces significant pressure to transition toward cleaner and more sustainable energy sources. Despite this trend, coal-fired power plants continue to serve as a primary energy source for meeting electricity demands in various countries, including Indonesia. These plants remain a cornerstone of the national energy strategy, offering a cost-effective solution with coal being readily available due to the abundance of domestic coal mines [1]. Among the prominent coal-fired power plants in Indonesia is the Lontar Extension 4 Coal-Fired Power Plant (1 x 315 MW) [2], which is part of a national strategic project. This facility plays a critical role in ensuring a stable electricity supply, particularly for Jakarta and its surrounding areas, thus underscoring its strategic importance.

Figure 1. Lontar Power Plant Unit 4
(Source: Personal Documentation, 2022)

The Lontar Unit 4 facility is equipped with a boiler, a critical component designed to convert liquid fluid into superheated steam under operational parameters of 550°C and 25 MPa. The steam drives the turbine rotor to generate electricity. The boiler operates on coal as its primary fuel, with a capacity of 42 tons/hour per pulverizer to achieve full load (O&M Document, PLTU Lontar Unit 4). However, the combustion of coal poses significant operational challenges, particularly regarding the management of ash generated during the process.

Ash accumulation in the flue gas represents one of the main challenges in coal-fired power plants, including PLTU Lontar Unit 4. Ash, especially in its molten state, can adhere to and solidify on convection heating surfaces, such as the Superheater, Economizer, Reheater, and Air Heater. This accumulation reduces heat transfer efficiency, increases fuel consumption, and may lead to equipment damage [3-5]. If left unaddressed, soot deposition on boiler tube surfaces further impairs heat transfer, ultimately affecting both boiler efficiency and overall plant performance [6,7]. Consequently, regular maintenance and the deployment of soot blowers are essential to remove residual soot and maintain optimal boiler operation.

Performance testing of coal-fired power plants serves as a benchmark to evaluate whether the plant operates within its design specifications. Among the key performance parameters is the Net Plant Heat Rate (NPHR), which reflects the thermal efficiency of the plant. The NPHR measures the amount of fuel or thermal energy supplied to the boiler to generate 1 kWh of electricity, typically expressed in kJ/kWh or kcal/kWh [8-10]. A lower NPHR indicates higher efficiency [11]. As environmental concerns surrounding coal-fired power plants escalate, improving boiler efficiency becomes imperative to reduce emissions and enhance the sustainability of plant operations [12]. The utilization of soot blowers is instrumental in maintaining boiler efficiency by removing soot deposits, enhancing heat transfer, lowering NPHR, and optimizing fuel consumption [13].

This study aims to analyze boiler efficiency and Net Plant Heat Rate (NPHR) as critical performance parameters while highlighting the pivotal role of soot blowers in sustaining boiler efficiency in coal-fired power plants. Such analyses are especially relevant within the current context of the power generation industry, which increasingly prioritizes efficiency and sustainability.

2. Methods

Research Approach

This study adopts a comparative quantitative method, designed to compare the operational performance of PLTU Lontar Unit 4 before and after the use of a soot blower. The research approach focuses on analyzing actual operational data obtained from the plant's Distributed Control System (DCS) under different load conditions. The quantitative analysis allows for identifying differences and similarities in performance metrics, making it possible to assess the impact of soot blower operation on plant efficiency [14,15]. The following is the research flow diagram.

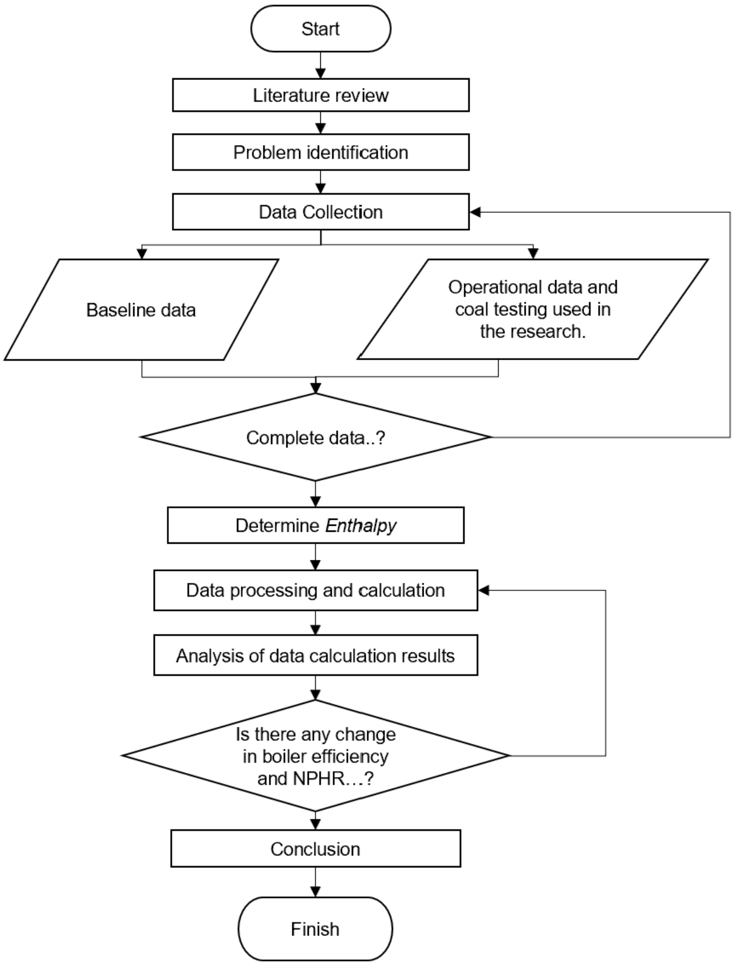

Figure 2. Experiment Flowchart

Data Collection

The data collection was conducted over two operational load conditions:

Full Load 100% (±315 MW): Data were recorded from October 19, 2023, to October 27, 2023.

50 % Load (±157.5 MW): Data were collected from November 2, 2023, to November 11, 2023.

In each of these periods, measurements were taken three times before and after the soot blower was activated, capturing its operational impact on key performance metrics. The soot blower functions as part of the plant's maintenance system, clearing ash and soot deposits on boiler tubes [16].

Operating Parameters and Measurement Tools

Key operational parameters monitored include steam parameters (flow rate, temperature, and pressure), feedwater parameters (flow rate, pressure, and temperature), fuel consumption, GCV of coal, power consumption, and generator output. The DCS control system was used to log and monitor these parameters during operation [17]. The soot blower operates at scheduled intervals to clean boiler tubes, which improves the heat transfer process and, consequently, boiler efficiency [18].

Data Processing and Key Parameter Calculations

After the data collection phase, several key performance indicators were computed, including:

- Boiler Efficiency is calculated using the heat balance method, which compares energy input (fuel energy) to energy output (useful heat) [19].
- Total Heat Rate (THR) reflects the total amount of energy required to generate a unit of electricity.
- Gross Plant Heat Rate (GPHR) measures the energy consumption per unit of gross electricity output.
- Net Plant Heat Rate (NPHR) considers the auxiliary power consumption, providing a more accurate measure of plant efficiency.

The calculations for these parameters were based on the standard thermodynamic equations used in power plant performance analysis. In particular, the enthalpy values were employed to determine the energy flows and efficiency improvements.

In the experimental, there are equations required for analysis including:

Turbine Heat Balance

Extraction flow

Extraction flow refers to the extraction of steam flows 1 and 2 that outlet the turbine, functioning as preheaters in the power generation system, thereby increasing system efficiency.

$$M_{h1ext} = M_{ffw}x(H_{ffw} - \frac{H_{h1\in)}}{(H_{h1ext} - H_{h1drn})} \tag{1}$$

$$M_{h2ext} = M_{ffw}x \tag{2}$$

where,

M_{h1ext} = Extraction Flow for HP heater 1, kg/hr

M_{h2ext} = Extraction Flow fork HP heater 2, kg/hr

M_{ffw} = Feedwater Flow for outlet HP heater 1, kg/hr

H_{hzin} = Feedwater Entalphy for inlet HP heater Z, where Z= 1,2 kJ/kg

H_{hzext} = Extraction Entalphy for inlet HP heater Z, where Z= 1,2 kJ/kg

H_{hzdrn} = Heater Drain Entalphy for HP heater Z, where Z= 1,2, kJ/kg

H_{do} = Feedwater Entalphy for BFP, kJ/kg

H_{dv} = Deaerator tank saturated steam enthalpy, kJ/kg

H_{con} = Condensate water enthalpy to deaerator, kJ/kg

Seal Leakage

Seal leakage can be calculated using the equation

$$M_{hpslk} = G_{s3} + G_{s2} + G_2 + G_{11} + G_{12} + G_{s1} \tag{3}$$

where,

G_{s3} = CV steam leak untuk SSH line, kg/hr

G_{s2} = CV steam leak untuk IP Extraction, kg/hr

G_2 = #2 (Mid Span) steam packing leak-off flow, kg/hr

G_{11} = #1 gland steam packing leak-off flow, kg/hr

G_{12} = #1 gland steam seal flow, kg/hr

G_{s1} = CV steam leak untuk HP Extraction, kg/hr

Cold Reheat and Hot Reheat

$$M_{crh} = M_{ms} - M_{ex1} - M_{ex2} - M_{hpslk} \tag{4}$$

$$M_{hrh} = M_{crh} + M_{rhs} \tag{5}$$

where,

M_{rhs} = Spray Desuperheating Reheat Flow from BFP, kg/hour

Boiler Efficiency

Boiler efficiency can be calculated direct method (Input-Output)

$$\eta_B = \frac{(m_{sf}h_1 - m_{ffw}h_2) + (m_{hr}h_3 - m_{cr}h_4)}{m_{bb}GCV} \tag{6}$$

THR

The calculation of THR (Turbine Heat Rate) can be calcuated.

$$T_{hr} = \frac{(M_{ms}xH_1 - M_{ffw}xH_2) + (M_{hrh}xH_3 - M_{crh}xH_4) - (M_{aux}xH_5 - M_{sh}xH_6 - M_{rh}xH_7)}{Pgross} \tag{7}$$

GPHR

The following is the formula for calculating GPHR (Gross Plant Heat Rate).

$$GPHR = \frac{m_{bb}xGCV}{P_{gross}} \tag{8}$$

NPHR

The following is the formula for NPHR (Net Plant Heat Rate) where the thermal energy required to produce net power is considered.

$$NPHR = \frac{(M_{ms}xH_1 - M_{ffw}xH_2)+(M_{hrh}xH_3 - M_{crh}xH_4) - (M_{aux}xH_5 + M_{sh}xH_6 + M_{rh}xH_7)}{Pnet.\eta_B} \tag{9}$$

where,

P_{net} = Power netto, (kW)
P_{gross} = Power output generator (kW)
M_{ms} = Main Steam Flow at Boiler Outlet, kg/hr
M_{hrh} = Main Steam Enthalpy at Boiler Outlet, kJ/kg
H_3 = Hot Reheat Steam Flow at Boiler Outlet, kg/hr
M_{ffw} = Feedwater Flow at HP Heater 1 Outlet i.e. boiler inlet, kg/hr
H_2 = Feedwater Enthalpy at HP Heater 1 Outlet i.e. boiler inlet, kJ/kg
M_{crh} = Cold Reheat Flow at Boiler reheater Inlet, kg/hr
H_4 = Cold Reheat Enthalpy at Boiler reheater Inlet, kJ/kg
M_{aux} = Auxiliary steam flow, kg/hr
H_5 = Auxiliary steam enthalpy, kJ/kg
M_{sh} = Superheater spray flow, kg/hr
H_6 = Superheater spray enthalpy, kJ/kg
M_{rh} = Reheater spray flow, kg/hr
H_7 = Reheater spray enthalpy, kJ/kg

Scope and Limitations

The study focuses on two operational conditions full load and partial load (50%) operations. Based on operational data from PLTU Lontar Unit 4, collected between October and November 2023. During this period, the plant was operating under normal conditions at full load, using Low-Rank Coal (LRC) with a High Heating Value (HHV) between 3900 and 4500 kcal/kg.

The boiler efficiency was calculated using the indirect method (input-output) according to the ASME standard, which evaluates efficiency by accounting for heat losses [20]. The Net Plant Heat Rate (NPHR) was determined using the Steam Turbine Heat Balance method, assessing how effectively the plant converts heat into electrical energy [21]. The operation of the soot blower was focused on the Heat Recovery Area (HRA), where soot buildup can reduce heat transfer. Regular soot blowing helps maintain efficiency in this critical area [22].

After all the data is obtained, the next step is to determine the enthalpy value and calculate several key parameters, including boiler efficiency, THR, GPHR, and NPHR. The calculation results will be used to analyze the performance of the power plant using a soot blower with a quantitative approach to compare two or more conditions.

3. Result and Discussion

Result

The following is a summary of the calculation results for boiler efficiency, turbine heat rate (THR), gross plant heat rate (GPHR), and net plant heat rate (NPHR) under normal operation and after employing the soot blower. These performance metrics, which are critical in assessing the operational efficiency of a coal-fired power plant, show significant changes when comparing the two conditions. Based on the data presented in Tables 1, 2, and 3, it is evident that the boiler efficiency has increased, while the values for THR, GPHR, and NPHR have decreased, reflecting improvements in both energy utilization and overall system performance.

The differences observed between the calculated results and the tabulated data highlight the impact of using the soot blower on plant efficiency. By removing soot and ash deposits from heat exchange surfaces, the soot blower enhances heat transfer efficiency and reduces system resistance, leading to better combustion and energy conversion processes. The improvements in boiler efficiency and the reductions in heat rate values underscore the effectiveness of this maintenance practice in optimizing plant performance. A detailed breakdown of these differences is provided to further illustrate these enhancements.

Table 1. 100% Load Calculation Results

Date	Before Soot Blower					After Soot Blower				
	MW	E. Boiler	THR	GPHR	NPHR	MW	E. Boiler	THR	GPHR	NPHR
Load 100 %										
19-Oct-2023	298.43	81.170%	1706.86	2080.41	2218.82	298.70	81.574%	1668.11	2068.63	2156.69
	298.58	81.046%	1681.93	2092.10	2189.64	298.26	80.996%	1660.16	2078.10	2163.34
	298.42	81.114%	1678.06	2087.95	2182.85	298.64	81.102%	1648.94	2062.48	2145.21
Average	298.47	81.110%	1688.95	2086.82	2197.10	298.53	81.224%	1659.07	2069.73	2155.08
20-Oct-2023	298.51	78.769%	1658.06	2131.71	2220.94	299.55	81.689%	1670.85	2069.99	2156.00
	298.52	79.053%	1651.90	2117.78	2205.06	298.67	80.260%	1646.36	2078.53	2162.88
	298.47	78.282%	1622.72	2106.14	2187.02	299.01	79.753%	1589.95	2029.19	2100.31
Average	298.50	78.702%	1644.23	2118.54	2204.34	299.08	80.567%	1635.72	2059.24	2139.73
21-Oct-2023	298.38	83.880%	1738.76	2085.11	2188.05	299.03	84.128%	1725.69	2065.80	2161.38
	298.56	84.116%	1762.70	2111.48	2210.71	298.76	84.143%	1752.32	2093.34	2195.32
	298.58	83.793%	1766.75	2124.88	2224.15	298.91	84.591%	1749.54	2076.25	2180.27
Average	298.50	83.930%	1756.07	2107.16	2207.64	298.90	84.287%	1742.52	2078.46	2178.99
22-Oct-2023	297.54	84.469%	1737.02	2079.33	2168.94	298.29	85.422%	1766.36	2083.19	2183.20
	296.63	85.347%	1788.52	2110.03	2211.48	298.42	86.783%	1802.05	2083.76	2191.71
	298.45	85.856%	1814.12	2121.54	2229.10	298.47	84.794%	1752.44	2086.10	2180.50
Average	297.54	85.224%	1779.89	2103.63	2203.17	298.39	85.666%	1773.62	2084.35	2185.14
23-Oct-2023	298.37	82.710%	1743.94	2124.05	2225.73	299.05	85.564%	1775.91	2085.28	2186.63
	298.32	85.122%	1761.01	2084.34	2183.09	298.87	85.725%	1790.34	2095.94	2199.91
	298.59	85.619%	1774.50	2084.65	2186.79	299.05	82.759%	1710.39	2085.16	2177.06
Average	298.43	84.484%	1759.82	2097.68	2198.54	298.99	84.683%	1758.88	2088.79	2187.86
24-Oct-2023	298.66	82.411%	1796.37	2191.63	2298.60	299.23	83.563%	1803.55	2165.34	2273.13
	298.43	83.300%	1807.75	2178.76	2288.57	299.32	83.108%	1803.52	2177.24	2284.77
	298.97	83.318%	1804.30	2173.68	2282.50	298.97	83.391%	1799.58	2165.15	2272.19
Average	298.69	83.010%	1802.81	2181.36	2289.89	299.17	83.354%	1802.21	2169.24	2276.70
25-Oct-2023	298.77	84.234%	1784.49	2127.68	2233.50	299.06	84.993%	1797.02	2121.18	2226.62
	298.54	83.316%	1770.96	2133.89	2241.37	299.19	82.650%	1706.72	2089.71	2174.63
	298.92	82.951%	1765.75	2136.49	2243.57	299.03	83.108%	1742.99	2112.97	2208.70
Average	298.74	83.500%	1773.73	2132.68	2239.48	299.09	83.584%	1748.91	2107.95	2203.32
26-Oct-2023	293.80	82.881%	1728.89	2103.22	2201.14	293.96	88.611%	1755.44	1995.24	2089.26
	293.39	84.580%	1785.54	2121.54	2229.20	293.90	87.442%	1804.14	2070.74	2176.41
	293.45	86.356%	1817.46	2112.34	2222.27	293.84	83.985%	1743.93	2091.21	2189.36
Average	293.55	84.606%	1777.30	2112.37	2217.54	293.90	86.679%	1767.84	2052.40	2151.68
27-Oct-2023	293.81	81.301%	1735.54	2153.28	2251.96	293.96	81.841%	1717.30	2117.73	2213.18
	293.65	82.006%	1751.36	2150.50	2253.90	293.82	83.739%	1763.20	2117.04	2221.56
	293.45	83.281%	1770.31	2140.66	2244.33	293.77	83.782%	1776.64	2128.25	2237.34
Average	293.64	82.196%	1752.40	2148.14	2250.06	293.85	83.120%	1752.38	2121.01	2224.03

Table 2. 50% Load Calculation Results

Date	Before Soot Blower					After Soot Blower				
	MW	E. Boiler	THR	GPHR	NPHR	MW	E. Boiler	THR	GPHR	NPHR
Load 50 %										
2-Nov-2023	147.82	83.806%	1957.98	2349.50	2496.81	147.64	84.513%	1970.88	2344.46	2491.24
	147.93	84.477%	1961.14	2334.80	2481.82	148.07	85.358%	1967.81	2317.54	2461.98
	147.71	84.812%	1973.98	2340.70	2488.38	148.04	84.006%	1939.87	2321.61	2466.29
Average	147.82	84.365%	1964.37	2341.66	2489.00	147.92	84.626%	1959.52	2327.87	2473.17
3-Nov-2023	147.64	83.192%	2004.10	2422.26	2578.57	147.79	84.990%	1958.53	2316.58	2465.63
	147.63	85.391%	2026.31	2385.97	2539.42	147.77	85.743%	1970.22	2309.77	2459.10
	147.90	85.865%	2004.72	2347.47	2496.09	147.71	85.309%	1966.14	2316.63	2466.19
Average	147.72	84.816%	2011.71	2385.23	2538.03	147.75	85.348%	1964.97	2314.33	2463.64
4-Nov-2023	147.43	84.003%	1994.04	2316.63	2540.02	147.66	84.735%	1966.25	2332.93	2479.04
	147.74	83.929%	2010.66	2387.03	2563.62	148.17	85.466%	1981.75	2331.12	2476.17
	147.53	83.356%	1996.64	2408.67	2563.03	147.96	84.879%	1977.94	2342.78	2489.05
Average	147.57	83.763%	2000.45	2370.78	2555.56	147.93	85.027%	1975.32	2335.61	2481.42
5-Nov-2023	147.52	86.294%	2001.68	2332.77	2481.66	147.56	86.549%	1942.15	2256.49	2400.92
	147.75	85.786%	2009.19	2355.27	2505.40	147.69	86.127%	1938.21	2262.92	2407.65
	147.60	85.235%	1994.46	2353.08	2503.00	147.68	86.120%	1957.88	2286.01	2432.36
Average	147.62	85.772%	2001.78	2347.04	2496.69	147.64	86.265%	1946.08	2268.47	2413.65
6-Nov-2023	147.68	81.821%	1864.43	2292.73	2436.48	147.96	83.377%	1869.21	2255.18	2392.54
	147.57	82.068%	1879.41	2304.22	2449.12	148.06	85.819%	1892.95	2218.67	2354.97
	147.58	84.796%	1926.83	2286.00	2429.93	148.03	83.107%	1891.35	2289.13	2429.74
Average	147.61	82.895%	1890.22	2294.32	2438.51	148.02	84.101%	1884.50	2254.33	2392.42
7-Nov-2023	147.44	84.117%	1975.31	2364.29	2515.53	148.06	83.412%	1949.92	2349.87	2497.41
	147.53	83.875%	1972.82	2373.23	2520.12	148.12	84.347%	1966.51	2343.49	2491.62
	147.38	84.839%	1968.11	2344.49	2485.39	150.26	86.488%	1988.93	2311.37	2459.67
Average	147.45	84.277%	1972.08	2360.67	2507.02	148.81	84.749%	1968.46	2334.91	2482.90
9-Nov-2023	145.50	84.225%	1929.08	2302.88	2484.81	147.96	86.382%	1953.91	2273.57	2415.69
	147.78	84.977%	2011.55	2379.53	2531.99	147.85	85.751%	1981.59	2322.48	2467.15
	147.62	84.632%	1982.42	2354.93	2505.68	147.81	83.610%	1971.12	2369.57	2517.58
Average	146.97	84.611%	1974.35	2345.78	2507.49	147.87	85.248%	1968.87	2321.87	2466.81
10-Nov-2023	147.07	83.920%	1994.72	2390.04	2550.31	147.59	83.790%	1973.32	2367.99	2526.00
	146.82	84.437%	2005.14	2387.68	2548.47	147.81	86.294%	1998.72	2328.67	2480.58
	147.13	85.410%	1983.93	2336.29	2490.92	148.06	84.610%	1991.30	2366.15	2518.55
Average	147.00	84.589%	1994.60	2371.34	2529.90	147.82	84.898%	1987.78	2354.27	2508.38
11-Nov-2023	146.86	85.218%	2025.80	2389.81	2544.47	148.46	85.239%	2013.06	2373.40	2523.31
	147.02	85.988%	2025.64	2368.38	2521.08	148.98	86.650%	2001.56	2321.82	2466.70
	146.76	84.787%	2020.95	2396.49	2550.93	149.33	85.597%	1998.10	2346.51	2492.61
Average	146.88	85.331%	2024.13	2384.89	2538.83	148.93	85.829%	2004.24	2347.25	2494.21

Table 3. Load Deviation

Date	Deviation				
	MW	E. Boiler	THR	GPHR	NPHR
	Load 100 %				
19-Oct-23	0.06	0.11%	29.88	17.09	42.02
20-Oct-23	0.58	1.87%	8.51	59.31	64.61
21-Oct-23	0.40	0.36%	13.55	28.69	28.64
22-Oct-23	0.85	0.44%	6.27	19.28	18.03
23-Oct-23	0.56	0.20%	0.94	8.89	10.67
24-Oct-23	0.49	0.34%	0.59	12.11	13.19
25-Oct-23	0.35	0.08%	24.82	24.73	36.16
26-Oct-23	0.35	2.07%	9.46	59.97	65.86
27-Oct-23	0.21	0.92%	0.03	27.14	26.04
Average	0.43	0.71%	10.45	28.58	33.91

Date	Deviation				
	MW	E. Boiler	THR	GPHR	NPHR
	Load 50 %				
02-Nov-23	0.09	0.26%	4.85	13.79	15.83
03-Nov-23	0.03	0.53%	46.74	70.91	74.39
04-Nov-23	0.36	1.26%	25.13	35.17	74.14
05-Nov-23	0.02	0.49%	55.70	78.57	83.04
06-Nov-23	0.41	1.21%	5.72	39.99	46.09
07-Nov-23	1.36	0.47%	3.63	25.77	24.12
09-Nov-23	0.91	0.64%	5.48	23.90	40.69
10-Nov-23	0.82	0.31%	6.82	17.07	21.53
11-Nov-23	2.04	0.50%	19.89	37.65	44.62
Average	0.67	0.63%	19.33	38.09	47.16

Discussion

Analysis Boiler Efficiency and NPHR

Boiler Efficiency

The analysis of boiler efficiency demonstrates significant improvements following the operation of the soot blower. At 100% load, the largest efficiency increase was observed on October 26, 2023, with a rise of 2.07% (from 84.61% to 86.68%), while the smallest increase occurred on October 25, 2023, at 0.08% (from 83.50% to 83.58%). On average, the boiler efficiency at full load improved by 0.71%. At 50% load, the highest efficiency increase was recorded on November 4, 2023, with a rise of 1.26% (from 83.76% to 85.03%), and the smallest increase was 0.26% on November 2, 2023 (from 84.36% to 84.63%). This resulted in an overall average efficiency increase of 0.63%.

Boilers utilizing low-quality coal often experience higher rates of coal combustion and ash deposit accumulation, leading to fouling and slagging [23]. These deposits obstruct heat transfer in the Heat Recovery Area (HRA), elevate the exhaust gas temperature exiting the furnace, and consequently reduce boiler efficiency. The observed improvements in boiler efficiency are primarily attributed to the soot blower's ability to remove fouling and slagging from boiler tubes, thereby enhancing heat absorption in the HRA. This finding is consistent with existing literature, which reports that soot blowers effectively mitigate fouling, improve heat exchanger performance by increasing the effective heat transfer area, and reduce airflow resistance within the system [24]. By ensuring smoother gas flow and minimizing heat transfer obstructions, soot blowers play a critical role in boosting boiler efficiency [25,26].

NPHR

The operation of the soot blower consistently results in a reduction in the Net Plant Heat Rate (NPHR), highlighting its effectiveness in improving boiler efficiency. NPHR measures the amount of heat energy required to generate one unit of electrical energy, and a lower NPHR indicates enhanced performance. At 100% load, the most significant decrease in NPHR was recorded on October 26, 2023, at 65.86 kcal/kWh, while the smallest reduction occurred on October 27, 2023, at 0.03 kcal/kWh. These changes reflect the soot blower's ability to optimize boiler performance, achieving peak efficiency by reducing energy losses associated with fouling and slagging.

At partial load conditions, the impact of the soot blower remains evident. At 50% load, the largest decrease in NPHR was observed on November 5, 2023, with a reduction of 78.57 kcal/kWh, while the smallest decrease occurred on November 2, 2023, at 13.79 kcal/kWh. These reductions demonstrate that the soot blower is effective across varying operational loads, maintaining its role in improving heat transfer and reducing resistance within the boiler system. The ability to enhance performance under both full and partial load conditions makes the soot blower an essential tool for ensuring consistent efficiency improvements in power plants.

The decrease in NPHR values with soot blower operation reflects enhanced efficiency in converting heat into electrical energy. This improvement is consistent with the principle that a lower NPHR signifies a more efficient system requiring less heat input for the same electrical output [27]. Supporting literature further highlights the direct relationship between fouling mitigation, improved heat transfer efficiency, and NPHR reductions [28][29]. The high correlation between soot blower operation and improved NPHR underscores the importance of maintaining clean heat transfer surfaces. By reducing fouling and ensuring optimal heat transfer, the soot blower not only enhances boiler performance but also contributes significantly to overall plant efficiency and energy savings.

Analysis of Net Output Power and Fuel Consumption

Table 2 shows the generator power output parameters at 100% load and 50% load with the use of a soot blower.

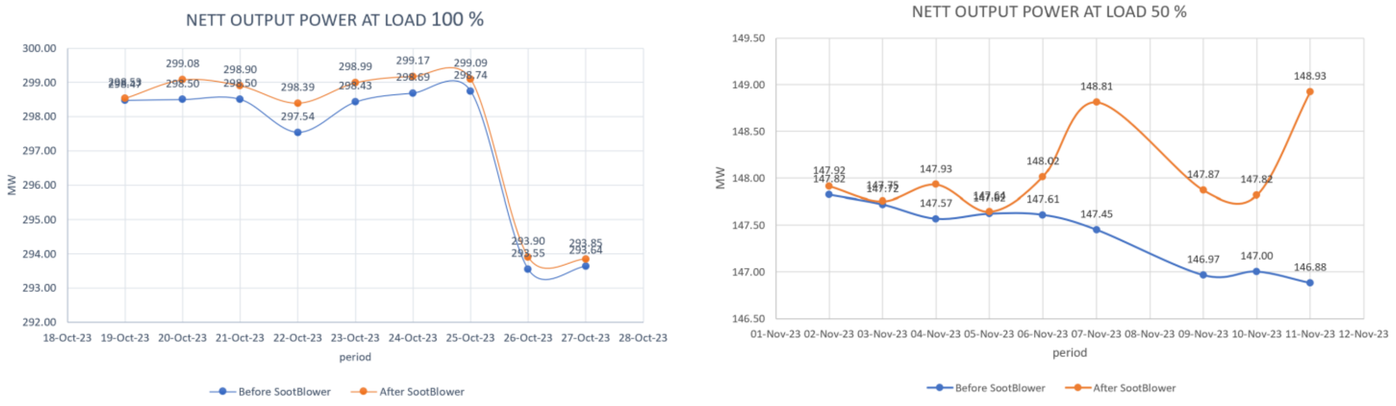

Figure 3. Load Net Power Graph

The power output changes generated by the generator, both at 100% load and 50% load, tend to fluctuate, influenced by several factors including coal calorific value, coal flow, parameter values for feedwater, main steam, cold reheat, hot reheat, SH spray, RH spray (enthalpy, pressure, temperature). With the usage of the soot blower, the average highest increase in power output was 0.85 MW at 100% load on October 22, 2023, and 0.91 MW at 50% load on November 9, 2023. The increase in power output value generated will impact the Company's profits in selling electricity to the community.

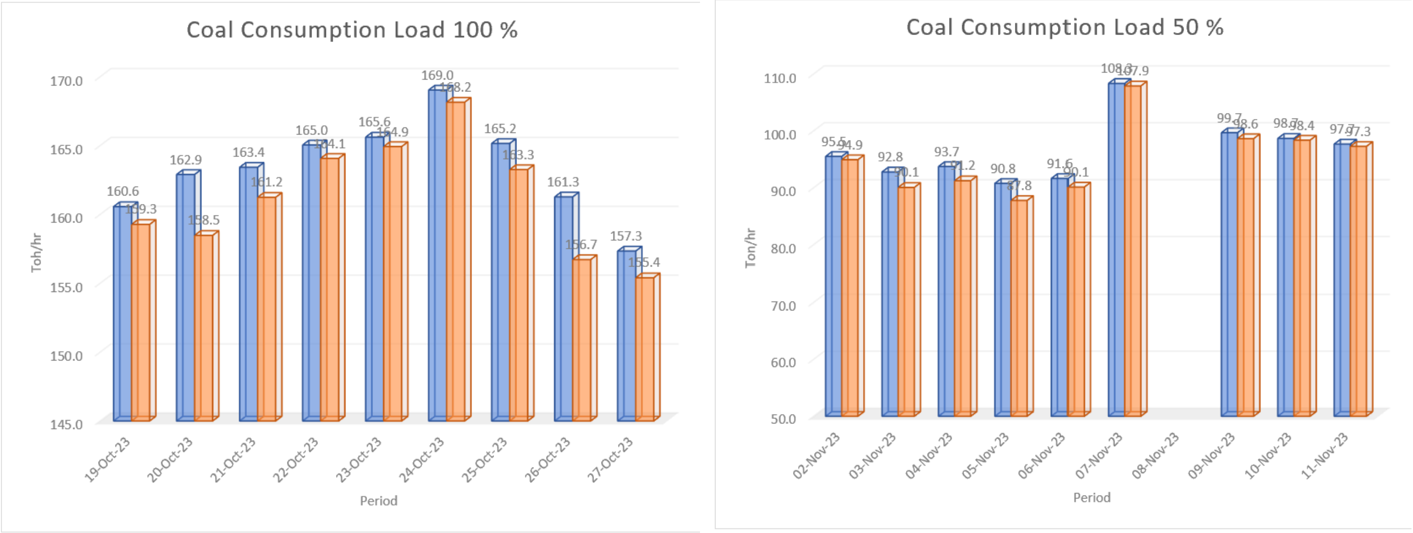

Figure 4. Coal Consumption

Additionally, the usage of the soot blower, which functions to clean slagging and fouling adhering to the boiler tubes, thus improving heat transfer, it has an impact on the tendency for coal fuel consumption rates to decrease, as seen in the following figure 4. In general, the use of a sootblower will lead to a reduction in coal fuel consumption, which is beneficial for the Company.

4. Conclusion

The analysis of soot blower operation highlights its significant role in improving boiler efficiency and reducing the Net Plant Heat Rate (NPHR), both of which are essential for enhancing overall power plant performance. At both 100% and 50% load conditions, notable increases in boiler efficiency were observed following soot blower operations, with the highest improvements recorded at 2.07% and 1.26%, respectively. Similarly, the reduction in NPHR, including a substantial decrease of 65.86 kcal/kWh at full load, demonstrates more efficient heat-to-electricity conversion. These findings are consistent with established principles emphasizing the importance of reducing fouling and enhancing heat transfer efficiency.

The operational and financial benefits of soot blower usage are further evidenced by improved power output and reduced coal consumption, driven by better heat transfer performance. By minimizing fouling and slagging on heat transfer surfaces, soot blowers not only optimize energy efficiency but also extend the operational lifespan of boiler components, reducing maintenance costs. These improvements underline the critical value of soot blowers in achieving both technical and economic advantages in coal-fired power plants.

Overall, the results of this study emphasize the vital role of soot blowers in optimizing boiler performance, reducing energy consumption, and enhancing plant profitability. The ability to achieve consistent efficiency improvements across varying load conditions underscores the importance of regular soot blower operation as a key maintenance strategy for modern power plants.

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