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Exhaust Temperature Control of Double Tail Flue Boiler

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ABSTRACT

The performance of the DG230 / 9.81-II16 pulverized coal boiler at a thermal power plant in Indonesia has been compromised by consistently high exhaust gas temperatures, which have adversely affected its thermal efficiency and increased operational risks. The issue, first identified in late 2019, was linked to several factors, including misalignment of the burner, coking on the superheater surfaces, blockages in the economizer, and improper damper settings. These issues led to inefficiencies in heat transfer, increased fuel consumption, and operational instability. The research involved comprehensive field inspections, operational data collection, and collaborative analysis with technical experts to pinpoint critical problem areas. Data collection focused on exhaust gas temperatures and pressure differentials, with sensors installed at strategic points throughout the boiler. Following the diagnosis, corrective measures such as adjusting burner angles, optimizing superheater cleaning, clearing blockages in the economizer, and fine-tuning damper settings were executed. Results from the corrective actions, implemented in 2023, demonstrated a significant reduction in exhaust gas temperatures, bringing them within the design range. The adjustments improved the overall efficiency of the boiler by achieving more uniform heat distribution and enhancing combustion stability. After six months of monitoring, the exhaust temperatures remained stable, confirming the success of the interventions. This study underscores the critical role of burner alignment and damper control in managing exhaust gas temperatures and offers practical recommendations for improving operational efficiency and safety in similar boiler systems.

Introduction

Boiler exhaust temperature is a critical parameter in thermal power plant operations, significantly impacting thermal efficiency and overall system economy. Elevated exhaust temperatures can result in suboptimal heating of the working medium in downstream heat exchange surfaces, leading to reduced thermal efficiency, increased fuel consumption, and, in severe cases, safety risks due to potential unplanned shutdowns. Maintaining exhaust temperature within an optimal range is essential for ensuring both safety and efficiency. This requires stringent control over thermal deviations across the various heat exchange surfaces in the boiler's rear section to keep flue gas temperature within prescribed safety limits.

The DG230 / 9.81 - II16 pulverized coal boiler, produced by Dongfang Boiler Co., Ltd., is a high-temperature, high-pressure natural circulation drum boiler. It features four-corner tangential combustion, known for stable and efficient combustion. The design includes a full-radiation superheater tube screen in the upper furnace, a high-temperature superheater above the flame folding angle, and a low-temperature superheater in the horizontal flue. While these components optimize heat exchange and minimize thermal losses, issues such as improper burner alignment, coking, ash accumulation, and ineffective damper control can disrupt this balance, leading to increased exhaust temperatures.

In late 2019, two units of this boiler were commissioned at a power plant. By October 2020, operators noted a gradual increase in exhaust gas temperature in both boilers, coupled with a rise in flue gas differential pressure before and after the high-temperature economizer and an increase in induced draft fan current. These deviations risked operational stability and boiler efficiency.

A comprehensive inspection and analysis, conducted in collaboration with the Central South Institute and technical experts, identified several contributing factors: misalignment of the boiler flame centre due to incorrect burner tilt, coking on superheater surfaces, and blockage in the high-temperature economizer. The flue gas regulating dampers also contributed to the issue. A technical rectification plan was proposed in January 2023, and implemented in February and August of the same year. Continuous monitoring and adjustment over six months confirmed the success of the corrective measures.

Recent studies have investigated various strategies for controlling flue gas temperature in boilers, emphasizing burner tilt adjustments. Liu et al. (2024) and Tian et al., (2015) Found that optimizing burner tilt angles could significantly reduce exhaust temperatures while maintaining stable combustion. Chen et al., (2017) Demonstrated that dynamic control of burner tilt and real-time flue gas monitoring enhance boiler efficiency. Wu et al., (2024) Explored the impact of burner tilt on combustion characteristics, highlighting environmental benefits. (Park et al., 2013) and Chen et al., (2017) Showed that burner configuration and operation mode significantly affect boiler performance, particularly in large-scale, ultra-supercritical boilers.

Chang, Wang, Zhou, Chen, & Niu, (2021) emphasized integrating advanced control systems with burner tilt adjustments to optimize heat distribution and reduce exhaust temperatures. (Xue et al., 2024) demonstrated that machine-learning algorithms can predict optimal burner tilt angles in real time, enhancing temperature control efficiency. (Xue et al., 2024) demonstrated that online monitoring and optimization of soot-blowing frequency in air preheaters enhance temperature control efficiency. (Zhang et al., 2015) examined how ash fouling and soot-blowing influence heat exchanger efficiency, contributing to both efficiency and emissions reduction. (Wu et al., 2021) and Hu et al. (2018) examined how burner tilt can mitigate thermal NOx formation, contributing to both efficiency and emissions reduction.

Research on boiler structure and its influence on exhaust temperatures is also relevant. Guo et al. (2021) studied heat exchanger configurations and found that optimized layouts reduce temperature gradients and improve efficiency. Wang et al. (2019) investigated economizer design and its impact on thermal performance, highlighting the need for precise engineering to avoid temperature deviations. Advancements in sensor technology and data analytics, as reported by Zhao et al. (2020) and Liu et al. (2021), offer new tools for monitoring and controlling exhaust temperatures, enabling more responsive adjustments.

This paper aims to analyze the causes behind high exhaust temperatures in the DG230 / 9.81 - II16 pulverized coal boilers and present the results of the implemented corrective actions. The findings contribute to a broader understanding of flue gas temperature control in high-temperature, high-pressure boilers, with implications for enhancing the efficiency and safety of similar units.

Method

The study began with a literature review, including an examination of the Dongfang boiler manual, international journals, and other relevant sources. Field visits were conducted to collect operational data on various parameters. During unit shutdowns, conditions within the flue gas flow were inspected. New operational patterns were trialled, followed by an analysis of their effects. Subsequent shutdowns involved inspections to evaluate the outcomes of the implemented changes.

The following steps were taken to complete the research methodology:

1. Research Location:

   This research was conducted at a Thermal Power Plant utilizing the DG230 / 9.81 - II16 pulverized coal boiler. The research site is located at [PT DSSP Power Kendari, IPP PLTU kendari-3], [Jl. Poros Kdi.- Moramo, Tj. Tiram, Kec. Moramo Utara, Kabupaten Konawe Selatan, Sulawesi Tenggara 93891], [Indonesia]. This location was selected due to the issue of high exhaust gas temperatures in the boiler units, which became the focus of this study.

2. Research Subjects:

   The research subjects were two units of the DG230 / 9.81 - II16 pulverized coal boiler operating at the power plant. These units experienced a significant increase in exhaust gas temperature, making them the target for analyzing and resolving this issue.

3. Data Collection Techniques:

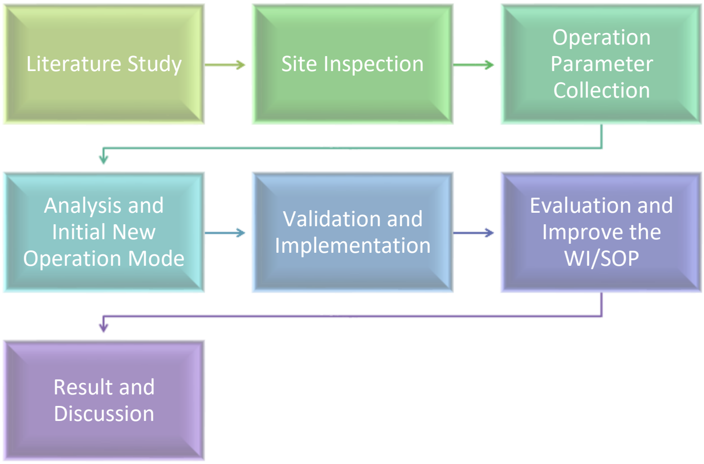
   a. Direct Observation: Operational data were collected through direct observation and recording of boiler performance parameters during operation. Recorded parameters included exhaust gas temperature, pressure differentials, hot air temperature, secondary air temperature, and data from various sensors and actuators.

b. Sensor Data: Continuous data were collected from strategically placed temperature sensors across key areas of the boiler, including the furnace outlet, high-temperature economizer inlet and outlet, and preheater. Pressure sensors monitored differentials across critical points in the economizer and preheater, capturing fluctuations related to the buildup of ash or coking.

4. Data Analysis
   a. Trend Analysis: Historical data on exhaust gas temperature and pressure differentials were analyzed to identify patterns or trends associated with changes in operational or environmental conditions. This analysis helps distinguish between long-term issues and transient fluctuations.
   b. Comparative Analysis: A comparison of key parameters before and after corrective actions, such as exhaust gas temperature and furnace outlet temperature, was used to measure the effectiveness of the technical interventions. This includes evaluating the impact of burner position adjustments and damper settings on temperature stability.
   c. Root Cause Analysis: Root cause analysis was conducted to identify the primary factors contributing to the increase in exhaust gas temperature. By evaluating field inspection data and expert input, this analysis uncovered specific issues such as burner misalignment and economizer blockages that affected heat balance.
5. Research Instruments:
   a. Temperature Sensors: Temperature sensors were strategically placed at various points within the boiler, including the furnace outlet, high-temperature economizer inlet and outlet, and preheater. These sensors were used to monitor exhaust temperatures in real-time.
   b. Burner Actuators: Actuators were used to adjust the tilt angles of the burners. These adjustments were made to optimize heat distribution within the furnace.
   c. Pressure Measurement Devices: Pressure measurement devices were used to measure the pressure differential of exhaust gas across the economizer and preheater.
6. Field Visits and Inspections :

   During unit shutdowns, conditions within the flue gas flow were thoroughly inspected. Inspections were conducted to identify blockages, coking, and other structural issues that might affect the exhaust gas temperature.
7. New Operational Patterns:

   Trials of new operational patterns were conducted by implementing suggested changes to burner tilt angles and damper settings. The effects of these changes were monitored and analyzed to evaluate their impact on exhaust gas temperature. Evaluations were performed during subsequent shutdowns to assess the outcomes of the adjustments and improvements made.



The study involved a detailed analysis of a double-tail flue boiler with adjustable burners. Temperature sensors were strategically placed throughout the boiler to monitor exhaust temperatures, and actuators were used to adjust burner angles. Experimental methods were employed to evaluate the effectiveness of control strategies.

Results and Discussion

The corrective measures for high exhaust temperatures in the boiler resulted in significant improvements. Initial issues included deviations in burner positions, coking on superheaters, ash blockage in the high-temperature economizer, and improper use of the flue gas regulating damper.

1. Burner Position Adjustment: calibration of burner angles was performed to ensure consistent positioning. Adjusting the bottom burner to -10° and the middle and upper burners to -15° maintained the flue gas temperature below the design value of 916°C. This adjustment addressed the issue of flue gas overheating at the furnace outlet.

Table 1
Boiler Main Parameters Before Adjustment (January 2023)

Parameter	Unit	Design value	No. 1 Furnace Completion Value	No. 2 Furnace Completion Value
Furnace outlet flue gas temperature	°C	143	187	178
Flue gas pressure difference at inlet and outlet of upper economizer	KPa	0.75	1.47	1.54
Hot air temperature	°C	386	423	417
Hot secondary air temperature	°C	362	338	325
Boiler outlet flue gas temperature	°C	916	1043	1121
High-temperature economizer inlet flue gas temperature	°C	594	679	703

High-temperature economizer outlet flue gas temperature	℃	410	478	469

Table 2
Boiler Main Parameters After Adjustment (March 2024)

Parameter	Unit	Design Value	No. 1 Furnace Completion Value	No. 2 Furnace Completion Value
Furnace outlet flue gas temperature	℃	143	141	139
Flue gas pressure difference at inlet and outlet of upper economizer	KPa	0.75	0.34	0.51
Hot air temperature	℃	386	383	379
Hot secondary air temperature	℃	362	367	353
Boiler outlet flue gas temperature	℃	916	932	927
High-temperature economizer inlet flue gas temperature	℃	594	601	588
High-temperature economizer outlet flue gas temperature	℃	410	417	422

2. Superheater Coking and Ash Accumulation: During maintenance, Coking on superheater surfaces was removed using high-pressure water guns, which improved heat exchange efficiency. Soot blowing frequency was optimized to prevent excessive coking due to poor heat exchange.
3. Economizer and Preheater Blockage: Blockages in the high-temperature economizer and air preheater pipelines were addressed using mechanical dredging and high-pressure water jetting. These methods effectively cleared coke blocks, restoring heat exchange and reducing flue gas temperature increases.
4. Flue Gas Damper Adjustment: The flue gas damper was adjusted based on temperature measurements at the terminal preheater inlet. Reducing the damper opening from 90% to approximately 10% balanced temperature across preheaters and minimized heat loss, addressing uneven flue gas temperatures.

The improvements recorded in this study align with many findings from previous studies that have examined the optimization of burner angles to enhance thermal performance in boilers. For example, the adjustment of the burner angle in the DG230 / 9.81 - II16 boiler, which significantly reduced flue gas temperature and improved operational stability, confirms similar results found by (Liu et al., 2024) Numerical investigation of stable combustion at ultra-low load for a 350 MW wall tangentially fired pulverized-coal boiler: Effect of burner adjustments and methane co-firingZhang et al., who reported that burner tilt affects temperature distribution within the boiler and reduces heat wastage (Zhang et al., 2020. Similarly, Liu et al. (2019) and Tan et al. (2017) also noted that adjusting the burner angle can improve combustion and optimize flue gas temperature by balancing the heat distribution throughout the boiler. Therefore, these findings not only support the existing theoretical framework but also demonstrate the relevance of this solution in the broader context of industrial boilers.

The theoretical principle behind the burner angle adjustment relates to optimizing airflow and combustion to maintain flame stability and ensure proper distribution of flue gas temperature. Burner imbalance can lead to overheating in certain areas of the furnace, which in turn may cause flue gas temperatures that deviate from the design specifications, thus reducing boiler efficiency. Based on this principle, the burner angle adjustments applied in this study—-10° for the lower burner and -15° for the upper and middle burner successfully returned the flue gas temperature closer to the original design values, as also evidenced by previous studies highlighting the importance of burner alignment in pulverized coal boilers.

Additional improvements, such as the removal of superheater coking and proper damper settings, corroborate findings by (Pattanayak et al., 2015), who demonstrated that optimal soot-blowing frequency can enhance boiler performance and prevent excess coking and dynamically adjusting operational parameters can maximize thermal efficiency. Moreover, Shi et al. (2015) highlighted the importance of online monitoring and soot-blowing optimization for convective heat exchangers, which further validates the method used in this study to manage ash accumulation and blockage in the economizer. In their study, adjusting burner parameters not only improved energy efficiency but also reduced the accumulation of unburned carbon in fly ash, which could affect the overall system efficiency. Similar findings were presented by Wu et al., (2024), who stated that proper burner settings could reduce NOx emissions, although this study focused more on emission control than on flue gas temperature.

Overall, the results obtained in this study are consistent with the existing literature, supporting the idea that burner adjustments and management of other operational parameters, such as dampers and soot cleaning, are key steps in controlling high flue gas temperatures. However, this study also highlights the importance of managing other often-overlooked factors in the literature, such as blockage in the economizer and coking issues in the superheater, which also contribute to overall boiler performance degradation. Therefore, a more comprehensive approach to managing flue gas temperature and boiler efficiency could be adopted to mitigate broader issues in industrial combustion systems. (Niu et al., 2015).

In summary, this study’s adjustments and improvements align with the literature and strengthen our understanding of operational mechanisms that influence thermal performance in pulverized coal boilers. Further research could explore integrating control systems with advanced optimization technologies in various industrial boiler settings to enhance efficiency and stability.

Conclusion

The high exhaust temperature issue in the plant's boiler was primarily caused by deviations in burner position, resulting in an inefficient flame centre. Additionally, coking on superheaters and ash blockage in the high-temperature economizer exacerbated the problem. The lack of an intuitive basis for using the flue gas regulating damper also contributed to high exhaust temperatures. By adjusting burner positions and the flue damper, the deterioration in furnace operating conditions was addressed, leading to a reduction in exhaust temperature and maintenance within design limits. Corrective actions, including addressing coking and blockages, successfully controlled exhaust temperatures and restored normal boiler operation. This study demonstrates that burner tilting adjustments can significantly improve exhaust temperature control and heat distribution in double-tail flue boilers. Future research should explore the integration of these control systems with other boiler optimization technologies and their application in different industrial settings.

Bibliography

Chang, J., Wang, X., Zhou, Z., Chen, H., & Niu, Y. (2021). CFD modelling of hydrodynamics, combustion and NOx emission in a tangentially fired pulverized-coal boiler at low load operating conditions. *Advanced Powder Technology*, *32*(2), 290–303.

Chen, S., He, B., He, D., Cao, Y., Ding, G., Liu, X., Duan, Z., Zhang, X., Song, J., & Li, X. (2017). Numerical investigations on different tangential arrangements of burners for a 600 MW utility boiler. *Energy*, *122*, 287–300.

Liu, T., Wang, Y., Zou, L., Bai, Y., Shen, T., Wei, Y., Li, F., & Zhao, Q. (2024). Numerical investigation of stable combustion at ultra-low load for a 350 MW wall tangentially fired pulverized-coal boiler: Effect of burner adjustments and methane co-firing. *Applied Thermal Engineering*, *246*, 122980.

Niu, Y., Liu, X., Zhu, Y., Tan, H., & Wang, X. (2015). Combustion characteristics of a four-wall tangential firing pulverized coal furnace. *Applied Thermal Engineering*, *90*, 471–477.

Park, H. Y., Baek, S. H., Kim, Y. J., Kim, T. H., Kang, D. S., & Kim, D. W. (2013). Numerical and experimental investigations on the gas temperature deviation in a large scale, advanced low NOx, tangentially fired pulverized coal boiler. *Fuel*, *104*, 641–646.

Pattanayak, L., Ayyagari, S. P. K., & Sahu, J. N. (2015). Optimization of soot blowing frequency to improve boiler performance and reduce combustion pollution. *Clean Technologies and Environmental Policy*, *17*(7), 1897–1906.

Tian, D., Zhong, L., Tan, P., Ma, L., Fang, Q., Zhang, C., Zhang, D., & Chen, G. (2015). Influence of vertical burner tilt angle on the gas temperature deviation in a 700 MW low NOx tangentially fired pulverised-coal boiler. *Fuel Processing Technology*, *138*, 616–628.

Wu, X., Hu, F., Ding, C., Yang, Y., Yang, C., Liao, H., Lu, K., Li, B., Liu, T., & Liu, C. (2024). Progress in numerical simulations and fundamental characteristics of pulverized coal co-firing with ammonia. *International Journal of Hydrogen Energy*, *82*, 740–758.

Wu, X., Liu, W., Gao, H., Alfaro, D., Sun, S., Lei, R., Jia, T., & Zheng, M. (2021). Coordinated effects of air pollution control devices on PAH emissions in coal-fired power plants and industrial boilers. *Science of The Total Environment*, *756*, 144063.

Xue, W., Lu, Y., Wang, Z., Cao, S., Sui, M., Yang, Y., Li, J., & Xie, Y. (2024). Reconstructing near-water-wall temperature in coal-fired boilers using improved transfer learning and hidden layer configuration optimization. *Energy*, *294*, 130860.

Zhang, S., Shen, G., An, L., & Li, G. (2015). Ash fouling monitoring based on acoustic pyrometry in boiler furnaces. *Applied Thermal Engineering*, *84*, 74–81.