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Study of Improving the Combustion Rate of Fuel Used in Steam Electric Power Stations Using PentoMag

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ABSTRACT

This study aims to evaluate the effect of the commercial treatment material (PentoMag) on combustion completeness in fossil-fueled steam power plants, using the unburned carbon fraction in the ash as a key indicator. Ash samples were collected daily over 10 days, purified, weighed, and combusted in a laboratory furnace to determine unburned carbon content. The concentrations of carbon monoxide (CO) and carbon dioxide (CO_2) were also measured using a specialized gas analyzer. Results indicated that the unburned carbon fraction was significantly high prior to treatment, reflecting incomplete combustion. Following treatment with the material, a notable reduction in the percentage of unburned carbon was observed, indicating greater fuel oxidation and improved overall combustion efficiency. Additionally, CO and CO_2 emissions decreased, demonstrating improved environmental performance of the combustion process. These findings suggest that the treatment material can effectively promote complete combustion and reduce harmful emissions in thermal power plants.

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1. INTRODUCTION

Electrical energy is generated by converting other forms of energy, such as mechanical, thermal, or chemical energy [1], and power plants play a critical role in supplying the energy required by industrial, commercial, and residential sectors [2]. Despite advancements in renewable energy technologies, the vast majority of global energy consumption, approximately 80%, still relies on fossil fuels [3]. Improving fuel combustion is crucial to increasing efficiency and reducing harmful emissions. Steam power plants burn fossil fuels to generate heat, which is converted to electricity. Combustion of fossil fuels produces unburned carbon and gases such as CO and CO_2, which affect both efficiency and environmental performance [4]-[6].

The commercial treatment material PentoMag, mainly composed of magnesium oxide (MgO), was selected for this study because of its ability to enhance fuel oxidation, reduce unburned carbon, and decrease CO and CO_2 emissions[7]. Previous studies have focused on general emission control or boiler efficiency [8]-[10], but the effect of PentoMag on unburned carbon and combustion completeness has not been fully investigated [8],[11]-[12]. This study aims to evaluate the effect of PentoMag on the completeness of combustion in fossil fuel-powered steam power plants by measuring the unburned carbon fraction in ash and the concentration of CO and CO_2 over ten days [13]-[15].

The experiment was conducted at the Waste Thermal Station due to the boiler's large size and its significant environmental impacts and effects on nationwide electrical energy production.

2. METHODOLOGY

2.1 Materials used

First, unburned carbon (ash) is prepared by opening it inside, where gases and vapors exit, and placing a container to collect the unburned carbon. The company's staff designs the container opening, and the carbon is collected from the designated extraction site, placed in a 100-milliliter can, and prepared for shipment. Weigh and burn every day during the trial period. Second: PentoMag: The company prepares this material in tanks.

2.2 Tools and equipment

The list includes a German-made burning furnace with a capacity of 600 degrees Celsius; a ceramic bowl; an electronic scale; a spoon; a clip to purify the oven of impurities; an electrical source; large tongs; a heat carrier; and thermal gloves. A gas-measuring device (TESTO) installed by the company pumps the substance treatment with the fuel used for incineration inside the plant.

3. RESULTS

Table 1 presents the amount of unburned carbon collected during the experimental period prior to adding the treated material to the fuel. It was observed that the weight of unburned carbon ranged from approximately 49 to 50 g, indicating a relatively high amount of unburned carbon in the samples prior to treatment with the treatment material. The table summarizes the ten experimental days, showing a consistent weight range without repeating each daily value in the text.

Table 1. Weight of unburned carbon during the experimental period before treatment

Days	10	9	8	7	6	5	4	3	2	1
Wt. of Unburned Carbon (g)	50	50	49	47	50	49	48	49	50	50

Table 2 presents the steps for determining the combustion efficiency of unburned carbon over 10 days prior to the application of the treated material. Ash was collected from the designated container, and 1 gram of unburned carbon (SW) was placed in a ceramic bowl (CW). The bowl was weighed before burning (54 g), and the total weight of the ash and bowl before burning was 55 g. The sample, along with the lid (CSW), was then placed in the burning oven for 2 hours at a temperature close to the station boiler combustion temperature (350 °C). After removal and cooling, the combined weight (CSW) ranged from 54.93 to 54.98 g over the ten days. The remaining unburned carbon was calculated using the formula:

$$\%\text{Burned Carbon} = 100 - \frac{(C_{\text{SW}} - C_{\text{W}})}{SW} \times 100$$

Where SW is the weight of the unburned carbon sample, CW is the weight of the empty ceramic bowl, and CSW is the combined weight of the bowl and sample before and after burning. Using this method, the combustion efficiency of unburned carbon ranged from 93% to 98% over the 10 days preceding the treatment.

Table 2. Combustion Rate of Unburned Carbon Before Treatment.

Day	Weight (SW) Un b.c.(g)	Wt. of CW (g)	Wt. of (CW) and Ash before Burning	(Burn) two hours	Wt. Of (CSW) (g) after Burning	Wt. of (CSW-CW) (g)	% Un b.c. before adding pento, Mg
1 Day	1 gm	54 gm	55 gm	2	54.93	0.07	93
2 Day	1 gm	54 gm	55 gm	2	54.95	0.05	95
3-Day	1 gm	54 gm	55 gm	2	54.96	0.04	96
4-Day	1 gm	54 gm	55 gm	2	54.98	0.02	98
5-Day	1 gm	54 gm	55 gm	2	54.94	0.06	94
6 Day	1 gm	54 gm	55 gm	2	54.97	0.03	97
7 Day	1 gm	54 gm	55 gm	2	54.96	0.04	96
8 Day	1 gm	54 gm	55 gm	2	54.94	0.06	94
9 Day	1 gm	54 gm	55 gm	2	54.95	0.05	95
10 Day	1 gm	54 gm	55 gm	2	54.98	0.02	98

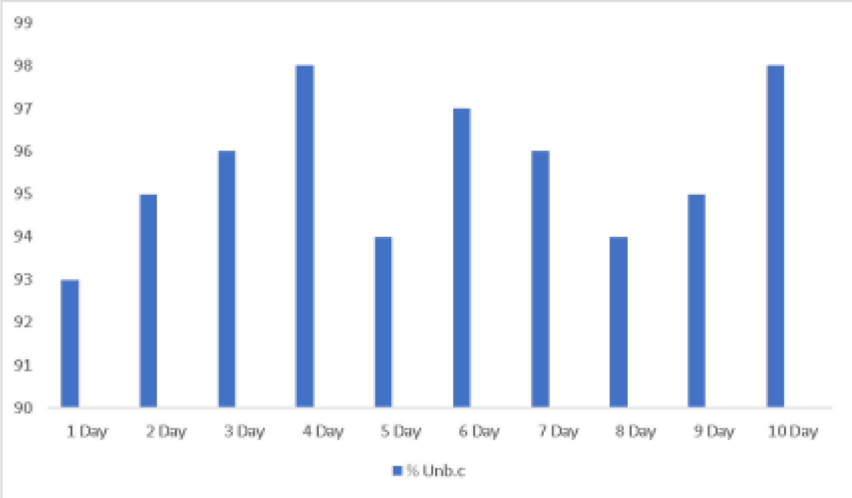

Figure 1. Combustion Rate of Unburned Carbon Before Treatment.

Figure 1 illustrates the combustion rate over 10 days before the application of the treated material. The results indicate that the combustion efficiency of the unburned carbon increased gradually from 93% on the first day to 97% on the tenth day, reflecting the samples' stable baseline performance before treatment. This figure highlights the consistently high combustion efficiency of the unburned carbon before adding the treated material.

Table 3. Concentrations of CO and CO_2 Gases Before Treatment

Day	1	2	3	4	5	6	7	8	9	10
CO_2 (ppm)	13.5	14	13.8	13.4	13.8	13.7	13.9	14	13.2	13.15
CO (ppm)	6	6.4	6.8	6.6	6.3	5.9	6.9	7	6.8	6.8

Table 3 presents the measured concentrations of carbon dioxide (CO_2) and carbon monoxide (CO) emitted from the power station over 10 days prior to the application of the treated material. Measurements were performed using a calibrated Testo device. CO_2 concentrations ranged from 13.15 to 14 ppm, while CO concentrations ranged from 5.9 to 7 ppm, indicating relatively stable emission levels during the experimental period. These results provide a baseline for assessing the impact of the treated material on gas emissions in subsequent experiments.

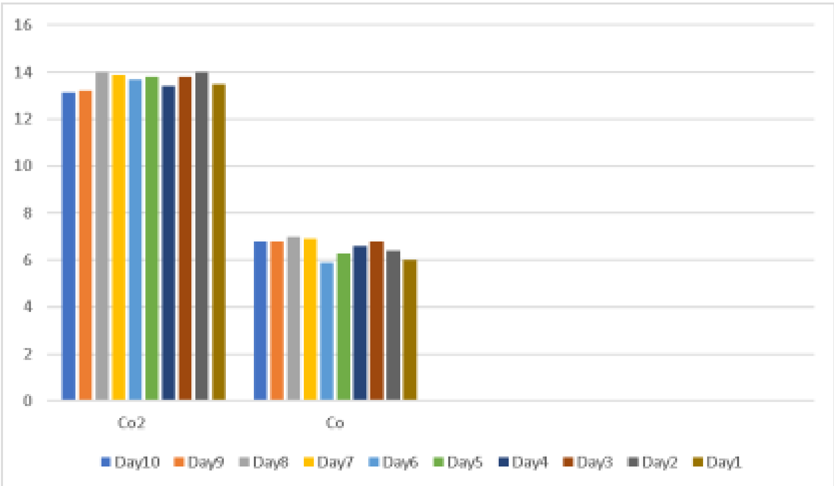

Figure 2. Concentrations of CO and CO_2 Gases Before Treatment

Figure 2 illustrates the concentrations of carbon dioxide (CO_2) and carbon monoxide (CO) over ten days before the application of the treated material. Observations show that CO_2 levels remained relatively stable, ranging between 13.15 and 14 ppm, while CO concentrations fluctuated slightly between 5.9 and 7 ppm. This figure visually confirms the consistency of gas emissions during the pre-treatment period and provides a baseline for evaluating the effect of the treated material on emission reduction.

Table 4. Shows the weight of unburned carbon during the experimental period after treatment.

Day	1	2	3	4	5	6	7	8	9	10
Wt. Un b.c. (g)	2	1.98	1.88	2	1.95	1.97	1.98	1.99	1.5	1.6

Table 4 presents the weight of unburned carbon (Wt. Un b.c.) collected from the designated container during the ten days after applying the treated material. The results show a significant reduction in unburned carbon compared to pre-treatment values, with daily weights ranging from 1.5 to 2 g. The combustion efficiency of unburned carbon was calculated using the relationship:

$$\%\text{Combustion} = 100 - \frac{W_{\text{after}}}{W_{\text{initial}}} \times 100$$

Where:

W_{after} = Weight after burning (g)
$W_{initial}$ = Initial sample weight (g)

These results indicate that the treated material effectively reduced the amount of unburned carbon, demonstrating its positive impact on fuel utilization and overall combustion efficiency.

Table 5. shows the results of the combustion rate of unburned carbon after treatment.

Day	Weight (SW) Un b.c.(g)	Wt. of CW (g)	Wt. of (CW) and Ash before Burning	(Burn) two hours	Wt. Of (CSW) (g) after Burning	Wt. of (CSW-CW) (g)	% Un b.c. after adding pesto Mg
1 Day	1 gm	54 gm	55 gm	2	54.32	0.68	32
2 Days	1 gm	54 gm	55 gm	2	54.3	0.7	30
3 Days	1 gm	54 gm	55 gm	2	54.35	0.65	35
4 Days	1 gm	54 gm	55 gm	2	54.4	0.6	40
5 Days	1 gm	54 gm	55 gm	2	54.39	0.61	39
6 Days	1 gm	54 gm	55 gm	2	54.41	0.59	41
7 Days	1 gm	54 gm	55 gm	2	54.35	0.65	35
8 Days	1 gm	54 gm	55 gm	2	54.43	0.57	43
9 Days	1 gm	54 gm	55 gm	2	54.36	0.64	36
10 Days	1 gm	54 gm	55 gm	2	54.35	0.65	35

Table 5 presents the procedure and results of burning unburned carbon after treatment. Ash was collected from the designated container, and 1 gram of unburned carbon (SW) was placed in a ceramic bowl (CW). The bowl weighed 54 g before burning, and the total ash weight was 55 g. The sample with the bowl (CSW) was then placed in a combustion oven for 2 hours at approximately 350°C, simulating the boiler combustion temperature. After cooling, the weight of CSW ranged from 54.3 to 54.4 g over the ten days.

Mathematical calculations were performed to determine the remaining unburned carbon, with residual sample weights ranging from 0.59 to 0.7 g. The combustion efficiency of unburned carbon was calculated using the relationship:

$$\%\text{Combustion} = 100 - \frac{(C_{\text{SW}} - C_{\text{W}})}{SW} \times 100$$

Where:

C_{SW} = Carbon in sample with water
C_W = Carbon in water
SW = Sample weight

The results show that the percentage of unburned carbon combustion ranged from 30% to 43% over the ten days following treatment. Compared to the pre-treatment values, this decrease indicates that the treated material effectively reduced the amount of unburned carbon, demonstrating its positive impact on fuel utilisation and overall combustion efficiency.

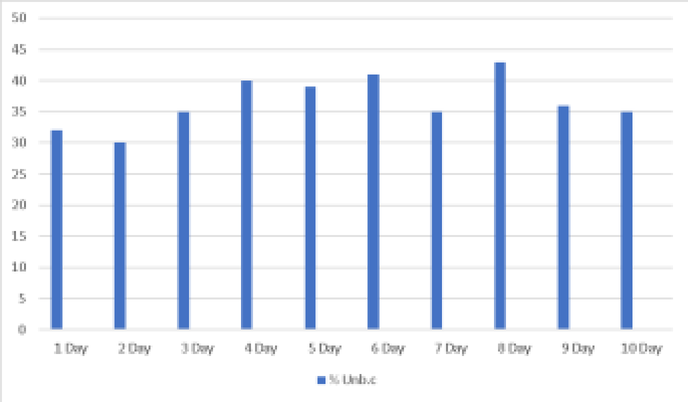

Figure 3. Combustion Rate of Unburned Carbon Before Treatment.

Figure 3 illustrates the combustion rate of unburned carbon over ten days after adding the treated material. The results show a significant decrease in the combustion efficiency of unburned carbon, ranging from 30% to 43%. This reduction reflects the lower amount of unburned carbon remaining after combustion, indicating improved fuel utilization and overall combustion efficiency.

Table 6. Shows the concentrations of gases leaving the station after treatment.

Gas type (ppm) 0	Day 1	Day 2	Day 3	Day 4	Day 5	Day6	Day 7	Day 8	Day 9	Day 10
CO_2	0.2	0.7	0.5	1	0.7	0.78	2	1.6	1.2	1
Co	0	0.02	0.4	0.03	0.5	0.98	0.3	0.4	0.23	0.01

Table 6 presents the concentrations of CO and CO_2 gases emitted from the station over ten days after the application of the treated material. Measurements were taken using a Testo device provided by the company. The results indicate a substantial decrease in gas emissions compared to pre-treatment values. The concentration of carbon dioxide (CO_2) ranged from 0.2 to 2 ppm, while the concentration of carbon monoxide (CO) ranged from 0 to 0.98 ppm. These reductions demonstrate the effectiveness of the treated material in enhancing combustion and minimizing harmful gas emissions.

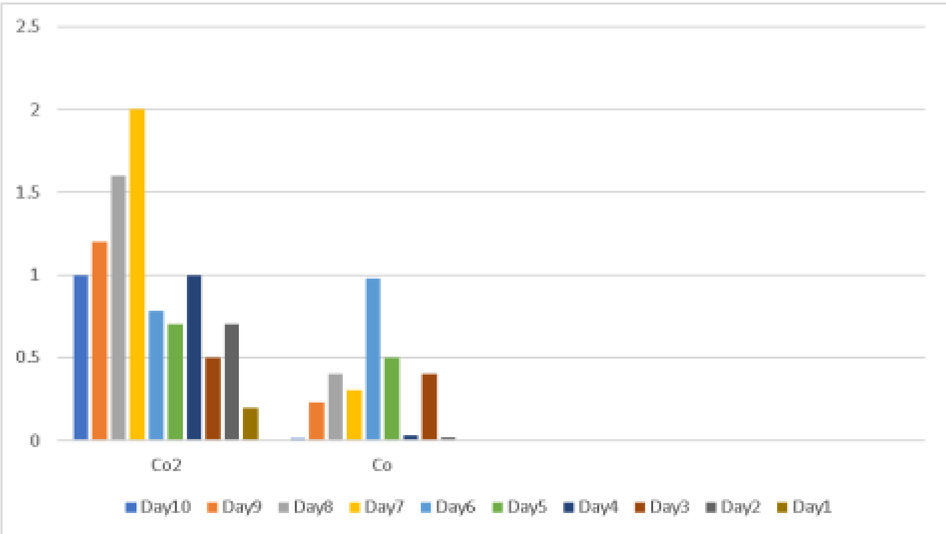

Figure 4. Shows the concentration of CO and CO2 gases exiting the plant after treatment.

Figure 4 illustrates the concentrations of CO and CO_2 gases emitted from the station over ten days following the application of the treated material. The results show a significant reduction in gas emissions after treatment. Specifically, the CO_2 concentration decreased from 1 ppm to 0.2 ppm, while the CO concentration decreased from 0.98 ppm to near zero, indicating the treatment's effectiveness in reducing unburned carbon and improving combustion efficiency. Measurements were taken periodically using a calibrated Testo device

4. DISCUSSION

By comparing the ash collected in the designated container, it was observed that, before treatment, the ash weight ranged from 49 to 50 g (Table 1). In contrast, after treatment, it decreased significantly to 1.5–2 g (Table 4). This indicates that combustion was incomplete in the burning area before the addition of the treated material and became nearly complete after its application. The combustion efficiency of unburned carbon was also affected. Before treatment, the percentage of unburned carbon ranged from 93% on the first day to 98% on the tenth day (Figure 1), whereas after treatment, it decreased to 30–41% (Figure 3). These results confirm that a substantial accumulation of unburned carbon occurred in the unit components before treatment, and the application of the treated material significantly enhanced fuel utilization and reduced unburned residues [16]-[17].

Gas concentration measurements further support these observations. Before treatment, CO_2 concentrations ranged from 13.15 to 14 ppm, and CO concentrations ranged from 5.9 to 7 ppm (Table 3). After treatment, CO_2 decreased to 0.2–2 ppm, and CO decreased to nearly zero (0–0.98 ppm, Table 6), indicating improved combustion and reduced emissions [13],[18]-[19]. The positive effects observed during the study, including reduced unburned carbon, lower ash accumulation, and decreased emission of toxic gases, can be attributed to the treated material (PentoMag), which contains magnesium oxide (MgO). The additive contributes to:

A. Cleaning boilers and furnaces by reducing carbon and ash deposits within the combustion system.
B. Enhancing the combustion process by eliminating harmful gases and improving fuel efficiency.
C. Reducing harmful emissions, thereby protecting the environment and ensuring compliance with environmental standards [20].

5. RECOMMENDATIONS

1. Implement more advanced and environmentally friendly technologies to enhance electrical energy production.
2. Develop specialised devices and materials to improve fuel combustion in thermal power stations.
3. Conduct regular maintenance and periodic on-site inspections of fuel-burning systems to ensure optimal performance.
4. Consider locating fossil-fuel-powered electrical stations away from residential areas to mitigate their significant environmental impacts.
5. Promote the planting of trees and vegetation around power stations to improve local air quality and reduce pollution.

6. CONCLUSION

There's a lot going on here – PentoMag changes how fossil-fueled plants burn. It cuts unburned carbon from 49 to 50 g down to 1.5to 2 g, and combustion efficiency drops from 93-98% to 30-43%. Thing is, CO_2 levels fall sharply – from 13.15 - 14 ppm to barely 0.2 - 2 ppm, and CO nearly disappears. That means more fuel burns clean and less pollution floats into the air. Magnesium oxide does this job by reacting directly with incomplete parts of the fuel chain – a real shift in how heat is managed. This isn't some lab trick, and it works at scale in real power stations. Emissions drop fast, costs stay low, and operations feel smoother over time. The data supports it – this additive delivers measurable gains without new infrastructure.

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