Some Field Studies on Catalytic Combustion in Power Boiler

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ABSTRACT

To prove the worthiness of the Combustion Monitoring Chemical, a long duration performance evaluation trial was planned on 94 kg/cm² pressure, 515°C temperature and 325T/h steam generating, Lignite fired power boilers at Unit No.1 & Unit No.3 of 70 MW capacity each at Panandhro Thermal Power Station of GEB Located at Panandhro, Kutch during 15th July, 2001 to 4th Sept, 2001 in two stages. The first 500 hours formed the base date while in next 500 hours the combustion catalyst was dosed at 30 ppm level (gms/tonne of Lignite) and the influence of this fuel additive was assessed. The results of these investigations show a clear reduction in average unburnt carbon levels in ash from 12.59% to 7.56%, indicating a relative decrease by 39.95%. This clearly establishes the strong catalytic effect of Combustion Monitoring Chemical. The pressure drop across the boiler is reduced by 4.19% in Ist Unit and 6.77% in and Boiler through use of this combutstioin catalyst. The increased rate of bottom ash removal rates and softness of clinkers evidences the anti-clinkering tendency of Combustion Monitoring chemical. There is a remarkable reduction in SO_2 *emisions through use of Combustion Monitoring Chemical. This reduction is of the order of 19.95% in Ist Unit and 23.88% in 2nd Unit. This reduction is obtained inspite of the increase in sulphur content by about 14% during second stage of trial. Reduction in SPM by 30.7% is also a remarkable achievement.*

INTRODUCTION

Combustion and thermal resistance to heat transfer essentially governs the efficiency of boiler. The combustion efficiency may be improved through the use of suitable combustion catalyst while the fouling of the surfaces can similarly be reduced by arranging the particle and surface character through use of fuel additives. Combustion Monitoring Chemical is a special catalytic fuel additive developed for Solid Fuel fired boilers. This additive incorporates cobalt and iron based catalyst for improved combustion and anti-clinkering and anti-fouling agent to reduce fouling caused by fuel ash. It improves conductivity of ash and thereby helps in reduction of particulate emissions. The catalyst also helps in reducing SOx emission, NOx emision and SPM thereby reduces environmental pollution.

The thermal efficiency of boiler depends on combustion efficiency and thermal resistance to heat transfer. The combustion efficiency may be improved through use of suitable combustion catalyst. The thermal resistance to heat transfer may be reduced by reducing fouling tendency of the surfaces either by chemical treatment to the surface or by changing the particle morphology and eutectic structure of ash through use of combustion additives (1-17).

Combustion Monotoring Chemical is an advanced cobalt and iron based combustion catalyst developed by the author. It possesses many desirable properties such as catalytic effect for improvement in combustion efficiency, anti-fouling property, altering ash structure for reduced clinkering and anti-emission characteristic for reducing the emission levels.

Action of Combustion Monitoring Chemical

The Combustion Monitoring Chemical possesses catalytic, anti-fouling anti-clinkering and anti-emission characteristics. All these actions are hypothesized as follows :

Catalytic Action

The high velocity cobalt and iron catalyst penetrates the coal particle and enhances the micro surface area for reaction. The oxychlorate provides ionic oxygen for catalytic combustion and all the major reactions get enhanced. The nitrate decomposition provides N_2O_2 which catalyses gas phase reactions and volatiles combustion. (1-9, 13). The presence of Co enhances gas solid reactions. The sequence of reactions may be represented as:

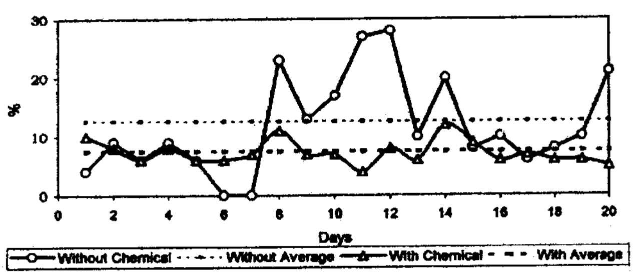

Fig. 1 Reduction in unburnt carbon levels in botom ash through use of compustion monitoring chemical (Fuel Additive) Ist Unit.

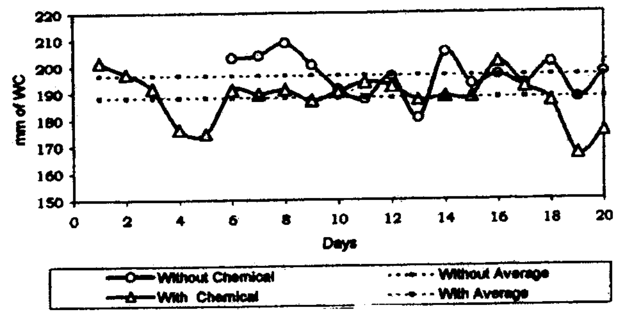

Fig. 3 Pressure drop across boiler during both stages of trial in Ist Unit.

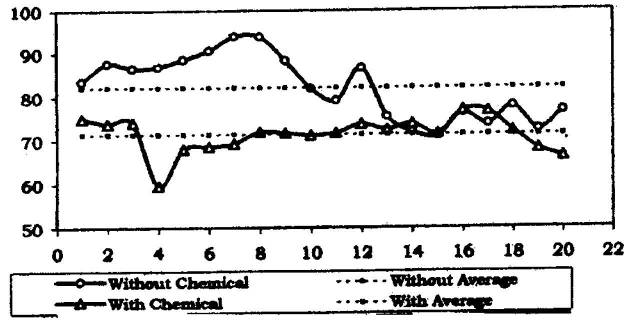

Fig. 2 Pressure drop across air-preheater during both stages of trial in Ist Unit.

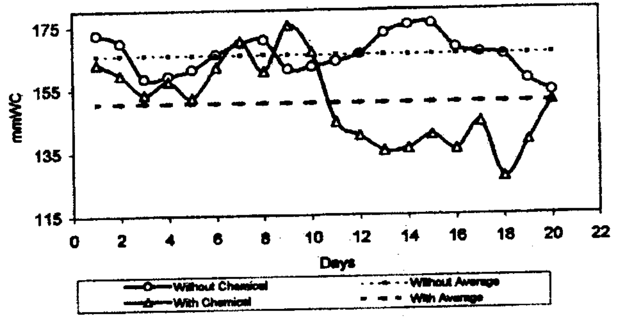

Fig. 4 Pressure drop across air-preheater during both stages of trial in 2nd Unit.

Nitrate Decomposition

$$2NO_3 \xrightarrow{\qquad} N_2O_2 + 2O_3$$

Gas Phase Reactions

$$H_2 + 2\,\bar{o} \xrightarrow{N_2O_2} 2\,\bar{o}H$$

$$2\,\bar{o}H + H_2 \xrightarrow{N_2O_2} 2\,H_2O$$

$$CO + \bar{o} \xrightarrow{N_2O_2} CO_2$$

Volatile Combustion

$$CxHyOz + (x + y)\ O \xrightarrow[Co]{N_2O_2} XCO + y\_OH + z/2\ O_2$$

Gas Solid Reactions

$$S + 2O \xrightarrow{Co} SO_2$$

$$C + O \xrightarrow{Co} CO$$

Antifouling Action of Combustion Monitoring Chemical

Anti-Fouling effect may be obtained by the following routes: (1, 2,12)

- By changing preferred direction of orientation of particles.
- By forming a protective layer of vapours on surfaces.
- By retarding ash reactions leading to formation of Sodium and Potassium Sulphates and Pyrosulphates.

NH_4Cl and $Mg(OH)_2$ vapours has high affinity towards SO_3 and they form ammonium and magnesium sulphates which has much higher melting points than that of sodium and pottasium sulphates.

- By increasing Ash Fusion temperature through changing the Eutectic Structure of ash.

$$3Na_2O.V_2O_5 + MgO \xrightarrow{\qquad} 3MgO.V_2O_5 + 3Na_2O$$

(Parent Eutectic) Modified Eutectic)
(m.p 621°C) (m.p 1243°C)

Anti-emission characteristic of combustion monitoring chemical (14)

$$CO + \tfrac{1}{2}\ O_2 \xrightarrow{Co} CO_2$$

Redn Catalyst

$$2NOx \xrightarrow{Co} N_2 + XO_2$$

Oxdn Catalyst

$$SO_2 + 2\,\bar{o} \xrightarrow{Co\ \&\ N_2O_2} SO_4 \text{ (In Ash)}$$

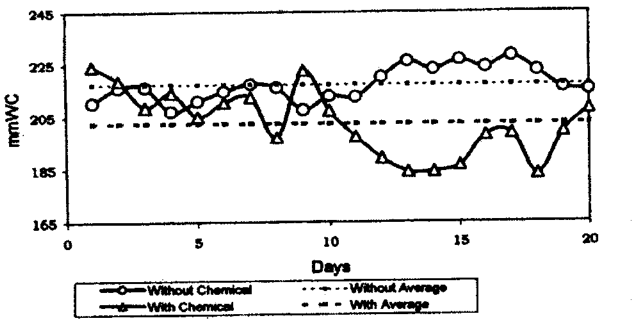

Fig. 5 Pressure drop boiler during both stages of trial in 2nd Unit.

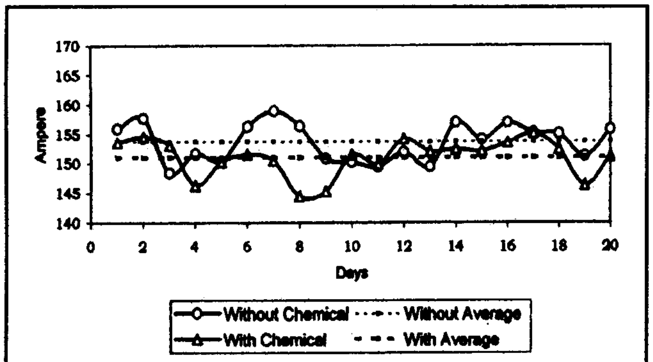

Fig. 6 Total fan ampere load during both stages of investigations in Ist Unit.

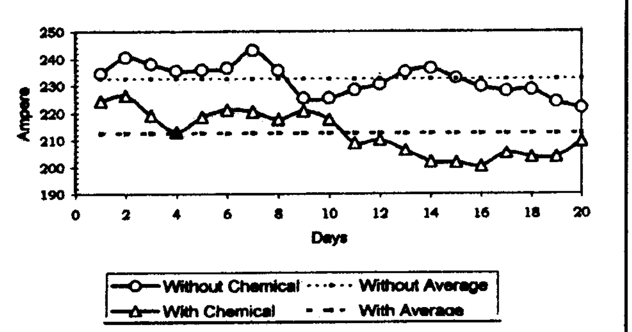

Fig. 7 Total fan ampere load during both stages of investigations in 2nd Unit.

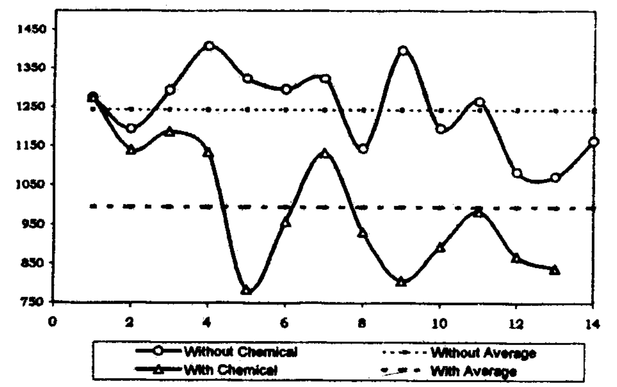

Fig. 8 Influence of Combustion Monitoring chemical (Fuel Additve) on SO_2 Emissions in Ist Unit

Control of Particulate Emissions

- The Parent Ash in fuel and unburnt carbon will appear as particulate emissions in stack.
- The only solution is to increase collection efficiency of ESP.
  - Collection Efficiency $=1-e^{-wk}$

K = Specific Collection Area = A/Q

A = Projected area of electrodes, m^2

Q = Volume flow of gas, m^3/s

w = Effective migration velocity, m/s.

Combustion Monitoring Chemical promotes formation of magnesium and ammonium sulphates, which increases "ash conductivity" which enhances "effective migration velocity" and hence improves ESP Collection efficiency.

Methodology and Measurements

To assess the correct qualitative and quantitative influence of Combustion Monotoring Chemical in reducing unburnt carbon levels in ash, fouling of heat transfer surfaces, clinkering and SO_2 emissions, two stages of investigations were planned on the two Lignite based Units Boiler of Ist Unit is essentially multi-tier, tangentially fired PF boiler employing beater wheel type mills and generating steam at 94 kg/cm^2 pressure, 515°C temperature and 325 T/h flow rate. The boiler of 2nd Unit is a single tier, PF boiler having the same rated parameters. During the first stage of trial various data on boiler parameters and emission characteristics was collected without use of any fuel additive. This data forms the basis of comparison.

The data collected include hourly variation of steam pressure, steam temperature, feed water flow rates, steam generation rates, various temperature levels and draft levels. The SO_2 emissions were measured once or twice in a day as per the convenience.The hourly data of boiler parameters SO_2 collected is transformed in daily averages and finally to an overall average over a trial period. (One overall average data point represents the average of about 500 hourly data points). This data formed not only the base data but provided sufficient insight on the actual operation of both the boilers.

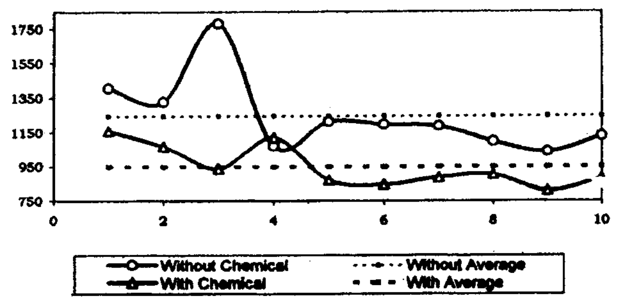

Fig. 9 Influence of Combustion Monitoring chemical (Fuel Additve) on SO_2 Emissions in 2nd Unit.

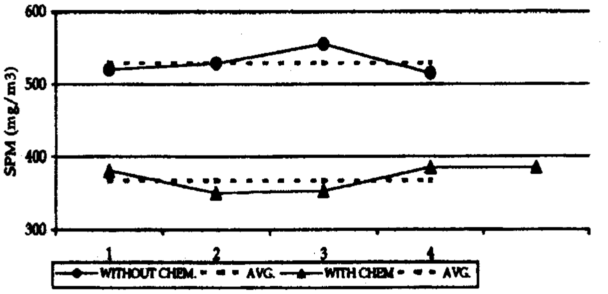

Fig. 9-A Reduction in SPM with the use of Combustion Monitoring Chemical

In the second stage of trial, Combustion Monitoring Chemical was dosed at 30 ppm level (30 gms/tonne of lignite) and the data was collected in a similar way as in stage-I. The water quality, fuel quality, unburnt carbon levels in ash and SO_2 emissions were regularly measured as per relevant standards (18-31) for both stages of trial. The samples of lignite from each mill feeders were collected twice in a day from Ist Unit and Unit No. 3.The daily samples so collected were mixed and its proximate analysis and GCV were evaluated for both the boilers. The overall average values are given below in Table 1.

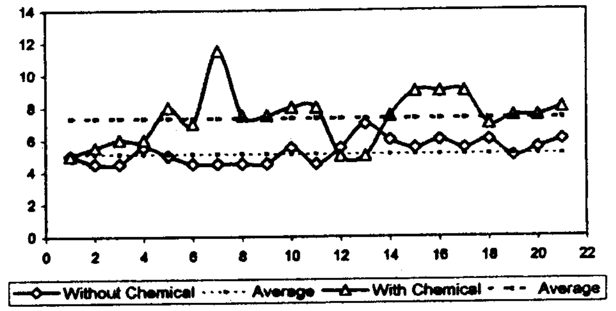

Fig. 10 Bottom Ash Removal Rates During Both Stages of Trial in 2nd Unit.

RESULTS AND DISCUSSION

The salient features of the results obtained based on the exhaustive data collected for the period of more than 1000 hours in two stages (more than 500 hours in each stage of investigation) for assessing the influence of Combustion Monitoring Chemical is discussed below:

Catalytic Effect

The catalytic effect of Combustion Monitoring Chemical (fuel additive) may be ascertained by reduction in unburnt carbon levels in Ash. Fig. 1 shows the variation of unburnt carbon in bottom ash of Unit No.1. It is observed that average unburnt carbon is reduced from 12.59% to 7.56% indicating a relative decrease by 39.95% through the use of Combustion Monitoring Chemical (fuel additive). It is also worth to note here that this decrease is achieved inspite of the fact that the fuel contains more ash in second stage of trial. There is also marginal reduction in unburnt carbon levels in bottom ash of Unit 2nd. The reduction in Unit and is marginal which is due to problem of single tier firing. This reduction in unburnt carbon levels in bottom ash clearly signifies catalytic effect of this fuel additive which improves

Table 1 Overall average lignite quality during both stages of trial

Parameter	Unit No. 1		Unit No. 3	
	Stage-I	Stage-II	Stage-I	Stage-II
Total Moisture, %	34.85	33.29	33.18	31.75
Fixed Carbon, %	19.7	18.23	21.17	19.12
Volatile Matter, %	27.89	26.04	29.68	27.61
Ash Content, %	17.56	22.44	15.97	21.52
Sulphur, %	1.93	2.204	1.93	2.204
GCV, MJ/kg	11.886	11.309	13.024	11.677

reaction area and oxygen penetration. Due to such multiple chain action, the unburnt carbon levels in ash reduces.

Anti-fouling Effect

Fig. 2 and Fig. 3. show the pressure drops across air-preheater and boiler for Ist Unit while Fig. 4 and Fig. 5 give the same parameters for 2nd Unit. It is observed that the average pressure drop across air-preheater and boiler for both the units is decreased. In Ist Boiler, the pressure drop aross air-preheater is reduced from 82.07 mm of H_2O to 71.26 mm of H_2O i.e. by about 13.17% while across the boiler as a whole it reduced from 196.39 mm of H_2O to 188.16 mm of H_2O indicating a reduction by 4.19%. Similarly in 2nd Unit the pressure drop across air-preheater is reduced from 165.61 mm of H_2O to 150.51 mm of H_2O i.e. by 9.12% while across boiler as a whole it is reduced from 217.14 to 202.45 mm of H_2O showing a reduction of 6.77%.

This reduction in pressure drop is obviously due to reduced flow resistance offered by cleaner sufaces made available in second stage of investigations with Combustion Monitoring Chemical (fuel additive). This fact clearly establishes the anti-fouling characteristics of this fuel additive. It is worth observing here that the reduction in pressure drop across the boiler in Unit No. 3 is more than that in Unit No.1. It is found that Unit No.3 faces serious problems of clinkering and due to Combustion Monitoring Chemical (fuel additive), clinker formation on water walls, super heater zone etc reduces which further reduces the flow resistance and offer reduces pressure drops in Units No.3.

Further, if the flow resistance is reduced, fan ampere load must reduce. This has what exactly happened as seen for Fig. 6 and Fig. 7 for Unit No.1 and Unit No.3, respectively. A decrease in fan ampere load from 153.57 amps to 150.93 amps i.e. by 1.72% in Unit No.1 and from 232.25 amps to 212.47 amps in Unit No.3 indicating a reduction by 8.52% once again reconfirms the anti-fouling effect of Combustion Monitoring Chemical.

Anti-Emission Characteristics

Fig. 8 and Fig. 9 highlight the influence of Combustion Monitoring Chemical (fuel additive) on SO_2 emission in Unit No. 1 and Unit No. 3, respectively. A remarkable decrease from 1242.35 ppm to 994.54 ppm i.e. 19.95% in Unit No. 1 and from 1243.41 ppm to 946.52 ppm indicating a decrease by 23.88% in Unit No. 3 is observed through use of Combustion Monitoring Chemical (fuel additive).

Further, it is worth to mention here that during second stage of trial, sulphur content was higher (2.204% in second stage) as compared to that in 1st stage (1.93% in 1st stage). If one assumes same sulphur content in fuel, SO_2 emission may be reduced by about 40%.

The SO_2 in the flue gas is catalysed to SO_3 in presence of Fe_2O_3 and Co and the ionic oxygen supplied by Combustion Monitoring Chemical (fuel additive). This activated SO_3 recombines with another ionic oxygen in presence of cobalt catalyst to form suitable sulphate. It preferably forms magnesium and ammonium sulphates (1, 2, 7, 12-14). This not only reduces the SO_2 emissions but also increases the conductivity and fusion temperature of ash which helps in reducing particulate emissions and clinker formation.

Fig. 9A shows the reduction in SPM by 30.7%, this highlights one of the benefits of Anti Property attained by Combustion Monitoring Chemical. The reduction in SPM is due to change in the ash morphology i.e. change in eutectic structure of ash which would not allow the ash to settle on the surface. Besides this it also increases the conductivity of ash. This can be analyzed from the angle of repose. The more the angle the better the conductivity of ash.

CONCLUSION

There is a reduction in unburnt carbon levels by 39.95% in botom ash of Unit No.1 with the use of Combustion Monitoring Chemical. The pressure drop across the boilers is reduced by 4.19% in Unit No.1 and by 6.77% in Unit No.3. Further there is a corresponding decrease in fan ampere load by 1.72% in Unit No.1 and by 8.52% in Unit No.3, through use of Combustion Monitoring Chemical. The physical observation of clinkers indicated that the clinkers had become much porous and soft during the second stage of investigations with the use of Combustion Monitoring Chemical as compared to that without use of this fuel additive. This is further evidenced by increased rate of clinker detachment and bottom ash removal rates in Unit No.3. There is a definite reduction in SO_2 emissions through use of Combustion Monitoring Chemical., This reduction is of the order of 19.95% in Unit No.1 & 23.88% in Unit No.3. This reduction is obtained inspite of the increase in sulphur content by about 14% during second stage of trial. It is believed that optimization of dosage levels of Combustion Monitoring Chemical will lead to further reduction in SO_2 levels.

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