Appraisal of SOx Emission from Flue Gas in Thermal Power Station and Dry Sorbent Injection (DSI) Method to Reduce SOx

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Abstract: Electrical vitality created in any nation is one of the advancement estimates happens in that nation. The vitality delivered is principally founded on the accessible assets, for example, streaming water, coal, oil, gas, atomic fills, wind, sunlight based and so forth.

The accessibility of wealth coal in India had incited the influence plant organizers to introduce coal based warm influence stations. During the pre-autonomy and post-freedom period in mid fifties, the need was to produce control and consequently much consideration was not paid to the contamination perspective and this proceeded up to late seventies.

Most of intensity plants in India extending from not many MW to 500 MW or more are of pummeled fuel terminated boilers using low calorific, low coal sulfur, high debris content sub-bituminous coal. Because of consuming of the coal, discharges, for example, Particulate Matter (PM), Oxides of Sulfur (SOx) and Oxides of Nitrogen (NOx) aside from CO2, CO are diverted to the climate through the vent gas. The mindfulness made by contamination impact on the general public and the tremendous measure of disintegration exposed to the gear constrained the specialists to make contamination standards increasingly stringent.

In this paper, the methodology to reduce SOx from flue gas in an old lower capacity power station is discussed and the optimum and cost effective methodology adopted is Dry Sorbent Injection (DSI) by injecting sodium bicarbonate or sodium carbonate or trona in the flue gas path after furnace and before/after Air-preheater to remove SO2/SO3 from the flue gas. The removed sulphate will be collected along with ash in ESP or Fabric Filter in a Bag house

Key words: Dry Sorbent Injection (DSI), Trona, Sodium carbonate, sodium bicarbonate, Air-preheater, ESP, Baghouse..

I. INTRODUCTION

In India seventy percent of the electricity is generated through fossil fuels like coal. Due to more burning of fossil fuels for power generation, high air pollution has been observed in flue gas emitted from thermal power plants.

The primary discharges from coal burning at warm power plants are Carbon dioxide (CO2), Nitrogen oxides (NOx), Sulfur oxides (SOx), Chlorofluoro carbons (CFCs), carbonaceous material (ash), and air-borne inorganic particles, for example, fly debris, otherwise called Suspended Particulate Matter (SPM) and other follow gas species (21). Around half of the complete SOx, 30% of all out NOx, and

8% of absolute PM2.5 outflows are ascribed to the vitality part, inside which coal TPPs are the greatest givers (IEA and IIASA, 2015)

Even though the emission norms have been mentioned for Particulate Matter (PM) by the MoEF, there were no emission norms for Oxides of Sulphur (SOx), Oxides of Nitrogen (NOx) and Mercury (Hg) before 2015.

Coal from Indian mines have high debris content (which adds to PM discharges), while imported coal from South Africa and Indonesia have high sulfur content. Expecting normal plant working conditions and ignition change factors from writing, CSTEP's investigation shows that so as to fulfill the guidelines, convergences of SOx should be diminished by 67–95%, NOx by 41–95% and PM10 by 50–85%.

A. Effects Of Sox On Environment

One of the key emissions from the power plants is SOx. SOx emissions result in acid rain, corrosion of buildings and structures, and deterioration of human health. SOx emissions depend directly on the sulphur content in the coal being used to fire a plant. Studies indicate that SOx emissions from imported coal are lower as compared to Indian coal. [1]-[5]

B. Effects Of Combustion Of Coal In Thermal Power Plants And Process Industries

The poisons transmitted from warm power plants depend to a great extent upon the fuel consumed, the heater structure, the overabundance air, and any extra gadgets used to lessen the discharges. At present, the main control gadget utilized in warm power plants in India is Electrostatic precipitator (ESP) to control the emanation of fly debris (SPM). CO2, SO2, nitric oxide (NO), sediment, and SPM emanations from every one of the warm (coal-terminated) control plants in India have been processed utilizing fundamental standards of burning. Expanding interest for power and reliance on petroleum products will concentrate later on advancements to diminish outflows of numerous contaminations.[6]-[10]

At present scenario, FGD leads the way in reducing the SOx emission from the flue gas due to its efficiency to reduce SOx upto 99 % from flue gas.. However for lower capacity and old thermal plants where space is a main constraint to install FGD system, the Dry Sorbent Injection (DSI) methodology is one of the optimum methodologies for reducing SOx from the flue gas.

II. MEASUREMENTS AND DATA COLLECTION

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A. A. Indian Standard Method For Measurement Of So2

IS : 11255 (Part 2):1985

This standard prescribes the IPA-Thorin method for measurement of sulphur dioxide emissions. A gas sample is extracted from the sampling point in the stack. The acid mist, including sulphur trioxide, is separated from the sulphur dioxide and the sulphur dioxide fraction is measured by the barium thorin titration method (13)

B. B. Sampling Train

In this project work, we are going to study the SOx emission level of a thermal power plant in India after the implementation of new environmental norms. For this SOx emission data has been collected before the implementation of suitable methodology[11]-[15]
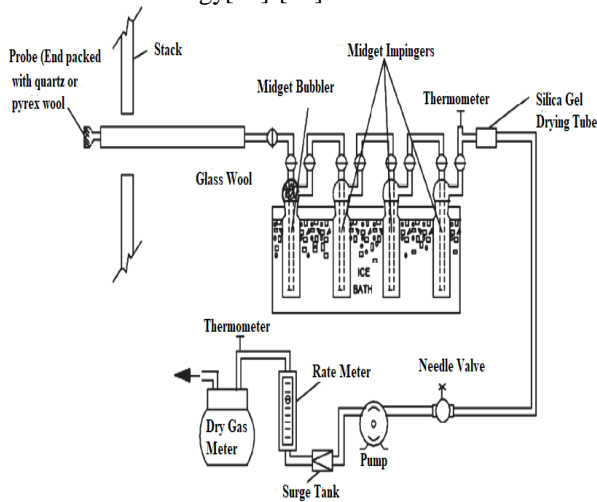

Fig. 1 sampling Train
Table I Initial readings taken in flue gas

| PASS | Sample No. | Stack Temp. (°C) | Velocity (m/s) | Actual Values | |
				SO2 (mg/Nm3)	Oxygen as O2 (%)
PASS A	Sample I	126	13.7	870	8.75
	Sample II	127	14.2	898	8.46
PASS B	Sample III	129	14.4	913	8.68
	Sample IV	127	14.0	928	8.52

C. Oxygen Corrections

The results of SO2 has been compared with MoEF&CC Emission Norms (2015) for Thermal Power Plants. It is observed that value of SO_2 is exceeding the norms. The stack temperature is in the range of 126 to 129 °C and the oxygen measured for the flue gas is in between 7.52 to 7.97 % as can be seen from the data presented in the Table above

The excess air may be considered reason for dilution of flue gas and reducing the stack temperature <135°C. This low stack temperature causes condensation in exhaust duct line and stack. This may result into acid corrosion in flue gas path. There may be leakage from Air Pre Heater (APH) tubes, Electrostatic precipitator (ESP) – hopper bottom flange and multiple inspection window and fan inlet flange connection.

Hence Oxygen corrections are applied at 6% O_2 to the flue gas emissions for Sulphur Dioxide (SO_2) from the measured O_2% by using CPCB Guidelines on Methodologies for Source Emission Monitoring, LATS/80/2013-2014. An amendment was issued vide GOI, MoEF & CC Extraordinary Gazette dt. 29.06.2018. for O_2 correction. The data of SO_2 at measured O_2 and calculated at 6% O_2.

Concentration values in mg/Nm3 = Actual Concentration in mg/Nm3x [(21-Os)/(21-Om)]

(Corrected Values with 6% O_2),

Where,

Os = standard oxygen concentration (6%)

Om = measured oxygen concentration

D. Readings After Oxygen Corrections

Table II
Readings after oxygen correction
METHODS TO CONTROL SULPHUR EMISSIONS

➢ Lower Sulfur Fuel
➢ Dry Sorbent Injection
➢ Dry Scrubber With Fabric Filter
➢ Wet Scrubber

PASS	Sample No.	Stack Temp. (°C)	Velocity (m/s)	Corrected Values with 6% O2 SO2 (mg/Nm3)
PASS A	Sample I	126	13.7	1065
	Sample II	127	14.2	1074
PASS B	Sample III	129	14.4	1112
	Sample IV	127	14.0	1115

➢ Limestone Injection
➢ Wet Flue Gas Desulphurization
 (1) Wet Limestone FGD
 (2) Sea Water FGD

III. CHOOSING THE RIGHT TECHNOLOGY

A. The Need For Dry Sorbent Injection (Dsi) Method

According to an estimation made by CSE, the imported coal having

0.5% sulphur content with NCV of 5500 Kcal/kg generates about 950 mg/Nm^3 of SO2, while Indian coal with NCV of 4100 Kcal/kg and sulphur content 0.5 % generates about 1300 mg/Nm^3. Even at 0.3% sulphur content, the SO2 emissions are estimated to be around 750 mg/Nm^3 for Indian coal. The imported coal having sulphur content as high as 1.0% will have 1900 mg/Nm^3.

However as per the standards notified by the MoEF & CC in 2015, the emissions need to be below 200 mg/Nm^3 for units with 500 MW or more capacity and below 600 mg/Nm^3 for units with less than 500 MW of capacity. For new plants (commissioned after January 1, 2017), the SOx emission limit is only 100 mg/Nm^3.

Since in our study, we have taken a 210 MW unit commissioned before 2003, the permissible SOx emission level should be below 600 mg/Nm^3.

The challenge is to select the most appropriate technology, given the t___ ___ ____ ____ __ __ ____. ___ _____ will depend on: the sulfur content of the coal being burned; the level of desulfurization required to meet regulations; the efficiency of the process, given that parasitic energy consumption varies from technology to technology; and, not least, the increasingly pressing issue of water usage, especially in arid areas or areas subject to drought.

Based on the above criteria, Dry Sorbent Injection (DSI) methodology has been adopted for reducing SOx level from flue gas in thermal power station with lower capacity.[16]-[19]

IV. KEY REQUIREMENTS FOR DSI SYSTEMS

1. Moderate SO2 & SO3 removal
2. high reliability
3. saleable or usable by-product
4. almost no water consumption;
5. removal of HCl along with SOx
6. requires less space
7. optimum for low capacity units
8. low investment cost

V. PRINCIPLES OF DRY SORBENT INJECTION (DSI) METHOD

The sodium carbonate or sodium bicarbonate (SBC) [NaHCO$_3$] or trona (Sodium sesqui carbonate) [NaHCO$_3$·Na$_2$CO$_3$2H$_2$O] is injected into the flue gas path either before or after Air preheater (APH) for the removal of SO$_2$ and SO$_3$.

In India most of the DSI system uses sodium bicarbonate (SBC) as sorbent due to its easy availability, low cost and high efficiency. The sorbent can be injected into several locations throughout the flue gas path, depending on preferred operation. Performance can vary based on mixing, injection location, and whether the station employs an electrostatic precipitator (ESP) or fabric filter (FF) as their particulate removal device.[25-34]

Normally, SBC sorbent was injected before the Air preheater (APH) to improve APH performance and reduce H$_2$SO$_4$ corrosion. With this type of DSI, the performance of APH can be improved, more heat will be returned to boiler and thus the boiler heat rate and efficiency will improve.

In some cases, injection was carried out after the air pre-heater and before the Electrostatic precipitator (ESP) or Fabric Filter (FF). This proved very effective at eliminating visible plumes at the stack.

SBC is the most available sodium sorbent for DSI. The material is delivered with a relatively large particle size to ease the handling and storage process. Therefore, it must be pulverized prior to injection in the flue gas path. For pulverizing/milling the SBC, different types of Mills are available according to the requirement, size and capacity of the power stations and the percentage of SOx to be removed.

Separate storage yard/silos are required for storing of SBC in a power plant. However Mobile DSI injection system is also available on temporary basis or for power stations with lower capacities.

Different capacity pulverizes were used specifically to achieve required size of the sorbent particle, increase the surface area. For this purpose blowers are used to convey the material from the silo through the mill to the duct.
While injecting the SBC sorbent, the flue gas temperature is very much essential since below 135°C the SBC will remain crystalline and above 345°C , the SBC particles becomes soften, which reduces its porosity and therefore reactivity.

Therefore SBC should be injected in the flue gas zone where the temperature lies between 135°C and 345°C so as to achieve high level of SOx removal. (upto 60 to 70 %). However higher removal efficiency can be achieved if a Fabric filter is used instead of ESP in the system (upto 90% SOx removal).
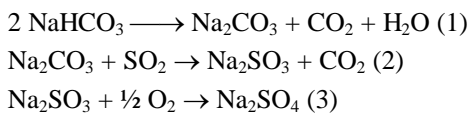
VI. EFFECT OF SORBENT AND PROCESS

PARAMETERS ON SO2 REMOVAL

The SO_2 removal in flue gas by DSI depends on the following parameters:

9. Sorbent type
- sorbent amount
- injection temperature
- temperature-time history
- sorbent surface area
- sorbent particle size
- initial SO2 level
- Particulate capture device.

VII. ABSORPTION PROCESS OF SO2 IN DSI USING SODIUM BICARBONATE

Using Sodium bicarbonate in DSI enables a good removal result for SO2 at comparatively high temperatures and regardless of the flue gas humidity.

$$2\ NaHCO_3 \longrightarrow Na_2CO_3 + CO_2 + H_2O \quad (1)$$
$$Na_2CO_3 + SO_2 \rightarrow Na_2SO_3 + CO_2 \quad (2)$$
$$Na_2SO_3 + \tfrac{1}{2}\ O_2 \rightarrow Na_2SO_4 \quad (3)$$

VIII. MAJOR COMPONENTS OF DSI

- Storage yard/Silo for storing sodium bicarbonate
- Mill for grinding sodium bicarbonate into fine particles
- Spraying system into flue gas duct (Before or after Air preheater)
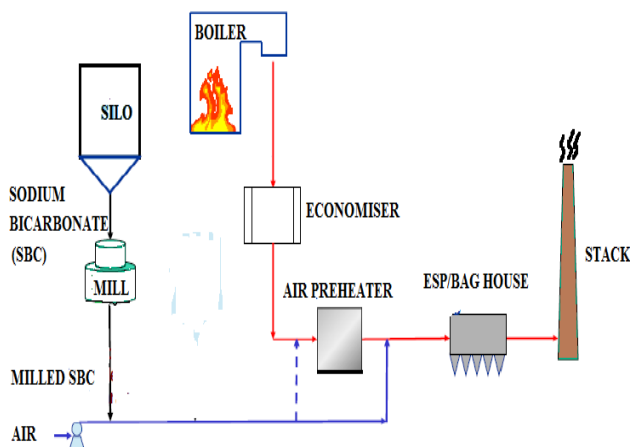
SCHEMATIC DIAGRAM OF DSI

Fig. 2 Schematic diagram of DSI

ADVANTAGES OF DRY SORBENT INJECTION (DSI)

- A dry sorbent injection (DSI) system enables plants to remain in operation when the capital cost of a wet or

semi-dry flue gas desulphurization (FGD) system is too high. Injection of these alkali sorbents can also offer other benefits to the plant including lower operating costs, less corrosion and reduced activated carbon usage for mercury removal in high SO_3 environments.

10. DSI is an easily retrofitted, low capital cost system that is capable of relatively high (upto 80 per cent) SO_2 removal, especially with a fabric filter. DSI employs SBC, trona, or hydrated lime as sorbents of choice depending upon local availability and removal levels required. Operating costs of a DSI system have shown to be comparable to other FGD systems in the right application.

- Ideal solution for both coastal/hinterland locations
- Can be used for all fuels
- Low environmental impact
- Compliance with all legal emissions and discharge regulations
- Maximum plant availability at optimum overall system costs
- Energy-optimised plant operation thanks to flexible adaptation to the boiler operation
- Space-saving installation concept due to the concentric basin geometry
- Flexibility in narrow spaces
- Short construction time when compared with other types of FGD systems
- Simple & reliable
- Proven Technology
- Uses only dry sorbents and no need for any additional water requirement in case of wet FGDs.
- No by-product handling
- Fully automated operation

IX. RESULT ANALYSIS

A. Final Measurements With Actual Oxygen Value

The final measurements have been taken in the stack and tabulated as below:

Table III
Final Measurement of SOx

PASS	Sample No.	Stack Temp. (°C)	Velocity (m/s)	Actual Values	
				SO2 (mg/Nm3)	Oxygen as O2 (%)
PASS A	Sample I	123	15.0	434	8.30
	Sample II	127	14.8	450	8.61
PASS B	Sample III	129	15.3	417	8.48
	Sample IV	127	14.5	428	8.83

Final Values After Oxygen Correction

Oxygen corrections are applied at 6% O_2 to the flue gas emissions for Sulphur Dioxide (SO_2) from the measured $O_2\%$ by using CPCB Guidelines on Methodologies for Source Emission Monitoring, LATS/80/2013-2014.

Table IV
Final Measurement of SO_2 after oxygen correction

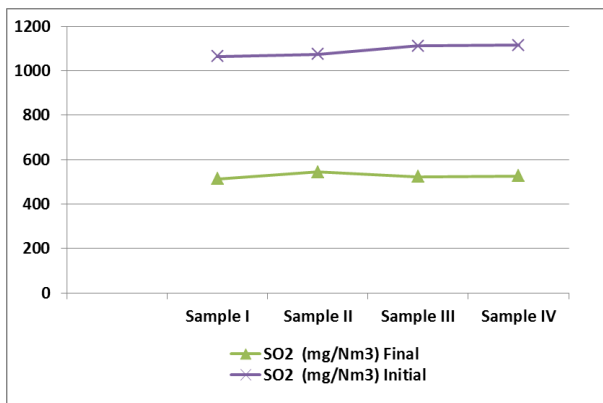| PASS	Sample No.	Stack Temp. (°C)	Velocity (m/s)	Corrected Values with 6% O2
				SO2 (mg/Nm3)
PASS A	Sample I	135	15.0	513
	Sample II	137	14.8	545
PASS B	Sample III	142	15.3	523
	Sample IV	139	14.5	527

C. Comparing Effectiveness Of Dsi

Fig. 3 SOx values before and after implementation of DSI

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