SOx Control during Combustion of Coal by Adding LimeStone

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Abstract— If we are using higher sulfur content fuel, i.e. Coal then we requires to mix the higher amount of Lime Stone to reduce the SOx. It depends upon the requirement for desulfurization. If we are mixing higher amount of Limestone then we get high amount of Calcium Oxides (CaO). It will help to desulfurize higher Sulfur or Sulfur dioxides (SO_2). So it is most important to know the amount of Calcium Oxides (CaO) present in the lime stone that we are using. Lower the Calcium Oxides (CaO) will increases the Lime stone consumption.

Index Terms — SOx, Calcination, Desulfurization, Sulfur Dioxide, Sulfur Trioxide.

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1 INTRODUCTION

SOx emission control is most essential requirement in today scenario because High concentrations of sulfur dioxide (SO_2) can result in breathing problems with asthmatic children and adults who are active outdoors.
Apart from health hazard it is very harmful for environment because Sulfur dioxide and nitrogen oxides are the major precursors of acid rain, which has acidified soils, lakes and streams, accelerated corrosion of buildings and monuments, and reduced visibility.

Sources of SOx emission from combustion of fuel containing sulfur -- mostly coal and oil and also produced during metal smelting and other industrial processes.

So control in SOx emission is most essential for Environmental aspect & also as per Govt. Pollution control board rules & regulation it must not exceed 100 PPM. To control the same it need to Desulphurises the Sulphur present in Fuel which is used in various Industries basically at Thermal Power plant in Boiler as a combustible material.

2 STATEMENT OF PROBLEM

Health Effects: High concentrations of sulfur dioxide (SO_2) can result in breathing problems with asthmatic children and adults who are active outdoors. Short-term exposure has been linked to wheezing, chest tightness and shortness of breath. Other effects associated with longer-term exposure to sulfur dioxide, in conjunction with high levels of particulate soot, include respiratory illness, alterations in the lungs' defenses and aggravation of existing cardiovascular disease.
Environmental Effects: Sulfur dioxide and nitrogen oxides are the major precursors of acid rain, which has acidified soils, lakes and streams, accelerated corrosion of buildings and monuments, and reduced visibility. Sulfur dioxide also is a major precursor of fine particulate soot, which poses a significant health threat.
Sources: Combustion of fuel containing sulfur -- mostly coal and oil. It is also produced during metal smelting and other industrial processes.
So control in SOx emission is most essential for Environmental aspect & also as per Govt. Pollution control board rules & regulation it must not exceed 100 PPM.

3 DEFINITION OF TERMS

3.1 Sulphur(S)

Sulphur is a constituents of fuel found from its ultimate analysis about 1% to 8% as per quality of fuel. Basically Pet coke having higher sulfur percentage which is a byproduct of Petroleum refinery. Sulfur reacts with oxygen to produce sulfur dioxide (SO_2) & sulfur trioxide (SO_3).

Molar mass: 32.065 gm/mol
Formula: S
Melting point: 115.2°C

3.2 Sulfur dioxide(SO_2)

Sulfur dioxide is the chemical compound with the formula SO_2. It is a toxic gas with a pungent, irritating smell that is released by volcanoes and in various industrial processes.

Molar mass: 64.066 gm/mol
Formula: SO_2
Density: 2.63 kg/m³
Boiling point: -10 °C
Melting point: -72 °C

3.3 Sulfur Trioxide(SO_3)

Sulfur trioxide is the chemical compound with the formula SO_3. In the gaseous form, this species is a significant pollutant, being the primary agent in acid rain. It is prepared on massive scales as a precursor to sulfuric acid.

Formula: SO_3
Molar mass: 80.066 gm/mol
Density: 1.92 gm/cm³
Melting point: 16.9 °C

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3.4 Sulfuric Acid (H_2SO_4)

Sulfuric acid is a highly corrosive strong mineral acid with the molecular formula H_2SO_4.

It is a pungent-ethereal, colorless to slightly yellow viscous liquid which is soluble in water at all concentrations.

Formula: H_2SO_4

Density: 1.84 gm/cm³

Molar mass: 98.079 gm/mol

Melting point: 10 °C

Boiling point: 337 °C

IUPAC ID: Sulfuric acid

3.5 Calcinations Process

The process of heating a substance to a high temperature but below the melting or fusing point, causing loss of moisture, reduction or oxidation, and dissociation into simpler substances. The term was originally applied to the method of driving off carbon dioxide from limestone to obtain lime (calcium oxide). Calcinations is also used to extract metals from ores.

3.6 Desulfurization Process

It the process of removing sulfur from flue gas by using wet process, Semi-dry process or Dry process.The reaction between the SO_2 and the alkali can take place either in bulk solution ('wet' FGD processes) or at the wetted surface of the solid alkali ('dry' and 'semi-dry' FGD processes).

4 Theory Involved

For proper Desulfurization process the desulfurising agent (lime stone) is required as per the sulfur content in the fuel used.

5 Calculation

Input data sheet

5.1 Sulfur percentage in Coal

The below mentioned data is taken from analysis of coal in laboratory:

Type of Coal	% Of Sulfur In Coal
Pet coke	6%
Lignite	3%
South African B-Grade	0.5%
Philippines	1%
Indian	1%

5.2 Limestone parameter

The below mentioned data is taken from analysis of coal in laboratory:

Parameters of LimeStone	Quantity in %
$CaCO_3$	82
$MgCO_3$	2.14
FeO_3	3.72
SiO_2	9
Al_2O_3	2.86

5.3 Molecular weight of some Molecules

Molecules	Molecular Weight
Calcium (Ca)	40
Oxygen (O_2)	32
Sulfur (S)	32
Carbon (C)	12
$CaCO_3$	100
CaO	56
CO_2	44
SO_2	64
$CaSO_4$	136

5.4 Calculation Sheet

The reaction of Sulfur with Lime stone for desulfurization is occurs after the calcinations process as:

5.4.1 Calcinations reaction @ 600 °C to 750°C temperature

$$CaCO_3 \xrightarrow{\text{Heat}} CaO + CO_2\,(g)\uparrow$$

$$100\text{ g} \qquad\qquad 56\text{ g} + 44\text{ g}$$

5.4.2 Desulfurization reaction @ 700 °C to 850 °C temperature

$$CaO + SO_2 + \tfrac{1}{2}O_2 \xrightarrow{\text{Heat}} CaSO_4$$

$$56\text{ g} + 64\text{ g} + 16\text{ g} \qquad\qquad 136\text{ g}$$

$$56/64\text{ g} \quad 64/64\text{ g} \quad 16/64\text{ g} \qquad\qquad 136/64\text{ g}$$

From above reaction we can get how many grams of CaO & O_2 are required to desulfurization of sulfur.

We get 0.875gms of CaO & 0.25gms of O_2 required to desulfurization of 1gm of sulfur Dioxide (SO_2) and produce 2.125gms of $CaSO_4$.

5.5 Output Sheet

From above reaction it is found that 1 gm of Sulfur dioxide (SO_2) required 0.875 gms of CaO and therefore 1 gm of Sulfur(S) required 1.75 gram of CaO.

On the same way we can find out the requirement of desulfurization agent are as mentioned below:

Desulfurization Agent	Requirement of Desulfurization agent Per Gram of Sulfur(S)	Requirement of Desulfurization agent Per Gram of Sulfur Dioxide (SO_2)
Ca	1.25	0.63
CaO	1.75	0.88
$CaCO_3$	3.13	1.56
Lime Stone (46% CaO as per Laboratory Result)	3.80	1.90
Lime Stone (82% $CaCO_3$ as per Laboratory Result)	3.81	1.91

On the same we calculated the requirement of Desulfurization agent for different type of fuel, i.e. Coal:

Coal	Sulfur %	Requirement of Desulfurization Agent			
		Ca	CaO	$CaCO_3$	Lime Stone
Pet Coke	6	0.075	0.105	0.188	0.228
Imported South African-B Grade	0.5	0.006	0.009	0.016	0.019
Lignite	3	0.038	0.053	0.094	0.114
Indian	1	0.013	0.018	0.031	0.038
Philippines	1.5	0.019	0.026	0.047	0.057
Indonesian	1	0.013	0.018	0.031	0.038

From above table we found if sulfur content in coal is higher than we have to mix higher ratio of lime stone to reduce the SOx level.

6 Conclusion

From the above calculation we found that if we are using higher sulfur content fuel, i.e. Coal then we requires to mix the higher amount of Lime Stone to reduce the SOx. It depends upon the requirement for desulfurization.
If we are mixing higher amount of Limestone then we get high amount of Calcium Oxides (CaO). It will help to desulfurize higher Sulfur or Sulfur dioxides (SO_2).
So it is most important to know the amount of Calcium Oxides (CaO) present in the lime stone that we are using.
Lower the Calcium Oxides (CaO) will increases the Lime stone consumption.

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[1] Thermal Power Plant, UltraTech Cement Limited, Kovaya