Desulfurization of Flue Gas

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Introduction

- Flue-Gas Desulfurization (Post-Processing)
  - Removes sulfur dioxide from flue gas emissions (often chemically)
- Flue Gas
  - The effluent stream of a process; composed of a mixture of gases
  - Some products formed from combustion reactions:
    - Carbon Dioxide, Carbon Monoxide, Water Vapor
    - Sulfur Dioxide, Hydrogen Sulfide
  - Other products are non-reactive species
    - Nitrogen
Introduction

- **Sulfur Dioxide**
  - 93% of SO$_2$ emissions arise from fossil-fuel combustion at power plants or other industrial facilities

- **Issues with SO$_2$**
  - causes respiratory problems
  - air pollutant
  - reactive acid
    - oxidizes to form H$_2$SO$_4$

Regulations on Sulfur Dioxide

- Natural atmospheric concentration is 1ppb
- Two standards of differing tolerance
  - Primary- stricter to protect elderly, children
    - Level averaged over 3 years must not exceed 75 ppb.
  - Secondary- to protect public welfare (plants, animals)
    - Must not exceed 0.5 ppm more than once per year
- These numbers for the basis for the design of a power plant


Flue-Gas Desulfurization Methods

- **Scrubbers**
  - Wet
  - Spray Dry
  - Dry Sorbent Injectors
- **SNOX**
- **Wet sulfuric acid process**
Wet Scrubber Process

- Designed to collect gaseous pollutants
- Spray tower optimizes gas-to-liquid contact
- Scrubber Liquid
  - Limestone Slurry
    \[
    \text{CaCO}_3 (s) + \text{SO}_2 (g) \rightarrow \text{CaCO}_3 (s) + \text{CO}_2 (g)
    \]
  - Lime Slurry
    \[
    \text{Ca(OH)}_2 (s) + \text{SO}_2 (g) \rightarrow \text{CaSO}_3 (s) + \text{H}_2\text{O} (l)
    \]
- Mist eliminator entrains excess slurry liquid
- 85% of all scrubbers are wet scrubbers in the United States

Wet Scrubber Process

Advantages

- Relatively high removal efficiency (90-95%)
- Low cost of operation
- Minimal safety hazardous (explosions, fires)
- Collects both gas and particulate matter

Disadvantages

- Wet waste production (contaminated scrubber liquid)
- Formation of highly corrosive acids
- High power requirements

Dry and Semi-dry Scrubbing

- Uses quicklime (CaO) to remove pollutants rather than saturating flue gas with moisture

\[ \text{CaO(s)} + \text{SO}_2 (g) \rightarrow \text{CaS (s)} + 1.5\text{O}_2 \]

- Produces solid salt waste (CaS)
  - minimal hazard
  - less requirements for disposal
- Does not produce corrosive material or waste water
  - Less maintenance and disposal costs
- Less overall efficiency than wet scrubbing

Dry and Semi-dry Scrubbing

Spray Drying (Semi-dry)

- the quicklime sorbent contains a slight amount of water that will remain as vapor within flue gas at end of process
- sprays a quicklime slurry into the flue gas
- 12% of all scrubbers used in the US
- at least 70% efficiency, higher in recent years


Dry and Semi-dry Scrubbers

Dry Sorbent injection

- entirely dry quicklime sorbent is sent into the flue gas
- 3% of all scrubbers used in the US
- upwards of 70% efficiency, not as high as wet or semi-dry scrubbing

Sulfur Dioxide is oxidized at high temperature on Vanadium oxide catalyst

\[ \text{NO}_x \text{ reduced to } N_2 \text{ in catalytic converter} \]

\[ \text{SO}_2 + O_2 \leftrightarrow \text{SO}_3 + \text{H}_2\text{SO}_4 \]

Sulfur Trioxide converted to commercial grade Sulfuric acid

Environmentally friendly
- Produces steam instead of waste water
- NO\(_x\) (NO and NO\(_2\)) also reduced to N\(_2\)
- NO\(_x\) are a dangerous pollutant

Wet Sulfuric Acid Process (WSA)

Same as SNOX but without nitrogen processing

Application to Project

- **Claus process produces residual sulfur dioxide**
  - Intermediary Reaction \[2\text{H}_2\text{S} + 3\text{O}_2 \rightarrow 2\text{SO}_2 + 2\text{H}_2\text{O}\]
  - Final Reaction \[2\text{H}_2\text{S} + \text{SO}_2 \rightarrow 3\text{S} + 2\text{H}_2\text{O}\]
  - Residual \(\text{H}_2\text{S}\) could also be sent to scrubber

- **Wet, dry scrubbers and SNOX all potential methods**
  - Wet scrubbers are most efficient
  - Dry scrubbers do not produce waste streams
    - salt needs to be sent to landfill
  - SNOX process most energy-efficient method
    - produces commercial sulfuric acid \((\text{H}_2\text{SO}_4)\)
    - does not produce waste products or waste water
    - ideal for processes at elevated temperatures \((\text{NO}_2)\)
Block Flow Diagram (SNOX)

Questions?