Desulfurization of Flue Gas

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Outline

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- Flue-Gas Desulfurization Methods
  - Scrubbers
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- Application to Project

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_2SO_4

"Sulfur Dioxide." *EPA*. Environmental Protection Agency, 08 Jan. 2014. Web. 03 Feb. 2014.

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

Owen, Lewis A.; Pickering, Kevin T (1997). *An Introduction to Global Environmental Issues*. Taylor & Francis. pp. 33–. ISBN 978-0-203-97400-1.

"US Environmental Protection Agency." *EPA*. Environmental Protection Agency, n.d. Web. 01 Feb. 2014. <http://www.epa.gov/air/criteria.html.

Flue-Gas Desulfurization Methods

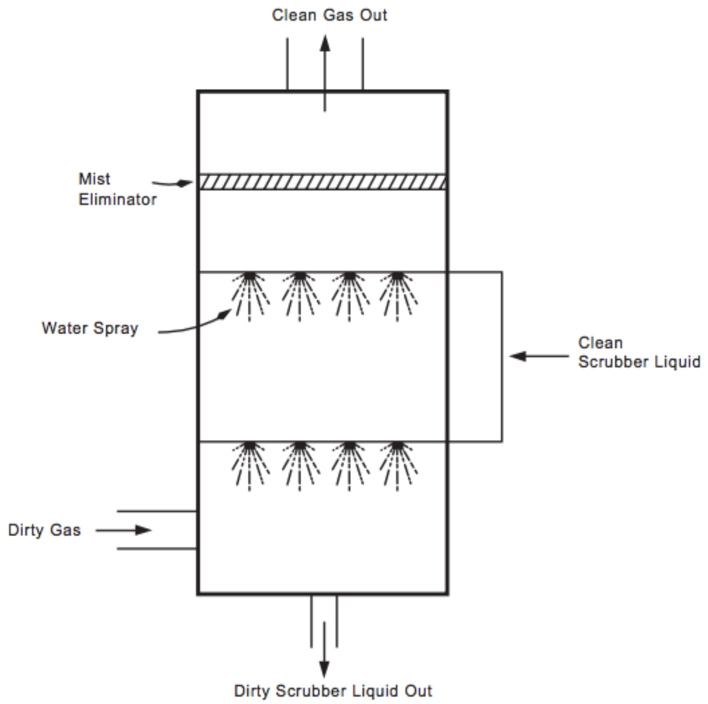
- Scrubbers
  - Wet
  - Spray Dry
  - Dry Sorbent Injectors
- SNOX
- Wet sulfuric acid process

Wet Scrubber Process

- Designed to collect gaseous pollutants
- Spray tower optimizes gas-to-liquid contact
- Scrubber Liquid
  - Limestone Slurry

    $CaCO_3$ (s) +SO_2 (g) -> $CaCO_3$ (s) +CO_2 (g)
  - Lime Slurry

    $Ca(OH)_2$ (s) +SO_2 (g) -> $CaSO_3$ (s) +H_2O (l)
- Mist eliminator entrains excess slurry liquid
- 85% of all scrubbers are wet scrubbers in the United States



Lesson 9: Flue Gas Desulfurization (Acid Gas Removal) Systems. *Yosemite EPA*(n.d.): n. pag. EPA. Web. 2 Feb. 2014.

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

Semrau, K. T. 1977. Practical process design of particulate scrubbers. Chemical Engineering. 84:87-91.

Dry and Semi-dry Scrubbing

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

$$CaO(s) + SO_2\,(g) \rightarrow CaS\,(s) + 1.5O_2$$

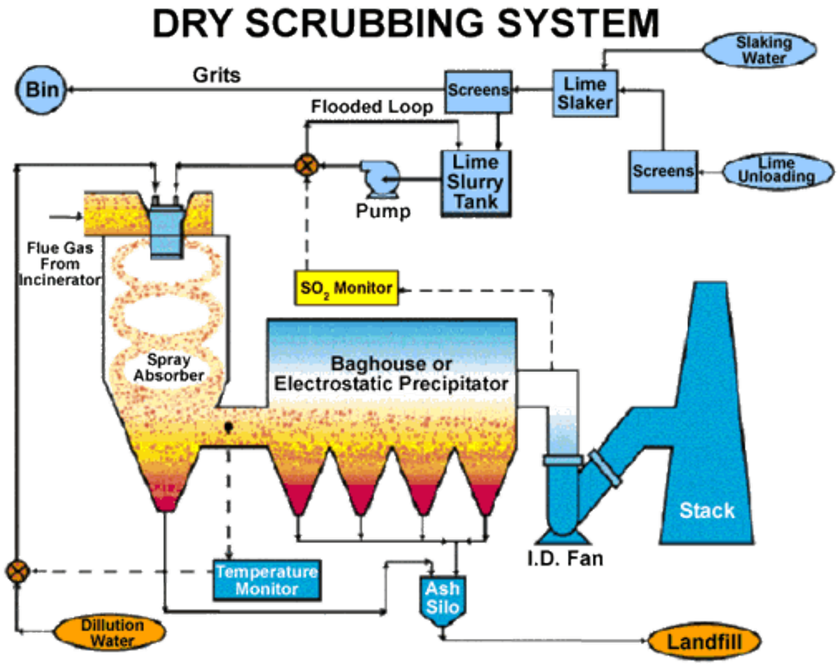
- Produces solid salt waste (CaS)
  - minimal hazard
  - less requirements for disposal
- Does not produce corrosive material or waste water
  - Less maintenance and disposal costs
- Less overall efficiency than wet scrubbing

Lesson 9: Flue Gas Desulfurization (Acid Gas Removal) Systems. *Yosemite EPA*(n.d.): n. pag. EPA. Web. 2 Feb. 2014.

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



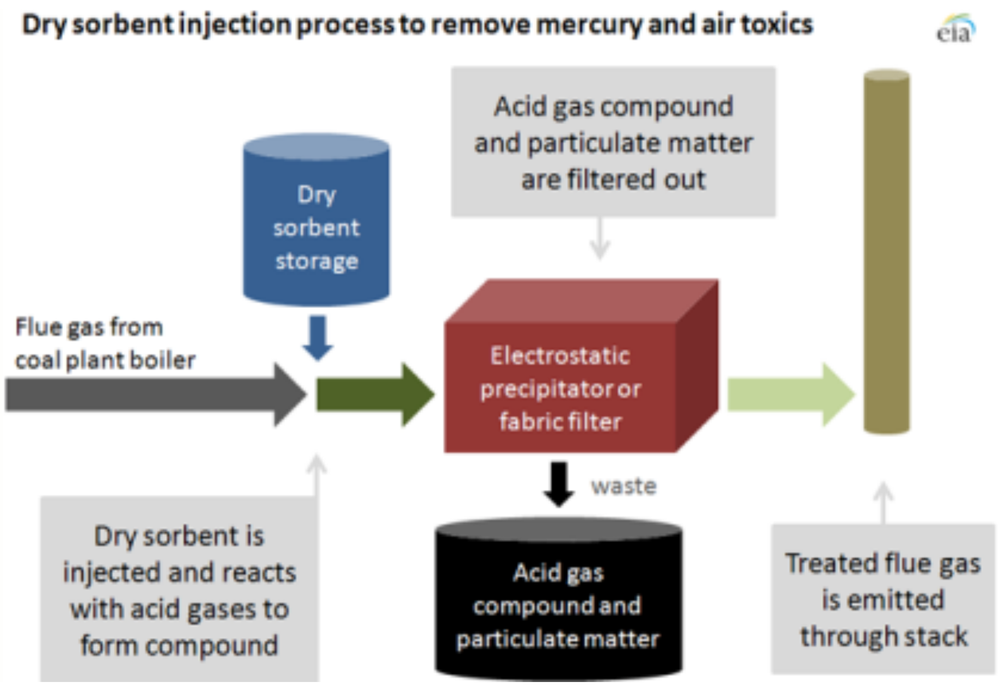
Lesson 9: Flue Gas Desulfurization (Acid Gas Removal) Systems. *Yosemite EPA*(n.d.): n. pag. EPA. Web. 2 Feb. 2014.

Dry Flue Gas Desulfurization. *Integrated Solutions for a Clean Environment*. Hamon Research - Cottrell, Inc., n.d. Web. 2 Feb. 2014.

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



Dry Sorbent Injection May Serve as a Key Pollution Control Technology at Power Plants. *Today in Energy*. U.S. Energy Information Administration, n.d. Web. 04 Feb. 2014.

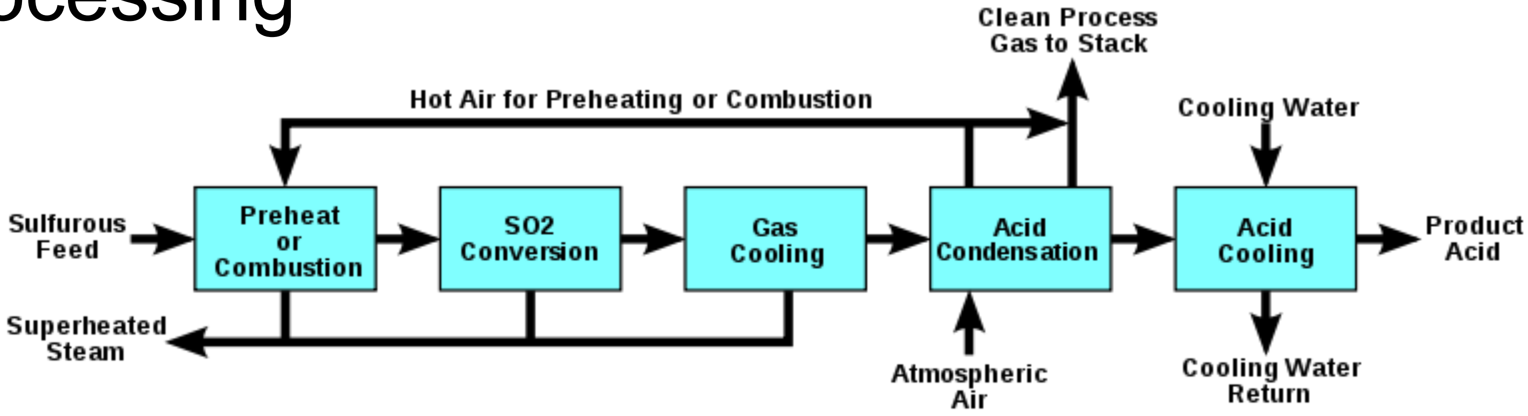
SNOX

- Sulfur Dioxide is oxidized at high temperature on Vanadium oxide catalyst
- NO_x reduced to N_2 in catalytic converter
- $SO_2 + O_2 \Leftrightarrow SO_3 + H_2SO_4$
- 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
    - NOx are a dangerous pollutant

"GCSE CHEMISTRY - The Reaction of Sulfur Dioxide with Oxygen to Make Sulfur Trioxide for The Contact Process to Make Sulfuric Acid - GCSE SCIENCE." *GCSE CHEMISTRY - The Reaction of Sulfur Dioxide with Oxygen to Make Sulfur Trioxide for The Contact Process to Make Sulfuric Acid - GCSE SCIENCE.* N.p., n.d. Web. 05 Feb. 2014.

Wet Sulfuric Acid Process (WSA)

Same as SNOX but without nitrogen processing

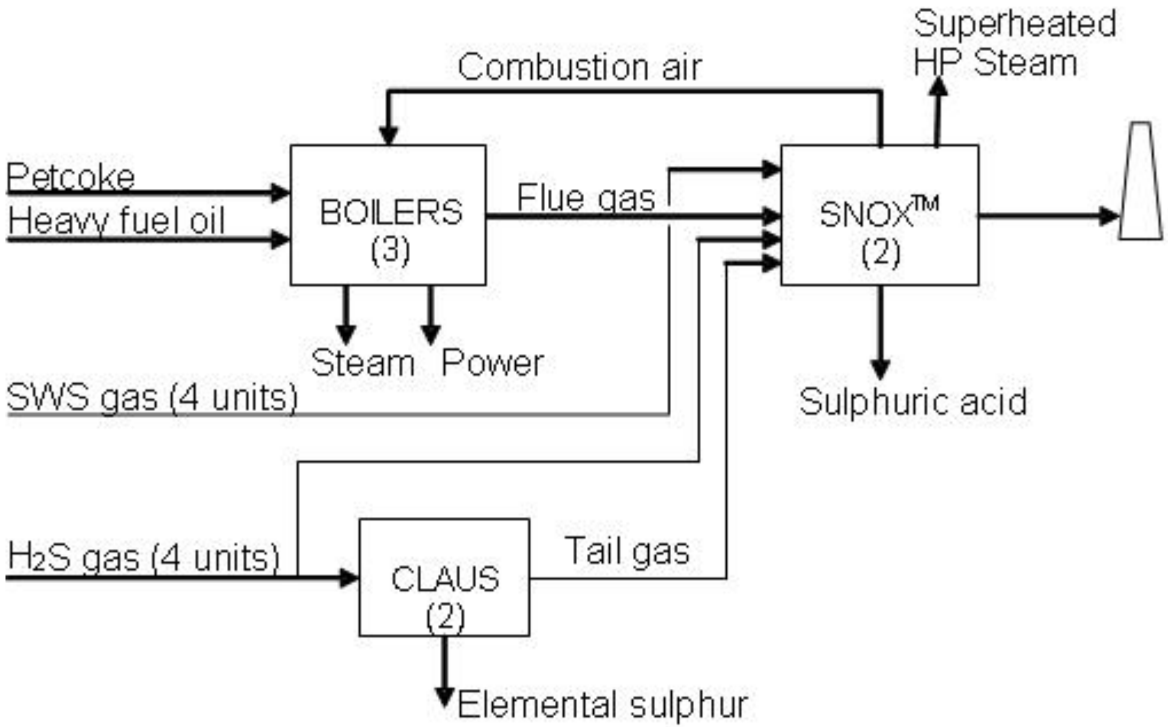


"File:WetSulfuricAcidProcessDiagram.svg." *Wikipedia*. Wikimedia Foundation, 22 Jan. 2014. Web. 05 Feb. 2014.

Application to Project

- Claus process produces residual sulfur dioxide
  - Intermediary Reaction $2\ H_2S + 3\ O_2 \rightarrow 2\ SO_2 + 2\ H_2O$
  - Final Reaction $2\ H_2S + SO_2 \rightarrow 3\ S + 2\ H_2O$
  - Residual H_2S 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 (H_2SO_4)
    - does not produce waste products or waste water
    - ideal for processes at elevated temperatures (NO_2)

Block Flow Diagram (SNOX)



"SNOX Process." *Wikipedia*. Wikimedia Foundation, 20 May 2013. Web. 05 Feb. 2014. <http://en.wikipedia.org/wiki/SNOX_process>.

Questions?