Scrubber Fundamentals

TVA's Experience With The Basics

APC Round Table and Expo

July 25, 2005

Presentation Topics

1) Basic Types of Scrubber Systems
2) TVA's Specifics of Different Scrubber Designs
3) TVA's Approach to New Scrubber System Design

Basic Types of Scrubber Systems

Most Common Systems:

1) Limestone wet scrubbing with forced oxidation
2) Wet scrubbing with lime
3) Spray dry scrubbing

Basic Types of Scrubber Systems

Limestone wet scrubbing with forced oxidation

- Preferred method in utility industry
- Ideal for units burning high sulfur coal and wanting a high SO_2 removal efficiency
- Forced oxidation improves the dewatering and structural characteristics of the waste product

Basic Types of Scrubber Systems

Wet Scrubbing with Lime

- Lime as reagent more costly
- Higher SO_2 removal can be achieved

Basic Types of Scrubber Systems

Spray Dry Scrubbing

- Lime slurry is atomized into gas directly after air pre heater and absorbs SO_2 very quickly
- Reaction products, along with fly ash, are then collected in a precipitator downstream of air pre heater
- Atomization of lime slurry is the most important unit operation in spray dry scrubbing

Basic Types of Scrubber Systems

Other Systems Not Widely Used:

1) Sodium sulfite / dual alkali
2) Magnesium oxide
3) Activated carbon absorption

Basic Types of Scrubber Systems

Sodium Sulfite / Dual Alkali

- SO_2 is absorbed and waste products are formed in separate components
- Cost of sodium reagents is high
- Requires large solid / liquid separation equipment
- Good SO_2 removal efficiency with lower L/G ratios

Basic Types of Scrubber Systems

Magnesium Oxide

- Requires ash free inlet flue gas
- Dried magnesium sulfite/sulfate crystals heated to high temperatures to regenerate the magnesium oxide
- A gas stream is then produced containing SO_2; this is then used for processes that manufacture sulfuric acid or elemental sulfur
- The regenerated magnesium oxide is then recycled back to the scrubber

Basic Types of Scrubber Systems

Activated Carbon Absorption

- SO_2 is absorbed on activated carbon granules in either fixed or fluidized bed reactors
- SO_2 is catalytically oxidized to SO_3 which then is converted to sulfuric acid, and then finally sulfur is produced

TVA's Scrubber Systems

1) Widow's Creek Unit 8: Stevenson, AL
   - 500 MW
   - In service 1977
2) Widow's Creek Unit 7: Stevenson, AL
   - 500 MW
   - In service 1981

TVA's Scrubber Systems

1) Paradise Units 1 & 2: Drakesboro, KY
   - 700 MW each
   - In service 1983
2) Cumberland Units 1 & 2: Cumberland City, TN
   - 1300 MW each
   - In service 1994

TVA's Specifics of Different Scrubber Designs

1) Positive / Negative Draft
2) Flue Gas Reheat or No Reheat
3) Regular SO_2 Scrubbers / Combination SO_2 & Particulate Scrubbers
4) Various Waste Disposal Methods

Positive / Negative Draft

Widows Creek Unit 8: 1st Scrubber

- Originally positive draft
  - Later converted to negative draft
    - Poor performance of precipitators upstream of scrubber
    - Erosion of fans and duct work
  - Situation has improved with negative draft
    - Occasional fan cleaning required since fans are downstream of scrubber

Positive / Negative Draft

- Widows Creek Unit 7 & Paradise:
  - Designed negative draft
- Cumberland:
  - Designed positive draft
  - Good performing precipitator upstream of scrubber
  - Lesson learned: To properly insulate around expansion joints

Flue Gas Reheat or No Reheat

Widows Creek Units 7 & 8:

- Designed with flue gas reheat
- Direct in line type using hot water
- Steam taken from boiler cycle at 400°F
- Uses 2 – 2.5% station service
- Hard to keep reheat tubes clean
- Corrosion on downstream ductwork
- Stack condition: DRY

Flue Gas Reheat or No Reheat

Paradise Units 1 & 2:

- Designed with flue gas cyclic reheat
  - Did not use steam from boiler cycle
- After 5 – 6 years, system removed
  - Very hard to keep tube bundles clean
  - Outlet ducts lined with 317L & drains added in preparation of wet exit gas
- Stack condition: Technically DRY
  - Fans heat of compression heats gas before exiting to stack

Flue Gas Reheat or No Reheat

Cumberland Units 1 & 2:

- Designed with no flue gas reheat
- Outlet ducts C – 276 for wet exit gas
- Stack condition: WET
  - No problems with moisture fall out from stack
  - During certain meteorological conditions, moisture fall out does occur

Regular SO_2 Scrubbers / Combination SO_2 & Particulate Scrubbers

Widows Creek Unit 7 & 8

- Designed as combo scrubbers
- 80% of fly ash collected by precipitator
- 2 tanks in scrubber system
  - Back mixing of tanks can cause chemistry problems
  - Aluminum fluoride blinding can occur

Regular SO_2 Scrubbers / Combination SO_2 & Particulate Scrubbers

Paradise Units 1 & 2:

- Designed as combo scrubbers
- Low inlet fly ash concentration: about 20% of ash in these cyclone boilers is fly ash
- 1 tank in scrubber system
  - Ash contaminates slurry
  - Can cause chemistry problems
  - Aluminum fluoride blinding can occur

Regular SO_2 Scrubbers / Combination SO_2 & Particulate Scrubbers

Cumberland Units 1 & 2:

- Designed as regular SO_2 scrubbers
- Open spray tower type
- Low inlet fly ash concentration due to good performing precipitators
- 1 tank in scrubber system

Various Waste Disposal Methods

1) Fix / Mix Method
   - Mix of dry ash & dewatered material in pug mill (semi dry) and then trucked to storage
2) Wet Pond Method
   - Fill pond with wet gypsum slurry until pond area is full
   - Original waste disposal method of Widows Creek units 7 & 8

Various Waste Disposal Methods

3) Dry Stack Method

- After dewatering gypsum (by use of thickener, etc), conveying and stacking dry material
- Original waste disposal method of Paradise units 1 & 2

Various Waste Disposal Methods

4) Wet Rim Ditch Stack Method

- Fill pond with wet gypsum slurry, let gypsum settle out as water runs off, & build pond walls with dry material
- Current method for Widows Creek units 7 & 8 and Paradise units 1 & 2
- Original waste disposal method for Cumberland units 1 & 2

Various Waste Disposal Methods

5) Gypsum Marketing

- Marketing and selling gypsum to a wall board manufacturing facility
- Current waste disposal method for Cumberland units 1 & 2
  - Wall board facility built adjacent to plant for easy access to TVA's gypsum

TVA's Approach to New Scrubber System Design

1) Positive draft
2) Wet limestone forced oxidation scrubber
3) Regular SO_2 scrubber with no major particulate removal
4) No flue gas reheat
5) Waste disposal methods:
   - Wet rim ditch stack
   - Gypsum marketing
   - New challenges due to plant locations and local permitting requirements

Scrubber Fundamentals

TVA's Experience With The Basics

Questions and Answers