REINHOLD ENVIRONMENTAL Ltd.

# 2014 APC Round Table
# & Expo Presentation

July 14-15, 2014, in Louisville, KY / Hosted by LG&E/KU

# Impact of MATS, Regional Haze, and Other Compliance Issues on FGD Wastewater Treatment Systems

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Workshop 4
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# Agenda

- Introductions
- Regulations and Guidelines that Impact Air Quality Control Systems (AQCS)
- Influence of Regional Haze (BART) and Mercury and Air Toxics Standards (MATS) on Waste Water Treatment Systems (WWTS)
- Impact of Potential Future Utility Effluent Guidelines on WWTS
- Potential Issues of Coal Combustion Residuals Rule on WWTS
- Natural Gas Conversion or Co-firing Impacts on WWTS
- WFGD and WWTS Equipment Potentially Influenced by More Frequent Ramp-up/Ramp-downs and Start-ups
- Purpose of WFGD Waste Water Treatment Technologies (WWTS)
- Typical Categories of WWTS Technologies
- Summary
- Acknowledgements

# Examples of Regulations, Guidelines, and Compliance Issues Related to Air Quality Control Systems

# Regulations Related to AQCS

- Regional Haze (BART, NOx, PM, $SO_2$)
- Mercury and Air Toxics Standards (MATS, Hg, PM, HCl, $SO_2$)
- Effluent Limitation Guidelines (WFGD WWTS, conversion of wet to dry flyash and bottom ash)
- Coal Combustion Residuals (potential CCR, potential pond conversion to new landfills, ash classification, and beneficial reuse)
- Possible replacement of parts of the Cross-State Air Pollution Rule (CSAPR, with regard to ambient Ozone standard, ppb concentration value)
- NPDES changes and Section 316 (a & b) (possible cooling water issues)
- Potential Green-house gas (GHG/$CO_2$) issues for existing units
- Permit Renewal Process
- Consent Decree (if applicable)
- Other regulations or permits (state or federal, e.g., SCR or SNCR $NH_3$ slip)

# Regional Haze (BART)
# Potential Impacts on
# Waste Water Treatment Systems (WWTS)

**Regional Haze technologies result in reduction of nitrogen oxides (NOx), sulfur dioxide ($SO_2$), and/or particulate matter (PM) and other species in stack flue gas.**

- BART related technologies evaluated for coal-fired utility application include the following (examples):
  - Low NOx Burners (LNB) to reduce **NOx** (may influence flyash UBC and flue gas **Hg**)
  - Over-fire Air (OFA) to reduce **NOx**
  - Selective Catalytic Reduction (SCR) to reduce **NOx** (minimize **$NH_3$** slip) (increase **Hg oxidation**)
  - Selective Non-Catalytic Reduction (SNCR) to reduce **NOx** (minimize **$NH_3$** slip)
  - SCR catalyst regeneration or new replacement catalyst to reduce **NOx** (increase **Hg oxidation**)
  - Dry sorbent injection (DSI, Hydrated Lime or Trona) to reduce $SO_3$ / $H_2SO_4$ and/or $SO_2$
  - Wet sorbent injection (WSI, SBS, $Na_2CO_3$) to reduce $SO_3$ / $H_2SO_4$ (reduce **Hg**)
  - Electrostatic precipitator (ESP) system upgrades (e.g. HFTRs) to reduce **PM** (filterable)
  - Fabric Filter (PJFF) to reduce **PM**
  - Wet flue gas desulfurization (WFGD) system upgrades to reduce $SO_2$, **PM** (reduce **HCl & Hg**)
  - Dry FGD (CDS/NID/EAD/SDA/DSI to reduce $SO_2$ (Dry FGD **may eliminate need for FGD WWTS**)
  - ReACT to reduce $SO_2$ (ReACT **may eliminate need for FGD WWTS**)
  - Fuel blending (blend existing higher sulfur coals with PRB coals) to reduce $SO_2$ ,**NOx**, & **HCl**
  - Natural Gas co-firing (or full conversion) of coal plant (reduce $SO_2$, **PM, NOx, Hg, HCl, Se, As**)
  - Other concepts

## SCR – Chemistry – examples

- $4\,NO + 4\,NH_3 + O2 \rightarrow 4\,N_2 + 6\,H_2O$
- $NO + NO_2 + 2\,NH_3 \rightarrow 2\,N_2 + 3\,H_2O$
- $6\,NO_2 + 8\,NH_3 \rightarrow 7\,N_2 + 12\,H_2O$
- $2\,NO_2 + 4\,NH_3 + O_2 \rightarrow 3\,N_2 + 6\,H_2O$

**A key concept of a SCR system is to achieve the required $NO_X$ reduction, with minimum ammonia ($NH_3$) slip, in an effort to reduce the formation of ammonium bisulfate ($NH_4HSO_4$) deposits in the APH and minimize the amount of ammonium ($NH_4^+$) in the WFGD WWTS.**

# Dry Sorbent Injection (DSI) System for Sulfur Dioxide ($SO_2$) Control – example

## Boardman DSI System

- Portland General Electric's (PGE)
- 600 MW coal-fired plant
- Fires low-sulfur PRB coal
- Dry Sorbent Injection (DSI) using Trona
- UCC DSI Equipment
- CB&I Performed Contract as EPC

## Dry Scrubber – Chemistry – examples

- $CaO + H_2O \rightarrow Ca(OH)_2$
- $Ca(OH)_2 + SO_2 \rightarrow CaSO_3 \cdot ½ H_2O + ½ H2O$
- $Ca(OH)_2 + SO_3 + H_2O \rightarrow CaSO_4 \cdot 2H_2O$
- $Ca(OH)_2 + 2 HCl \rightarrow CaCl_2 + 2 H_2O$
- $Ca(OH)_2 + 2 HF \rightarrow CaF_2 + 2 H_2O$

**A key concept of a dry scrubber with pulse jet fabric filter is that it produces a dry byproduct waste material which can be mixed with dust suppression water and truck transported & disposed in a secure landfill, without the need for a WFGD WWTS.**

# Mercury and Air Toxics Standards (MATS)
# Potential Impacts on
# Waste Water Treatment Systems (WWTS)

# Influence of MATS Regulations and Technologies on WFGD Waste Water Treatment (WWTS)

**MATS technologies result in reduction of hydrochloride (HCl) or sulfur dioxide ($SO_2$) surrogate, particulate matter (filterable PM), mercury (total Hg), and other species in stack flue gas.**

- MATS-related technologies typically being evaluated for coal-fired utility application include the following (examples):
  - Calcium bromide ($CaBr_2$ or $CaCl_2$ coal additives or f.g. additives to oxidize **Hg**) (may oxidize **Se**)
  - Combustion additives (e.g., B&W PGG Mitagent $^{TM}$) to reduce **Hg**, P, **Se** emissions
  - SCR catalyst regeneration and/or new replacement catalyst to increase **Hg** oxidation
  - Dry sorbent injection (HL or Trona) to reduce $SO_3$ /$H_2SO_4$ before ACI for **Hg** removal
  - Wet sorbent injection (SBS, $Na_2CO_3$) to reduce $SO_3$ /$H_2SO_4$ before ACI for **Hg** removal
  - Activated carbon injection (ACI) or SBS to reduce **Hg**
  - Amended silicate injection (ASI) to reduce **Hg**
  - Electrostatic precipitator (ESP) system upgrades (e.g. HFTRs) to reduce **PM** (filterable)
  - Wet flue gas desulfurization (WFGD) system upgrades to reduce stack $SO_2$, **HCl**, **PM**, **Hg**
  - Activated carbon addition directly into WFGD system (e.g. Steag process, to reduce **Hg**)
  - Mercury re-emission (MRE) inhibitor chemical for WFGD service to reduce **Hg re-emission**
  - Gore™ process to reduce stack **Hg**
  - Fuel blending (blend existing higher chloride/sulfur coals with PRB coals) to reduce **HCl** & $SO_2$
  - Natural Gas Co-firing (or full conversion) of coal plant (to reduce $SO_2$, **HCl, PM, Hg, Se, As**)
  - Other concepts

# Dry Sorbent Injection (DSI) for Sulfur Trioxide ($SO_3$) Control Before PAC Injection

## Dry Sorbent Injection – Chemistry – Trona Reagent

- $2\ [Na_2CO_3 \cdot NaHCO_3 \cdot 2H_2O] + heat \rightarrow 3\ Na_2CO_3 + CO_2 + 5H_2O$
- $Na_2CO_3 + SO_2 + \frac{1}{2}\ O_2 \rightarrow Na_2SO_4 + CO_2$
- $Na_2CO_3 + SO_3 \rightarrow Na_2SO_4 + CO_2$
- $Na_2CO_3 + 2\ HCl \rightarrow 2\ NaCl + H_2O + CO_2$
- $Na_2CO_3 + 2\ HF \rightarrow 2\ NaF + H_2O + CO_2$

## Dry Sorbent Injection – Chemistry – Hydrated Lime Reagent

- $Ca(OH)_2 + SO_2 \rightarrow CaSO_3 \cdot \frac{1}{2}\ H_2O + \frac{1}{2}\ H_2O$
- $Ca(OH)_2 + SO_3 + H_2O \rightarrow CaSO_4 \cdot 2H_2O$
- $Ca(OH)_2 + H_2SO_4 + H_2O \rightarrow CaSO_4 \cdot 2H_2O$
- $Ca(OH)_2 + 2\ HCl \rightarrow CaCl_2 + 2\ H_2O$
- $Ca(OH)_2 + 2\ HF \rightarrow CaF_2 + 2\ H_2O$

**The primary purpose of a DSI upstream of PAC injection is to reduce the concentration of $SO_3/H_2SO_4$ in the flue gas, but an interesting side chemistry is that DSI can slightly reduce the amount of HCl in the flue gas, thus increasing the amount of chloride (Cl) of the flyash (ESP or PJFF) and reducing the amount of HCl entering the WFGD and Cl in the WWTS.**

# PAC or AS Injection – Hg Reduction - examples

**The injection of powdered activated carbon (PAC), amended silicates (AS), or other mercury adsorbents or absorbents will result in reduced mercury (Hg) entering the Wet Flue Gas Desulfurization (WFGD) system and Waste Water Treatment System (WWTS).**

# Upgraded Electrostatic Precipitators (ESP) – examples

## An upgraded ESP results in less PM entering the WFGDS.

- Concepts – Upgraded ESPs
  - HFTR
  - Sectionalization
  - RD electrodes
  - Upgraded rappers
  - Additional fields
  - Demolish existing ESP and retrofit new ESP in parallel
  - Convert ESP to PJFF
  - Other concepts

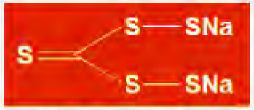
**Various Types of HFTR Systems**

# Mercury Re-emission (MRE) Control Using WFGD Additives

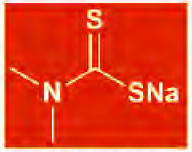
## Per ICAC, WFGD mercury re-emission inhibitor additives include below groups.

$NaHS$

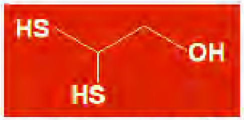
**Inorganic Sulfides**
Sodium bisulfide



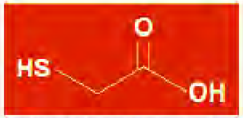
**Organic Sulfides**
polythiocarbonate, disodium salt



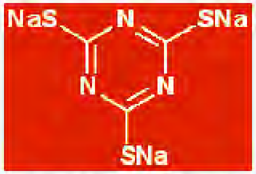
**Organic with nitrogen and sulfur**
Dimethyl dithiocarbamate



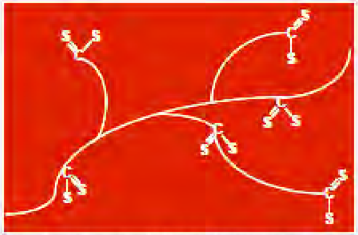
**Organic with oxygen and sulfur**
2,3-dimercaptopropanol



**Organic with oxygen and sulfur**
mercaptoacetic acid



**Organic with nitrogen and sulfur**
trimercaptotriazine



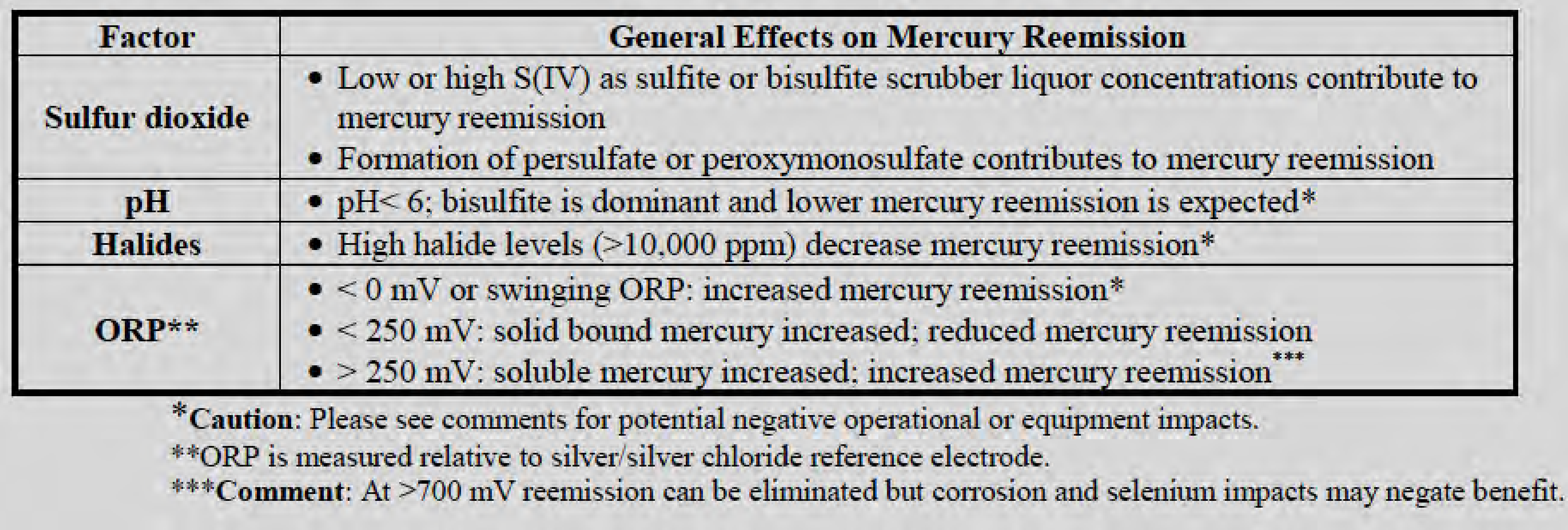
**Low molecular weight polymers with sulfur**
polydithiocarbamate polymers

- **Per ICAC recent whitepaper (June 2014), several mercury sequestering agents have been tested.**
- **Scrubber additives collect “soluble ionic mercury” by forming a complex ion utilizing sulfur as the mercury ligand.**
- **The resulting mercury-containing complex ion prevents ionic mercury reduction to elemental mercury in the scrubber liquor.**

**Field testing can determine if WFGD MRE are complimentary to WWTS Hg ppt chemicals .**

# WFGD Operational Impacts Mercury Re-emission – examples

## Per ICAC below table, WFGD operational variables impact mercury re-emission.



| Factor | General Effects on Mercury Reemission |
|---|---|
| **Sulfur dioxide** | • Low or high S(IV) as sulfite or bisulfite scrubber liquor concentrations contribute to mercury reemission<br>• Formation of persulfate or peroxymonosulfate contributes to mercury reemission |
| **pH** | • pH< 6; bisulfite is dominant and lower mercury reemission is expected* |
| **Halides** | • High halide levels (>10,000 ppm) decrease mercury reemission* |
| **ORP**** | • < 0 mV or swinging ORP: increased mercury reemission*<br>• < 250 mV: solid bound mercury increased; reduced mercury reemission<br>• > 250 mV: soluble mercury increased; increased mercury reemission*** |

*__Caution__: Please see comments for potential negative operational or equipment impacts.

**ORP is measured relative to silver/silver chloride reference electrode.

***__Comment__: At >700 mV reemission can be eliminated but corrosion and selenium impacts may negate benefit.

- **Per above ICAC recent whitepaper (June 2014) table, a number of WFGD operational variables have been shown in laboratory studies to impact mercury re-emission.**
- **The variable range and extent of impact is different for each of the variables depending on scrubber design and required $SO_2$ removal efficiencies.**
- **Ultimately, the purpose of the WFGD is to control sulfur dioxide emissions.**
- **Per ICAC, alterations in WFGD or unit operations can potentially become a compromise between maximizing sulfur dioxide removal along with maximizing mercury capture as well as addressing other issues such as byproduct purity, corrosion and scale formation.**

# Steam Electric Effluent Limitation Guidelines
# Potential Impacts on
# Waste Water Treatment Systems (WWTS)

## Steam Electric Effluent Limitation Guidelines Potential Impacts

- No comingling of wastewaters to achieve water quality discharge standards – standards met at internal outfalls
- Wet fly ash systems – convert to dry ash handling
- Large coal-fired stations – convert to dry bottom ash handling
- FGD and ash leachate wastewater – both traditional precipitation and anaerobic biological treatment or advanced physical/chemical treatment or Zero Liquid Discharge
- Proposed Effluent Guidelines reduced discharge standards (monthly avg) for:
  - Selenium (Se) – 10 ug/L
  - Arsenic (As) – 6 ug/L
  - Mercury (Hg) – 119 ng/L
  - Nitrates & Nitrites ($NO_3^{-1}$, $NO_2^{-1}$ expressed as N) - 0.13 mg/L
- Regulation may impact WFGD WWTS equipment and reagents
- Regulation is not finalized (final rule may be Fall 2015).

# Coal Combustion Residuals Rule
# Potential Impacts on
# Waste Water Treatment Systems (WWTS)

# Coal Combustion Residuals Rule

- Coal combustion residuals (CCR) includes fly ash waste, bottom ash waste, slag waste, and flue gas emission control waste, generated from the combustion of coal.

- Coal Combustion Residuals Rule (CCRR) proposed details have not been finalized (expected within the next year).

- **Impact Question** – how will EPA finally classify different CCR materials?

- **Impact Question** – how will final CCRR impact WFGD WWTS (e.g., WWTS byproduct sludge, WFGD liquid slurry in impoundments, liners and controls, groundwater monitoring, fugitive dust controls, treatment of CCRs, etc.)?

# Natural Gas Conversion or Co-firing
# Potential Impacts on WFGD
# Waste Water Treatment Systems (WWTS)

# Flue Gas Composition and Properties entering AQCS

- Coal to gas conversion (or co-firing) will result in **changes to the flue gas composition and distribution** entering the existing AQCS, such as, moisture, $CO_2$, NOx, ash, $SO_2$, $SO_3$, $H_2SO4$, HCl, HBr, HF, Hg, trace metals, CO/VOC, etc.

- Coal to gas conversion (or co-firing) may result in **changes to the flue gas physical properties and distribution** entering the existing AQCS, such as, temperature, flow rate, distribution, adiabatic saturation temperature (due to moisture content), molecular weight, etc.

- Specific change in flue gas composition & properties will depend on degree of natural gas firing, type of natural gas and coal used (Bit, PRB, lignite), excess air employed, and furnace modifications & specifics, etc.

# Impacts on WFGD Waste Water Treatment (WWTS) due to Natural Gas Conversion or Co-firing - examples

**Some coal-fired utilities are considering natural gas conversion or co-firing as a means to meet air quality regulations and/or plant fuel economic reasons.**

- **WFGD waste water treatment systems can be impacted by natural gas conversion or co-firing in the following ways.**
  - Changes in influent waste water composition and temperature
  - Investigate if heat exchanger is required (e.g., adiabatic saturation temp)
  - Possible decreased WWTS sludge production
  - Possible change in WWTS reagent usage rates
  - Investigate influence of inlet flue gas VOC, $NH_3$ slip, NOx, etc., content on WFGD chemistry and WWTS influent during cases of high natural gas heat input
  - Possible more frequent checks of equalization tank composition to WWTS feed stream
  - Need to continue to maintain effluent quality
  - Investigate impacts to WWTS if WFGD system were bypassed
  - Other impacts

# Natural Gas Combustion Equations – examples

**The fundamental combustion equation for burning natural gas fuel is:**

**Eq 1) Natural Gas (fuel) + Oxygen ($O_2$ from air) → Carbon Dioxide ($CO_2$) + Moisture ($H_2O$)**

**There are a variety of chemical reactions during the combustion of natural gas with air including:**

| | |
|---|---|
| **Eq 2)** | **$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$ + heat** |
| **Eq 3)** | **$C_2H_6 + 3.5O_2 \rightarrow 2CO_2 + 3H_2O$ + heat** |
| **Eq 4)** | **Natural Gas (other hydrocarbons) + $O_2 \rightarrow CO_2 + H_2O$ + heat** |
| **Eq 5)** | **Natural Gas Hydrogen $2H_2 + O_2 \rightarrow 2H_2O$ + heat** |
| **Eq 6)** | **Nitrogen ($N_2$ from air and NG) + $O_2$ → NOx (NO + $NO_2$)** |
| **Eq 7)** | **Natural Gas (hydrocarbons) + $O_2$ → CO + $H_2O$** |
| **Eq 8)** | **Natural Gas (hydrocarbons) + $O_2$ → VOC + $H_2O$** |
| **Eq 9)** | **Natural Gas (trace sulfur compounds) → $SO_2$ (trace) + $H_2O$** |
| **Eq 10)** | **Other chemical reactions (trace)** |

# Flue Gas Composition – Bulk Composition – Entering AQCS System (e.g., FGD) Coal vs. Natural Gas - 100% Conditions – examples

| Flue Gas Component (% by vol) | Coal – A1 PRB (example) | Coal – A2 Bituminous (example) | Coal – A3 Lignite (example) | Natural Gas A4 (example) | Natural Gas A5 (example) | Natural Gas A6 (example) |
|---|---|---|---|---|---|---|
| $N_2$ | 71.26 | 75.27 | 69.03 | 72.25 | 72.22 | 71.89 |
| $CO_2$ | 12.08 | 10.76 | 11.07 | 7.04 | 6.85 | 7.55 |
| $O_2$ | 5.28 | 7.31 | 6.09 | 5.47 | 5.44 | 4.39 |
| $H_2O$ | 11.09 | 6.42 | 13.6 | 15.16 | 15.41 | 16.09 |
| Ash | yes | yes | yes | Nil | Nil | Nil |
| NOx | yes | yes | yes | yes | yes | yes |
| CO | yes | yes | yes | yes | yes | yes |
| VOC | yes | yes | yes | yes | yes | yes |
| $SO_2$ | yes | yes | yes | Nil | Nil | Nil |
| $SO_3/H_2SO_4$ | yes | yes | yes | Nil | Nil | Nil |
| HCl/HF/HBr | yes | yes | yes | Trace | Trace | Trace |
| Trace Metals (Hg, Se, etc.) | yes | yes | yes | Trace | Trace | Trace |

# Flue Gas Adiabatic Saturation Temperature Values
# Coal vs. Natural Gas – 100% Conditions – examples

**Flue Gas Adiabatic Saturation Temperature (AST) Values, within a flue gas desulfurization (FGD) system, for various coal and natural gas types, at full firing conditions (examples, showing potential influence of flue gas moisture content)** [1]

| Parameter | Coal – A1 PRB (example) | Coal – A2 Bituminous (example) | Coal – A3 Lignite (example) | Natural Gas A4 (example) | Natural Gas A5 (example) | Natural Gas A6 (example) |
|---|---|---|---|---|---|---|
| **Adiabatic Saturation Temperature (FGDS, deg F)** | **134** | **124** | **138** | **141** | **142** | **143** |
| **Flue Gas Moisture (Inlet FGDS, % vol $H_2O$)** | **11.09** | **6.42** | **13.6** | **15.16** | **15.41** | **16.09** |
| **Flue Gas Molecular Weight (wet) (lb/lb-mole)** | **29.16** | **29.57** | **28.81** | **27.95** | **27.90** | **27.89** |

**Note: 1) in addition to flue gas moisture content, the AQCS inlet flue gas inlet temperature and composition can impact the flue gas adiabatic saturation temperature (AST) values, thus influencing the temperature of WFGD WWTS streams.**

# WFGD and WWTS Equipment Influenced by More Frequent Ramp-up/Ramp-downs and Startups

# Power Plant – More Frequent Ramp-up/Ramp-downs

- Designing, operating, and maintaining coal-fired plant FGD waste water treatment systems (WWTS) in compliance while accommodating more frequent ramp-up/ramp-downs (due to revised dispatch priority) is a **reality**.

- This includes potentially more frequent unit shutdowns and startups plus revised unit ramp rates (MW-minute values) to accommodate electrical grid load following.

# Example Reasons Why Existing Power Plants May Experience More Frequent Ramp-up/Ramp-downs, Derates, and Startups

- Revised Dispatch Priority (either due to internal or external reasons)
- Electricity Pricing
- Grid Load Demand
- Age and/or Heat Rate of Existing Power Plant
- Natural Gas Pricing vs. Coal Pricing
- Renewables Dispatching to Grid (e.g., Wind, Solar, Bio-mass, etc.)
- Newer Power Plants Connected to Grid (e.g. coal, NG-CC, NG-SC, nuclear)
- New Proposed Combined Heat & Power (CHP) Connected to Grid
- New Proposed Distributed Generation (DG) Power Plants Connected to Grid
- Limits and Changes in Electrical Transmission to Grid (e.g., new corridors)
- Environmental Issues, Regulations, and Guidelines
- Other reasons or issues

# WFGD and WWTS Equipment Impacted by Load Following More Frequent Ramp-up/Ramp-downs & Start-ups (examples)

**Due to economic or other reasons, some coal-fired utilities are considering increased load following, more frequent ramp-up and ramp-downs, or seasonal dispatch, and more frequent startups, which may impact WFGD WWTS.**

- Wet flue gas desulfurization (LSFO, Lime, etc.) impacts (maintain proper pH, TSS, TDS, alkalinity, ORP, use of auxiliary storage tank for improved WFGD chemistry control and faster re-starts, adjust mist eliminator wash cycle duration or timing to address WFGD water balance issues, changes in byproduct gypsum or sludge dewatering sequence or timing, avoid flue gas recirculation solids/moisture deposits in absorber inlet ductwork at lower load conditions, energy consumption management issues including absorber recycle pumps and/or oxidation air blowers in service.
- Mercury re-emission inhibitor (MRE) in WFGD impacts (maintaining proper MRE conc., ORP, pH, testing for soluble Hg content in absorber slurry, increased duties of plant AQCS chemist).
- WFGD waste water treatment system impacts (WFGD WWTS, maintain effluent quality during load following, more frequent checks of equalization tank composition to WWTS feed stream, etc.)

# Proposed “Clean Power Plan” Potential Impacts on WFGD and WWTS

# Proposed "Clean Power Plan" (CPP) Rule Impacts on Waste Water Treatment Systems – potential examples

**The proposed "Clean Power Plan" (CPP) rule for existing power plants, includes four possible "building blocks" concepts for compliance, which may influence the frequency of start-ups/shutdowns, and ramp rates of WFGD/WWTS.**

- **Heat rate improvements** — on steam coal, assuming best practices and equipment upgrades. Reduce the carbon intensity of generation at specific plants through heat rate improvements.
- **Redispatch** — Increase utilization of natural gas fuel combined cycle gas turbines (CCGT) for power production.  Reduce emissions from the more carbon intensive plants by substituting generation from less carbon-intensive generation, for example by implementing renewable energy portfolio standards.
- **Renewables and nuclear** — Reduce emissions from carbon-intensive units by replacing it with lower- or zero-emitting units. Promote nuclear power plants. Promote renewable power plants.
- **Demand-side energy efficiency** — Reduce emissions by reducing demand for power by incentivizing consumer demand-response programs and investing in end-user energy efficiency improvements.

# Purpose and Overview of Example Wet Flue Gas Desulfurization (WFGD) Waste Water Treatment Systems (WWTS)

# Coal-Fired Flue Gas and Byproducts – examples

## Coal Fired Flue Gas & Byproducts

Stack
Emissions

Fuel

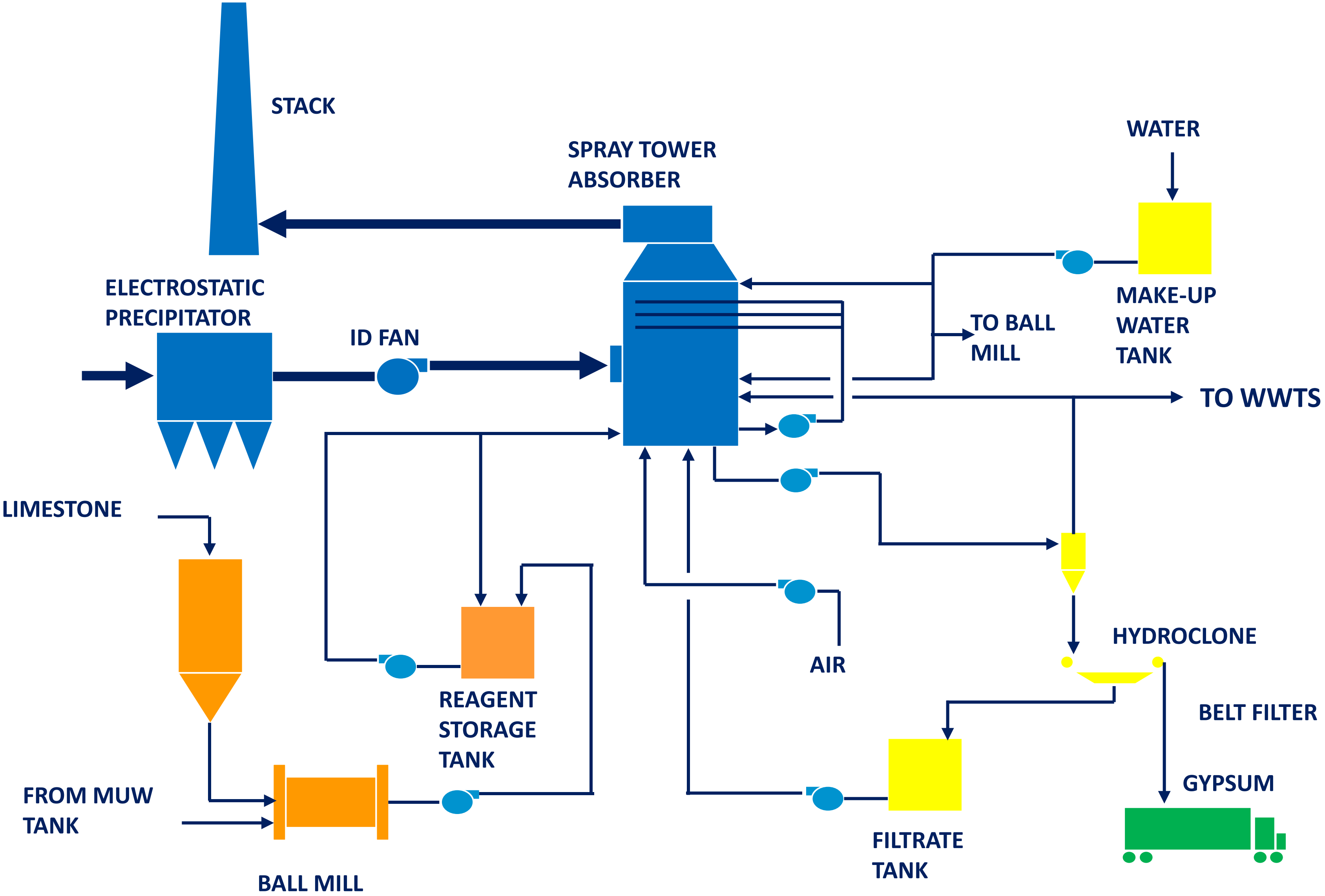
Bottom Ash

BH or ESP

Fly Ash & LOI

FGD
Byproducts
(solid & liquid)

# Wet Limestone FGD – Process Flow Diagram - Example



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# Purpose of WFGD Waste Water Treatment – Generic

- **A purpose of wet flue gas desulfurization (WFGD) waste water treatment system (WWTS) could be to remove from the WFGD system chloride purge "blowdown" stream (CPS) the following:**
  - Total suspended solids (TSS)
  - Trace metals (e.g. Hg, Se, As, etc.)
  - Adjust pH (as required)
  - Nitrogen-based species ($NO_3^-$, $NO_2^-$, $NH_4^+$, etc., if required)
  - Chemical oxygen demand (COD, as required)
  - Biological oxygen demand (BOD, as required)
  - Total dissolved solid species (TDS, if required)
  - Other constituents or parameters of the CPS (if required)
  - Other purposes (e.g., Zero Liquid Discharge ZLD, if required)

# Typical Categories of WWTS Technologies or Concepts

- Physical/Chemical Waste Water Treatment System (WWTS)
- Physical/Chemical plus Biological treatment processes
- Physical/Chemical plus Engineered Wetlands
- Physical/Chemical followed by additional physical/chemical steps for further treatment (e.g. Steag)
- Zero liquid discharge (ZLD) concept based on closed loop WFGD (gypsum dewatering, and/or sludge stabilization)
- ZLD-based evaporation of WFGD chloride purge stream (CPS) in spray dryer absorber (SDA)
- ZLD based on pretreatment (softening) followed by evaporation to produce a stream mixed with flyash & disposed in landfill (water recycled to WFGD)
- ZLD based on evaporation/crystallization of WFGD CPS
- Other types of WWTS Technologies
- DSI (Trona or Hydrated Lime for HCl removal) upstream of PM collector, resulting in less WFGD CPS flow rate, and impacts on flyash properties.
- Other types of AQCS (CDS/NID/EAD/SDA/DSI & PJFF or ESP, ReACT, etc.), with no WFGD CPS

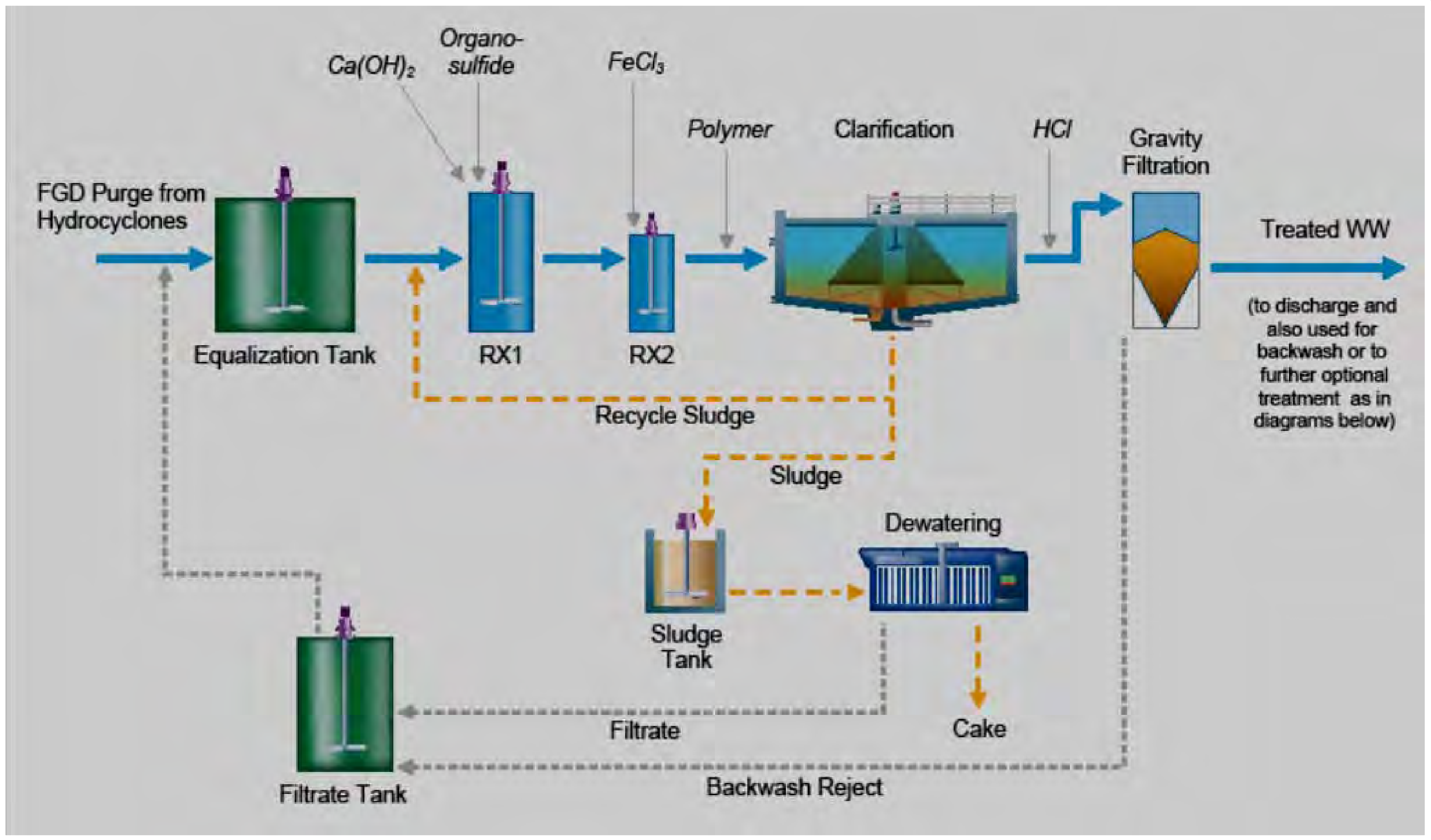
# WFGD Waste Water Treatment Description – Example

## Some wet FGD waste water treatment (WWT) systems employ an equalization tank

- An equalization tank can be installed upstream of the FGD WWTS to handle operating fluctuations in FGD system blowdown flow, chemistry, and suspended solids concentration.
- The equalization tank also accommodates more frequent boiler ramp-up, ramp-down, and shutdowns due to revised electrical grid dispatch of the coal-fired unit.

# WFGD Waste Water Treatment Physical / Chemical System – example

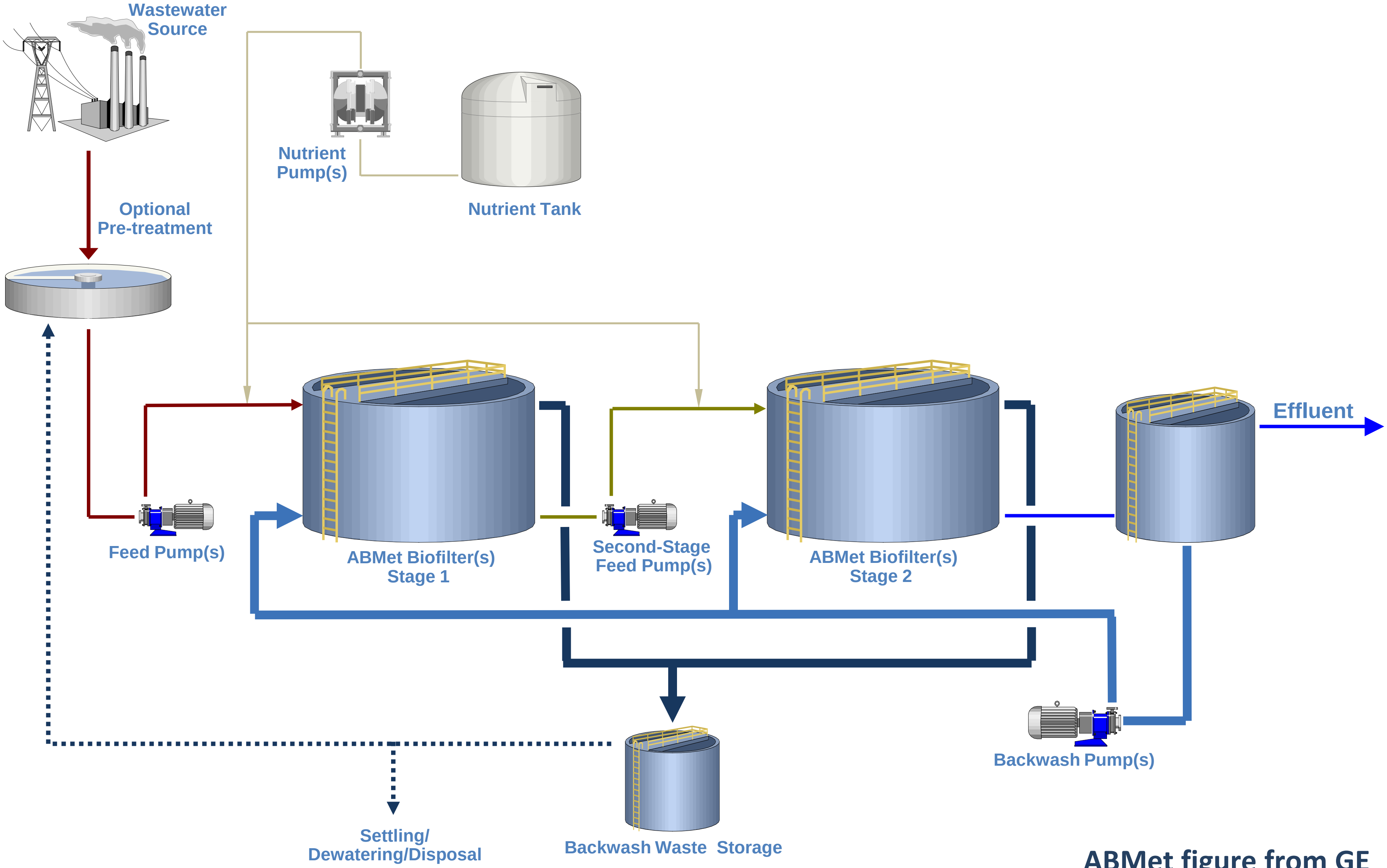
**A physical/chemical WWTS employs a series of physical unit operations and chemical processes to treat the WFGD waste water, as shown below.**



WWTS figure from Siemens

# ABMet Flow Diagram – Bio WWTS Technology - example

## Anoxic Bio Stage 1 for Nitrate & Selenium removal and Anoxic Bio Stage 2 for Selenium polishing removal



ABMet figure from GE

# Zero Liquid Discharge Concepts – Gypsum Dewatering or Sludge Stabilization – example

# WFGD Gypsum Fine Solids Handling - example (concept from European plant)

## A/D Power Plant (Baden-Württemberg, Germany)

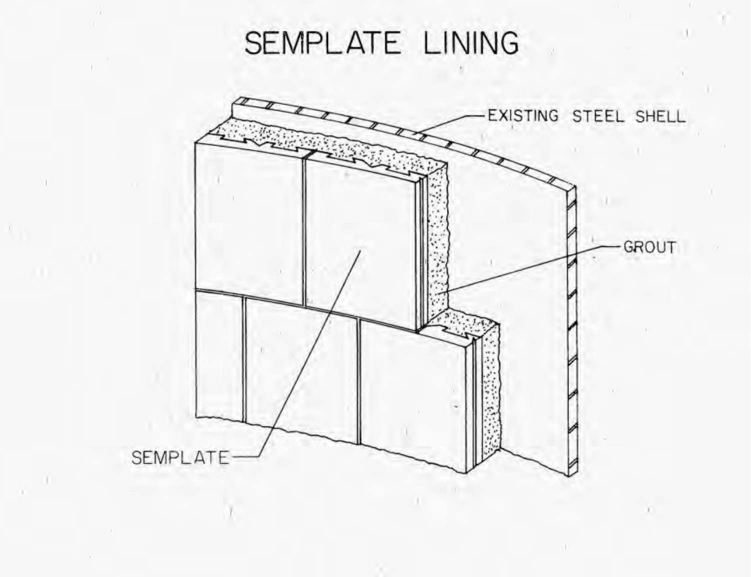
- 330 MW Coal-Fired - Wet FGD.
- Overflow from WFGD gypsum primary hydrocyclone goes to secondary hydrocyclone. Underflow from secondary hydroclone is sent back to the scrubber.
- Secondary hydrocyclone overflow goes to waste water treatment (WWTS) for heavy metal removal, pH adjustment and thickeners.
- From WWTS, the fines slurry is sent to a mixing tank. In this mixing tank, which is on load-cells, the WWTS slurry **(fine particles)** and some scrubber gypsum blowdown slurry are mixed to produce 8% solids feed to BHS candle filter.
- Dewatered gypsum from the candle filters is conveyed and mixed with dewatered gypsum from BHS belt filters and conveyed to a gypsum Euro-silo for storage and transport.

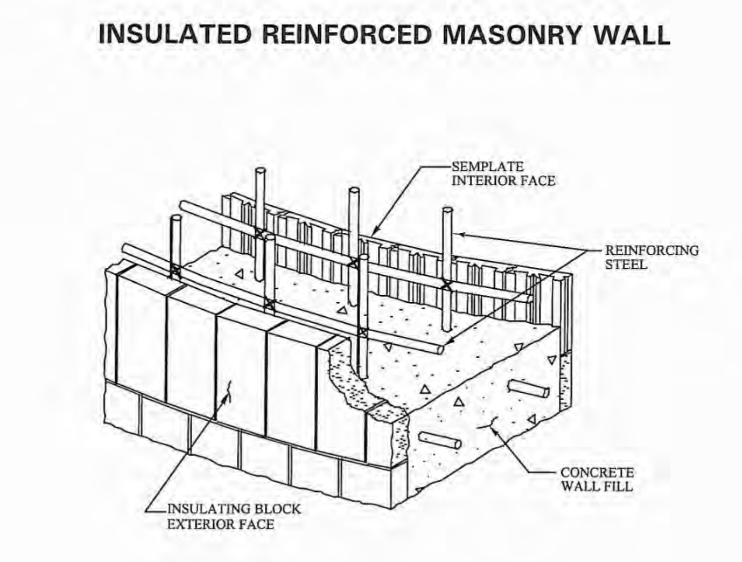
**BHS**

**SONTHOFEN**

**Figure from BHS**

# Materials of Construction for Closed Loop WFGD – example





Figures from Stebbins

# Zero Liquid Discharge (ZLD) WFGD WWTS Description – example

**There are different types of zero liquid discharge (ZLD) waste water treatment systems (WWTS) depending on site-specifics, below is one example concept.**

- WFGD waste water pumped to new equalization mix tanks.
- Flow from the equalization mix tanks is metered to two separate WWTS.
- The **1st WWTS** (physical/chemical) removes TSS by chemical addition in tanks and clarifier. The treated water is returned to the FGD scrubbers or limestone slurry preparation system.
- The remaining WFGD wastewater is pumped to a **2nd WWTS** (softener/evaporator), where it is softened and treated by thermal evaporation, producing a brine stream that is mixed with fly ash in pug mills and transported off-site to a secure solid waste landfill. The distillate stream from the evaporator is pumped back to the WFGD system or other plant systems.

# FGD Zero Liquid Discharge (ZLD) Case Study – example

## A2A S.p.A. (formerly Endesa Italia)

- Monfalcone Power Plant
- 336 MW Coal-Fired w/ LSFO Scrubber (MHI)
- Operational Summer 2008
- **Dry Cake for Landfill Disposal**

**Lime - Soda Ash Softener**

**Brine Evaporator**
**Brine Crystallizer**

**Figures from Veolia**

# Integrated AQCS

**INTEGRATED DRY AND WET FLUE GAS CLEANING PROCESS AND SYSTEM**

U.S. Patent No. 7,625,537

December 1, 2009

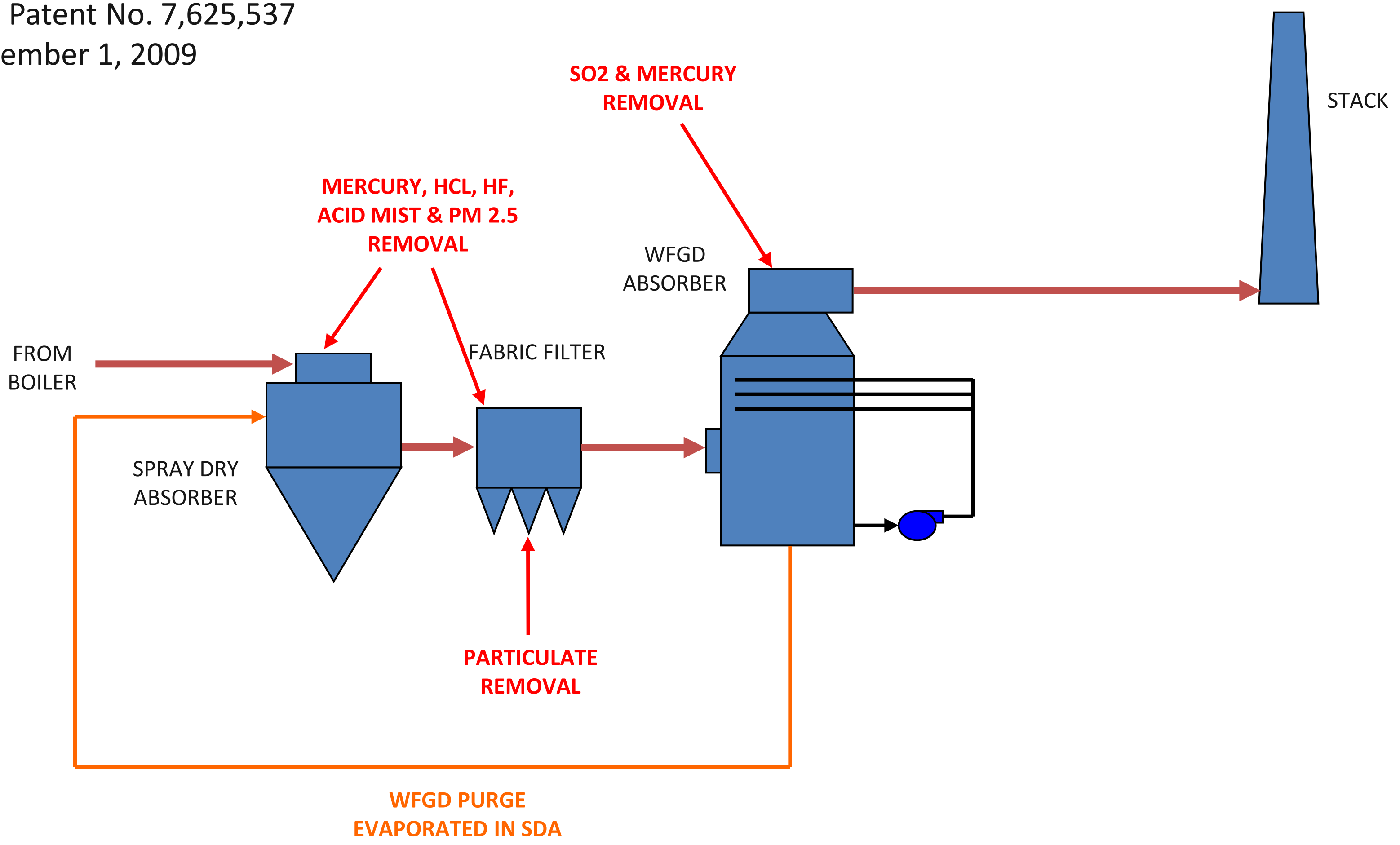


Figure from Alstom

# Waste Water Evaporation Concepts (from other industries – example)

## Lechler LOC system at E.ON Energy (Neunkirchen, Germany)

- Lechler LOC$^{TM}$ System with 6 nozzle lances.
- Each lance had its own LOC (Lechler Online Cleaning) box.

Figure from Lechler

# Summary

# Summary

- Retrofit AQCS designed to meet Regional Haze and MATS regulations may influence existing WFGD WWTS.
- Steam Electric Power Effluent Limitation guidelines may impact WFGD WWTS systems.
- Coal Combustion Residuals Rule may impact WFGD WWTS systems.
- Natural Gas co-firing in coal unit may impact WFGD WWTS.
- Load following and more frequent plant ramp-up/ramp-downs and start-ups may impact WFGD WWTS systems.
- Numerous WWTS technologies and operational techniques are available to treat the liquid blow down from wet FGD systems.

# Acknowledgements

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CB&I

# Continued

# Open Discussion


CB&I