# REINHOLD ENVIRONMENTAL Ltd.

# 2011 APC Round Table & Expo Presentation

July 11-12, 2011, in Cleveland, OH / Hosted by FirstEnergy

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# *Particulate Control Implications of Proposed UMACT*

*2011 APC Roundtable*

*Sam Kumar and Phil Roberts,  Babcock & Wilcox*

# *Support From These Folks Highly Appreciated!*

| | |
|---|---|
| **Tony Silva** | **Process Technology B&W** |
| **Paul Williams** | **Process Technology B&W** |
| **John Knapik** | **Technical Services B&W** |


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# *Reinhold Workshop Focus*

- Proposed PM Limits
- Definitions of PM
- Considerable focus on test methods
- Focus on ESPs only today as primary control. Baghouses covered by others.
- Co-benefits from Wet FGD
- Resistivity impacts from removing $SO_3$
- ESP performance upgrade techniques


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# *Proposed Total Particulate Matter Limits Existing Plants, Coal*

| | lb/MBtu | lb/MWh |
|---|---|---|
| • Total PM | 0.03 | 0.30 |

- PM limits based on ICR data analyses
  of top 12 percent of best performers
- EPA Test methods are 5B and " new" 202
  - Continuous monitoring of filterable through PM CEM
    at 5B temperature, with boiler system set at test conditions.
    Strong documentation needed.
    - 30 day average including start-up and shutdown
    - Malfunctions are excluded; but strong justification necessary


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# *Total Particulate Matter (PM)*

## Total particulate matter (PM)

**(also known as direct PM or Primary PM)**

- **Means particles that enter the atmosphere as a direct emission from a stack or an open source.**
- **Primary PM has two components:**
  - **filterable PM**
  - **condensable PM**
  - **These two PM components have no upper particle size limit**


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# *Filterable Particulate*

**Filterable particulate matter (PM)**

- **Means particles that are emitted directly by a source as a solid or liquid at stack or release conditions and captured on the filter of a stack test train**


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# *Condensable Particulate*

**Condensable PM (CPM) means material that is vapor phase at stack conditions, but condenses and/or reacts upon cooling and dilution in the ambient air to form solid or liquid PM immediately after discharge from the stack. Note that all condensable PM is assumed to be in the PM2.5 size fraction.**


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# *General Test Methods for Particulate*

***Which ones have you relied on so far?***

## *Filterable Particulate*

**EPA Method 5, 5B**

**EPA Method 17**

**EPA Method 201A**

## *Condensable Particulate*

**EPA Method 202**


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# Filterable Particulate - EPA Methods

## Method 5

- Heated probe and external filter (248F +/- 25F and >0.3u)
- Filter will catch some acid.
- Need to be "Front Half" Specific for "Filtered Particulate"

## Method 5B

- EPA method to measure "non-sulfuric acid" particulate
- External Heated Filter (320F +/- 25F and >0.3u)
- "Too Hot" to collect Sulfuric Acid Particulate

## Method 17

- Filter inside the stack "At Stack Temperature"
- Particulate concentration must be independent of temperature
- Eliminates glass probe and the heating systems


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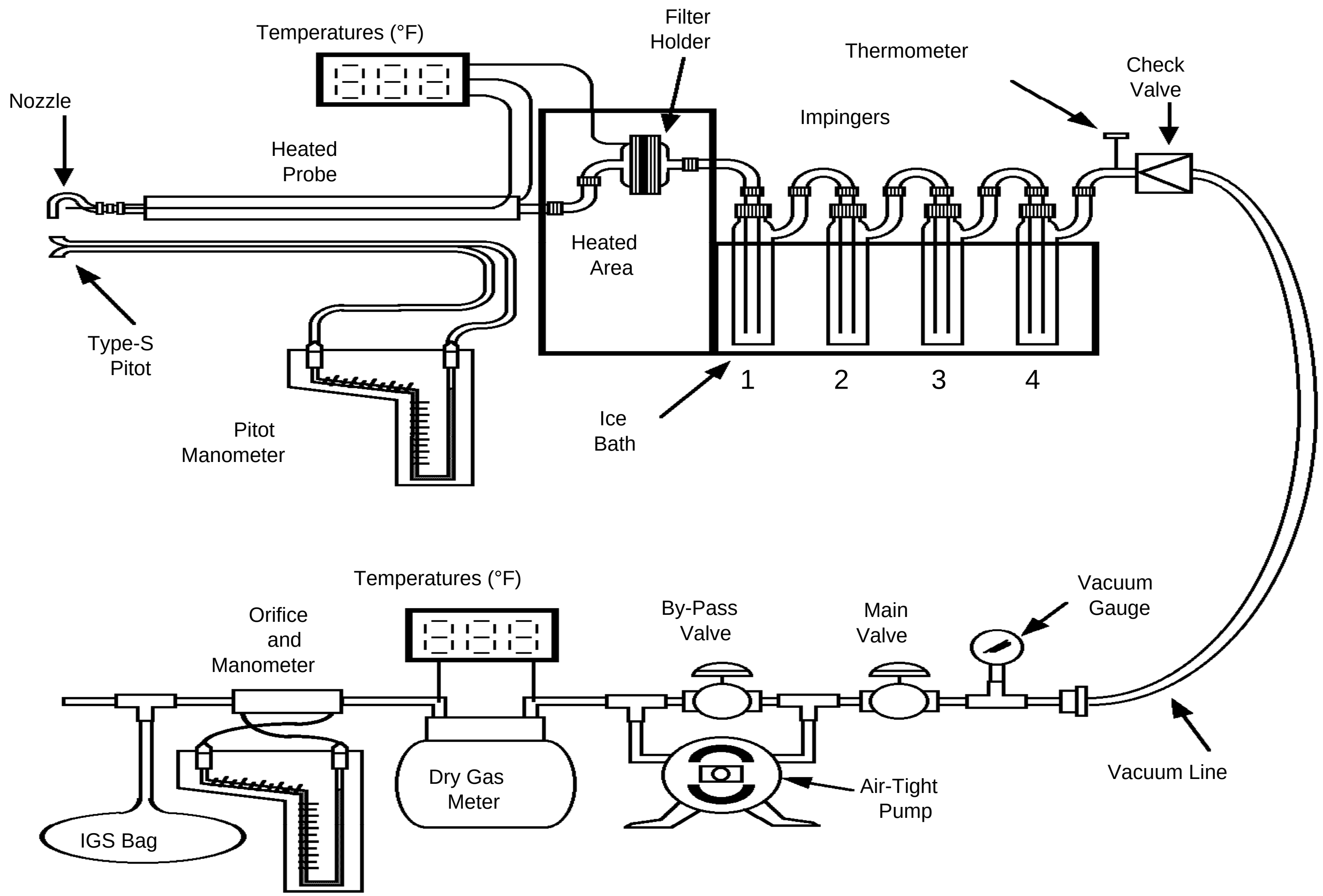
# *EPA Method 5 / 5B Sampling System*





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# Condensable Particulate – Test Method History

| | *Impinger* | *Comments* |
|---|---|---|
| Method 202 promulgated 1996 | Water | Water impinger created "pseudo-particulates" from reactions in water |
| Method 20X (2007) | Dry | Dry impinger replaced water to eliminate bias / artifact |
| Method OTM-28 (2008) | Dry | Refinement of first dry impinger procedure |
| "New" Method 202 promulgated 2010 | Dry | Final rule based on industry comments |


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# *Condensable Particulate – EPA "Old" Method 202*

- **Water impinger creates rapid cooling and dissolution of stack gas species in an attempt to simulate ambient air reaction with stack gases. Since the processes are different, the water impinger in fact creaes "pseudo-particulates" that would not normally form in the atmosphere.**

- **Method may not capture aerosols or ultra fine particles**

- **Nitrogen purging of impingers is only an option. This purge removes $SO_2$ gas from staying in the impinger and forming sulfates.**

- **Too many analytical options; IC and titration accepted, neutralizing with ammonia, drying at elevated temperature or room temperature, etc.**


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# *Water vs. Dry Impinger*

- **EPA studies in 2007 showed when sampling a simulated gas stream of 150 ppm $SO_2$ through a water impinger vs. a dry impinger that 10X more sulfate artifact is recovered in the water impinger. This is with both impingers in an ice bath and with a nitrogen purge of the impingers.**

- **Dry impinger procedure refined further to be kept in temperature controlled water bath between 65F and 85F to eliminate any sulfate artifact.**


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# *Condensable Particulate - EPA Method 202*

- **The new 202 now states that it cannot be combined with M-5B, M-5E, M-5F, M-5G, or M-5H. Only, M-5, M-17, or M-201A can be used as the front-half method.**

- **The front-half of the sample train must be operated at a high enough temperature to cause water droplets sampled through the probe to become vaporous, i.e., a heated probe liner is required.**


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# *Condensable Particulate - EPA Method 202*

- **CPM is collected in the water dropout impinger, the modified Greenburg Smith impinger, and the CPM filter of the sampling train as described in this method.**
- **The impinger contents are purged with nitrogen immediately after sample collection to remove dissolved sulfur dioxide ($SO_2$) gases from the impinger.**
- **The CPM filter is extracted with water and hexane. The impinger solution is then extracted with hexane. The organic and aqueous fractions are dried and the residues are weighed. The total of the aqueous and organic fractions represents the CPM.**


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# *Condensable Particulate - EPA Method 202*

- **The potential artifacts from $SO_2$ are reduced using a condenser and water dropout impinger to separate CPM from reactive gases. No water is added to the impingers prior to the start of sampling. To improve the collection efficiency of CPM, an additional filter (the "CPM filter") is placed between the second and third impingers.**

- **The new 202 defines "Ambient" as upper and lower temperature limits for the CPM filter exit temperature and now stipulates <85F AND >65F**


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# *Condensable Particulate - EPA Method 202*

- **Field Train Proof Blank. A field train proof blank is recovered on site from a clean, fully-assembled sampling train prior to conducting the first emissions test.**

- **A mandatory ‘field train recovery blank’ MUST must be completed on a set of glassware AFTER it has been used for at least one test run (i.e., after Run 1)**


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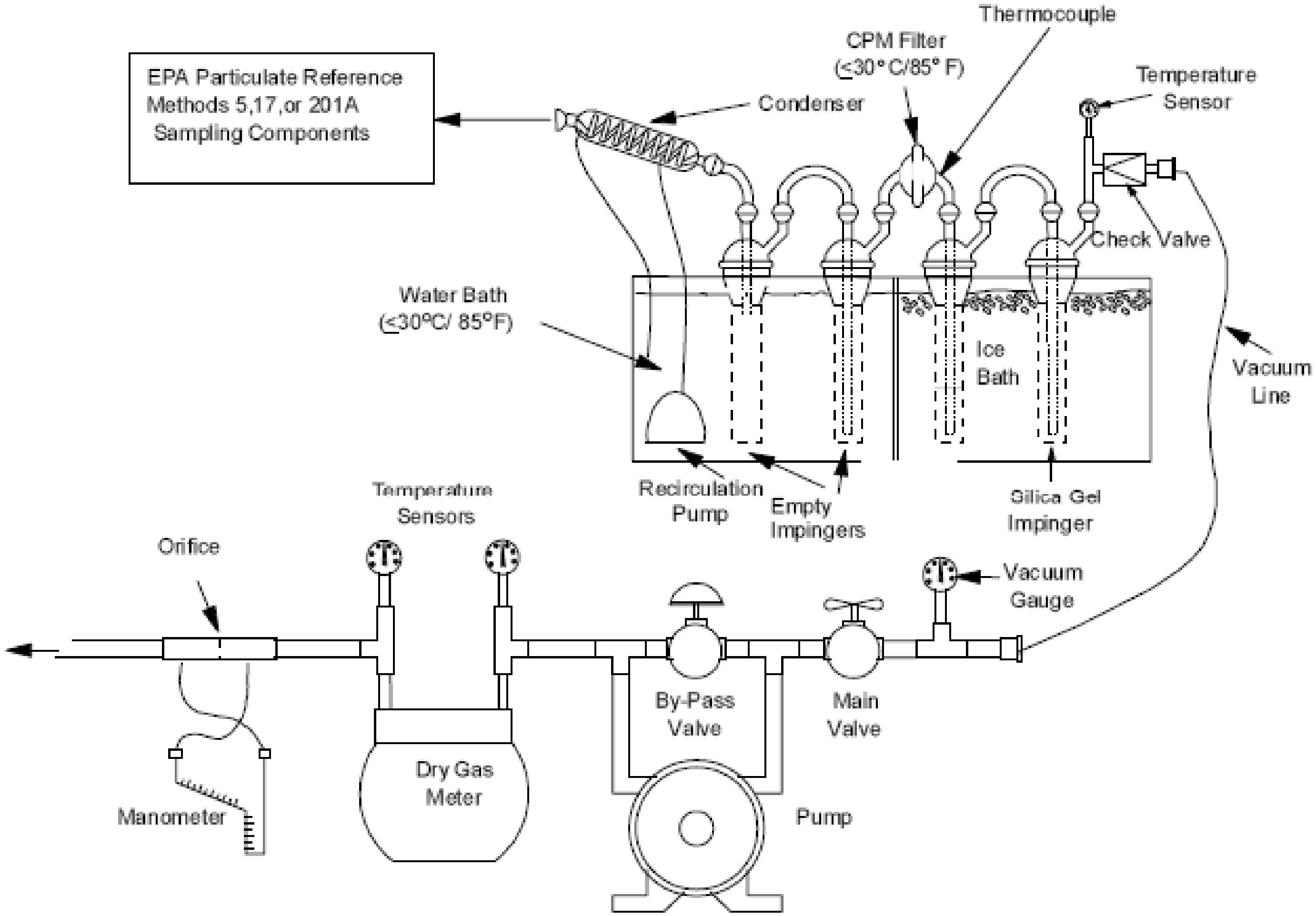
# *EPA Method 202 Sampling Method*





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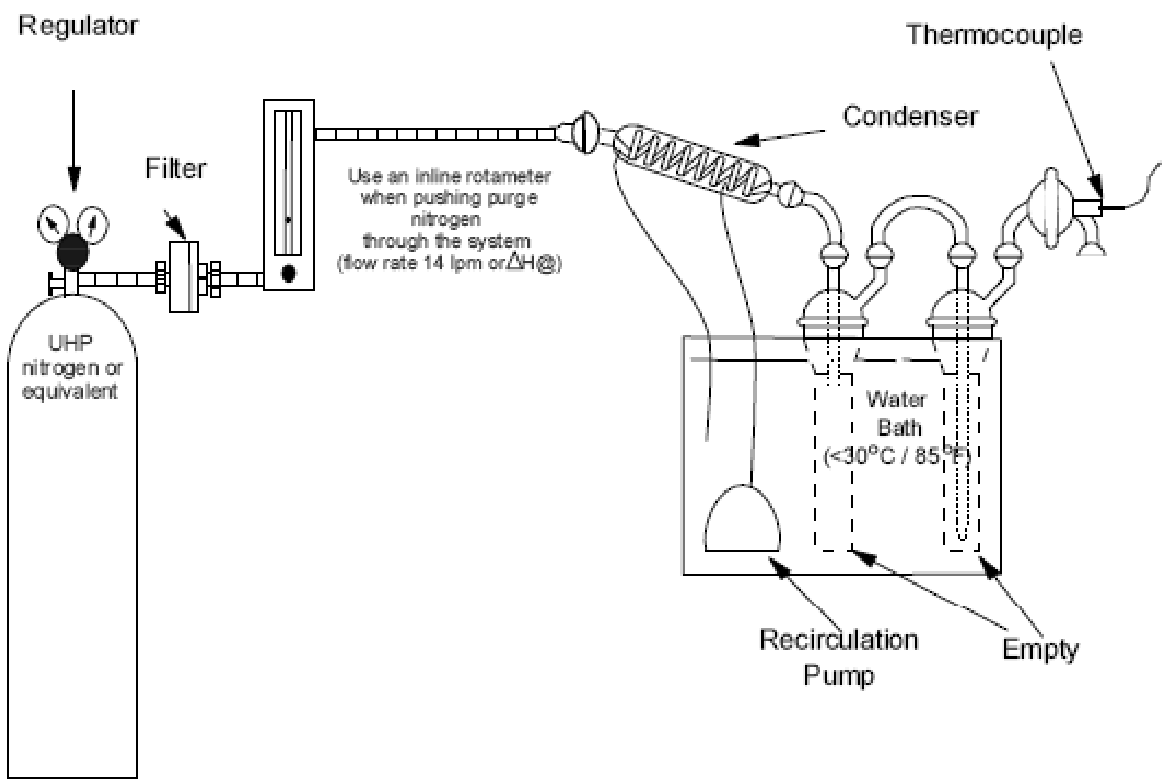
# EPA Method 202 – Nitrogen Purge (Pressurized)





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# Total Particulate Matter, Oil Existing Plants

| *HAPs* | *lbs/TBtu* | *lbs/MWh* |
|---|---|---|
| Total | 30 | 0.00030 |
| *Individual* | *lbs/TBtu* | *lb/GWh* |
| Antimony (Sb) | 0.20 | 0.0030 |
| Arsenic (As) | 0.60 | 0.007 |
| Beryllium (Be) | 0.06 | 0.007 |
| Cardmium (Cd) | 0.10 | 0.002 |
| Chromium (Cr) | 2.0 | 0.020 |
| Cobalt (Co) | 3.0 | 0.020 |
| Lead (Pb) | 2.0 | 0.030 |
| Manganese (Mn) | 5.0 | 0.06 |
| Nickel (Ni) | 8.0 | 0.08 |
| Selenium (Se) | 2.0 | 0.020 |

**Except for selenium, other HAPs are found in filterable particulates. Control through high efficiency ESPs. Outlet control to approximately 0.005 lbs/MBtu filterable seems necessary for total HAPs based on observation of EPRI's ICR data analysis.**

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# *Meeting Proposed UMACT PM, Coal*

- **Combine ESP upgrades with WFGD optimization**
  - **Co-benefit from WFGD**
- **Add a wet ESP field inside the WFGD for additional margin: 30 to 70 % reduction of Total PM**
- **DSI for $SO_3$ mitigation in addition to the above: ESP impacts could be significant. ESP performance enhancement may be required**
- **Integration of the above with HCl and mercury control techniques will be essential to meet overall UMACT requirements for PM plus HCl plus mercury control!!**


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# *Wet FGD Flyash Capture*

- Mechanical collection in wet scrubber
  - Impingement between flyash and droplets
  - Slurry flux and pressure drop in absorption zone
  - Flyash PSD
  - Open tower versus tray tower influences (additional ΔP)
  - Lower collection efficiency of fines
    - Pre-charging by ESP helping fines capture?


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# *Wet FGD Mist Eliminator Capture*

## Coarse Droplet capture in Mist Eliminators

- Inertial collection through gas flow change of direction
- Primarily sulfated particulate capture
- Efficiency affected by spacing of blades and velocity
- Typically 99.9% for droplets > 25 to 35 microns

## Guarantees

- 0.007 to 0.01 gr/acf of droplets
- Solids in carryover depend on TSS and TDS
- 0.003 to 0.006 lbs/MBtu solids


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# *Wet FGD Filtration Experience*

- Filterable collection efficiency varies
  - Between 20 to 90%
  - Performance related to inlet PSD and concentration
  - Maintenance of MEs is very important
  - Considerable re-entrainment if not maintained
- Condensable removal efficiency between 20 to 50%


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# Scenarios for Discussion
# # 1 High Condensable Plus Low Filterable

| *Emissions, lbs/MBtu* | *ESP Outlet* | *WFGD Outlet* | *WFGD Efficiency* |
|---|---|---|---|
| Filterable | 0.01 | 0.008 | 20% |
| Condensable | 0.06 | 0.040 | 33% |
| Total | 0.07 | 0.048 | |

**Notes:**

a. 1 ppm $SO_3$ is approx 0.003 lbs/MBtu sulfuric acid mist

b. Other condensable such as organics and ammonia salts may add 0.005 lbs/MBtu to total emissions

c. This scenario applicable to many high sulfur bituminous coals


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# *Mitigating $SO_3$ Seems Like the Right Answer*
## *What are the implications?*

- **ESP outlet emissions could increase depending on:**
  - **Coal ash properties**
  - **Sodium in ash**
  - **Sorbents for $SO_3$ mitigation**
  - **Operating flue gas temperature**

  - **But there are opportunities to reduce ESP emissions**
  - **With the right ESP/WFGD optimization you might just make it to the goal line!**


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# *With the Co-benefit of WFGD, Can We Make it with ESP Upgrades Alone?*

- **Get to know about ESPs**
- **Get more out of your ESPs**
- **Know when the dog won’t hunt – get to know about the baghouses!**


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# *SCA Requirements for Different Coal Types*

| *Collection Efficiency, %* | *Difficult* | *Moderate* | *Easy* |
|---|---|---|---|
| 99.00 | 500/600 | 300/400 | 150/200 |
| 99.90 | 1000/1500 | 500/600 | 300/400 |

**Notes**

- **SCA, $ft^2$/1000 acfm at 9 inch plate/plate spacing**
- **Easy ash: 10E8 to 10E10 ohm.cm**
- **Moderate: Mid 10E11 ohm.cm**
- **Difficult ash: greater than 10E12 ohm.cm**


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# Scenarios for Discussion
# # 2 High Filterable Plus Low Condensable
## Wonders of WFGD Co-benefit!

| Emissions, lbs/MBtu | ESP Outlet | WFGD Outlet | WFGD Efficiency |
|---|---|---|---|
| Filterable | 0.1 | 0.010 | 90% |
| Condensable | 0.01 | .008 | 20% |
| Total | 0.11 | 0.018 | |

**Notes**

a. 1 ppm $SO_3$ is approx 0.003 lbs/MBtu sulfuric acid mist
b. Other condensable such as organics and ammonia salts may add 0.005 lbs/MBtu to total emissions
c. This scenario applicable to some PRB coals with no $SO_3$ injection
d. High calcium PRB coals have negligible condensable


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# *Getting More Out of your ESP*
# *Maximize SCA utilization*

## Maximize, maximize, maximize……

- **The useful power in each operating electrical section**
  - **Can the electrical sectionalization be improved?**
  - **Can the rapping sectionalization be improved to clean the electrodes better?**
    - **Manage dust build-up issues**
  - **Are you operating at too cold a temperature?**
    - **Condensation can aggravate dust build up/re-entrainment**
    - **Has your $SO_3$ level increased?**


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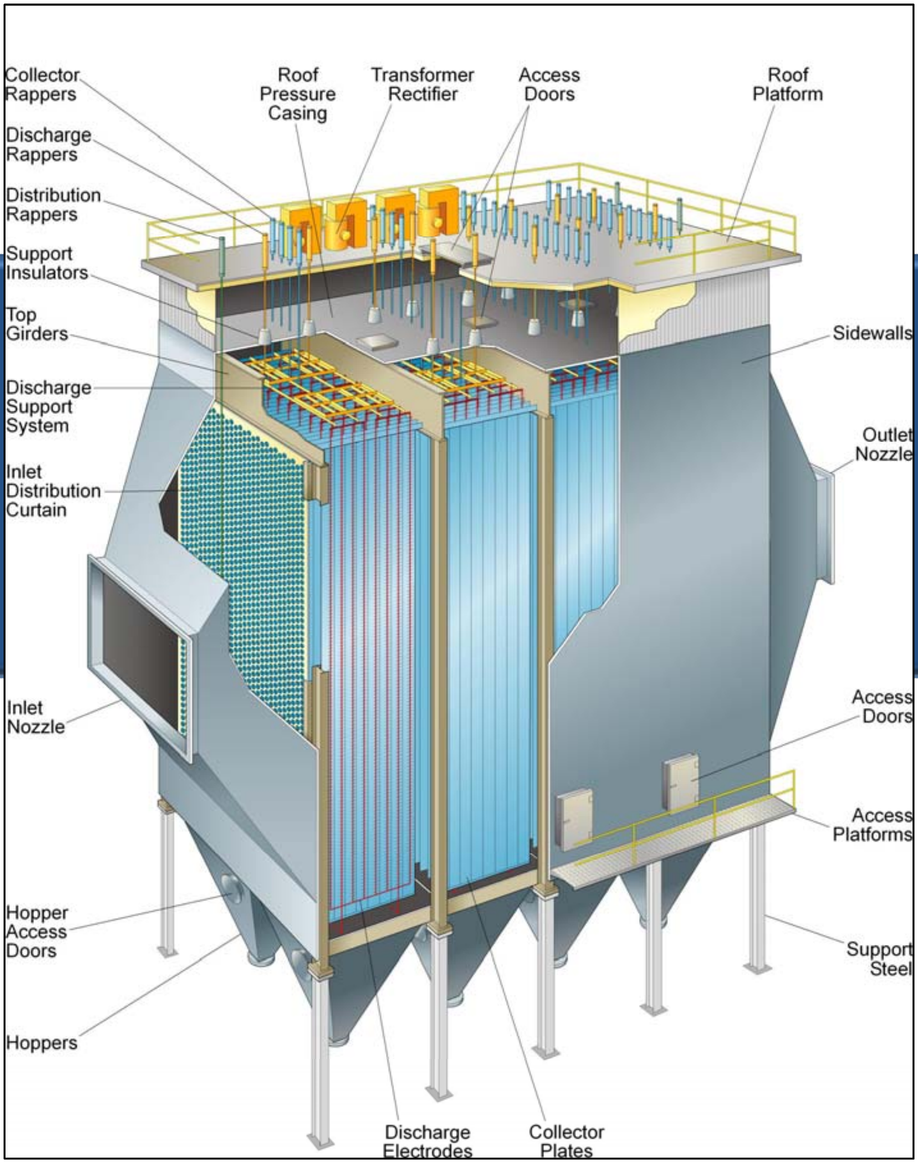
# Knowing your Dry ESP





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# *Getting More Out of your ESP…….*

**Maximize, maximize, maximize……**

- **The number of electrical sections always to be energized**
  - **Manage electrode failures**
  - **Manage purge air system**
  - **Inspect and eliminate poorly aligned areas**


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# *Getting More Out of your ESP…….*

## Keep what you have got…… re-entrain less

- **Improve gas flow quality**
- **Reduce rapping spikes**
- **Reduce sparking spikes**
- **Utilize your opacity monitor for these**
  - **It will also show opportunities to optimize soot blowing sequence**


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# *Evaluation of ESP Performance*
# *Can you Get it Done With Dry ESP Alone?*

| | |
|---|---|
| **Inlet Ash loading** | **10 lbs/MBtu** |
| **Collection Efficiency** | **ESP Outlet Emissions** |
| **99 %** | **0.1 lbs/MBtu** |
| **99.9 %** | **0.01 lbs/MBtu** |


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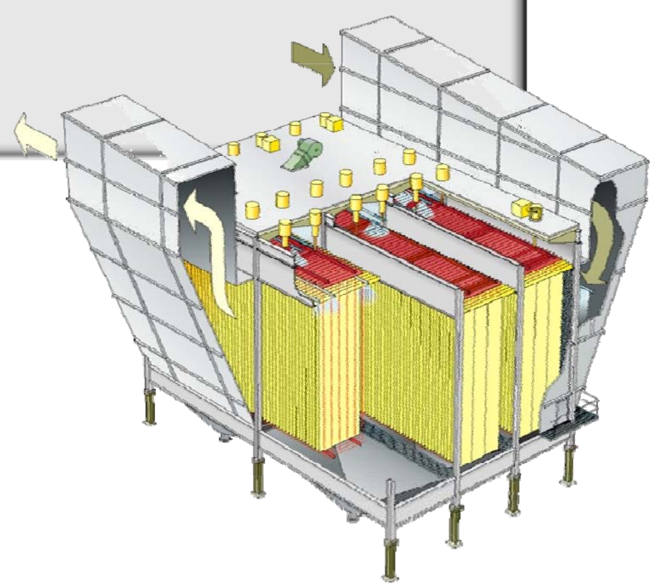
# *If You Must Do More Yet……*

- **Consider a wet ESP addition**
  - **Inside or outside the WFGD**
  - **30 to 50% PM reduction with a single field**
  - **90% plus reduction with a 3 or 4 field WESP**
    - **Increasingly required on several new plant permits**

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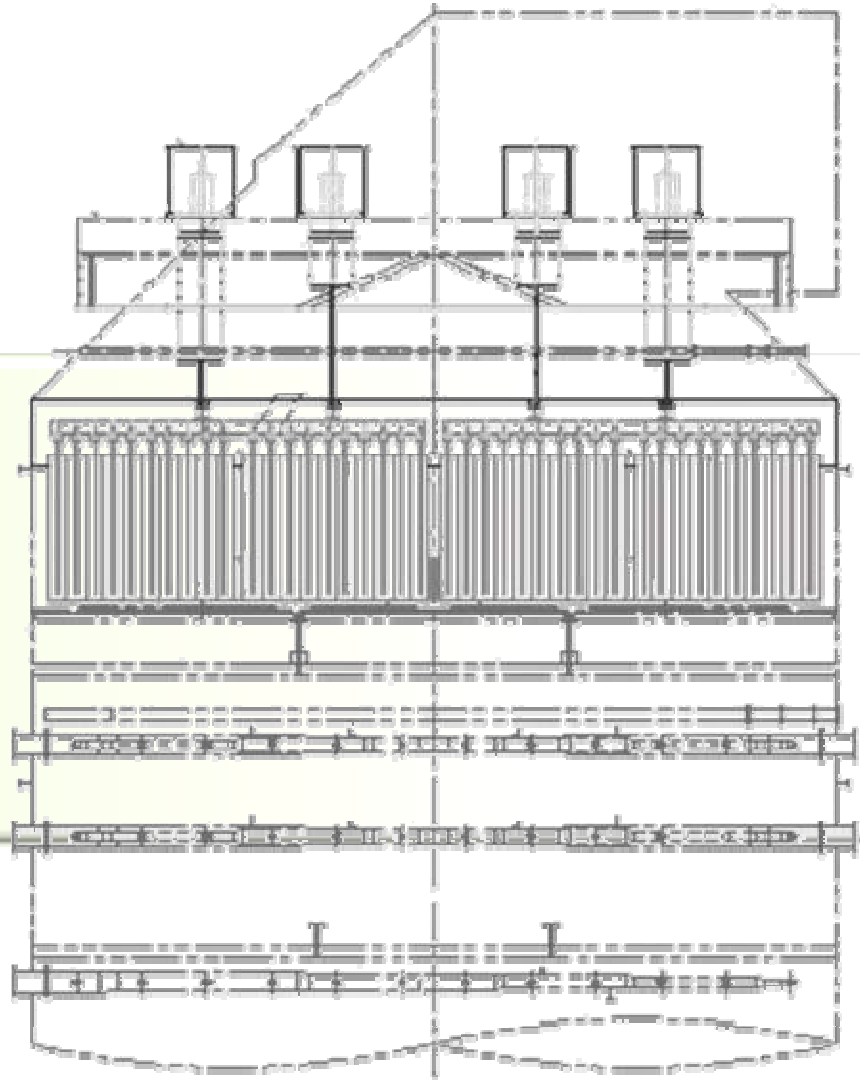
# New Brunswick Power

## Dalhousie Units 1 & 2

## Wet ESP

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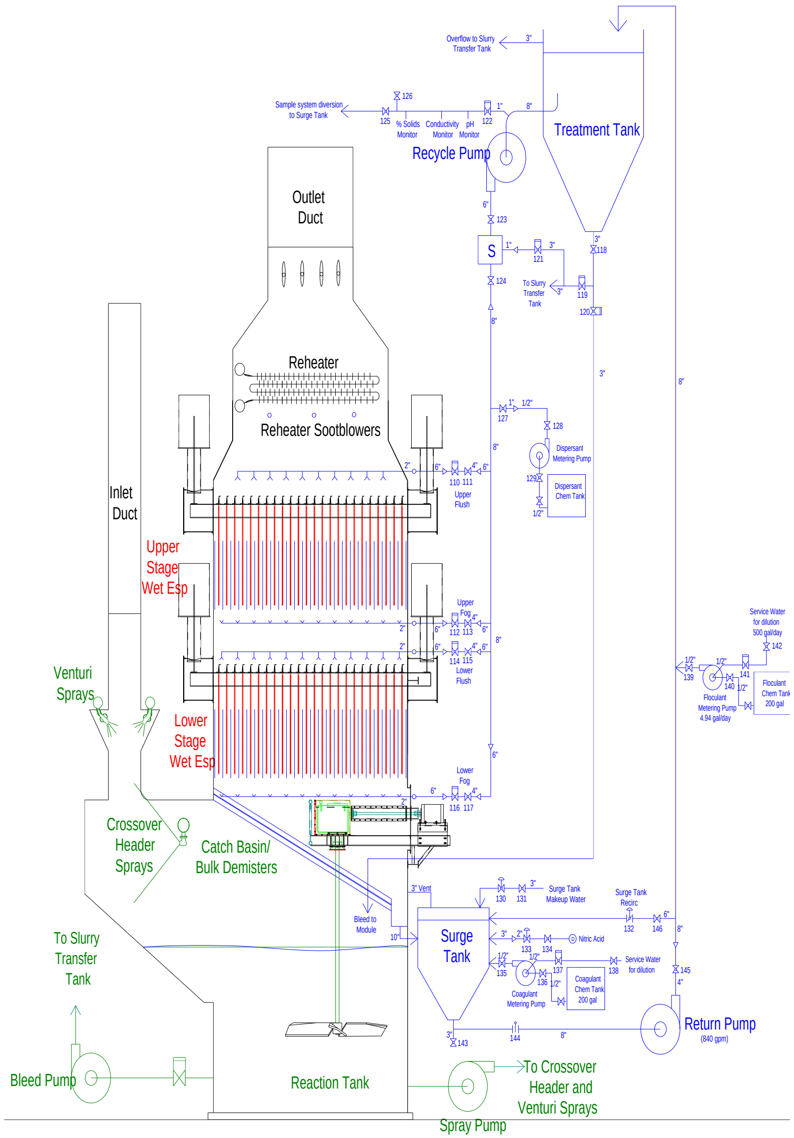


# *Xcel Energy – Sherco Units 1 & 2*

- **220,000 ACFM per scrubber module; 12/unit; two 750 MWe units**
- **Retrofitted a Wet ESP inside all scrubber modules**
- **2 collecting tube sections in series, 1.0 sec TT**
- **Up flow rectangular tubes with rigid discharge electrodes**
- **Stack opacity reduction from >42% to <10%**


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# *AES Deepwater Plant Operating Info*

- 160 MW gross
- 100% petroleum coke, typical analysis:
  - ~ 4% Sulfur
  - ~ 14,300 Btu/lb
  - < 1% Ash
  - ~ 1800 ppm Vanadium
  - SCR / Dry ESP / WFGD / WESP AQCS train
- B&W wet limestone absorbers with ex situ forced oxidation
- 12 WESP's (11 out of 12 in operating)
- Steam flue gas reheat


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# *AES Deepwater WESP Module "F" Total Particulate & $SO_3$ (corrected)*

| | *Total Particulate* | | *Filterable* | | *Condensable* | | *$SO_3$* | |
|---|---|---|---|---|---|---|---|---|
| | WESP inlet, lb/MBtu | WESP outlet, lb/MBtu | WESP inlet, lb/MBtu | WESP outlet, lb/MBtu | WESP inlet, lb/MBtu | WESP outlet, lb/MBtu | WESP inlet, lb/MBtu | WESP outlet, lb/MBtu |
| Ave | 0.0642 | 0.0090 | 0.0231 | 0.0019 | 0.0410 | 0.0071 | 0.0301 | 0.0035 |

**Total Particulate – Ave of 3 x 2 hr test runs**

**$SO_3$ – Ave of 3 x 1 hr test runs**


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# New Brunswick Power
# Coleson Cove Units 1, 2 & 3/350 MWe


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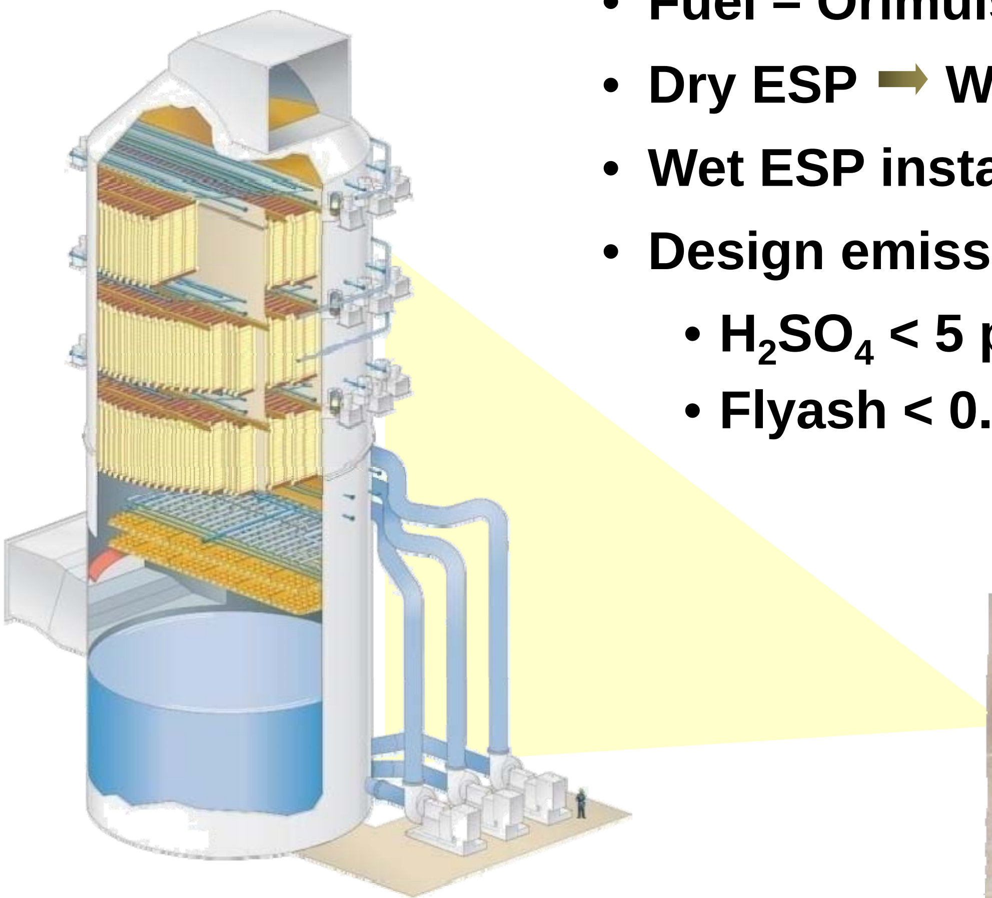
# *Wet ESP at New Brunswick Power Coleson Cove*

- **Fuel – Orimulsion / High Sulfur Oil**
- **Dry ESP ➡ Wet FGD ➡ Wet ESP**
- **Wet ESP installed in Wet FGD modules**
- **Design emission**
  - **$H_2SO_4$ < 5 ppmvd@3% $O_2$**
  - **Flyash < 0.015 lb/MBtu**

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# Two Stacks at NB Power in March 2005



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# *Conclusions*

**Total PM Control demands a process systems view of control: Coal/APH/DSI/ESP/COMs/WFGD/WESP/PM CEMs considerations**

**WFGD could perform critical co-benefit on PM control**

**For those clients wishing to pursue ESP upgrade options, several performance upgrade concepts exist**

**Start early planning & evaluation of your site**

- **You might retain more of your assets than you think!**


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*Thank you.*

*Questions?*