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SIEMENS

COMPARISON OF WET AND DRY ESP TECHNOLOGIES

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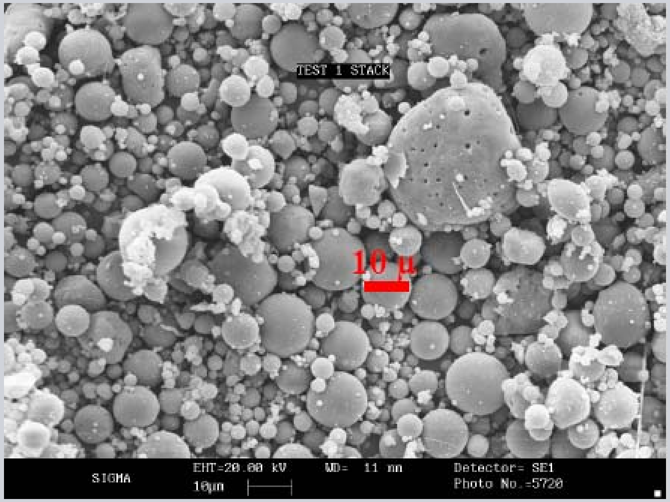
Abstract

- Dry & wet ESP technology comparison
- Dry & wet ESP technology basics
- Similarities and differences between technologies
- Advantages / disadvantages of each type
- Application of one technology versus the other
  - Dry for Coarse Particulate
  - Wet for Fine Particulate

Particle Size & Surface Area

Fine Particulate = harder to capture

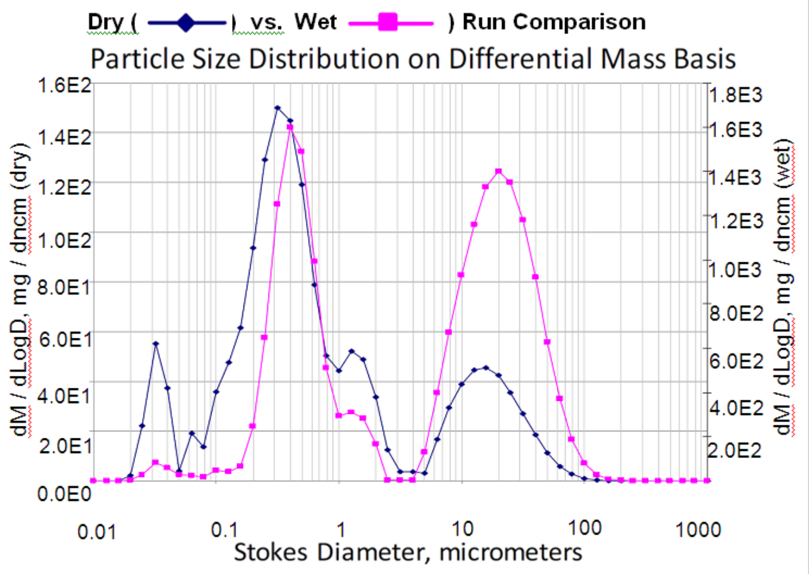
- Smaller particles
- Significantly more particles

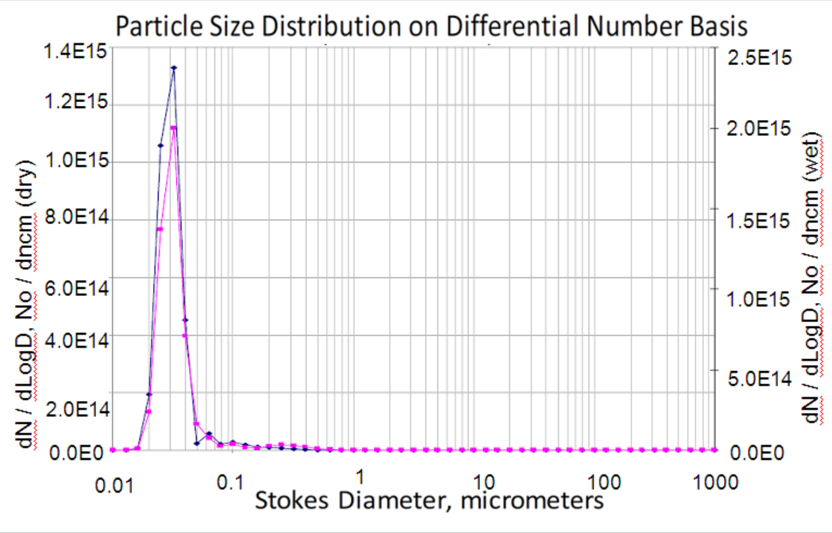


Particle Size, microns	Number of Particles (as compared to 10 microns)	Surface Area of Particles (as compared to 10 microns)
0.5	8000x	20x
1	1000x	10x
2.5	64x	4x
5	8x	2x
10	-	-

Particle Size & Surface Area

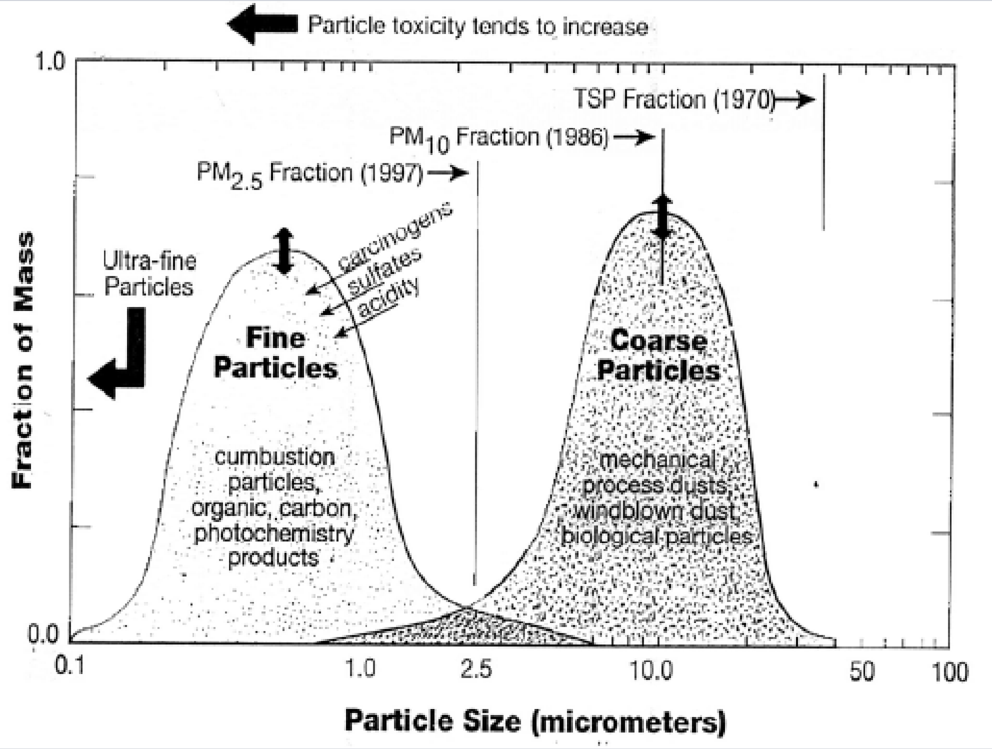
- Outlet Distribution from Coal fired Utility Wet Scrubber
  - Similar mass
  - Quantity overwhelmingly sub micron





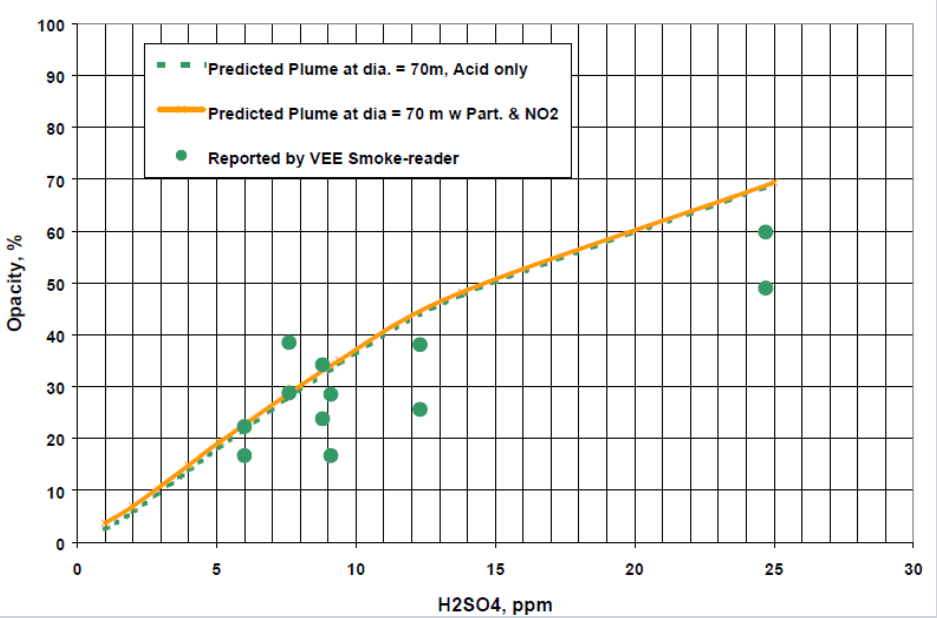
Particle Size & Surface Area

- Increasing Focus on Fine Particles
  - As they are more toxic



Opacity

- Plume visible due to light refracting off sub micron PM
- Greatest contributor to plume is H_2SO_4

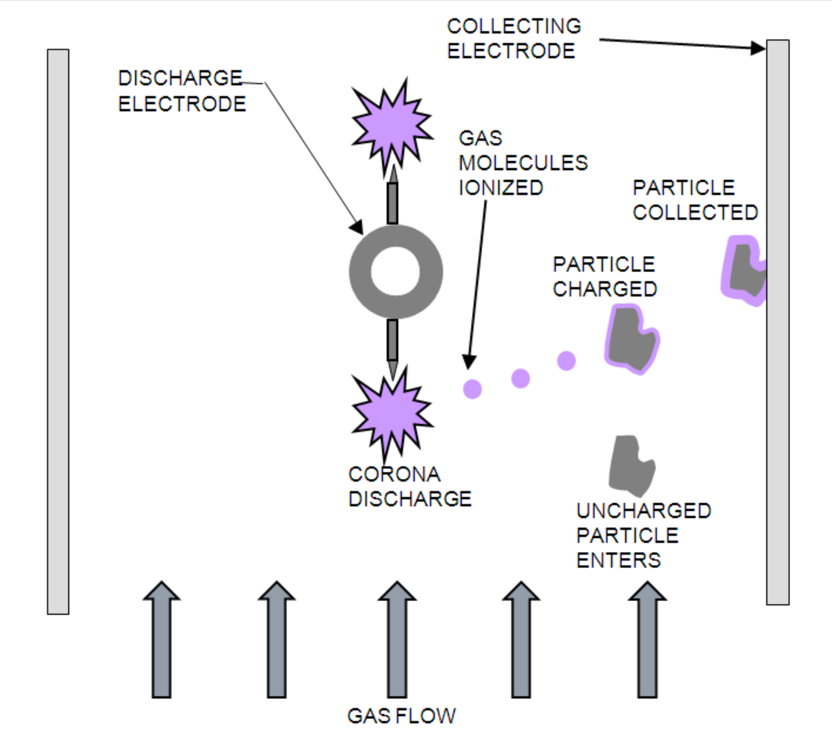


History

- 1^{st} reported ESP was a wet ESP in 1907
  - Continued use in sulfuric acid industry as process equipment
- Dry ESPs followed in 1910's in non-ferrous metals & cement industries
- 1^{st} dry ESP on coal-fired boiler in 1923
- Wet ESP needs being driven by current concerns with fine particulate matter emissions

Theory of Operation – Dry Wet ESP Similarities

- Both collect non-gaseous particulate
- Multi-stage process of particulate charging, collection and removal of particulate from collecting electrode



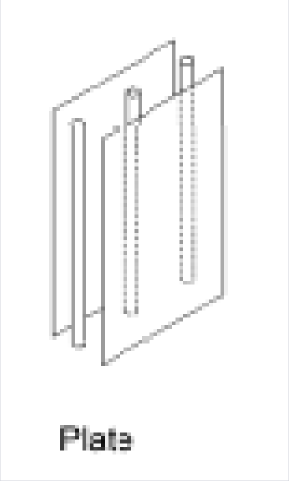
Theory of Operation – Dry Wet ESP Differences

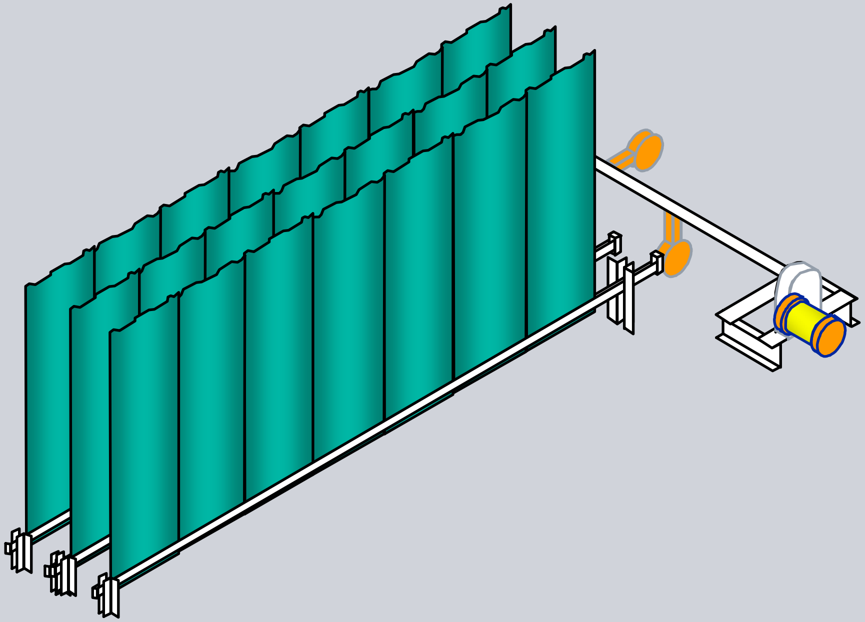
- Dry ESP particulate removal by mechanical rapping
  - Tumbling hammer, gravity impact, vibrators, pneumatic, drop rod
  - Dry ash collection in hoppers

- Wet ESP removal of particulate by water wash
  - Intermittent sprays, continuous irrigation
  - Bus section de-energization required with sprays

Configuration – Dry ESP

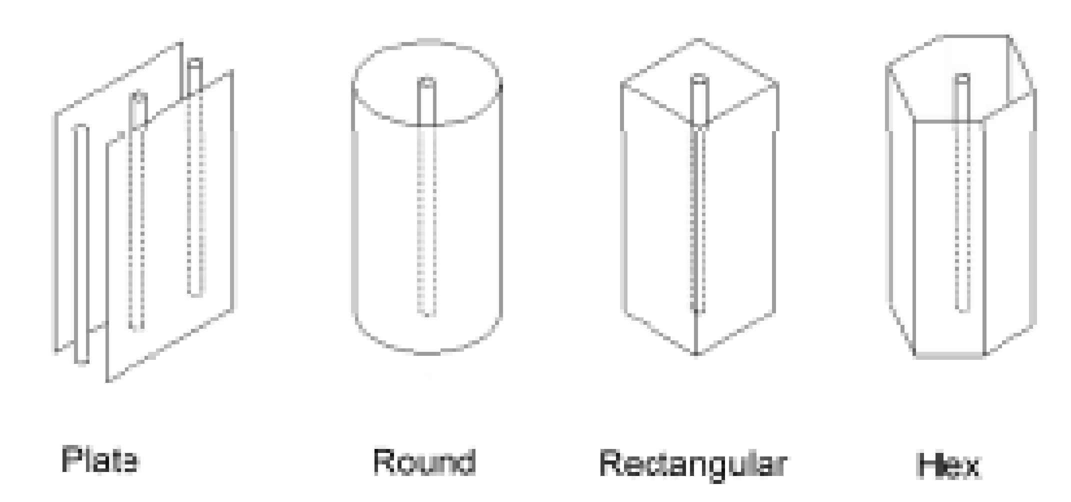
- Horizontal-flow configuration
- Vertical plates with discharge electrodes in middle
- Can handle heavy particulate loading
- Bottom hopper ash collection





Configuration – Wet ESP

- Flow orientation: up-flow, down-flow or horizontal-flow
- 2 main collecting electrode types: plate & tubular
  - Plate type (horizontal or vertical-flow)
  - Tubular type (vertical-flow; up or down): round, rectangular, hex
- Tubular designs offer higher efficiency per m^2; smaller size
- Cleaning of tubular bus sections in series is a challenge

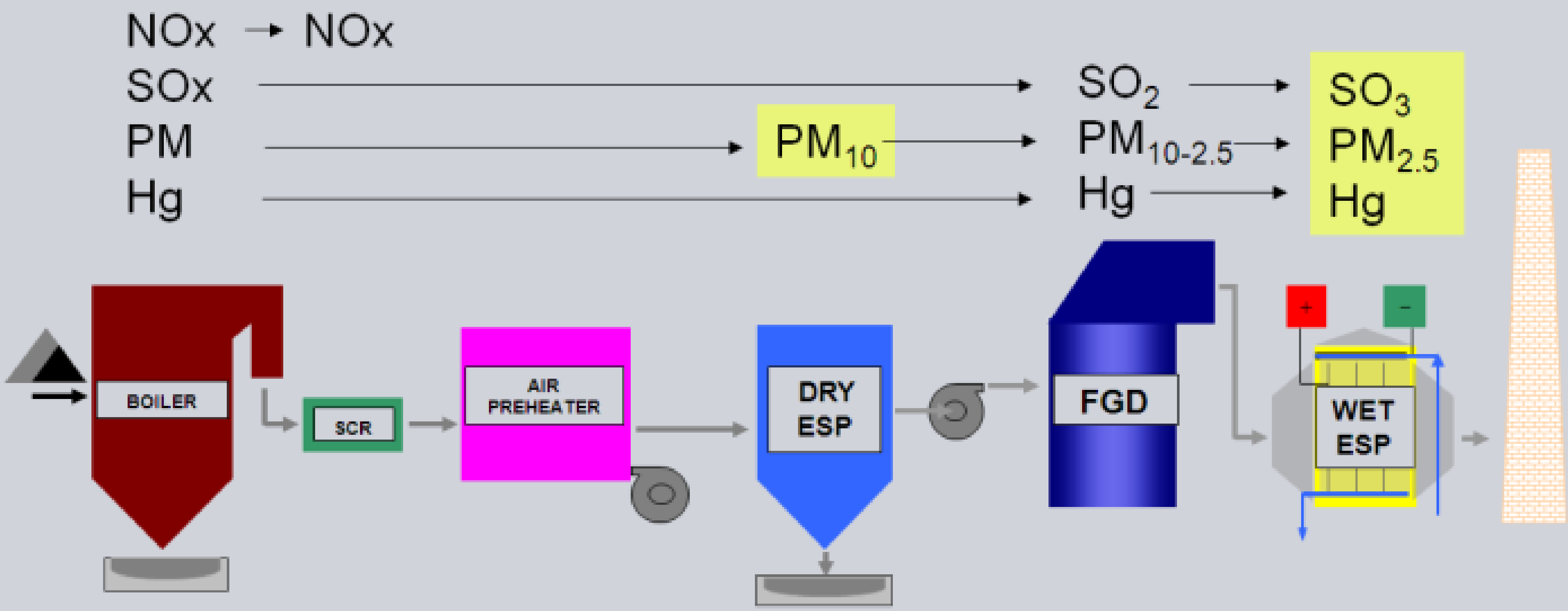


Process Comparison – Dry ESP

- Installed in high ash and high temperature environments
- Flue gas most often above acid dew point
- Primary collection of flyash
- Some older Utility ESPs installed in hot-side arrangement
- Majority of modern ESPs installed in cold-side arrangement (120-175°C)
- Some Industrial applications still use dry ESPs in very high temperature environments (315-425°C)
- Typical particulate loadings of 2-23 g/m^3
- Particulate is collected in hoppers as solid waste: land-filled, reused or sold

Process Comparison

Typical Utility Boiler

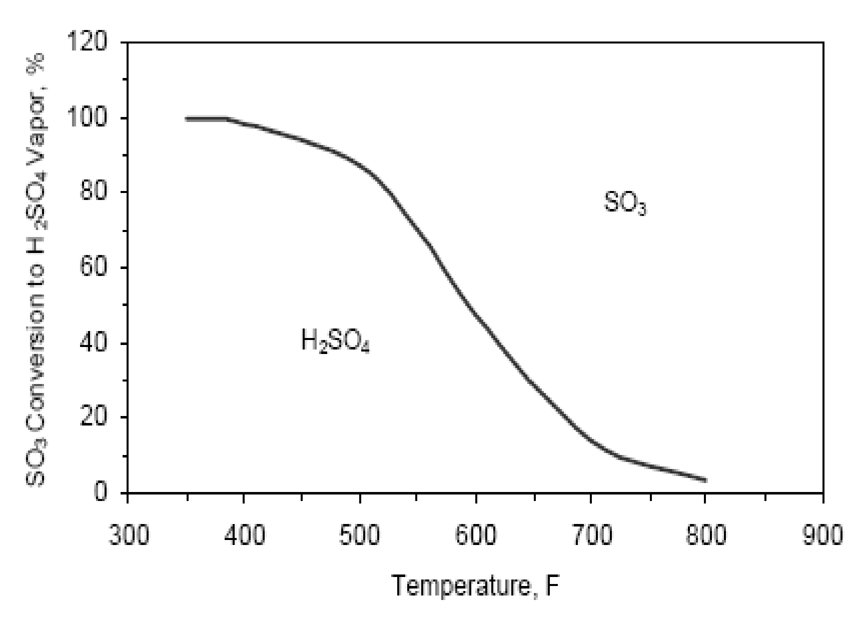


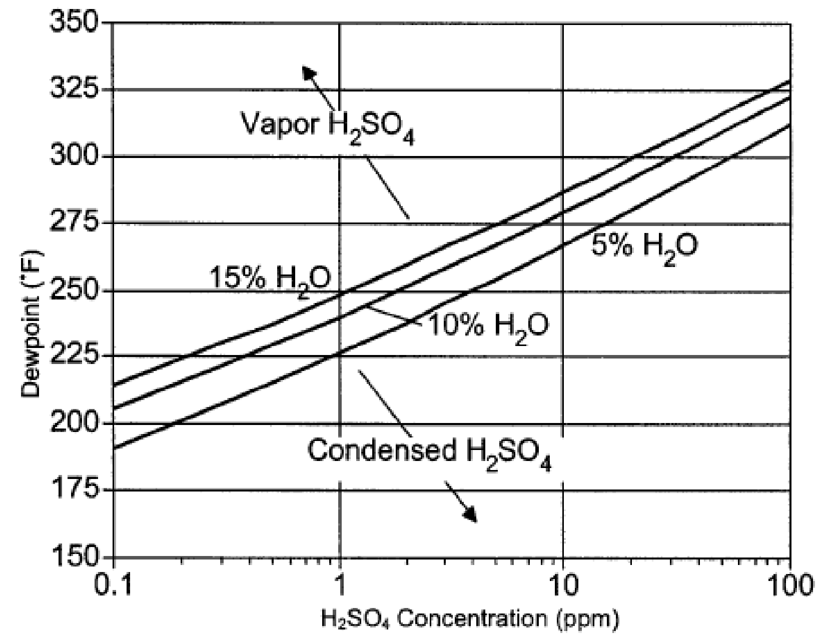
Process Comparison – Wet ESP

- Installed in saturated flue gas streams with low ash loading
- Typically follows a scrubber, temps of 55°C
- Primary collection of $PM_{2.5}$, H_2SO_4 and liquid droplets
- Flue gas below acid dew point temperature
- H_2SO_4 droplets of 0.1-0.3 microns
- Requires water usage; once-through water or recycle system. With scrubber, no additional water burden
- Effluent needs to be addressed; pumped into scrubber (mist eliminator wash water) or water treatment facilities

Process Comparison

- In a typical utility boiler, SO_3 is in gaseous form until air heater
- Converted to H_2SO_4 (in vapor form above 150°C)
- In saturated flue gas stream, condenses into aersol



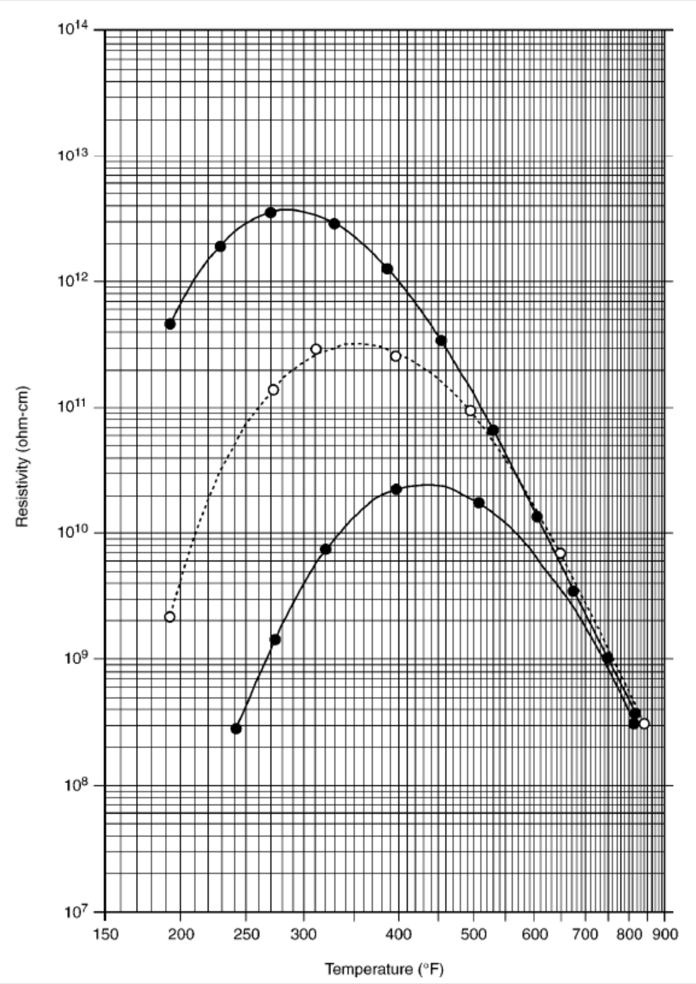


Process Comparison – Resistivity Wet ESP

- Inlet particulate at low resistivity, easy to collect
- Collecting plates are continually cleaned not allowing particulate to buildup on plates
  - Problems with back corona eliminated
  - No possibility of re-entrainment
- Allows higher ESP velocities and lower SCA than dry ESP
- High volumes of sub-micron inlet particulate can cause current (or corona) suppression

Process Comparison – Resistivity Dry ESP

- Resistivity of particulate plays significant role in sizing, performance
- 3 grades
  - low (<10^9 ohm-cm)
  - moderate (10^9-10^{11} ohm-cm)
  - high (>10^{11} ohm-cm)
- Moderate is best range, allows particulate to be collected on plates and shear off into hoppers
- High resistivity = back corona
- Low resistivity = re-entrainment



Installations

<u>Dry ESP</u>

- Installed on many different utility and industrial processes for flyash collection
- Fabricated from mild carbon steel
- Comparitively less expensive

<u>Wet ESP</u>

- Standard in sulfuric acid industry. Used in many industrial applications for plume, PM, H_2SO_4, odor, toxic metals
- Fabricated from alloy steel, FRP or plastics to withstand concentration of acid gases
- More expensive than dry ESP

Mercury Control

- Recent regulations in U.S. for mercury control
- Mercury exists as vapor or particulate in flue gas
- Vapor phase can be elemental or oxidized (water soluble)
- Dry ESPs will capture particulate Hg however, vapor phase Hg will not be captured
- Injection of activated carbon upstream of dry ESPs has shown capture of vapor phase Hg at 90%+ removal

Mercury Control

- Limited testing of mercury capture through wet ESP
- Testing that has shown that wet ESP will capture particulate, oxidized Hg at high efficiency
- Co-benefit of oxidizing the elemental Hg in the wet ESP

Incremental Hg Removal Efficiency

(Ontario Hydro Test Method)

	FGD Inlet		FGD outlet		Wet ESP outlet		Total
	μg/m³	Removal%	μg/m³	FGD %	μg/m³	WESP %	FGD/WESP Removal %
Ash Hg	4.37	0%	0.85	80%	0.20	76%	95%
Hg^{2+}	6.02	0%	1.88	69%	0.26	86%	96%
Hg^{0}	2.55	0%	2.92	-15%	2.39	18%	6%
Total Hg	12.94	0%	4.88	62%	2.85	41%	78%

Performance

Dry ESPs

- Consistently demonstrated 99%+ removal of filterable PM_{10}, 90%+ removal of filterable $PM_{2.5}$

Wet ESPs

- Consistently demonstrated 99%+ removal of total $PM_{2.5}$, droplets and H_2SO_4

- Future CO2 regulations will open market opportunities for wet ESPs

Summary

Parameter	Dry ESP	Wet ESP
Purpose	Primary PM Control Device	Polishing Device
Location	First APC Device	Last APC Device
Configuration	Horizontal Plate	Vertical Tubular or Horizontal / Vertical Plate
Humidity	5-20%	100%
Temperature	250-800°F (120-425°C)	<150°F (65°C)
High PM Loading	Yes	No
FPM_{10} Removal	High	Limited
$FPM_{2.5}$ Removal	Moderate	High
PM Condensables Removal	No	High
H_2SO_4 Removal	No*	High

Summary

Parameter	Dry ESP	Wet ESP
Mercury Removal	No*	Moderate
SCA (FT^2/1000 ACFM)	300-800	50-200
Gas Velocity	3-5 ft/sec 0.9-1.5 m/sec	6-10 ft/sec 1.8-3.0 m/sec
Pressure Drop	< 2 in.w.c. (0.5 kPa)	< 2 in.w.c. (0.5 kPa)
Water Usage	No	Yes
Waste Water Treatment	No	Yes
Resistivity Issue	Yes	No
Back Corona	Possible	No
Re-Entrainment	Possible	No
Mat'ls of Construction	Carbon Steel	Stainless Steel minimum
Cost	Low / Moderate	Moderate / High

Q&A

Questions?