MEMBRANE WESP

A Lower Cost Way to Reduce PM2.5, SO_3 & Hg^{+2} Emissions

Pilot Metal tube (background) and Membrane Wet ESP (foreground) at First Energy's Bruce Mansfield, PA Plant.

The Wet Membrane ESP design reduces the cost of Wet Electrostatic Precipitators to the point where they truly can be considered a cost effective way to control emissions in both utility and industrial applications.

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Advantages of Wet ESP over Dry ESP

- **Lower emissions**
- **No rapper re-entrainment**
- **Dust resistivity not a factor**
- **Higher Power levels**
- **High efficiency on sub-micron particulate**
- **Can collect aerosols (H_2S0_4 mist)**
- **Can collect soluble Hg^{+2}, HCI & some SO_2**
- **No moving parts**

Advantages of Membrane WESP over Metal Plate WESP's

- **20-30% cost savings compared to metal plate units**
- **Membrane wicking action eliminates channeling & dry spots**
- **Membranes cleaned continuously no spraying/misting-field disruptions**
- **Ultra-fine conditioning spray not required**
- **Operates in convenient up-flow arrangement**
- **No mist elimination required to eliminate droplet carryover**
- **Reduces weight of internals up to 50%**

Membrane WESP Lime Kiln Pilot

In the past, Wet Precipitators fabricated with metal collecting electrodes required expensive, high alloy stainless steels to withstand corrosion from the various wet environments. This increased the cost dramatically especially when high nickel alloy steels, such as Alloy C276, were required. Wet Membrane ESP's, using polypropylene or other chemically resistant material as the collecting electrode, significantly reduce these costs. The lower cost of these units allows their use in very large applications such as after Wet FGD scrubbers for $S0_3$ (sulfuric acid mist) Hg^{+2} & PM 2.5 control. In industrial applications the units can be added after an existing scrubber for fine particulate control.

The membranes are made from materials that transport flushing liquid by capillary action effectively removing collected material without spraying. Capillary action promotes well-distributed water flow across the entire membrane, easily achieving the wetting action necessary for particle collection, removal and transport. Low flushing liquid flow rates keep the membranes clean.

APPLICATIONS OF MEMBRANE WET PRECIPITATION

The main applications for the membrane WESP are to collect fine particulate, and acid aerosols, after scrubbers:

- **After FGD scrubbers in the Utility Industry.**
- **After upstream particulate scrubbers in industrial applications.**

For these applications, the membrane wet precipitator technology has several significant advantages over existing technologies as discussed below.

COST ADVANTAGE

We project that a 2-field, upflow, membrane WESP, located on top of an existing Wet FGD scrubber will cost less than $25/KW on an installed basis.

Further, the weight of the collecting electrodes can be reduced by as much as 75%, making it easier to install the membrane curtains in existing up-flow scrubbing towers.

PROBLEMS WITH EXISTING WET ELECTROSTATIC PRECIPITATORS

In most wet precipitators, both tubular and flat-plate, the collection surface normally is a plain, solid, continuous sheet of metal or plastic. Therefore, the flushing liquid (water) passing over the surface tends to "bead" due to both surface tension effects as well as the geometric imperfections (“hills and valleys”) of the surface. Because the flushing liquid cannot be uniformly distributed over the surface, this beading can lead to channeling and formation of "dry spots" of collected particles. The resulting build-up of collected material can cause the ESP electrical performance to degrade because the accumulated material is not as good a conductor as the underlying substrate or the water. As a result, current flow is inhibited, which results in increased emissions from that section of the electrostatic precipitator.

Most "old-design" wet precipitators employ spraying or fine mist atomization to more uniformly distribute liquid over the surface. Increasing the number of droplets and decreasing their respective size can minimize beading, and thus reduce the number of dry spots. However, any spraying onto the surface will inevitably produce a misting effect in the gas channel. This aqueous mist is much more conductive than the typical gas that is moving through the gas passages. As a result, the high voltage electric field, which is used to both charge the particles and drive them to the collecting plates, will have a conductive path to ground, shorting out the field. To avoid this grounding, called sparkover, the field

voltage is usually reduced or terminated during spraying, which effectively removes that field from collection service during the cleaning cycle.

Metal Plate type Wet precipitators also face problems of corrosion, so the internals must be made of expensive alloys.

MEMBRANE COLLECTING ELECTRODES SOLVE THESE PROBLEMS

Replacing the traditional metal collecting electrode (or solid Plastic tubes) with fabric membranes brings many benefits:

- **The membranes are lightweight, lower cost & much more corrosion resistant.**
- **Flushing liquid over the membrane removes collected particulate continuously with no spraying – the field stays continuously in service.**
- **Higher gas velocity & reduced collecting surface (since more collecting surface is always on line) significantly reduces cost of the total system.**
- **Water usage is reduced – only 0.75 – 1.5 GPM/1,000 ACFM (saturated gas) is adequate to keep the membrane clean.**

ADDITIONAL ADVANTAGES OF THE MEMBRANE WET PRECIPITATOR

Because the liquid film is also the collecting surface (i.e. it conducts electricity), the membranes can be made from corrosion resistant, nonconductive materials like polypropylene, Ryton, or reinforced plastics. These materials minimize corrosion problems, while offering an effective alternative to stainless steels and expensive alloys.

Capillary flow thru the membrane and surface flow over the membrane also serve as a shield, which at least partially protects the membrane over its entire surface against abrasion by particles and will also dilute various chemicals.

The membrane collecting electrode can be kept very flat with a small amount of tension – alignment is easy to maintain.

With the virtual elimination of spraying/splashing by the water delivery/distribution system, a continuous flow of flushing water can be maintained while the electric field is not interrupted.

Flushing liquid required to keep the membranes clean is only 20-30% of that required for a Metal Plate WESP.

Additionally, there is strong evidence that the membrane curtain can handle higher inlet dust loadings since it can be flushed continuously. This would allow the upstream scrubber to operate at a lower pressure drop, saving power and reducing operating cost. A 5” SPWG (△P) savings on 1,000,000 acfm of airflow is worth approximately $250,000 per year.

A potential additional benefit of the membrane is that by maintaining a 40^0F - 60^0F temperature difference between the membrane flushing liquid and the gas temperature, this seems to promote increased collection efficiency.

Results of Tests –

Testing in three pilot units has shown outstanding particulate collection efficiency comparable to, and in some cases superior to, a conventional metal plate WESP. Figure 2 shows the V-I-curve for the lime kiln pilot precipitator, for air & lime dust. Using the Power Plus transformer-rectifier set provided by NWL, the Membrane WESP exhibited power profiles comparable to conventional wet precipitators.

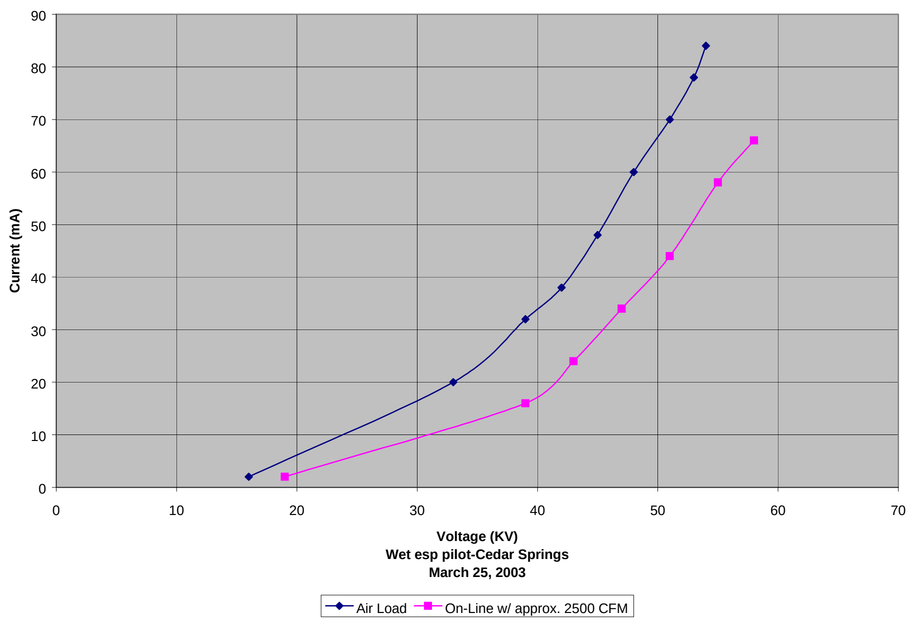

Figure 2. **V-I curves for the Lime Kiln Pilot wet membrane precip.**

Before tests were performed to quantify collection efficiency in the pilot-scale unit, a test run was performed to visualize the membrane's ability to remove particulate. Pictures were taken before energizing the field and a few seconds after the field was energized. The dust loading, temperature, and flow conditions were kept constant between the two displayed images of Figure 3, providing a visual indication of the effectiveness of the wetted collection membranes.

Figure 3. **Dirty and clean stack (ten seconds after energizing field)**

Membrane Chemical Resistance

In order to test how various membrane materials behave in highly corrosive environments at elevated temperatures, a closed loop testing system was constructed as schematically shown in Figure 4. The system is designed for long-term, continuous operation without interruption. The system produces hot water at 80°C (175^{0} F) elevated temperature testing of nine separate chemical solutions-fabric combinations.

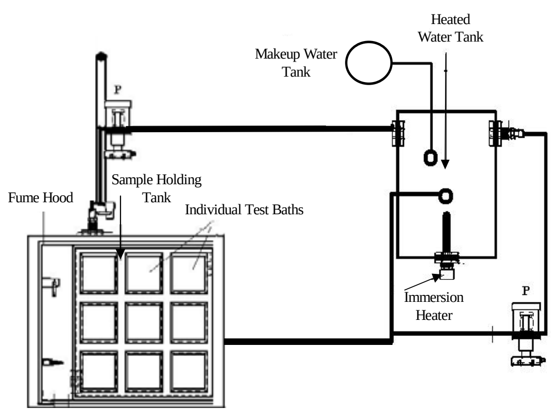

Figure 4. **Accelerated Chemical Corrosion Testing Apparatus**

The nine tanks contain combinations of the materials Ryton, Polypropylene and Teflon in solutions of acids and bases. Specifically, the solutions are:

- **"Sulfuric Acid" – H_2SO_4 and H_2O to pH of 1.5;**
- **"Ammonia" – 1500 ppm NH_4Cl, 1% $(NH_4)_2SO_4$ in distilled water;**
- **"Reactive" – 800 ppm HF, 30000 ppm HNO_3, 60000 ppm H_2SO_4, 8000 ppm HCl in distilled water.**

The materials were sampled and tested for Mullen Burst Strength over time. These results are shown in Figure 5.

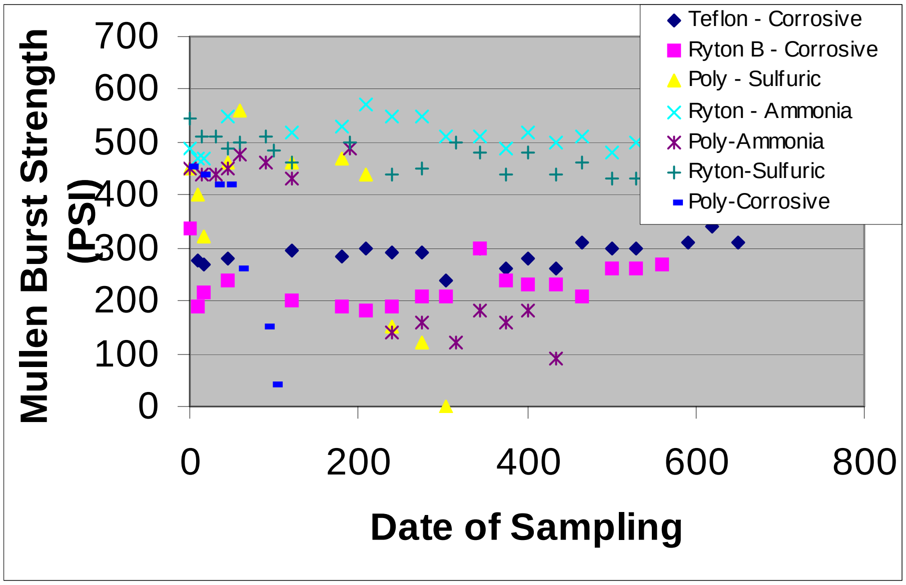

Figure 5. Accelerated chemical corrosion strength testing results

<u>TEST RESULTS</u>

Lime Kiln Pilot Plant Results -- after 5000 hr operation:

Inlet and outlet emissions test results are shown in Table 1 and indicate that the single field Unit captured 88-95% of the particulate and achieved very low outlet loading levels of 0.0015 to 0.005 Gr/ACF.

The gas velocity and the SCA goals of the pilot unit were met in that the test results were demonstrated at gas velocities of 10 –11 ft/sec. & SCA of < 65 ft^2/1000 ACFM.

No build up of lime dust was observed. At the end of the 5,000 hour test the polypropylene membranes appeared almost "as new." (See Attachment A) Also, Mullen Burst strength tests were run which showed that the membranes had lost less than 5% strength. This would suggest a membrane life of up to 5 years.

<u>Utility Pilot Plant</u> –

Under partial sponsorship from the U.S. Dept. of Energy we built a third pilot membrane WESP after an existing Wet FGD system at First Energy's Bruce Mansfield Station in Shippingport, PA.

The goal of this project was to compare the performance of the membrane design to a "conventional" metal, tubular WESP. Under all conditions the membrane unit performed somewhat better than the metal tubular unit as seen in Table 1.

WESP Performance Comparisons

UNIT	EXCEL/ SHERBORG	LIME KILN	DOE METAL	DOE MEMBRANE
Application	RB Fired Boiler	Lime Dust	SO3, PM	SO3, PM
Description	2 Fld Upflow Metal	1 Fld Upflow Membrane	2 Fld Upflow Metal	2 Fld Upflow Membrane
Downstream of:	Rod Deck Scrub	Rod Deck Scrub	Wet FGD	Wet FGD
Gas Vol. ACFM	245,000	7,000	8,000 15,000	8,000 15,000
Gas Temp. °F	120-150°F	130°F	125°F	125°F
SCA – 1st Fld.	34	65	35 19	34 18
2nd Fld.	51		35 19	39 21
Gas Velocity thru WESP, fps	9	11	9 16.7	9 16.7
Outlet Opacity, %	<10	<5	<2 <5	<2 <5
Inlet Loading, Gr/ACF		0 .04	0.054 0.05	0.046 .05
Outlet Loading, Gr/ACF		0.0027	0.004 0.015	0.0017 0.01
PM Efficiency, %		93	93 70	96 80
SO3 Efficiency, %	N/A	N/A	88 65	93 71
Hg^{+2} Efficiency, %	N/A	N/A	76 50	82 61

Table 1 – Perform comparisons of one full-size & 3 Pilot Units

BENEFITS OF A WET MEMBRANE UP-FLOW UNIT

Generally with "conventional" wet, upflow units such as the SEI metal–plate unit at Excel/Sherborg, the ESP must be designed with an "extra" field which can be out of service during cleaning, substantially increasing the cost of the wet unit. Because the membranes can be continuously flushed, the possibility exists to design the unit with a single field (for industrial applications) or 2-fields (for utility applications) and still collect fine particulate and SO_3 mist. Obviously this will significantly reduce the overall system costs.

Further, the membrane WESP weight is reduced by as much as 30%. Which makes it easier to install in existing, up-flow, FGD scrubbing towers.

These operational advantages and cost savings truly change the perception of Wet Electrostatic Precipitators to the point where they can be considered a cost effective emissions control device for PM2.5, SO_3 & Hg^{+2}.

ATTACHMENT A

Internals of Lime Kiln Pilot Unit after 5,000 hours operation.