

REINHOLD ENVIRONMENTAL Ltd.



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ESP's and Mercury Control

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ESP's and Mercury Control

- ESP technology has now advanced to the point where low (≤ 0.015 lb/Mbtu) particulate emissions can be routinely achieved.
- Several recent start-ups of rebuilt and retrofit ESP's have demonstrated this capability.



ESP's and Mercury Control

While these design improvements were a topic of recent webinars, they are worth mentioning again:

- **Attention to ESP 101 principles**
- **Customizable, current distributing discharge electrodes**
- **Advanced Power supplies**
- **Wide plate spacing**



ESP's and Mercury Control

ESP 101 PRINCIPLES

- Diligence in Gas flow modeling
- Hopper & anti-sneakage baffling
- Electrical Sectionalization
- Rapping Ratio



ESP's and Mercury Control

GAS FLOW DISTRIBUTION

- Uniform Gas Velocities at Inlet and Exit Ends of the ESP Collection Chamber, <15% RMS
- Possible Flow Biasing to Top or Bottom of ESP Chamber
- Protect Ash Collection Hoppers from Secondary Flows
- As Low as Possible System Pressure Loss
- Minimize Ash Fallout in ESP Inlet Ductwork



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ELECTRICAL SECTIONALIZATION

- Independent bus section energization and control.
- Loss of a single power supply becomes less of an issue.
- SEI experience is to sectionalize primarily in direction of gas flow.



ESP's and Mercury Control

RAPPING RATIO

- Effective cleaning of the ESP internals is a "must" for achievement of the low particulate emissions levels discussed herein.
- A conservative rapping ratio of ~1500 ft² of collecting surface per MIGI rapper is recommended, with adjustments up or down dependent upon ash constituents.



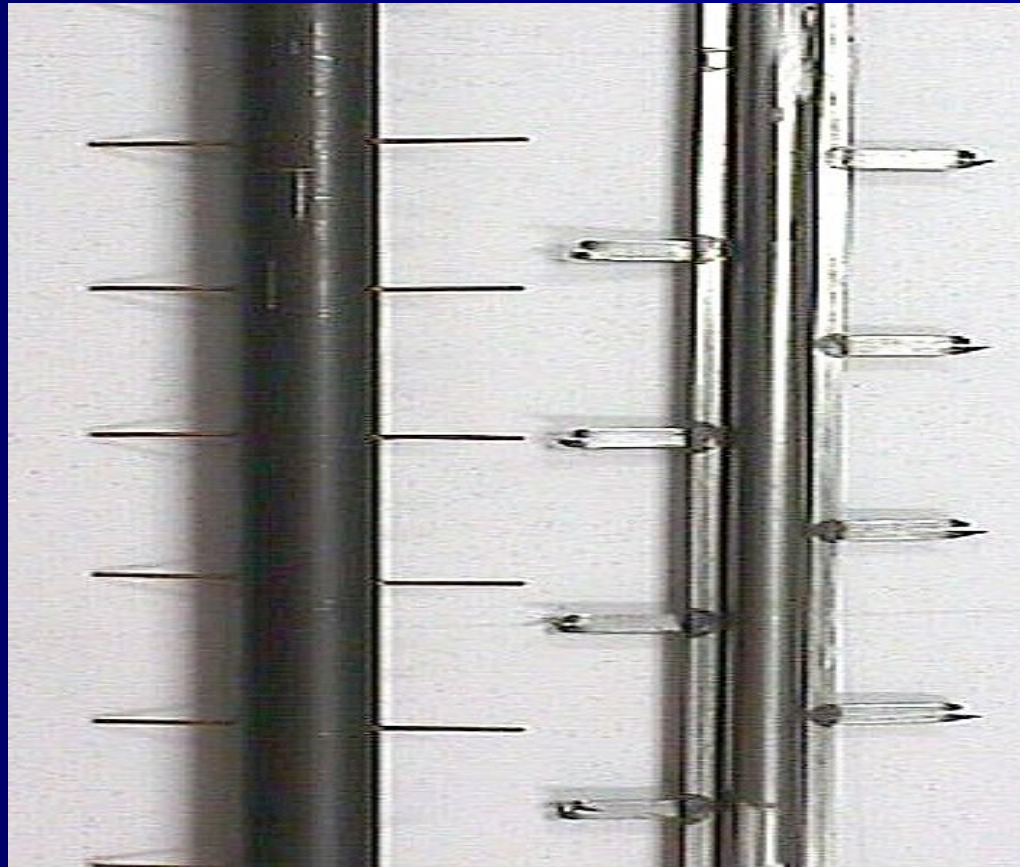
ESP's and Mercury Control

RIGID DISCHARGE ELECTRODE

- Can pump much more current into the ESP
- The current is more evenly distributed on plate.
- Can vary the discharge electrode's voltage/current output from one field to the next.
- Optimum voltage/current performance can be achieved in each field.
- These discharge electrodes have a slender profile, and are individually weighted.
- These RDE's provide enhanced performance at 16" plate spacing, per European and in-house data.



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RIGID DISCHARGE ELECTRODES

- High current producing rigid discharge electrodes on 16 inch plate spacing are ideal for low to moderate resistivity particulate collection.
- High current producing rigid discharge electrodes are ideal for fine particulate collection.
- Evenly distributed current improves ESP performance.
- Varying the discharge electrode voltage/current characteristics from field-to-field - "customizing the electrodes" – provides better particle charging and collection.
- Individually weighted discharge electrodes totally eliminate RDE frame distortions due to gas temperature maldistribution and uneven growth during operation.



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EXAMPLE OF CUSTOMIZED RDE PERFORMANCE

- 100 MW Coal-Fired unit firing PRB
- 403,429 acfm and 327 deg F at ESP Inlet
- SCA = 265.6 sq ft/kacfm, Gas Treatment Time = 5.98 sec, ESP Velocity = 6.02 fps
- Customized RDE's retrofitted on 9" Coll. Plate spacing
- Stack Emissions = 12.60 lb/hr or 0.0124 lb/mmBtu
- Stack Opacity = 4.6%
- ESP Efficiency = 99.61%



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- **Switch-Mode Power Supplies**
 - Micro-second vs. milli-second
 - response
 - 3-5% ripple vs. 35-45%
 - Up to 30% better performance
 - compared than TR sets.
 - Smaller, lighter vs. TR set
 - 3-ph with 0.94 pf vs. 1-ph with
 - 0.63 pf = energy savings

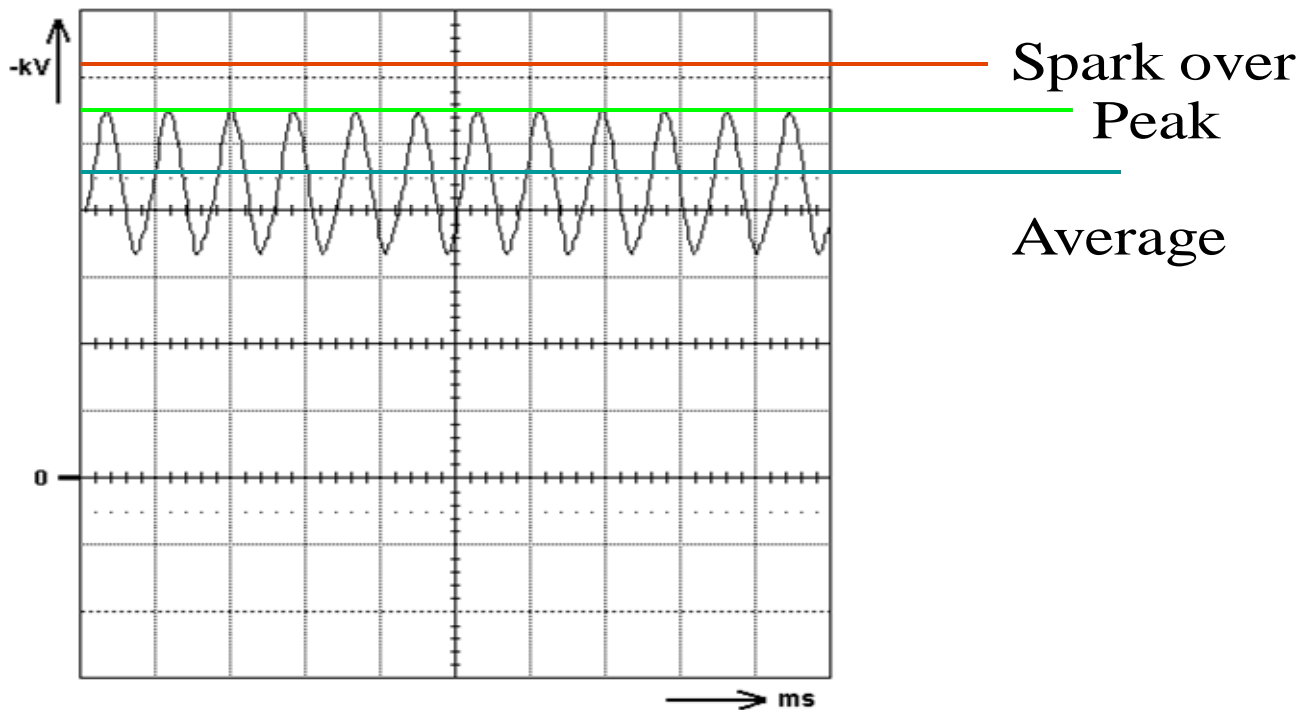


Switch-Mode Power Supply



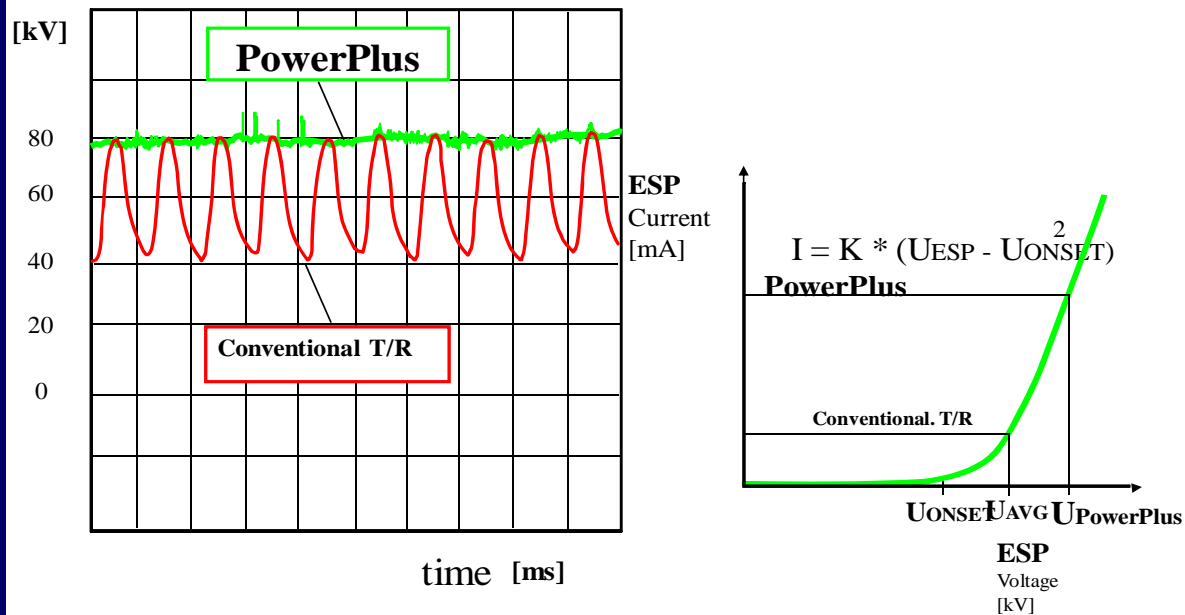
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kV RIPPLE – TR Set



ESP's and Mercury Control

kV Ripple – Switch-mode



ESP's and Mercury Control

HIGH FREQUENCY POWER SUPPLY

- Typically Provides 10% Increase in Secondary Voltage and 30% Increase in Secondary Current
- Enhancement Factor (w'/w) = About 1.20 for Moderate to Low Resistivity Fly Ash Applications
- Similar Installed Cost as Conventional T/R Sets



ESP's and Mercury Control

REBUILT ESP USING SMPS + RDE

- 1 ESP/ 3 MF / 4 CH / 27 GP per CH / 36 ft by 9/12/9 ft PL / 12-inch GP / Rigid Discharge Electrodes / (14) switchmode power supplies
- 180 MW P-C Fired Boiler
- Eastern Coals with 7.26% Ash Content, 11,867 Btu/lb HHV, and 1.1% Sulfur Content
- 1,066,600 acfm and 697 deg F at ESP Inlet
- SCA = 217.8 sq ft/kacfm, Gas Treatment Time = 6.53 sec, ESP Velocity = 4.70 fps
- Stack Emissions = 40.20 lb/hr or 0.0149 lb/mmBtu
- Stack Opacity = 4.6%
- ESP Efficiency = 99.49%



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WIDE PLATE SPACING

- 16 inch (400 mm) collecting plate spacing has been used successfully for years in Europe and Japan.
- Several plants have recently installed 16" plate spacing with outstanding results.
- The #2 ESP at the Baldwin Station of Dynegy was retrofitted with rigid discharge electrodes on both 12" and 16" spacing a few years back.
- Operation improved to the extent that the SO₃ conditioning system was retired.



ESP's and Mercury Control

WIDE PLATE SPACING

- ESP test results from a small industrial coal/bark fired unit using 16" plate spacing and SMPS follow:
- 1 ESP/ 4 MF / 1 CH / 27 GP per CH / 32 ft by 9 ft PL / 16-inch GP / Custom Discharge Electrodes / SMPS
- Bark/Coal Fired Boiler
- 270,000 acfm and 380 deg F at ESP Inlet
- SCA = 229 sq ft/kacfm, Gas Treatment Time = 9.02 sec, ESP Velocity = 3.91 fps
- Stack Emissions = 18.5 lb/hr or 0.0103 lb/mmBtu
- ESP Efficiency = 99.4%



ESP's and Mercury Control

The # 9 Unit at the Tecumseh Station of Westar Energies was the first unit that married all of these concepts in a rebuilt ESP:

- Customized rigid discharge electrodes
- Switch-mode power supplies
- Wide (~16") collecting plate spacing

Test results follow on the next slide:



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TECUMSEH UNIT #9 - 2008

- 1 ESP / 6 MF / 1 CH / 22 GP / 48 ft High PL / 9'+9'+9'+9'+6'+9' MF / 16-inch GP
- Custom Discharge Electrodes / PowerPlus Energization / Physical Model Study Conducted
- P-C Boiler Firing PRB Coal - 0.26% Sulfur in Coal & 1.31% Na₂O in Ash
- Upstream Mechanical Collector
- 330,500 acfm and 321 deg F at ESP Inlet
- SCA = 326 sq ft/kacfm, Gas Treatment Time = 13.04 sec, ESP Velocity = 3.91 fps
- ESP Efficiency = 99.71%
- Stack Emissions = 3.31 lb/hr or 0.0038 lb/mmBtu



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TECUMSEH #9

This unit was a full rebuild/conversion whereby the existing ESP internals of a European design ESP (PC Walther) were removed and replaced with a traditional American style RDE design employing customized RDE's, SMPS', and wide (16") plate spacing.

While the emissions testing produced outstanding results, the data may be viewed as "tainted", due to the presence of a mechanical dust collector upstream of the ESP.

In fact, this arrangement made the test results even more outstanding, given the high percentage of "finer fines".



ESP's and Mercury Control

A more "traditional" application of this modern ESP technology recently started up on a unit at another midwestern utility

This was a new ESP to be retrofitted into an existing gas stream on a 460 MW coal fired unit. The unit was bid competitively with a specified emissions guarantee of 0.015 lb/Mbtu.



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Site 1

- 1 ESP / 4 MF / 4 CH / 28 GP / 41 ft High PL / 12'+12'+12'+12' MF / 16-inch GP
- Customized Rigid Discharge Electrodes / PowerPlus Energization / Physical Model Study Conducted
- P-C Boiler Firing Blend of 70% PRB & 30% Eastern Bituminous coal – 1.07% sulfur and 6.80% ash in coal blend
- 1,657,000 acfm and 327 deg F at ESP Inlet
- SCA = 266 sq ft/kacfm, Gas Treatment Time = 10.64 sec, ESP Velocity = 4.51 fps
- ESP Efficiency 99.91%
- Stack Emissions = 18.67 lb/hr or 0.0047 lb/mmBtu



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- During this test, fractional efficiency data was also measured.
- Following is a comparison of that data to similar data extracted from a 2006 paper from the AWMA journal:



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	Yi, Hao, Duan, Li & Guo, 2006	Yi, Hao, Duan, Li & Guo, 2006	Site A
PM SIZE	ESP	FABRIC FILTER	ESP
PM	99.89	99.94	99.91 0.0047 lb/mbtu
PM 10	99.62	99.76	99.73
PM 5	99.16	99.72	99.63
PM 2.5	98.59	99.54	99.37 0.0027 lb/mbtu



ESP's and Mercury Control

SITE A

- As this unit was new from the ground up, and was sized, bid, and won competitively with very low emissions guarantees, the test results for emissions clearly validate the technology.
- There will be two additional large utility ESP's coming on line before the end of 2009 that employ this same technology, and similar results are anticipated.



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SUMMARY

- These are not cherry-picked test results -- they all are 3-test run averages of the only valid performance tests conducted on each of these ESPs
- There is a strong data-base with which to draw upon to confidently guarantee the performance of an ESP at **0.010 lb/mmBtu particulate** emissions.



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CONCLUSIONS

Previous to these findings, most efforts to deal with mercury emissions started with baghouses, as they were believed to be the only device capable of achieving particulate emissions at these low levels, and worked well with activated carbon in reducing Hg emissions.



ESP's and Mercury Control

CONCLUSIONS

Recent studies suggest that Hg removal levels >90% can be achieved without the use of fabric filters.

A rebuilt ESP utilizing components and principles discussed herein, along with the use of bromine compounds, and/or ACI injection into a downstream scrubber, may well provide a simpler and more cost effective solution than a FF/ACI combination.

