E P S C O International, Ltd.

WPCA/Dominion Particulate – Scrubber Seminar

Ways to Improve Performance of Marginal ESPs

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E P S C O International, Ltd.

- Credits to:

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for paper entitled

"REBUILDING AND UPGRADING ELECTROSTATIC PRECIPITATORS - A CONSULTANT'S PRESPECTIVE"

edited for presentation today by

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- **BASIC CONCEPTS OF ELECTROSTATIC PRECIPITATION**

Deutsch-Anderson Equation

Loss = $e^{-(A\,W/Q)}$ where
- e = base of natural log = 2.719
- A = effective collecting surface area
- W = particulate migration velocity
- Q = gas volume

$W = k\,a^2\,E_o\,E_p$ where
- a = particle radius
- k = related to gas velocity
- E_o = particle charging field strength
- E_p = particle collecting field strength

Equations show:

- "squaring" effect of operating voltage on ESP efficiency.
- Emphasizes effect of particle size on collection efficiency.
- Finer particles: lower migration velocities; difficult to collect.

Interpretation of Deutsch Equation

- **ESP Eff. = 1 - loss = $1 - e^{-(A\,W/Q)} = 1 - 1/e^{(AW/Q)}$**
  $= 1 - 1/\ 2.719^{(300{,}000 \times 20/1{,}200{,}000)} = 1 - 1/2.719^{(5)}$
  $= 1 - 0.0067 = 0.9933 = 99.33\%$
- **With A = 300,000 ft.^{2}, W = 20 fpm, Q = 1,200,000 acfm**

- **ESP Eff. = 1 - loss = $1 - e^{-(A\,W/Q)} = 1 - 1/e^{(AW/Q)}$**
  $= 1 - 1/\ 2.719^{(400{,}000 \times 20/1{,}000{,}000)} = 1 - 1/2.719^{(8)}$
  $= 1 - 0.0003 = 0.9997 = 99.97\%$
- **With A = 400,000 ft.^{2}, W = 20 fpm, Q = 1,000,000 acfm**

- **Maximize AW/Q to maximize collection efficiency.**
- **Maximize W by maximizing "a" and maximizing "E_o x E_p".**
- **To maximize efficiency: maximize A & W, minimize Q.**

REBUILD AND UPGRADE OPTIONS

- **Modify boiler operation.**
- **Gas/particulate conditioning.**
- **Humidification.**
- **Add collecting surface area.**
- **Increase field height/SCA.**
- **Increase DE sectionalization.**
- **Modify CE plate spacing.**
- **Modify DE geometry.**
- **Reduce air infiltration.**
- **Minimize heat loss.**
- **Modify gas distribution.**
- **Modify rappers & controls.**
- **Modify voltage controls.**
- **Modify power supplies.**
- **Upgrade auxiliary equipment.**

Modify Boiler/Process Operation

Check process operation. Minor changes can help chemistry, size and/or resistivity of particulate and improve ESP efficiency.

Examples:

- **Cleaner boiler tubes, or modifying soot blower operation will improve heat transfer, and reduce gas temperature.**
- **Reduced gas temp. may reduce resistivity & improve efficiency.**
- **Modifications to air heater to reduce gas temperature may increase ESP operating voltage and increase migration velocity.**

Gas/Particulate Conditioning

Typically low sulfur coal is fired: high resisitivity.

- **Condition gas stream with SO_3 to reduce resistivity, and in some cases, also inject ammonia to aid in agglomeration of fine particulate to reduce re-entrainment, reducing particulate emissions.**

  Reducing resistivity and increasing particle size via agglomeration will both increase migration velocity, improving ESP collection efficiency.

Humidification (Moisture Conditioning)

Injection of water: evaporation = drop in flue gas temp. which can improve ESP efficiency in four ways:

- **Lower temp. results in lower particle resistivity.**
- **Added moisture reduces resisitivity of gas stream.**
- **Temp. drop reduces gas volume, gas velocity.**
- **Reduced face velocity increases specific collecting area (SCA) – sq. ft. of CE plate area/1000cfm of gas.**

Adding Collecting Area within Existing Casing

- Test cost effectiveness of increasing ESP width, length, or height to increase SCA.
- Review & consider available space between fields.
- Consider RDEs with wider plate spacing and higher TR set voltages.

Additional collecting plate area will improve ESP collection efficiency, and RDEs will improve ESP reliability and reduce maintenance.

Increase Field Height

Most economical way to increase ESP size and SCA.

- **Since roof removal is required, consider RDEs also, but assure that aspect ratio (length/height) of rebuilt ESP approaches “1”.**
- **Review “penthouse” & weather enclosure requirements to minimize increased wind loads.**

Positive effects: increased SCA and ESP efficiency.

Increase Electrical Sectionalization

- Smaller bus section = less disturbance in rest of ESP from sparking, heavy dust load, or errant flue gas.
- Experience and studies show significant ESP performance enhancement when sectionalizing in direction of gas flow.
- Earlier rigid frames, with wires or RDEs, typically designed with very large electrical sections, in direction of flow; forced splitting frames across flow.
- O.E.M. designs now allow for sectionalization during rebuild both across and with gas flow, whether weighted wire, rigid frame wire/RDE, or RDE.

Modify Plate Spacing

- Deutsch equation: max. efficiency with plate area for given volume; implies close plate spacing; 8”- 9”.
- Last decade, increased plate spacing (10”, 12”, 16”).
- Why? Proved that migration velocity (W) increases proportionally with plate spacing, given appropriate DE configurations and adequate power supplies.
- Benefit: fewer internal components reduces cost.
- Caution: Due to “space charge effect”, which inhibits charging and collection of particulate, wide plate spacing not favored with high dust loading or fine particulate size.

Modify Discharge Electrode (DE) Geometry

- **Aggressive: RDEs (pipes) w/ spikes, barbed wire, metal strips w/ points, twisted squares.**
- **Passive: RDEs w/ bows or ribbons, smooth wires w/ weights, coiled springs in frames.**
- **Use aggressive DEs: heavy ash loading or fine ash.**
- **Use passive DEs: lighter ash loading or fewer fines.**
- **Why? Trying to match corona current w/operating voltage; charge and capture particulate, manage sparking to minimize re-entrainment.**
- **Not untypical to use aggressive DEs inlet fields and passive DEs in outlet fields.**

Reduce System Air Infiltration

- **Infiltration can be big problem re ESP performance; promotes corrosion of casing and internals, adverse affect on gas volume/distribution, re-entrainment.**
- **Sources: door seals, expansion joints, rapper penetrations, dampers; sometimes casing corrosion.**
- **Often overlooked source of ESP performance problem.**
- **If not addressed as part of routine maintenance, must be reconciled during any rebuild program.**

Minimize Heat Loss

- **Heat loss can lead to corrosion and efficiency loss.**
- **Caused by poor gas distribution and insulation.**
- **If local temperatures drop below the acid dew point, condensation will occur.**
- **Acid condensation will lead to corrosion, and make ash removal from electrodes & hoppers difficult.**
- **Build up on electrodes will reduce ESP operating voltages, and reduce ESP collection efficiency.**
- **Hopper accumulation causes build up into the CE & DE electrode area, shorting out fields.**

Modify Gas Distribution

- US practice: maximized ESP efficiency = uniform gas distribution; same velocity across ESP face.
- Uniform: 85% readings not more than 1.15 average, and 99% not more than 1.4 average (ICAC rules).
- Outside US: make ESP big enough to meet codes.
- Recent concept: skew gas flow from inlet to outlet and manage re-entrainment of particulate.
- ESKOM (South Africa) has met with good results.
- Uniform distribution concept dominates worldwide, and can typically be achieved; check gas sneakage.

Modify Rapping and Rapper Controls

- Objective: keep CEs & DEs clean, minimize buildup to max. migration velocity; minimize re-entrainment.
- How? Manage intensity & frequency of rapping.
- When rebuilding, be aware some easier to manage.
- Three types: gravity impact, tumbling/drop hammer.
- Impact: 10 – 20# slug, magnetically lifted, then falls.
- Tumbling: variable hammer wt., depends on # ducts.
- Drop: strikes rod or frame from adjustable arc.
- Consider variable acceleration required, ease of adjustment of both frequency and intensity.

Upgrade Automatic Voltage Controls (AVCs)

- **Why? Maximize conduction time & power input, reduce sparking voltage and re-entrainment.**

- **How? Replace analog with microprocessor controls; saturable core reactors with SCRs; consider pulse or intermittent energization; replace transformer rectifiers with switched integrated rectifiers.**

- **Added benefits: self-diagnostics; upgrade with chip changes; can be linked to central computer for remote data acquisition & control; feed data to plant process control computers to maximize migration velocity.**

Matching of Power Supplies to Loads

- **Premise: match power supply to load requirements.**
- **With mis-match, AVCs depress firing angle of SCRs, keeping corona current level lower than normal.**
- **Typical mis – match: 70 kV TR operating at 30 kV.**
- **Causes: improper application or process change.**
- **Corrective measures: change electrode geometry (type of discharge electrode or spacing), change TR input taps, add impedance such as linear reactor on primary side of TR.**
- **For ESP rebuild: consider age of TRs and possible presence of PCBs.**

Upgrade Auxiliary Equipment

- **When rebuilding/upgrading ESP, be aware that auxiliary equipment can effect ESP performance.**
- **Upgrade hopper heaters, level detectors, vibrators, and ash evacuation system, to minimize possible build up and loss of electrical fields, CE damage.**
- **Consider door seals, expansion joints, and dampers.**
- **Check heaters on support insulators, or, verify appropriate volume and heat required for air purge system, to avoid contamination, electrical leakage, or breakage of support insulators, which will cause power loss or failure.**

Example of ESP Rebuild and Upgrade

- Somewhat typical case: 3 field rigid frame ESP, 97%, gas temp. @ 338º F, high resistivity ash, casing in good condition, no corrosion problem.
- Must increase efficiency due to coal supply change.
- Recommended actions to increase efficiency to 99.5%.
- AH mod's to reduce ESP inlet gas temperature to 266º F.
- Rap inlet perf. plates to reduce build up, improve distribution.
- Use space between fields to increase CE area by 20%.
- Raise roof; increase plate height and CE area by 20%.
- Use RDEs, and split 3 fields in direction of gas flow to form 6 fields.
- Install first 2 fields w/12" spacing and very aggressive RDE's.
- Last 4 fields w/16" spacing & less aggressive RDEs or wires.
- Use gravity impact hammers to reduce re-entrainment.
- Upgrade power supplies and controls.
- Eliminate air infiltration and heat loss.

Summary

- **Rebuild/upgrade of ESP more cost effective than new, larger casing, new ESP, or installing FF.**
- **Particularly true for rigid frame ESP with RDEs.**
- **Savings: foundations, support steel, nozzles, ducts, casing, hoppers, ash handling, access, HI & lagging.**
- **Proven, successful technologies, worldwide.**
- **Keys to success: confidently predict performance of modified equipment; extensive understanding of ESPs; database of experience; modeling capabilities.**
- **Not a task for the inexperienced.**

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