

# **REINHOLD ENVIRONMENTAL Ltd.**



## **2010 APC Round Table & Expo Presentation**

July 18-20, 2010, in Concord, NC / Hosted by Duke Energy

All presentations posted on this website are copyrighted by Reinhold Environmental, Ltd (RE). Any unauthorized downloading, attempts to modify or to incorporate into other presentations, link to other websites, or obtain copies for any other uses than the training of attendees to RE's Conferences is expressly prohibited, unless approved in writing by RE or the original presenter. RE does not assume any liability for the accuracy or contents of any materials contained in this library which were presented and/or created by persons who were not employees of RE.

# **Effects of Biomass on Particulate Equipment O&M**

**By**

**Tom Lugar**

**Buell APC**

**Fisher Klosterman**

**A CECO Environmental Company**



# Types of Biomass Boilers

- **Traveling Grate Spreader Stoker**
- **Hydro Grate (Water Cooled Vibrating) Stoker**
- **Bubbling Fluidized Bed**
- **Circulating Fluidized Bed**
- **Existing PC Design with Lower Portion of Furnace Equipped with a Traveling Grate or Hydro Grate and Chipped Wood Spreader**

**Differences in Ash Characteristics Include Inlet Loading, Inlet Particle Size Distribution, LOI.**



**Traveling Grate Spreader Stoker**

## **Boiler Type: Traveling Grate Stoker**

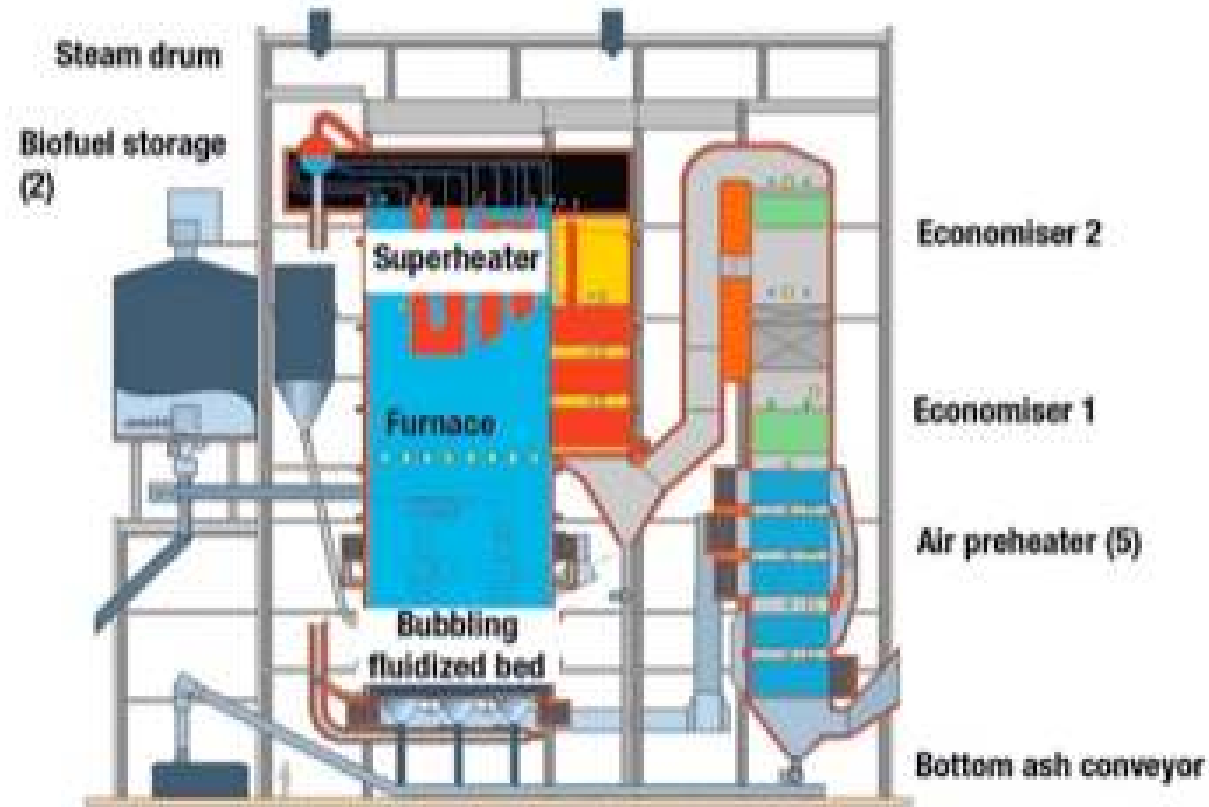
- **Reliable and efficient and can use a variety of fuels including wood waste, municipal solid waste, agri material and combination fuels including coal**
- **Higher unburned carbon losses than other biomass boiler types, carryover of burning char.**

## **Boiler Type: Hydro Grate Stoker**

- **Easier to operate and better control of combustion than traditional stoker.**
- **Unburned carbon losses are less than traditional stoker with less carryover of burning char.**

## **Boiler Type: Bubbling Fluidized Bed (BFB)**

- **More complete combustion than stokers, much lower LOI, no carryover of burning char.**
- **A bubbling bed of sand provides a heat sink which allows the boiler to handle various types of fuel of variable and high moisture contents.**
- **Lower combustion temperatures generate lower NO<sub>x</sub> and thus requires reduced SNCR reagent**



## Bubbling Fluidized Bed Boiler

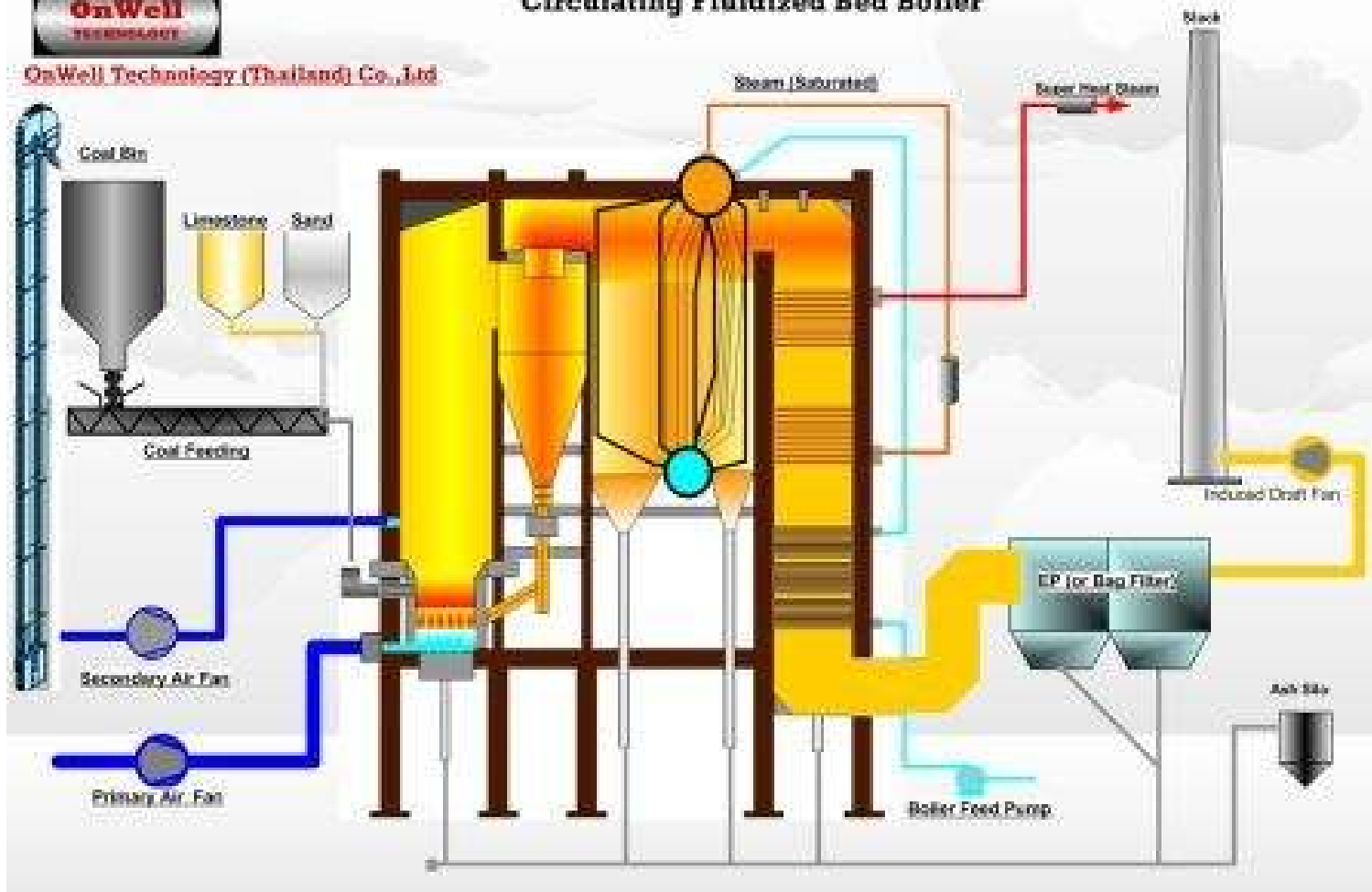
## **Boiler Type: Circulating Fluidized Bed (CFB)**

- **Typically not considered for 100% biomass but used used for combinations of fuels such as coal.**
- **Better than a BFB for a wider range of multiple or mixed fuels.**
- **Lower NO<sub>x</sub>, SO<sub>2</sub> than a grate stoker**



# Circulating Fluidized Bed Boiler

OnWell Technology (Thailand) Co., Ltd



## **Typical Biomass Fuels**

**Wood Chips, Wood Pellets, Tree Trimmings, bark**

**MSW: sewage sludge, paper waste**

**Agricultural: Switchgrass, rice hulls, straw**

**Animal Waste: Poultry Litter**

## **Impacts of Conversion of Coal-Fired PC Boiler to 100% Biomass-Fired (Wood) Bubbling Fluidized Bed (BFB) Technology**

<b><u>Parameter</u></b>	<b><u>Coal</u></b>	<b><u>Biomass</u></b>
<b>Generation Capacity</b>	<b>93 MW</b>	<b>91 MW</b>
<b>Net Heat Rate</b>	<b>12,359 Btu/kWh</b>	<b>16,340 Btu/kWh</b>
<b>Fuel Moisture Content</b>	<b>8.0%</b>	<b>45.0%</b>
<b>Fuel Heating Value as Rec'd</b>	<b>11,786 Btu/lb</b>	<b>4,675 Btu/lb</b>
<b>Full Load Coal Feed Rate</b>	<b>49 tons/hr</b>	
<b>Full Load Biomass Feed Rate</b>		<b>135 tons/hr</b>
<b>Fuel Ash Content</b>	<b>12.2%</b>	<b>2.3%</b>
<b>% Fly Ash</b>	<b>80.0</b>	<b>99.0</b>
<b>% Bottom Ash</b>	<b>20.0</b>	<b>1.0</b>
<b>Flue Gas Flow</b>	<b>489,684 ACFM</b>	<b>544,542 ACFM</b>
<b>Fly Ash Loading to ESP</b>	<b>2.3 gr/acf</b>	<b>1.3 gr/acf</b>

## **Biomass Burning Effects on the Boiler**

- **The chemistry of biomass ashes is dominated by the compounds of silicon, calcium, magnesium, potassium, sodium and phosphorous.**
- **There is propensity toward the formation of both slagging and fouling deposits especially with fuel having a high potassium and phosphorous content due to reduction in the ash melting point.**
- **The risks for corrosion are considered to be modest except where co-firing increases the chlorine content of the flue gases significantly.**
- **For BFB boilers, there is the possibility of tube erosion from excessive velocity and turbulence and sintering**

# Wood Chips Characteristics

## BTU/lb

Range = 3,700 - 7600

Average = 5,000

(Low as-fired heating value  
due to high moisture content)

## Moisture Content

Range = 10 - 56%

Average = 43%

## Ash

Range = 2 - 8%

Average = 3.6%

## Sulfur Content

0.02 – 0.1

## Flue Gas Characteristics After Conversion to Biomass Firing Combustion Analysis for Each Fuel and Composite, BFB Boiler

	T&L (1)	T&L (2)	Pine Chips (1)	Pine Chips (2)	Hardwood	Composite
Higher Heating Value - Btu/lb	3,625	4,827	3,961	4,675	5,072	4,773
Moisture - %	50.07	44.12	54.11	45	40.25	44.47
Carbon - %	21.68	28.85	24.03	28.06	30.25	28.61
Hydrogen - %	2.26	3.02	2.75	3.19	3.50	3.15
Nitrogen - %	0.15	0.19	0.04	0.26	0.14	0.18
Sulfur - %	0.02	0.03	0.04	0.02	0.02	0.06
Chlorine - %	0.0	0.0	0.0	0.03	0.0	0.0
Ash - %	11.59	4.20	0.31	2.28	0.90	2.44
Oxygen - %	14.23	19.59	18.72	21.15	24.94	21.08
Flue Gas - lb/hr	922,424	819,312	935,782	841,730	793,181	828,214
Flue Gas, 300 °F - acfm	308,082	267,751	312,885	276,334	258,442	271,235
Flue Gas, 330 °F - acfm	320,235	284,438	324,872	292,221	275,366	287,529
Flyash - lb/hr	25,241	6,423	676	3,678	1,336	3,821
LOI - %	0.2	1.0	8.0	1.4	4.0	1.3

Note: T&L is tree tops & limbs

# Ash Properties: Comparison of Wood to Coal

<u>Fuel and Ash Characteristics</u>	<u>Wood</u>				<u>Coal</u>			
	<u>Pine</u>	<u>Oak</u>	<u>Spruce</u>	<u>Redwood</u>	<u>Lig.</u>	<u>Sub-Bit.</u>	<u>Bit.(IL)</u>	<u>Bit.(WV)</u>
Ash Content %	2.9	5.3	3.8	0.4	12.8	6.6	17.4	12.3
Sulfur %	0.1	0.1	0.1	0.1	1.1	1.0	4.2	0.7
SiO <sub>2</sub>	39.0	11.1	32.0	14.3	41.8	24.0	47.5	60.0
Al <sub>2</sub> O <sub>3</sub>	14.0	0.1	11.0	4.0	13.6	20.0	17.9	30.0
Fe <sub>2</sub> O <sub>3</sub>	3.0	3.3	6.4	3.5	6.6	11.0	20.1	4.0
CaO	25.5	64.5	25.3	6.0	17.6	26.0	5.8	0.6
MgO	6.5	1.2	4.1	6.6	2.5	4.0	1.0	0.6
Na <sub>2</sub> O	1.3	8.9	8.0	18.0	0.6	0.2	0.4	0.5
K <sub>2</sub> O	6.0	0.2	2.4	10.6	0.1	0.5	1.8	1.5
TiO <sub>2</sub>	0.2	0.1	0.8	0.3	1.5	0.7	0.8	1.6
Mn <sub>3</sub> O <sub>4</sub>	0	0	1.5	0.1				
LOI	Typically 15-30%				Typically 1-5%			

## **Particulate Control Choices for Biomass Boilers**

**Stoker Boilers: Mechanical Collectors and ESP**

**BFB & CFB: Baghouse, ESP without Mechanical Collectors**

**In the Wood Products Industry, the Dry ESP Preceded by Multi-Clones is Presently Considered the Best Available Control Technology for Wood-Fired Boiler Emissions from traveling Grate Spreader Stoker Boilers**

## Typical Spreader Stoker Wood-Fired Ash Characteristics

- Inlet Loading = 0.3 - 0.6 gr/acf (after cyclones)
- Mean Particle Size = 4.0 microns
- LOI: 15 - 30%
- Resistivity:  $10^7 - 10^8$  ohm-cm

## Typical Fluidized Bed Wood-Fired Ash Characteristics

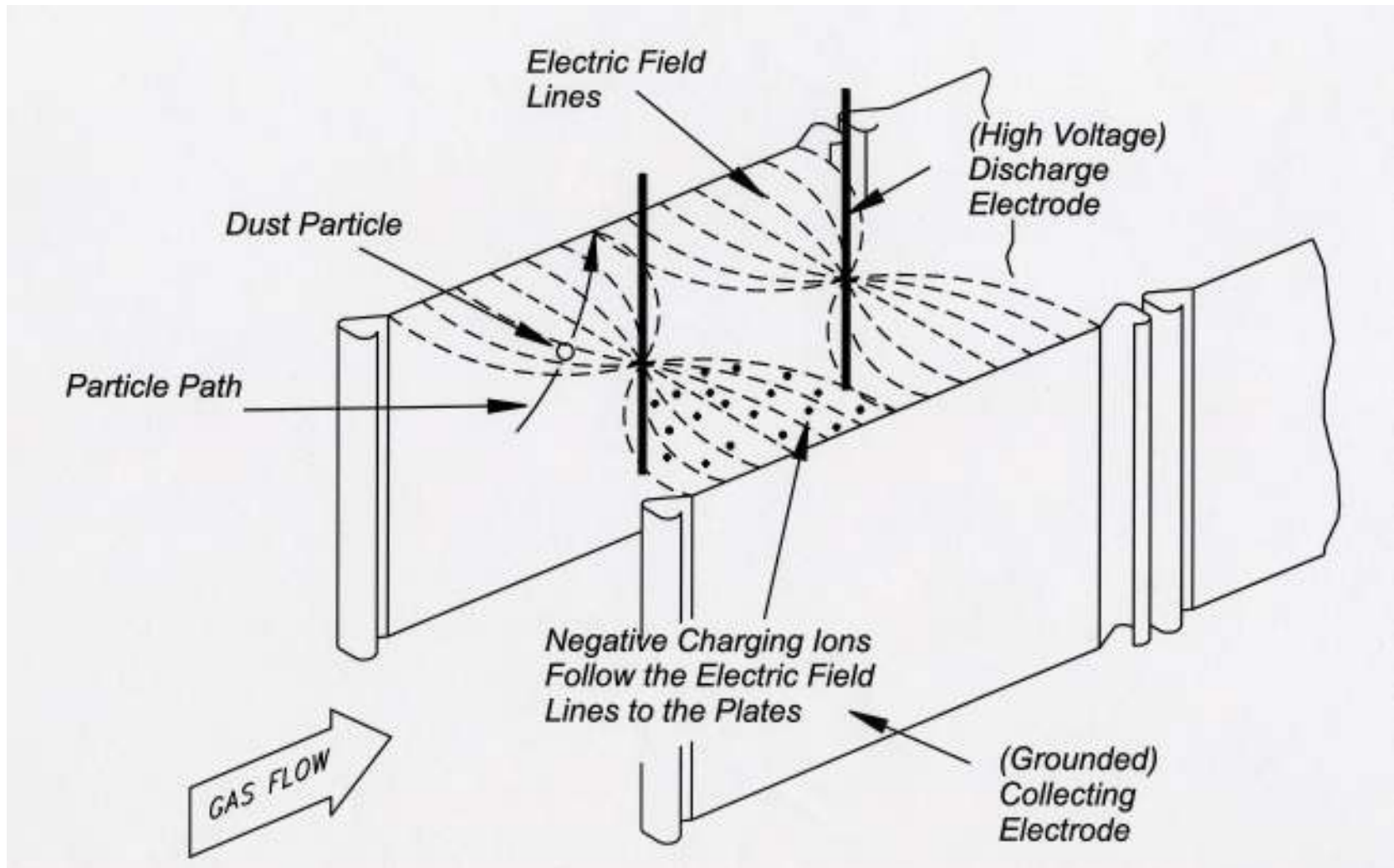
- Inlet Loading = 0.2 - 0.5 gr/acf
- Mean Particle Size = 3.6 micron
- LOI: 5-10%
- Resistivity:  $10^8 - 10^9$  ohm-cm

## Biomass Flyash Constituents vs. Higher Resistivity Coal Flyash

<u>Flyash Constituent</u>	<u>Coal Ash</u>	<u>Biomass Ash</u>
Silica, SiO <sub>2</sub>	50 - 75%	10 - 30%
Alumina Al <sub>2</sub> O <sub>3</sub>	25 - 35%	3 - 15%
SiO <sub>2</sub> + Al <sub>2</sub> O <sub>3</sub>	80 - 95%	20 - 40%
Sodium Oxide, Na <sub>2</sub> O	0.1 - 0.4%	1.5 - 6%
LOI	1 - 5%	10 - 30%

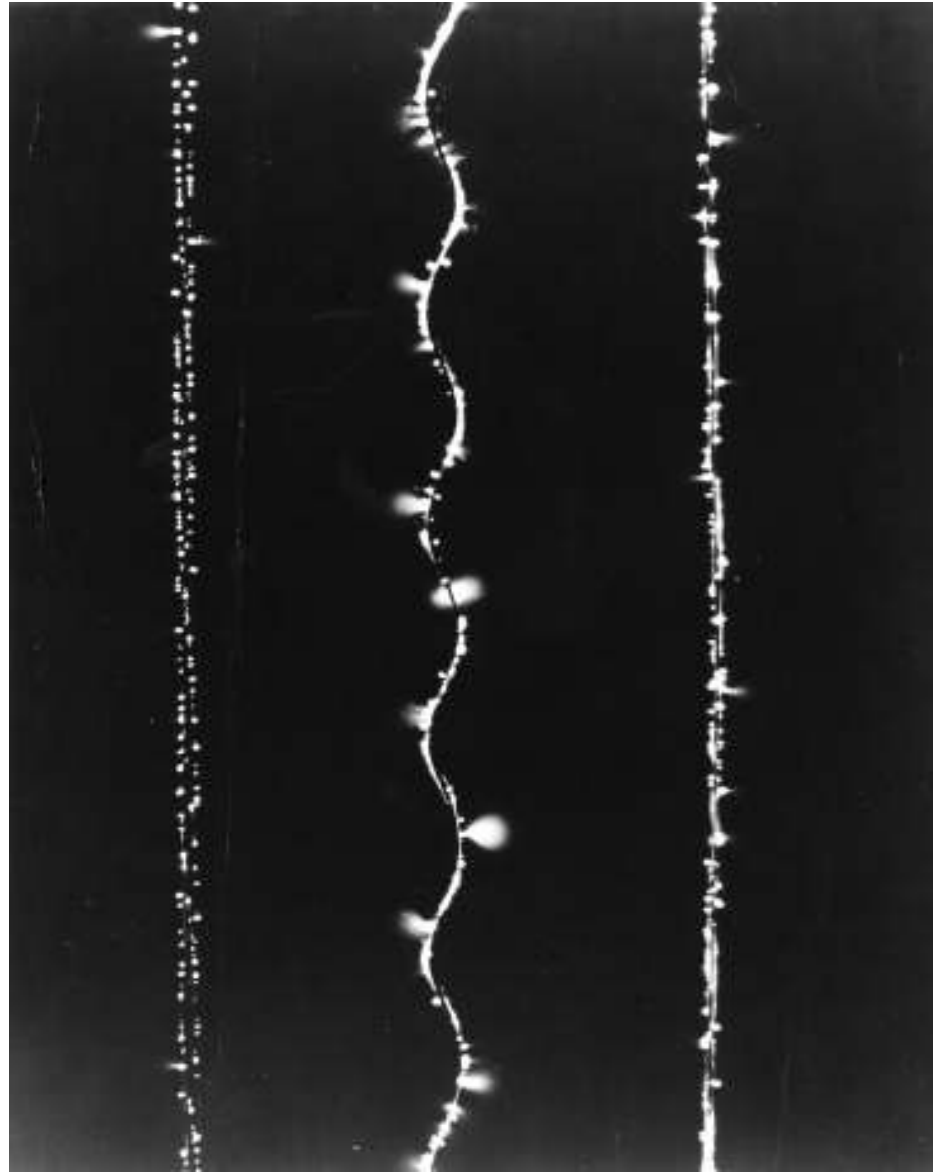
### Drivers for lower resistivity with biomass ash:

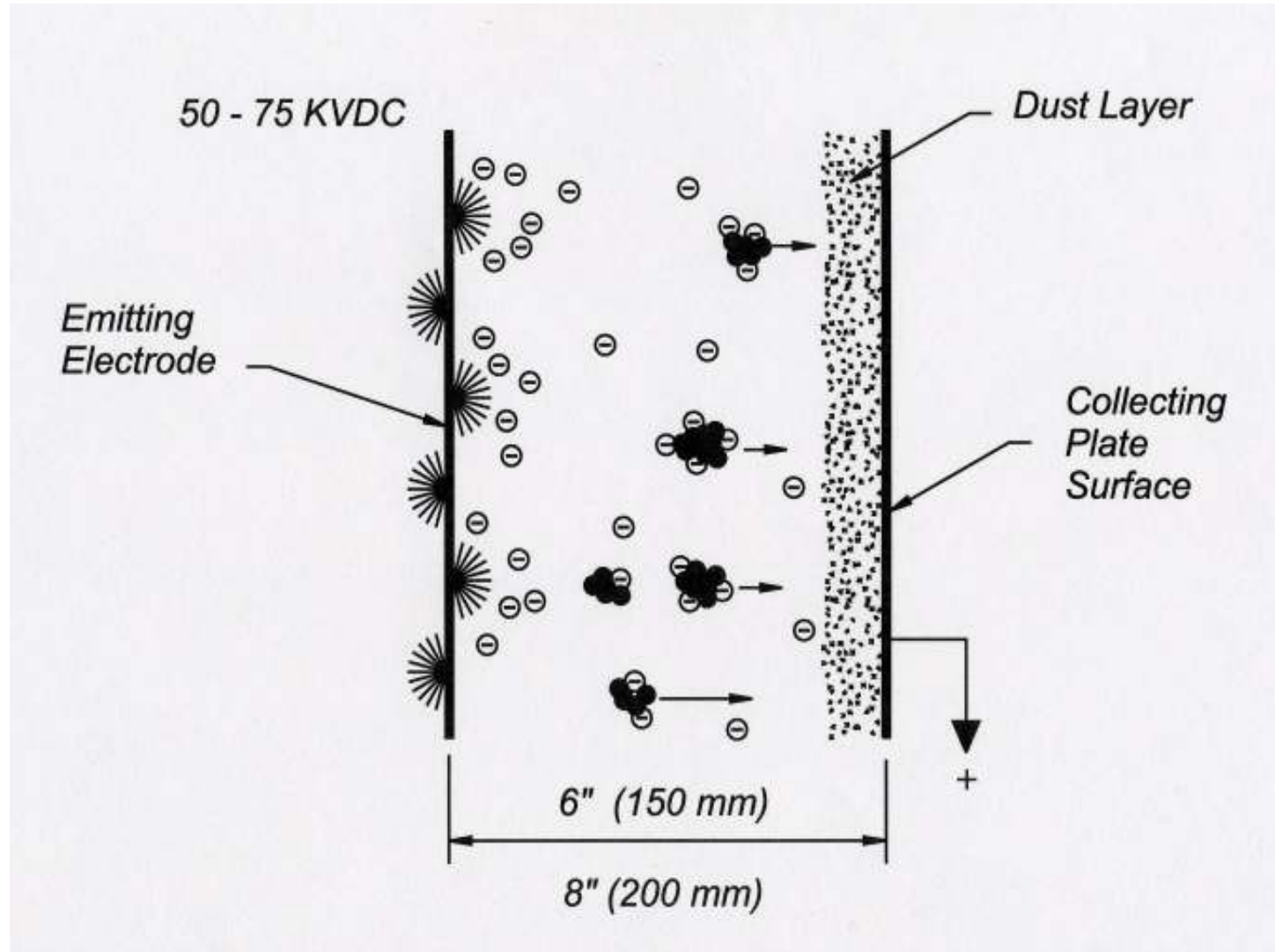
- Higher LOI with higher levels of higher conductive carbon
- Higher sodium content; sodium ions are charge carriers in the ash layer
- Moisture in biomass causes flue gas moisture to be 15-25%; moisture provides conductive film on surface of the ash.



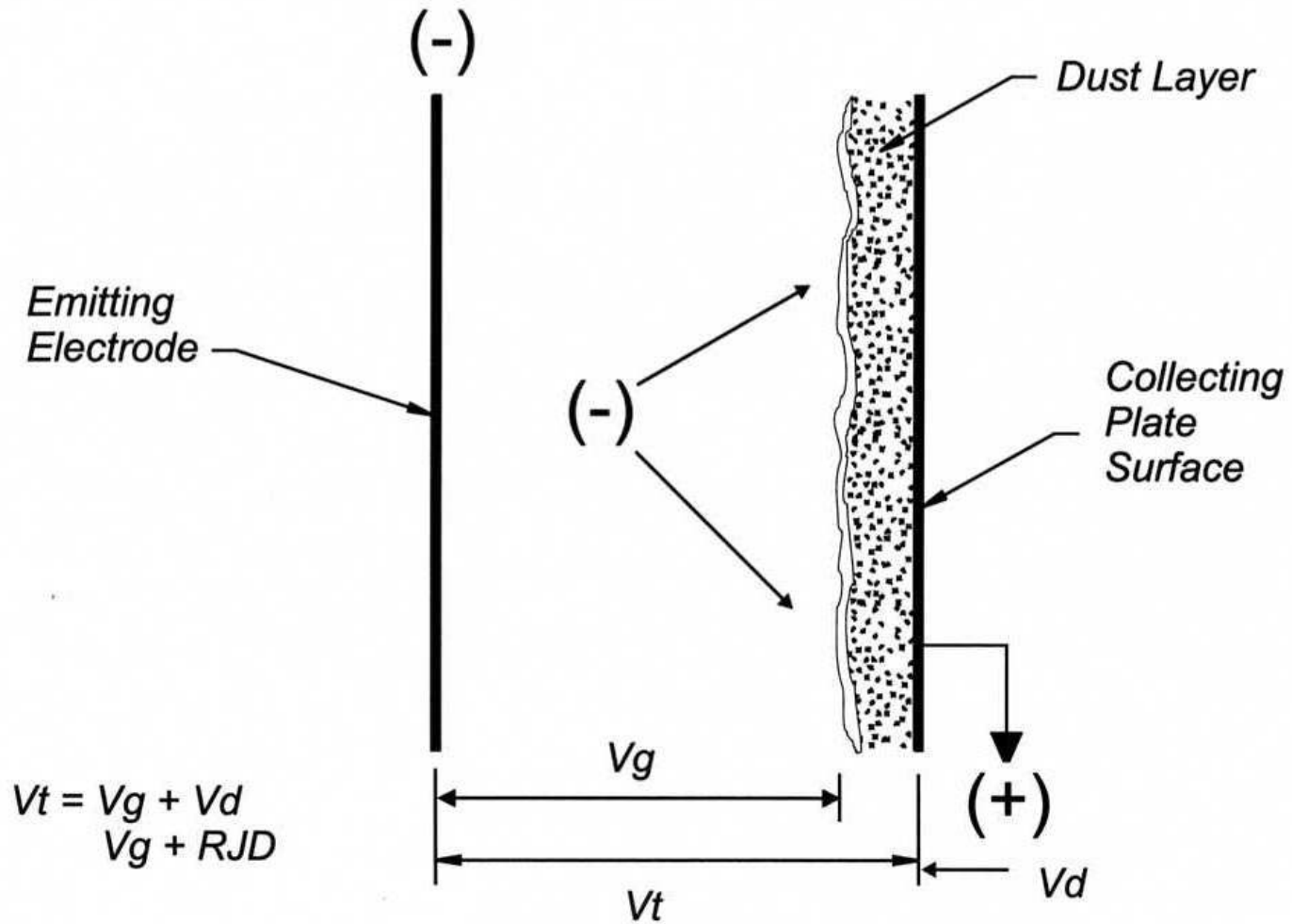
**ESP Particle Charging and Collection**

## Emitting Electrode Corona Emission





**ESP Particle Charging and Collection**



**Charge is stored on the resistive ash layer surface and current flows through the ash layer to the grounded plates at a rate depending On the ash resistivity**

# **Wood-Fired Boilers Ash Characteristics Traveling Grate Spreader Stoker**

- **Moderate to High Carbon Content Typically 15-30%, High Sodium Oxide Ash Content, High Flue Gas Moisture Levels**
- **Low Resistivity, Typically  $10^7 - 10^9$  ohm-cm**
- **Small Particle Size distribution after multi-clones, Typically 70% <10  $\mu$ , 20% < 1 $\mu$ , MMD = 4.0 $\mu$**
- **Low Density with Flake Shape (Light & Fluffy), Specific Gravity = 0.5, versus 2.3 for coal flyash; Bulk Density = 15 lb/ft<sup>3</sup> versus 45 lb/ft<sup>3</sup> for flyash**

# ESP Sizing Considerations

The ash characteristics pose the potential problem of ash re-entrainment due to low resistivity combined with low density.

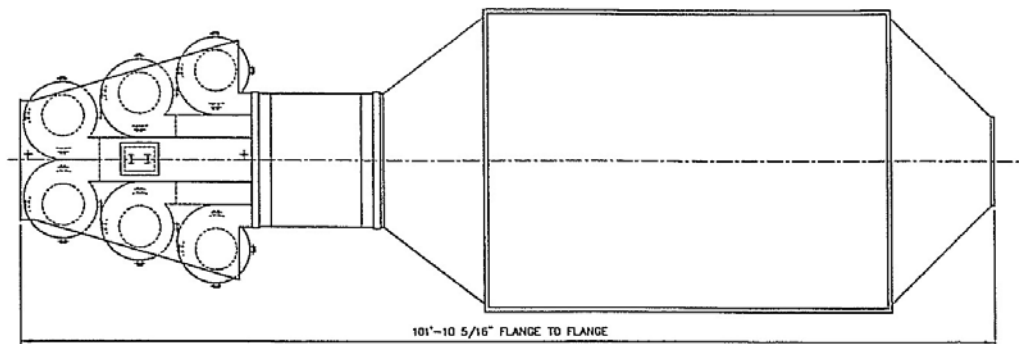
## ESP Sizing and Plate Rapping Design/Operation

- **Low Gas Velocity, 3 - 3.5 ft/sec**
- **L/H Ratio - Minimum 1.0**
- **Relatively Large SCA, 400 to 550 depending on Outlet Emission Requirements**
- **Optimum Gas Flow Distribution To and Within the ESP**
- **Electrical Sectionalization in Depth: Minimum of 3 or 4 Electric Fields depending on Outlet Emission Requirements**

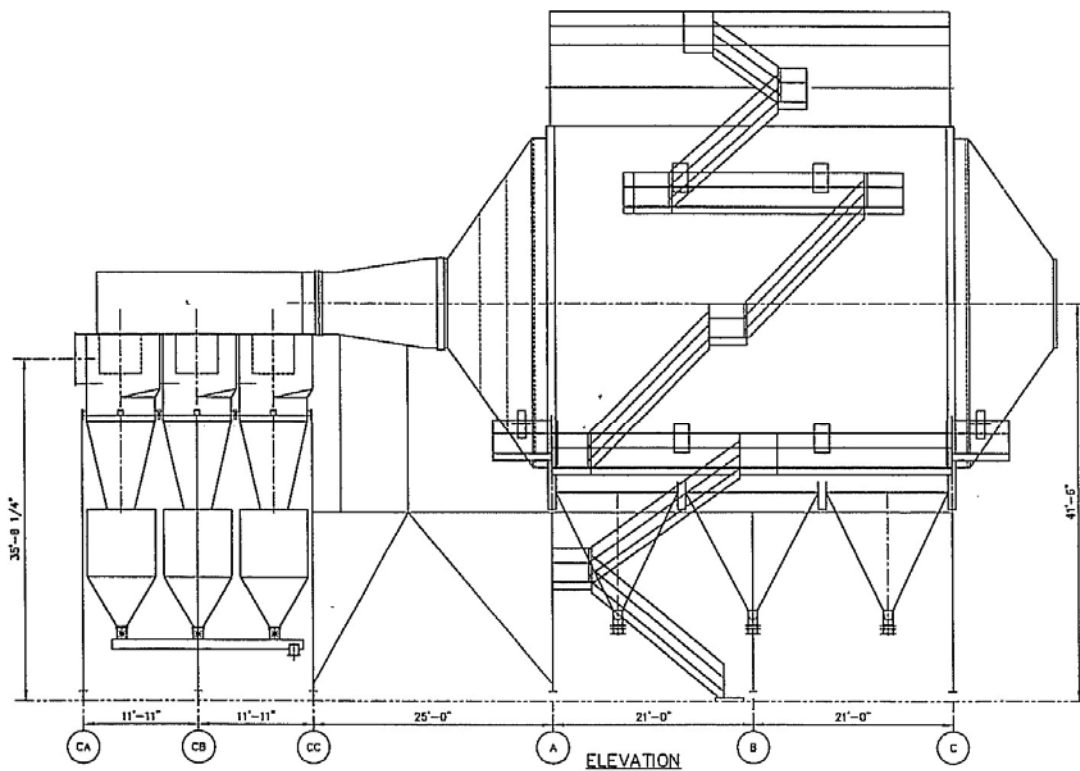
## ESP Sizing and Plate Rapper Design/Operation (Cont.)

- Minimize Re-entrainment Due to Rapping
  - Reduce plate area/rapper to optimize rapper force distribution (Increase the number of rappers)
  - Collecting plate rapping cycle time and lift (force) optimization is critical for the low resistivity conductive wood ash.
  - Low rapping intensities

**200,000 acfm  
Wood-Fired Boiler  
Application**



PLAN





**Pacific Lumber , Scotia CA**

# Wood-Fired Boiler ESPs

- **The sizing of wood-fired boiler ESPs is well established over the past 35 years and there have been no problems achieving required outlet emission requirements even for very low emission levels.**
- **Where problems have occurred, they have been due to fire damage to the ESP internals.**

## Wood-Fired ESP Performance

<u>Installation</u>	<u>SCA</u>	<u>Guarantee Outlet</u>	<u>Measured Outlet</u>
Hammermill Paper	505	0.05 lb/MMbtu	0.03 lb/MMbtu
Burlington Electric	672	0.013 lb/MMbtu	0.005 lb/MMbtu
Alternate Energy	357	0.03 lb/MMbtu	0.0015 lb/MMbtu
Fairhaven Power	289	0.05 lb/MMbtu	0.03 lb/MMbtu
Consolidated Paper	407	0.05 lbs/MMbtu	0.0055 lb/MMbtu
Pacific Lumber	375	0.05 lb/MMbtu	0.02 lb/MMbtu
Redding Power	330	0.05 lb/MMbtu	0.02 lb/MMbtu
Burney Forest	351	0.03 lb/MMbtu	0.012 lb/MMbtu

## Wood Fired Boilers – The Fire Issue

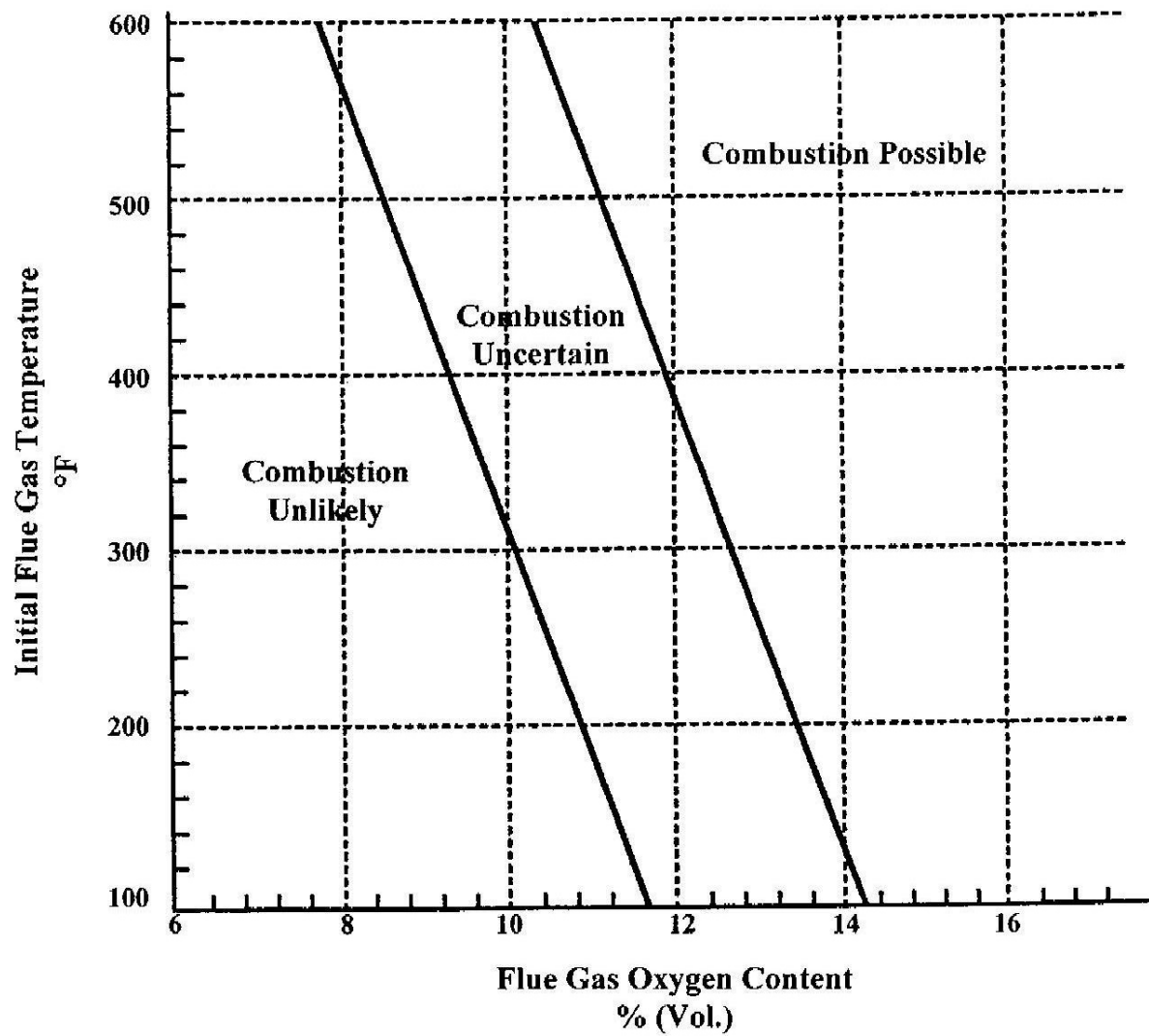
**1/3 of ESPs on wood waste applications in the U.S. have experienced fires on the collecting plates and/or in the hoppers.**

- **Usually fires have occurred during boiler upset conditions with flue gas oxygen levels increasing to high levels (10- 20%). ESP sparking then caused ignition of ash on the plates.**
- **ESP & multi-clone hopper fires occurred with increased oxygen levels due to the spontaneous ignition of ash buildup. Hopper door leaks with a negative pressure system causes ignition of ash buildup.**
- **The problems associated with dust removal seem to be restricted to those units equipped with pyramidal hoppers (as opposed to trough type) and pneumatic conveying systems.**
- **Hopper fires have occurred when ash buildup is left in the hoppers when the boiler comes off line and spontaneous ignition occurs when access doors are opened (even after several days off-line).**

## **Wood Waste ESP Fires**

- **Wood-Waste LOI results from cellulose or charcoal which is easier to ignite in the presence of oxygen than unburned coal.**
- **For flue gas temperatures of 300 to 550°F, a self-supporting fire will not occur unless flue gas oxygen is greater than 8 to 10%.**
- **The poorest combustion efficiencies are experienced during boiler startup.**

**OXYGEN REQUIRED TO SUPPORT**  
**ASH LAYER COMBUSTION**



## **Case Study: Burlington Electric, J.C. McNeil Station**

### **Traveling Grate Spreader Stoker Boiler**

- 480,000 lbs/hr Steam Generation**
- 50 MW**
- Fuel: Wood Chips**

### **Particulate Collection**

- GEESI ESP, Wire-Weight, BA Design**
- GEESI Refractory Lined Multi-Cycles**
- Cyclones Catch Re-Injected into the Boiler**

**Startup: 1984**

**At the time, McNeil Station had the largest wood-fired boiler in the U.S.**



**Burlington Electric, J.C. McNeil Station, Burlington VT**

## ESP Design Conditions

Gas Volume - 418,000 acfm  
Gas Temperature - 335°F  
Inlet Loading - 0.6 gr/acf from cyclones  
Flue Gas Moisture - 24%  
Flue Gas Free Oxygen - 3.2 to 5.0%

### Wood Chips

Heating Value - 8170 BTU/lb (dry)  
Moisture Content: 45 - 55%  
Ash Content - 0.9%

### Performance Guarantees

Outlet Loading - 0.003 gr/acf  
Efficiency - 99.5%

# ESP Design Parameters

## A/E Stone & Webster Specification

Model BA 1.2x52K4443-6.4P

SCA - 672

L/H - 1.5

Gas Velocity - 3.0 ft/sec.

Electrical Fields in Depth - 9

Powering Arrangement: 22222111

## Emission Test Results

0.001 - 0.0015 gr/acf

0.0013 - 0.003 lb.MMBtu

ESP Efficiency: 99.9%



# Burlington Electric ESP Problems

Several months after emission testing, problems developed:

- Cyclone and ESP Hopper Fires
- ESP fires occurring on collecting plates either initially or igniting from hopper fires below
- Major cyclone and ESP hopper pluggage
- In one incident, 3 days after boiler shutdown, flyash had bridged in an ESP hopper and bust into flames when an ESP casing access door was opened.

## Result:

Major bowing of collecting plates

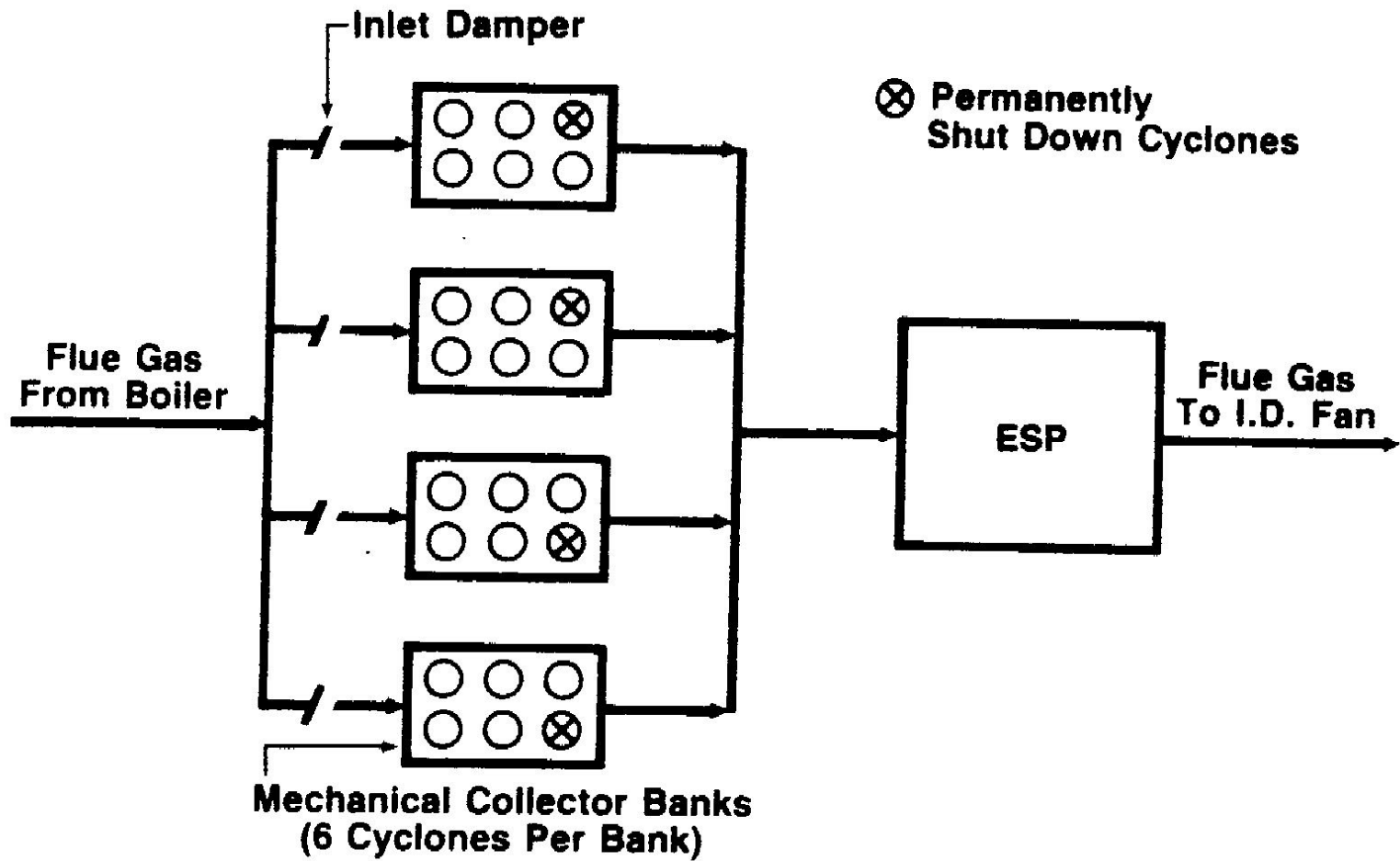
## **Burlington Electric ESP Problems (cont.)**

### **Causes:**

- **At full load, flue gas volume was 35% lower than design due to low excess air and low airheater outlet temperatures**
- **The low gas volume reduced the multi-clone efficiency to below 50% (83% design) which drastically increased the load of combustible rich and still burning particulate into the ESP.**

**Burning particulate that reach the cyclones are typically large and can be effectively removed in the cyclones.**

**Operators were not closing dampers on the banks of multi-clones to increase gas flow to maintain cyclone removal efficiency.**



**Burlington Electric, J.C. McNeil Station, Cyclone/ESP Configuration**

## Causes (cont.):

- **Hopper Pluggage:** Ash was not pulled frequently enough from the cyclone and ESP hoppers allowing smoldering ash and ash bridging to cause fires.

## Solution:

- **Damper off cyclones** to increase gas volume and maintain cyclone efficiency at 83%.
- **Avoid accumulation and bridging of ash in the hoppers** by continuously evacuating ash. For boiler shutdown, ash removal system to remain in operation until all ash is removed from the hoppers

## Result:

**Fire problem solved.**

## **To Avoid Fires, Design ESPs With Three Specific Features**

- 1. Locate ID fan upstream of the ESP for positive pressure operation to eliminate ambient air in-leakage and localized internal elevated O<sub>2</sub> levels that could support combustion.**
- 2. Use trough type hoppers equipped with screw conveyors to remove ash continuously.**
- 3. Fine-tuned rapper optimization to minimize collecting plate ash buildup (also required to minimize re-entrainment), i.e., short rapper cycle times.**

## **Avoiding ESP Fires: ESP Design Considerations**

- **With positive pressure operation, use a pressurization system for the insulator houses with insulator cover plates sealed to avoid gas flow through insulators in the event of a housing leak to avoid the potential buildup of high carbon ash inside the insulator and possible tracking.**
- **For negative pressure ESP operation, eliminating ambient air in-leakage is critical, i.e. door gaskets, areas casing/hopper corrosion, expansion joints, dampers, poor seal welds, etc.**
- **For negative pressure operation, do not use an insulator purge system which would increase O<sub>2</sub> levels in the box.**

## Fire Detection Monitors

- **Fire detection equipment such as temperature monitors, light detectors and gas analyzers are unproven for use in ESPs and have had limited use.**
- **Any fire detection device must have a rapid response time (15 to 30 seconds max.) as a serious fire can develop within 60 seconds.**
- **Using fire detectors and a ESP sprinkler system is a reaction after the fact. The key is to prevent the conditions for a fire to occur in the first place which is why a majority of wood fired ESPs have not had a fire.**

## **Avoiding ESP Fires: Process Considerations**

**In all circumstances, excess air is the most practical factor Which must be dealt with in order to prevent the occurrence Of a fire in an ESP.**

**Those wood-fired ESP applications with efficient boiler operation with O<sub>2</sub> levels not exceeding 5-7% and with continuous hopper ash removal have not experienced fires.**

**Best Insurance Measure: Install oxygen monitors far upstream Of the ESP. If the O<sub>2</sub> level exceeds the setpoint (i.e., 8%), ESP TR sets should be automatically turned off or powered down below the spark threshold.**

- **Oxygen monitors are defined as a benefit and not as a 'cure'. Good boiler combustion control with close control of fuel feed and O<sub>2</sub> levels are preventives.**

## **Boiler Process Issues**

- **The poorest combustion efficiencies are experienced during startup of the boiler. Thus, ESP energization should not occur prior to boiler stabilization if allowed by emission regulations. If the ESP must be energized, then operate in manual mode at reduced power levels below the sparking threshold.**
- **In the case of a boiler trip out, large quantities of O<sub>2</sub> would be dumped into the ESP giving rise to a high probability of fire.**
- **In the case of a feeder trip out, air flow to the boiler would remain constant for a short time while fuel flow would decrease substantially and large quantities of excess air would enter the ESP.**