Worldwide Pollution Control Association

WPCA-Duke Energy

Is Your Precipitator Ready for MATS?

Aug. 28, 2012 – Plainfield

Sept. 11, 2012 - Charlotte

WPCA

Visit our website at www.wpca.info

Process Impacts on ESP Performance

by John A. Knapik, B&W ESP Engineer

2012 WPCA/Duke Seminar

Most Important Factors Affecting ESP Performance

1. Ash Resistivity
2. Inlet Particle Size Distribution and Concentration
3. ESP Electrical Energization
4. ESP Specific Collecting Area (SCA)
5. ESP Dust Loss Factors

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E S P L O V E S S O 3

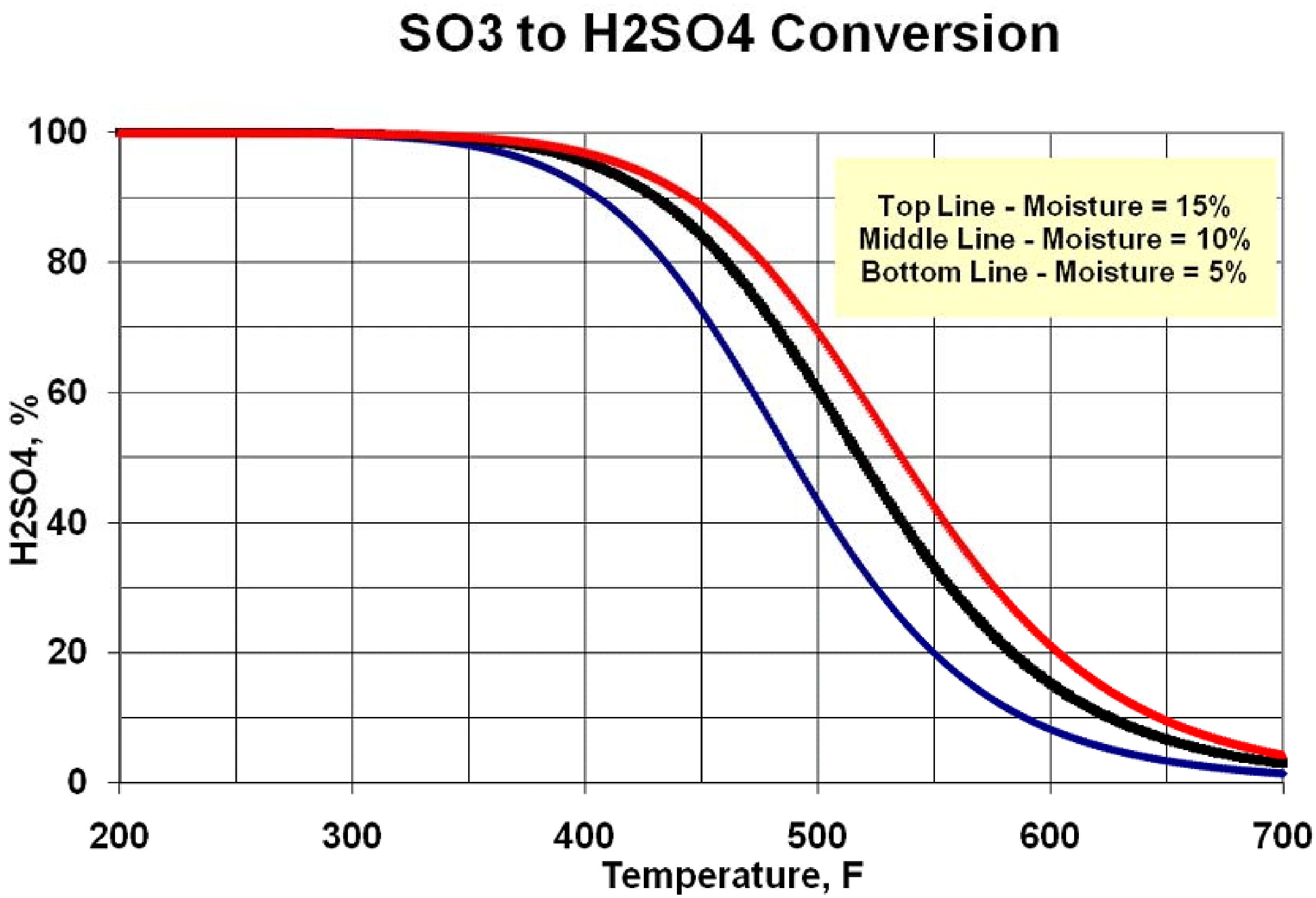
T-R LOCATION UNITS	T-R NAME	AREA ENRGZ'D FT^2	GAS PASS WIDTH IN.	TYPE HV ELECTRODE	SECONDARY CURRENT mA	CURRENT DENSITY uA/FT^2	SECONDARY VOLTAGE KV	SECONDARY POWER KW	SPARK RATE SPM
1A	A NORTH	14,400	9	WW	503	34.9	59.8	0.0	0
1B	A CENTR	14,400	9	WW	260	18.1	51.6	3.1	61
1C	A SOUTH	14,400	9	WW	236	16.4	55.8	3.4	61
2A	B NORTH	14,400	9	WW	755	52.4	49.7	37.5	0
2B	B CENTR	14,400	9	WW	742	51.5	43.2	32.1	0
2C	B SOUTH	14,400	9	WW	723	50.2	46.2	33.4	8
3A	C NORTH	14,400	9	WW	1006	69.9	36.3	36.5	0
3B	C CENTR	14,400	9	WW	1007	69.9	39.1	39.4	0
3C	C SOUTH	14,400	9	WW	1006	69.9	39.0	39.2	0
4A	D NORTH	14,400	9	WW	1006	69.9	39.5	39.7	0
4B	D CENTR	14,400	9	WW	1007	69.9	40.1	40.4	0
4C	D SOUTH	14,400	9	WW	1006	69.9	39.9	40.1	0
TOTAL		172800			9257			344.9145	130

SHOW T-R NAMES IN LOCATION, HERE:

		1	2	3	4	GAS PSG
GAS FLOW	A	AN	BN	CN	DN	40@9"
	B	AC	BC	CC	DC	40@9"
	C	AS	BS	CS	DS	40@9"
	TR SIZE	500	750	1000	1000	
	FIELD DIMENSION	6X30'	6X30'	6X30'	6X30'	

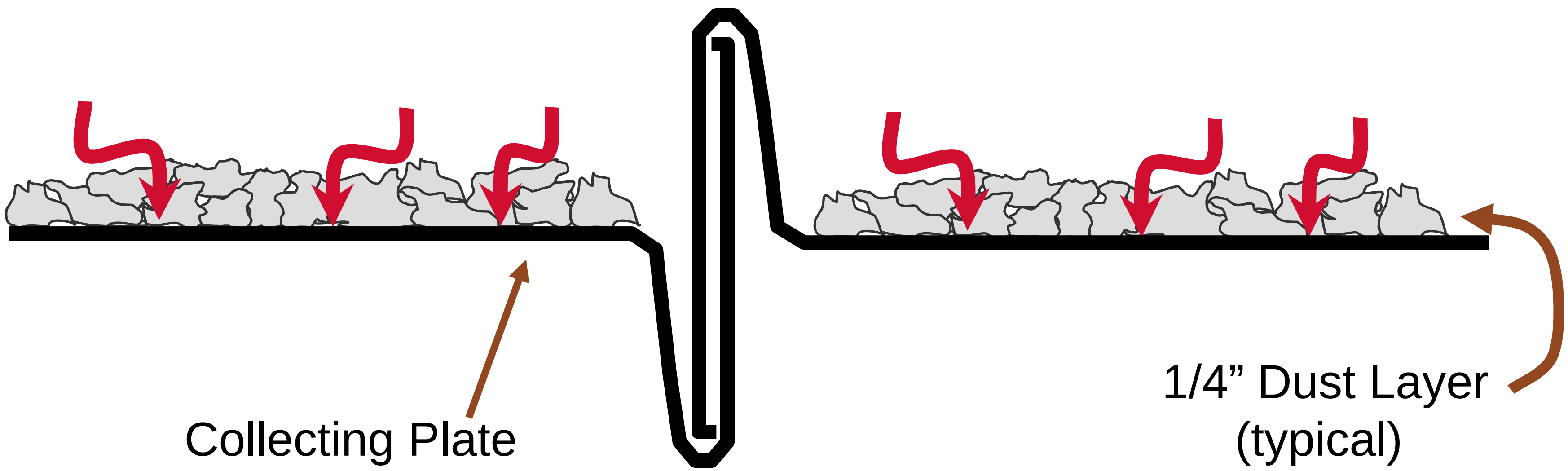
W/ FT^2	2.00
W/1000ACFM	320.0
TOTAL DENSITY	53.6
9/26/2011 PM TEST	#/MMBtu
TOTAL FLTERABLE CNDNSBLE	0.0092

It is Sulfuric Acid that Determines Surface Conduction, not SO_3. All the SO_3 has been converted to H_2SO_4 at Coldside Temperatures



Dust Resistivity – Surface Conduction < 290⁰F

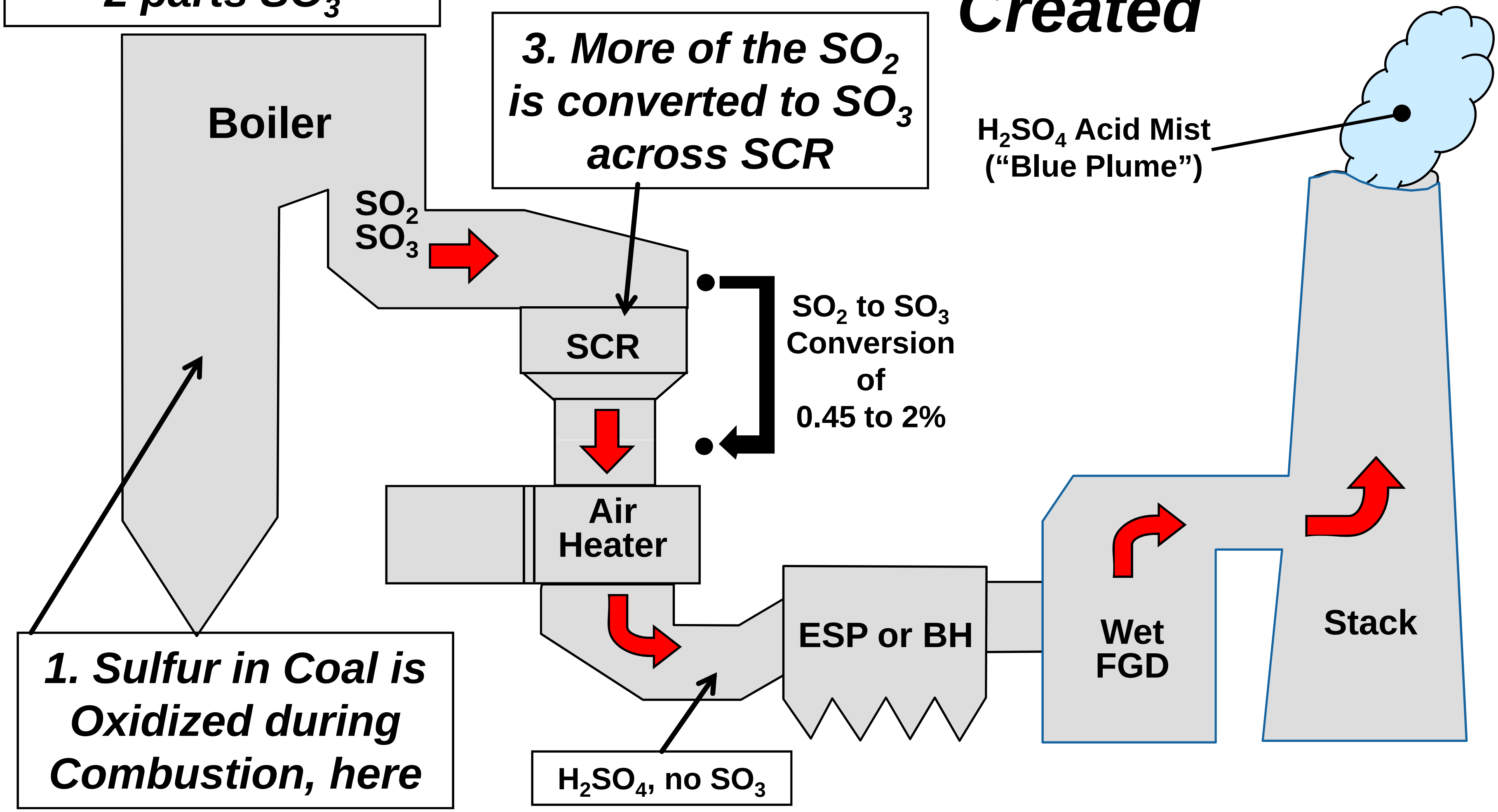
Ion Conduction is *over* surface of dust layer through sulfate and/or sodium ions present in surface moisture



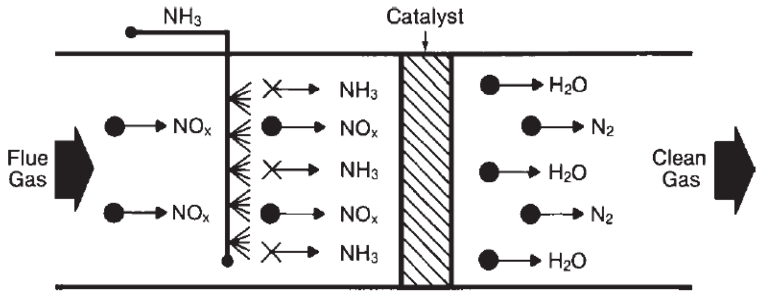
Cold Side ESP

If moisture is not present (boils off), surface conduction stops

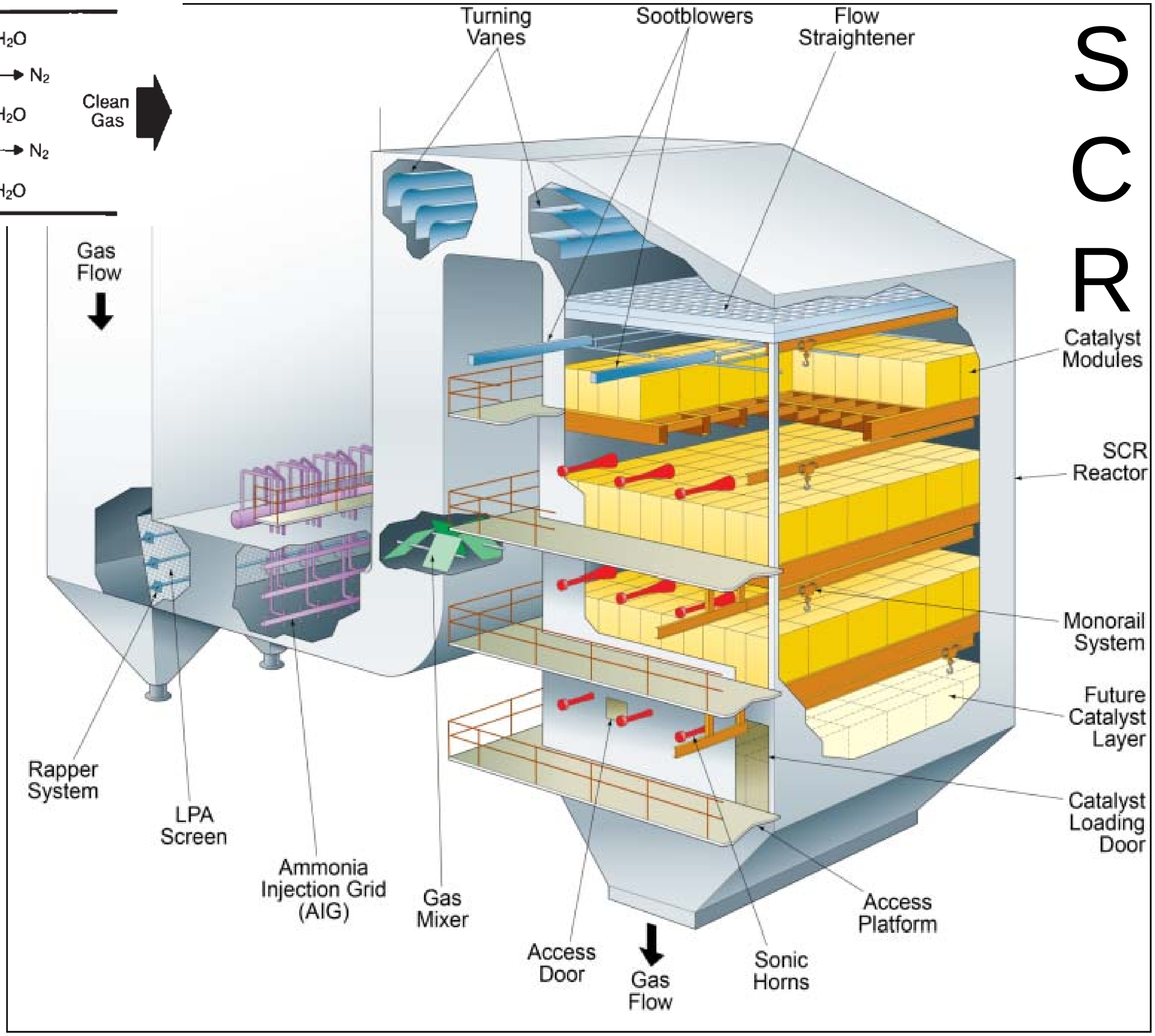
Where are SO_3 sulfates Created



Vaporous SO_3 turns to Vaporous H_2SO_4 at Air Heater



NH_3
Catalyst
Flue Gas
NO_x
NO_x
NH_3
NO_x
NH_3
NO_x
NH_3
H_2O
N_2
H_2O
N_2
H_2O
Clean Gas



S
C
R
Turning Vanes
Sootblowers
Flow Straightener
Gas Flow
Catalyst Modules
SCR Reactor
Monorail System
Future Catalyst Layer
Catalyst Loading Door
Access Platform
Sonic Horns
Gas Flow
Access Door
Gas Mixer
Ammonia Injection Grid (AIG)
LPA Screen
Rapper System

Usually, the ESP Loves an SCR

- **The increase in SO_3 creation can have the good effect of lowering flyash resistivity**
- **Ammonia slip in the neighborhood of 2ppm will aid in agglomerating flyash, making larger particles which are easier for the ESP to collect**
- **But because of impending mercury control and on units burning high sulfur coal with SCR's and scrubbers, SO_3 will need to be mitigated. This could impact ESP performance dependant on the quantity of sorbent used**

Sorbents to Limit SO_3 – ESP Impact

- Sodium sorbents help flyash resistivity and should not pose a resistivity or inlet loading problem
- Hydrated Lime will increase flyash resistivity and also be a finer particle size than trona, so you have to be careful with the ESP. If % is low & SCA decent, then no problem
- Trona has been shown to have deposition problems which can severely plug the ESP inlet perf plate. At first they thought it was a reaction with the ammonia slip. Rather, it was the formation of sodium bisulfite ($NaHSO_4$)
- Sodium bisulfite at temperatures above 370F becomes very sticky
- Good perf plate rapping and inlet ESP temperature control become important

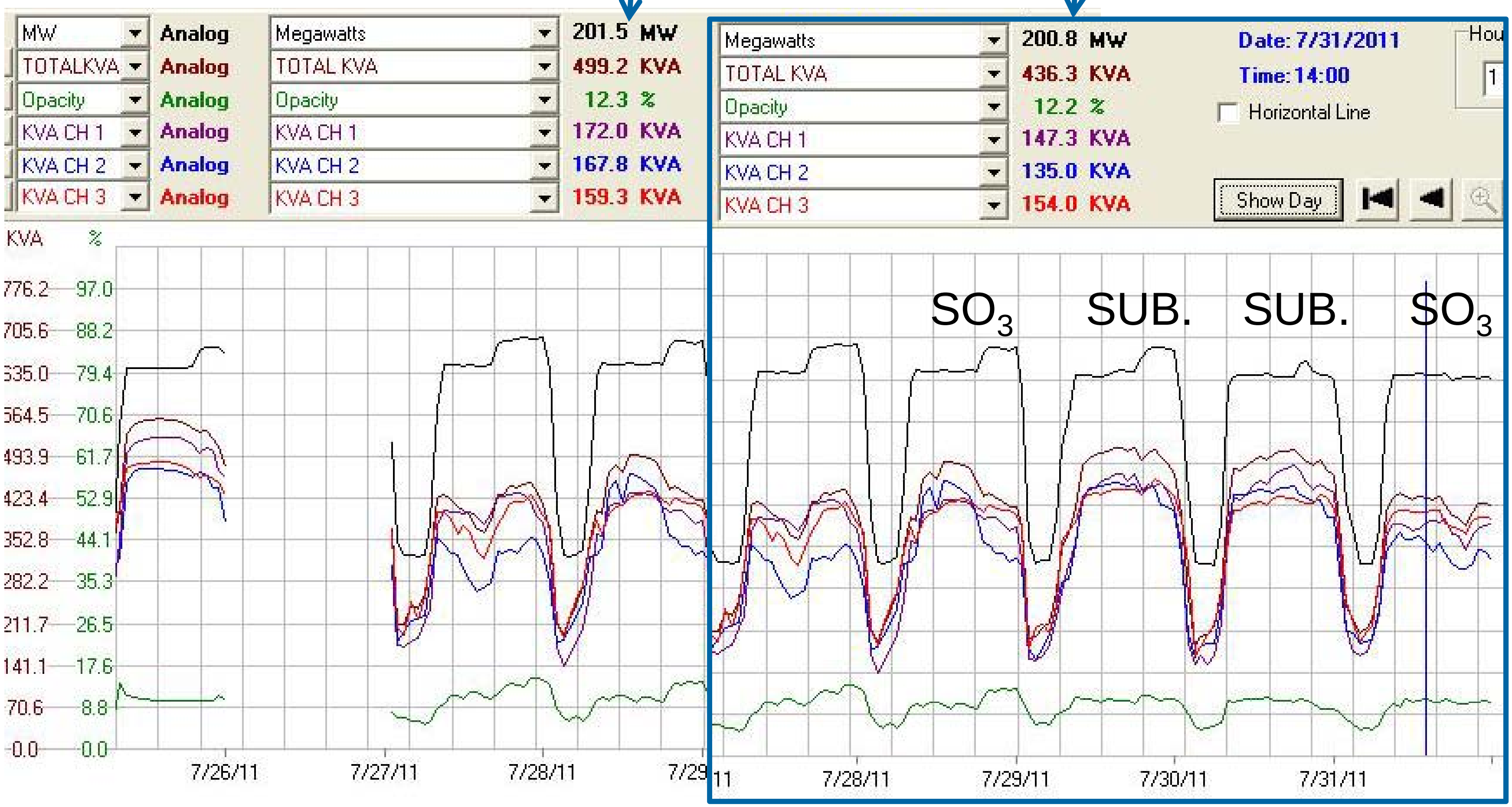
SO_3 Mitigation – 3.6% Sorbent + Low Conversion Catalyst (Case 5)

Case study	Case 1	Case 2	Case 3	Case 4	Case 5
Coal Sulfur Content	High	High	Medium	Low	High
SO2, ppm	2500	2500	1500	1000	2500
Boiler conversion	1.20%	1.20%	1.20%	1.00%	1.20%
Econ outlet SO3, ppm	30	30	18	10	30
SCR conversion	2%	0.75%	0.75%	0.75%	1%
SCR outlet SO3, ppm	79	49	29	17	49
AH outlet reduction	25%	25%	25%	25%	25%
AH outlet SO3, ppm	60	36	22	13	36
Trona or HL addition?	NO	NO	NO	NO	YES
ESP/PJFF reduction	10%	10%	10%	10%	85%
ESP/PJFF outlet SO3 ppm	54	33	20	12	5.5
WFGD removal	35%	35%	35%	35%	35%
Stack SO3 ppm	35	21	13	8	3.5
Blue plume?	YES	YES	YES	YES	NO

A Substitute Chemical for SO_3 Injection

Substitute

SO_3



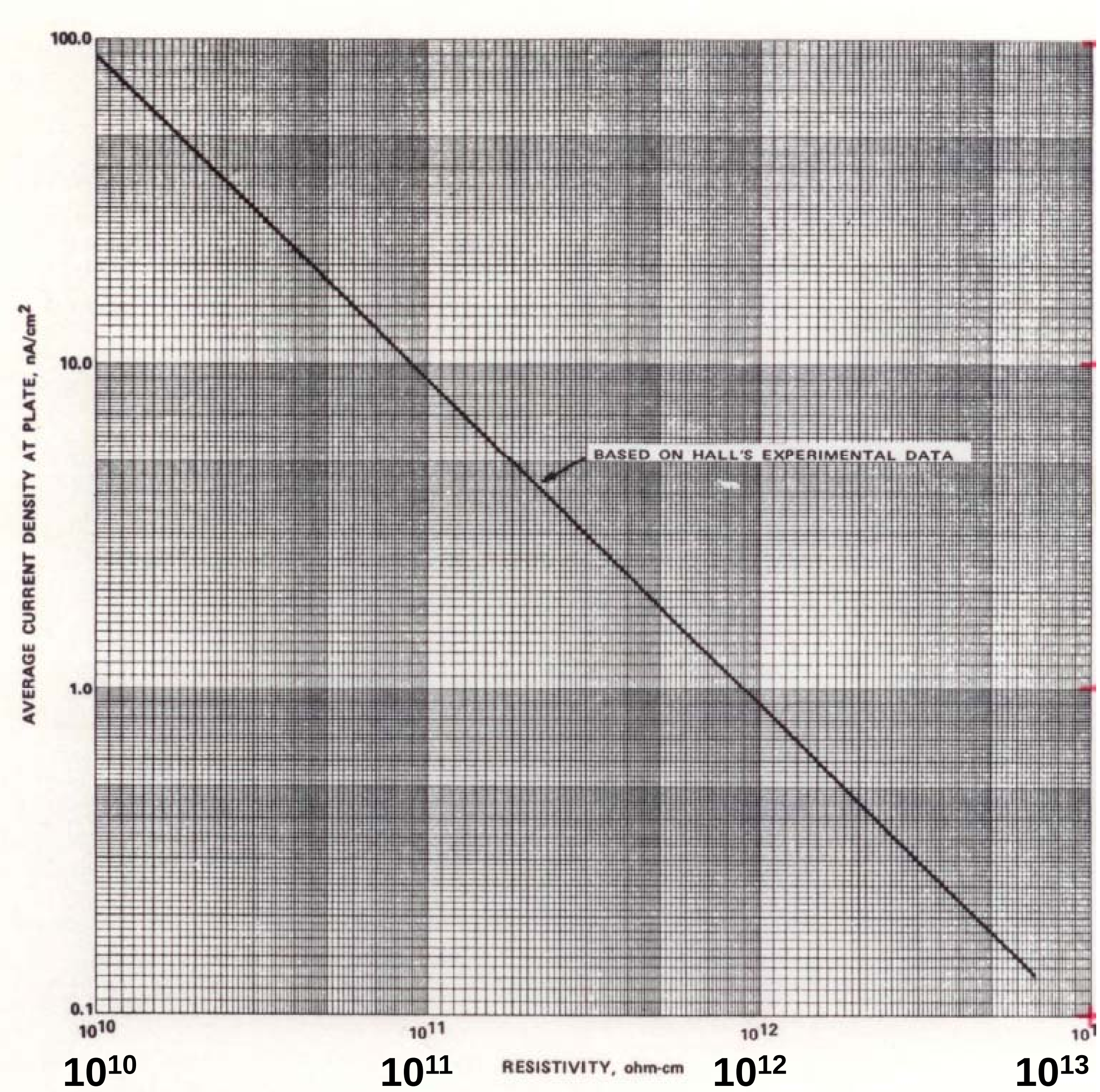


Figure 16. Experimentally Determined Effect of Resistivity on Allowable Current Density in a Precipitator

High ash resistivity (no SO_3) will severely limit operating corona current, that's an ESP Killer.

Most Important Factors Affecting ESP Performance

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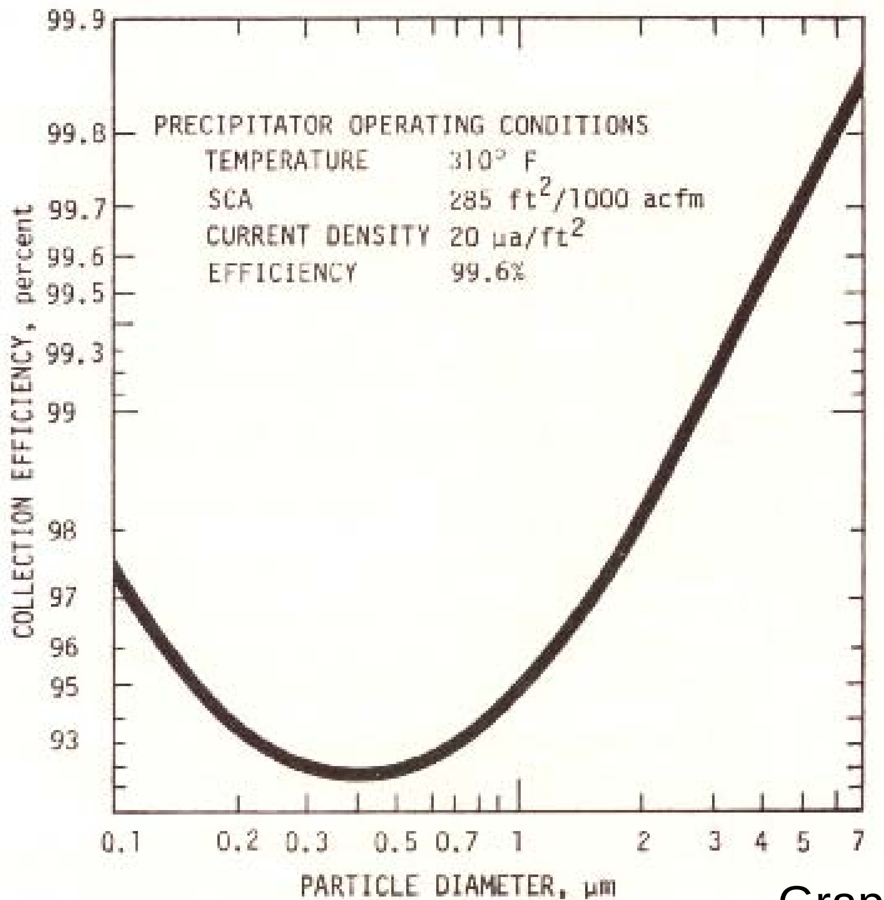
The Finer the Particle, the Harder it is for an ESP to Collect



1. Field Charging > 0.5 microns (electric field)
2. Diffusion Charging < 0.2 microns (thermal)
3. Both Methods - 0.2 to 0.5 microns

Graph from: Harry White, JAPCA 1977

Particulate Loading & How it can Change

1. Particulate Loading to the ESP is related to:
   A. T/Hr coal burned (Heating value of coal (BTU/lb) & boiler heat rate)
   B. Coal Ash Content
   C. Type of Boiler (PC Fired vs. Cyclone)

Example:

- 240 MW Unit, Coal HHV 12,000BTU/lb, PC Boiler 80/20 split
- Heat rate 10,000 BTU/ KwHr, Coal Ash Content 10%
- Fuel Use – (240,000*10,000)/(12,000*2000lb/ton)=100 TPH
- Total Ash – 100T/Hr *10% = 10 TPH
- Fly Ash – 10TPH * 80% = 8 TPH

Particulate Loading and the ESP

1. Usually, the collection efficiency of an ESP will increase with inlet dust concentration
2. Effect is usually greatest at low dust burdens
3. May be do to an increase in mean particle size
4. The greater the space charge (greater electric field)
5. If the resistivity of the ash changes (sorbent loading), then the ESP efficiency can go up or down.

Most Important Factors Affecting ESP Performance

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Another Important thing about ESP's -

ESP Current should Always* Increase from Inlet to Outlet of the ESP

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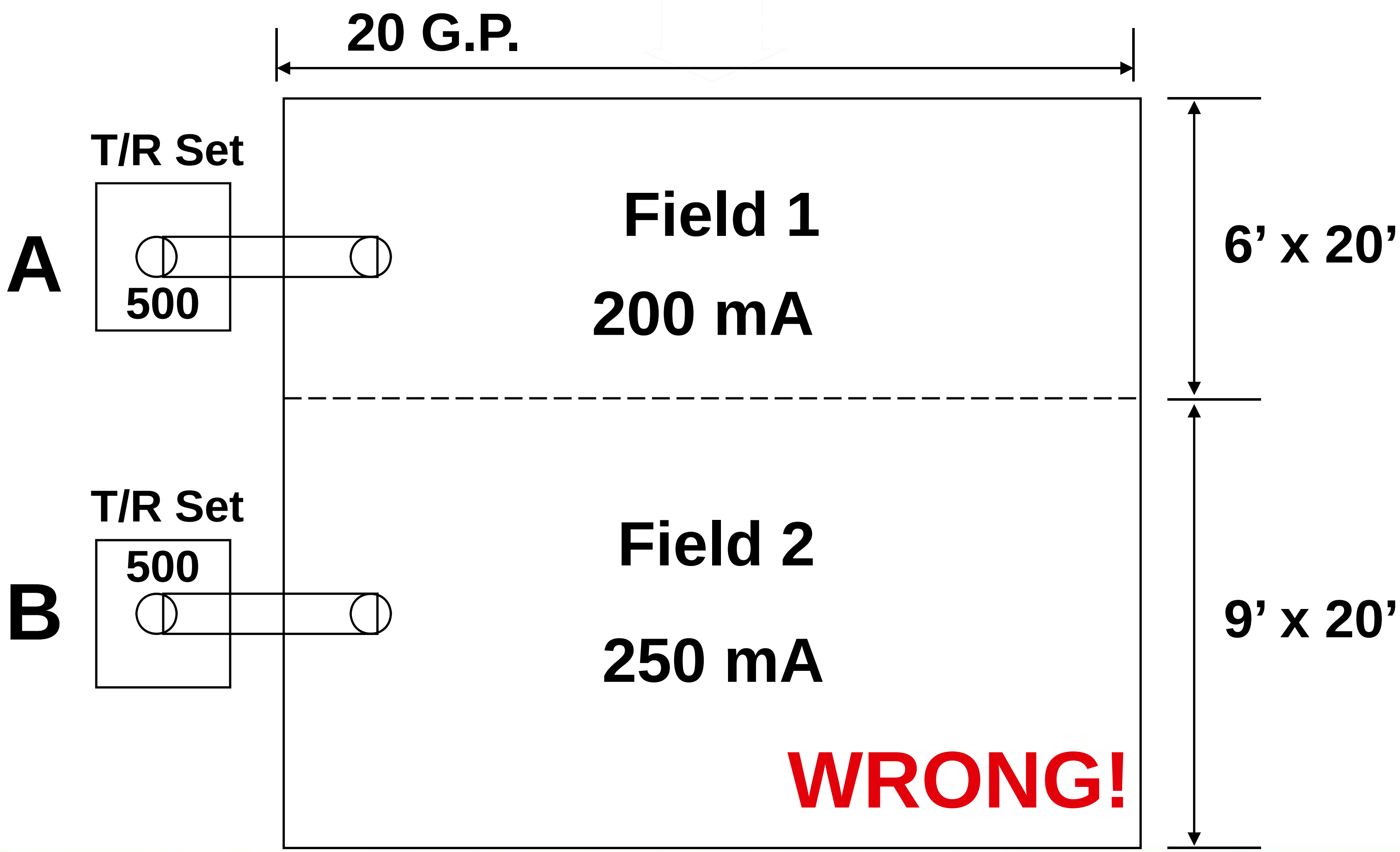
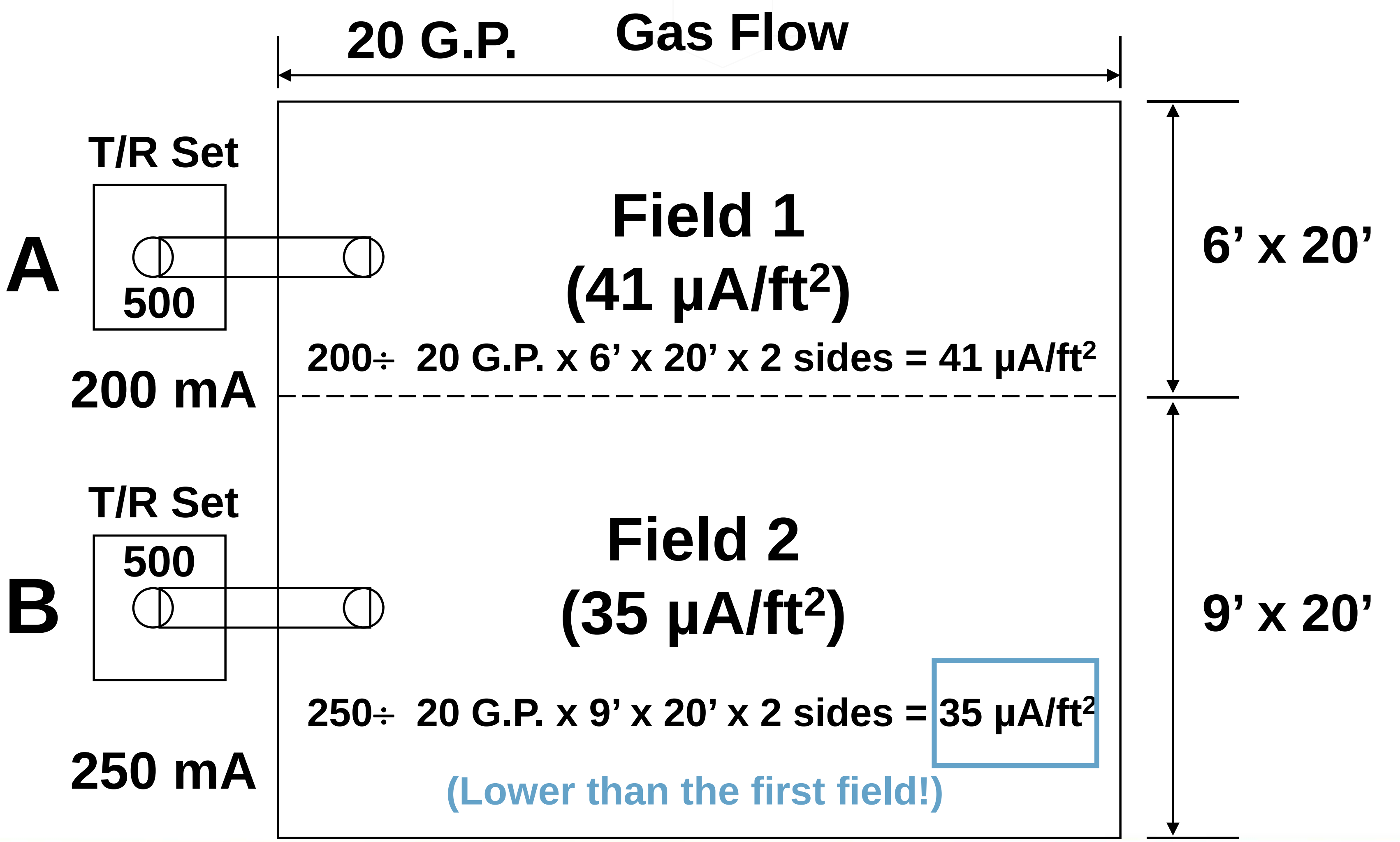
GAS FLOW	B	260	742	1007	1007	40@9"	9/26/2011 PM TEST		#/MMBtu
	C	236	723	1006	1006	40@9"		TOTAL	
	TR SIZE	500	750	1000	1000			FLTERABLE	0.0092
	FIELD DIMENSION	6X30'	6X30'	6X30'	6X30'			CNDNSBLE	

Based on what we learned in Rule 1, is this ESP OK?



Current Density will Always Increase from In to Out



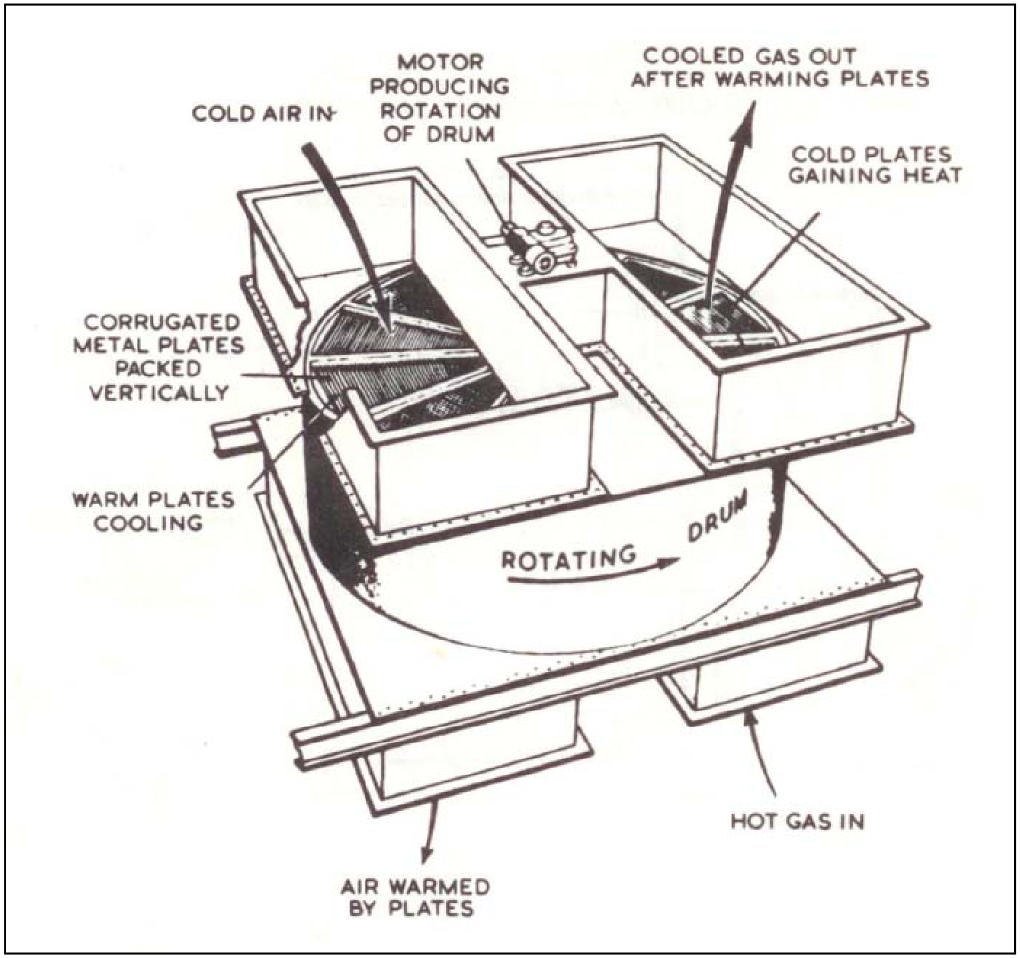
Rule 2 – T-R Sets in the Same Field Should Run at the Same Power Levels*

Do They Here?

Why?

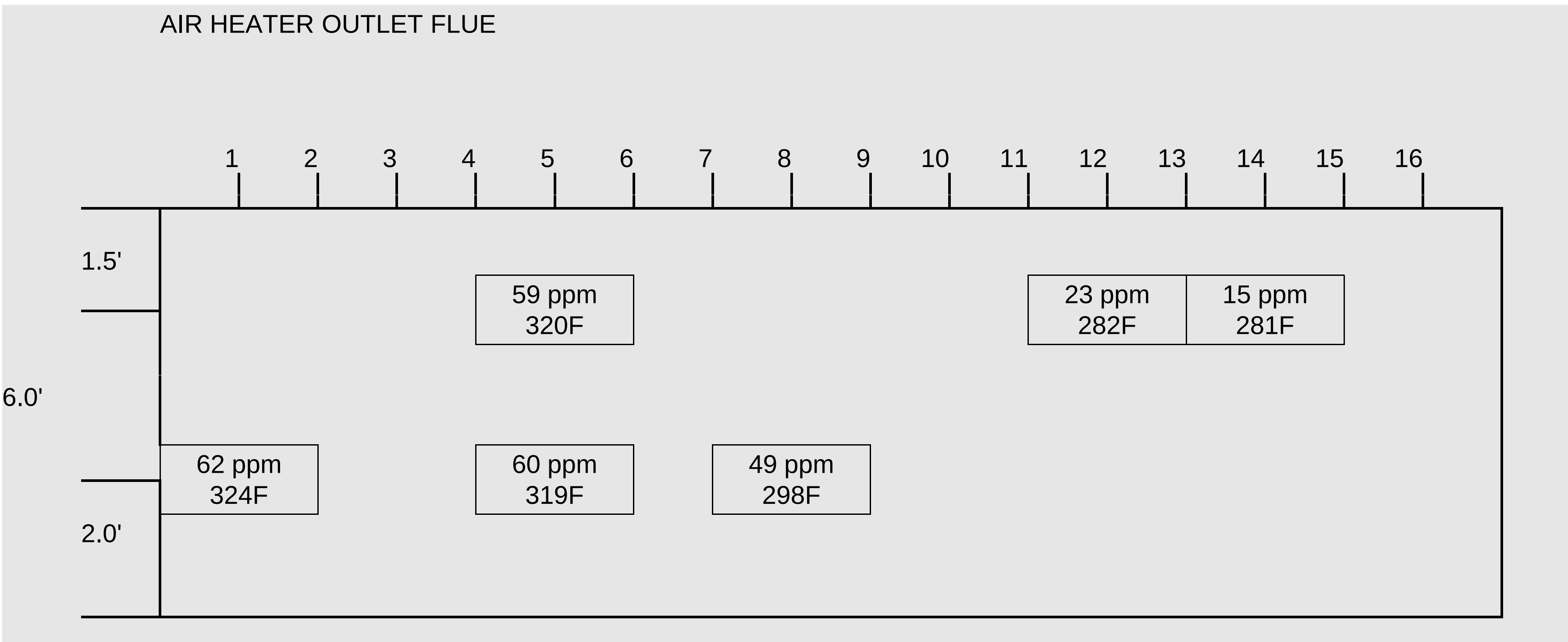
		COLD			HOT	
	LANE	1	2	3	4	TOTAL
	KV	47.7	49.1	44.8	47.8	189.4
1	MA	494	488	446	471	1899.0
	SPM	0	8	24	27	59.0
	DENSITY	52.8	52.1	47.6	50.3	202.9
	KW	23.6	24.0	20.0	22.5	90.0
	KV	50.2	50.5	49.9	48.6	199.2
2	MA	569	474	415	391	1849.0
	SPM	12	12	30	22	76.0
	DENSITY	60.8	50.6	44.3	41.8	197.5
	KW	28.6	23.9	20.7	19.0	92.2
	KV	54	52.1	49.1	50.5	205.7
3	MA	661	537	519	521	2238.0
	SPM	2	20	30	25	77.0
	DENSITY	70.6	57.4	55.4	55.7	239.1
	KW	35.7	28.0	25.5	26.3	115.5
	KV	52.7	52	46.4	42	193.1
4	MA	735	590	553	498	2376.0
	SPM	2	15	30	26.8	73.8
	DENSITY	78.5	63.0	59.1	53.2	253.8
	KW	38.7	30.7	25.7	20.9	116.0
	TOTAL KW	126.6	106.6	91.8	88.7	413.7

1. Ljungstrom Air Heater Creates Temperature Gradient



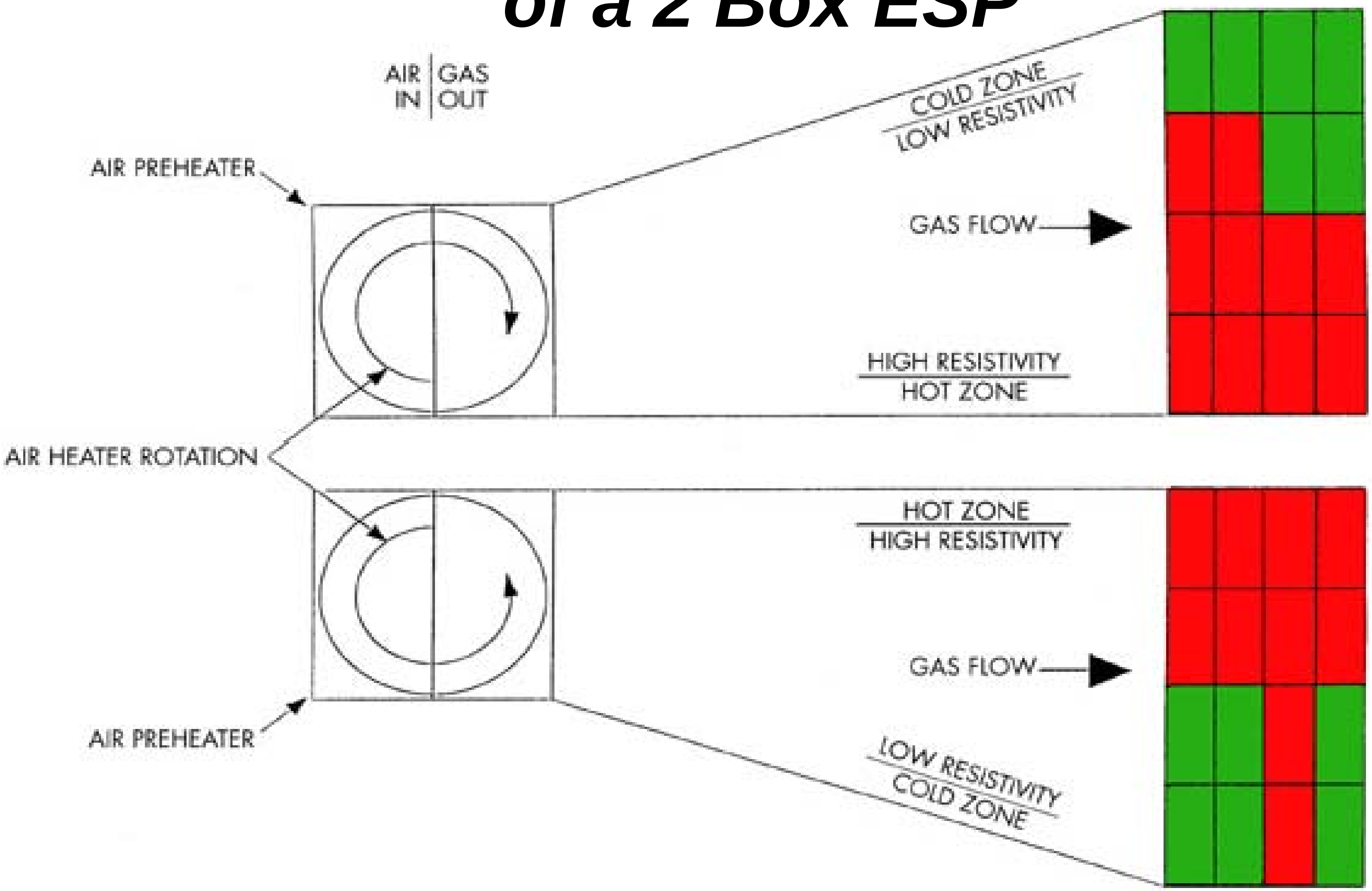
2. Which Effects ESP Performance (Watts/Resistivity)

Even though there is a Higher Concentration of SO_3 on the Hotside of the Duct!



SO_3 Distribution across the Inlet Face of an ESP

Example of Hot Half and Cool Half, of a 2 Box ESP



Ways to Address Hot Inlet ESP Gas Temperatures

- **Mixing vanes. Draft loss will depend on the mixing length available**
- **Keep the heating surfaces clean in the superheater, economizer, and air heater (sootblower audit)**
- **"Old Leaky Boiler" - Air leaking into the boiler from:**
  - **Expansion joint leaks, penthouse roof seal leaks**
  - **Corroded seals near hopper water seal**
  - **Excessive pulverizer tempering air**

Ways to Address Hot Inlet ESP Gas Temperatures

- **Increase the air heater rotational speed (typical speeds are 0.25 to 2 rpm)**
  - **Watch soot blower cleaning**
  - **Primary air temperature will change**
- **Change direction of air heater rotation**
  - **Would require replacement of air heater seals**
  - **Won't reduce temperature, just change orientation**
  - **On bisector or trisector air heaters, it is important to study air flow configuration and primary air temperature requirements to the mills (prb coal needs higher primary air)**

Low Nox Burners & Combustion

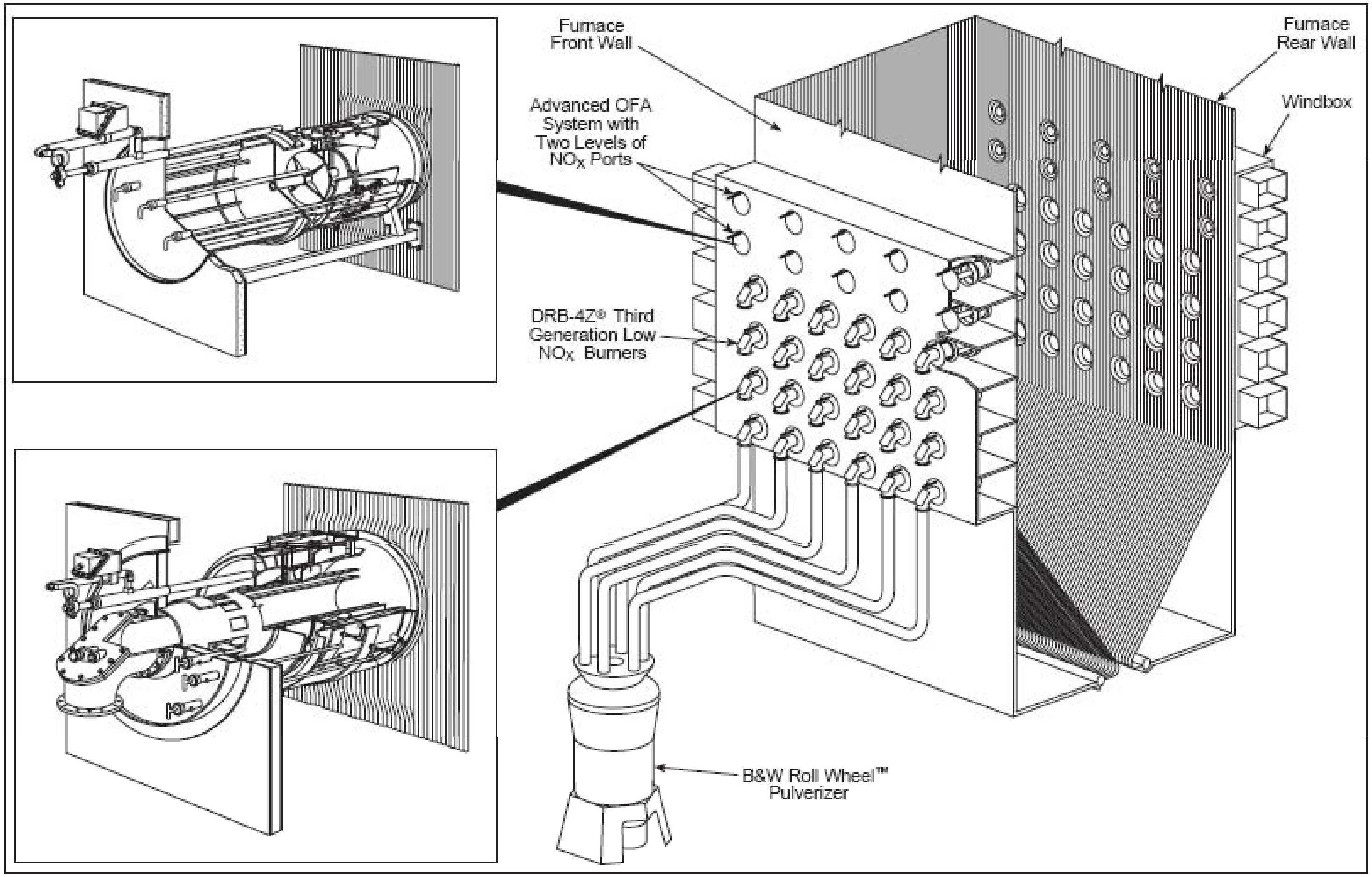


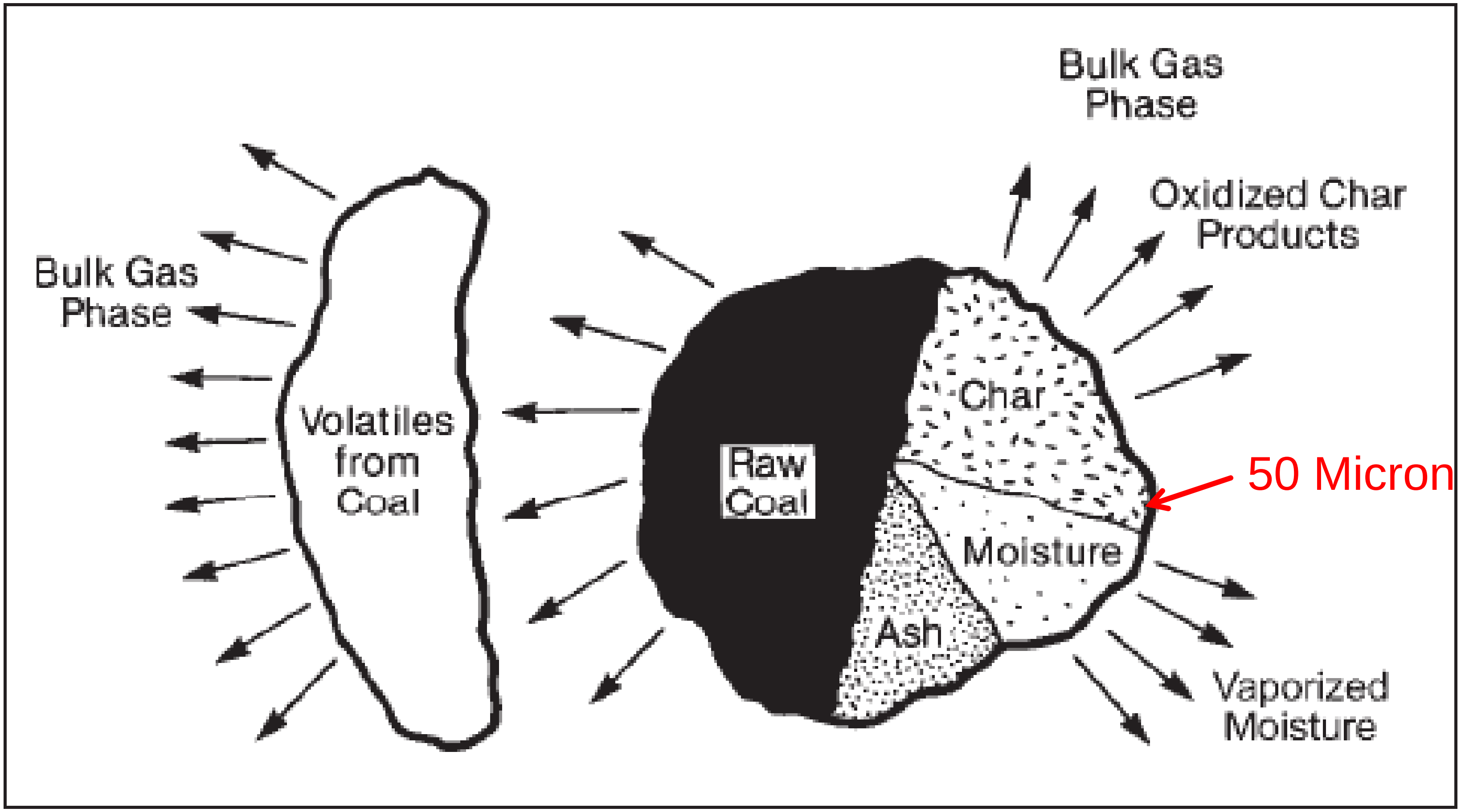
Fig. 1 Advanced low NO_x pulverized coal-fired combustion system.

UBC Related to Coal Fineness, Fuel Distribution, Fuel-Line Balance, & Primary Airflow Issues

The First Step in Reducing NOx, Low NOx Burners (LNB) & Overfire Air (OFA)

- **NOx formation is promoted by, previously utilized, good combustion (rapid fuel-air mixing)**
- **This produces a high peak flame temperature (thermal NOx) and excess available oxygen (fuel NOx)**
- **LNB & OFA reduce peak flame temperature and stage combustion (only part of combustion air is added at the burner)**
- **LNB can increase the amount of unburned carbon (UBC) in the flyash, 2 to 3 times, with bituminous coals. Usually not the case with PRB coals.**
- **OFA tends to increase UBC**
- **Advanced LNB tend to perform better for UBC than first generation LNB**

Coal Particle Combustion



Good Combustion is the correct mixture of air and suitably prepared coal, injected into the furnace in the right amounts, in the right location, and at the right time.

Low NOx Burners (LNB) & Overfire Air (OFA) can hurt ESP Performance (UBC)

- **Most units firing PRB coal are accustomed to < 1% carbon in ash. Eastern Bituminous units are more near 5%, but can be twice that for smaller units.**
- **A way to reduce UBC in Eastern Bituminous is pulverizer upgrades to reduce fineness**
- **The old standard of coal fineness of 99% minus 50 mesh, 70% minus 200 mesh (flyash geometric median size of about 12*u*m diameter) may not be enough. 99.9% thru 50 mesh and 80% thru 200 mesh, may be required on relatively low moisture coals.**

Other Impacts of UBC on ESP

- If finer grind is used to compensate for increased UBC, then this can lead to a finer ash sizing, which is more difficult for an ESP to collect
- Although UBC has a lower specific surface area than today's powder activated carbons (PAC), it still can be an absorber of SO_3/H_2SO_4. This may impact dust resistivity. Not enough is currently known.
- Carbon resistivity is typically < 10^6 ohm-cm and if finely sized and homogeneously mixed with flyash can lower the resistivity of the layer. However carbon sometimes tends to congregate in strata in the dust layer, not reducing the bulk resistivity.

Other Impacts of UBC on ESP

- **Perhaps the biggest impact of UBC is that because of their low resistivity, they are easily re-entrained into the gas stream, only to bounce to the next field, to get captured and bounced again.**
- **Therefore the ESP will be sensitive to excessive rapping, high gas velocities, and low treatment times.**
- **High current densities, it is believed, is necessary to hold it to the ESP collecting plate**
- **Large, low density char particles have been found in outlet ESP hoppers. Therefore, ESP performance can gain from skewing the gas flow away from the lower regions of the outlet field**
- **Large carbon particles can lead to high outlet mass loadings without impacting stack opacity**

Skewing flow away from hopper can reduce carbon based re-entrainment

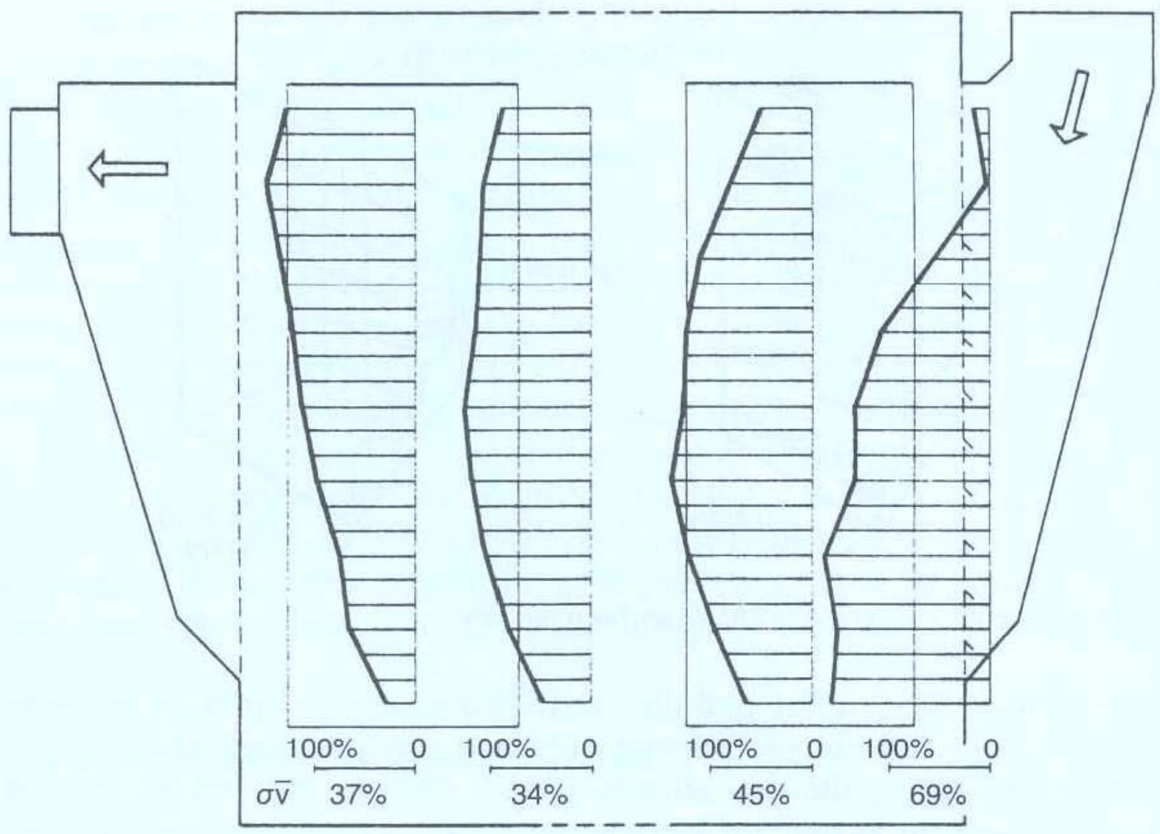


Figure 5-5. Skewed velocity distribution profile.

PAC Injection Impact on ESP

- Early problems with PAC injection impacting ESP seems to be a thing of the past
- Could be the lack of sophistication of original PAC formulas and grinds, meeting up with low SCA ESP's with high velocities
- PAC should improve flyash resistivity
- Some Utilities in Illinois where PAC injection of 5#/MMAcf is mandatory, report no problems on any of their ESP's

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O_2 and CO Levels

- During startup conditions O_2 (% volume wet) at the economizer is unavoidably near 20% (low firing rates and high air flow to meet NFPA85 requirements for purge). O_2 drops to 10% near 25% load, and near 5% at half load, and 2-3% at full load—depending on the coal being fired and the combustion equipment..
- Operation with higher than necessary excess O_2 (at higher loads) is uncommon since high O_2 increases NOx which is a regulated pollutant, and it also reduces boiler efficiency which utilities work to maximize. <u>But inadequate/inaccurate O_2 instrumentation is a contributing factor</u>. (2 to 5 probes in the duct)
- High O_2 impacts ESP performance by reducing its Specific Collecting Area (SCA)

Gas Flow Rate

- Collection efficiency of an ESP is determined by the migration velocity and the SCA
- Treating more gas reduces the treatment time which reduces efficiency
- Gas flow rate is determined by:
  - composition and amount of coal burned (ash content, heating value, boiler design)
  - combustion excess air (O_2)
  - unit air inleakage, principally from the Ljungstrom air heater
  - gas temperature (hotside esps and summertime operation)
  - gas pressure (plant at 5000 ft elevation, gas pressure is less and gas volume may be increased by 20%)
- Air inleakage could easily add 20% to gas volume, which could then double outlet emissions!

CO Levels

- CO emissions vary considerably due to combustion equipment, controls, instrumentation, and operating practices.
- CO emissions less than 200 ppm at full load are generally acceptable and with tuning can be less than 100 ppm. But much higher CO levels are not uncommon. CO emissions reduce with load as excess O_2 increases.
- Operation with high CO, particularly at high load, is not uncommon. CO is not regulated in many circumstances, and consequently not even monitored at many plants. Lowering O_2 to reduce NOx is a common practice, and can result in high CO emissions, which may not even be detected.
- High CO can be indicative of one mill with poor fineness

Fuel Oil Carryover at Start-Up

- **Oil firing is no different than firing coal. There needs to be the correct fuel/air mixture for proper combustion. Also excessive firing rate on some of the igniters at very low furnace temperatures.**
- **Cold start-up results in combustion being confined to the flame envelope near each operating burner. Oil spray or partially burned oil that escapes the luminous flame, chills and leaves the furnace incompletely burned. Unburned hydrocarbons will deposit on the ESP collecting electrodes.**
- **<u>After the unit heats up, these deposits can polymerize into a tough varnish type layer with high resistivity, causing high ESP SPM & low KW</u>**
- **Many times fuel oil systems do not get a lot of maintenance (inadequate atomizing media), until pulled "after" the start-up**
- **Severe cases of ESP fouling can last 2-3 weeks, affecting inlet fields more, but sometimes all fields. Hotside ESP's recover more quickly, in 1 or 2 days.**

B&W
power generation group

Questions?

Thank you.