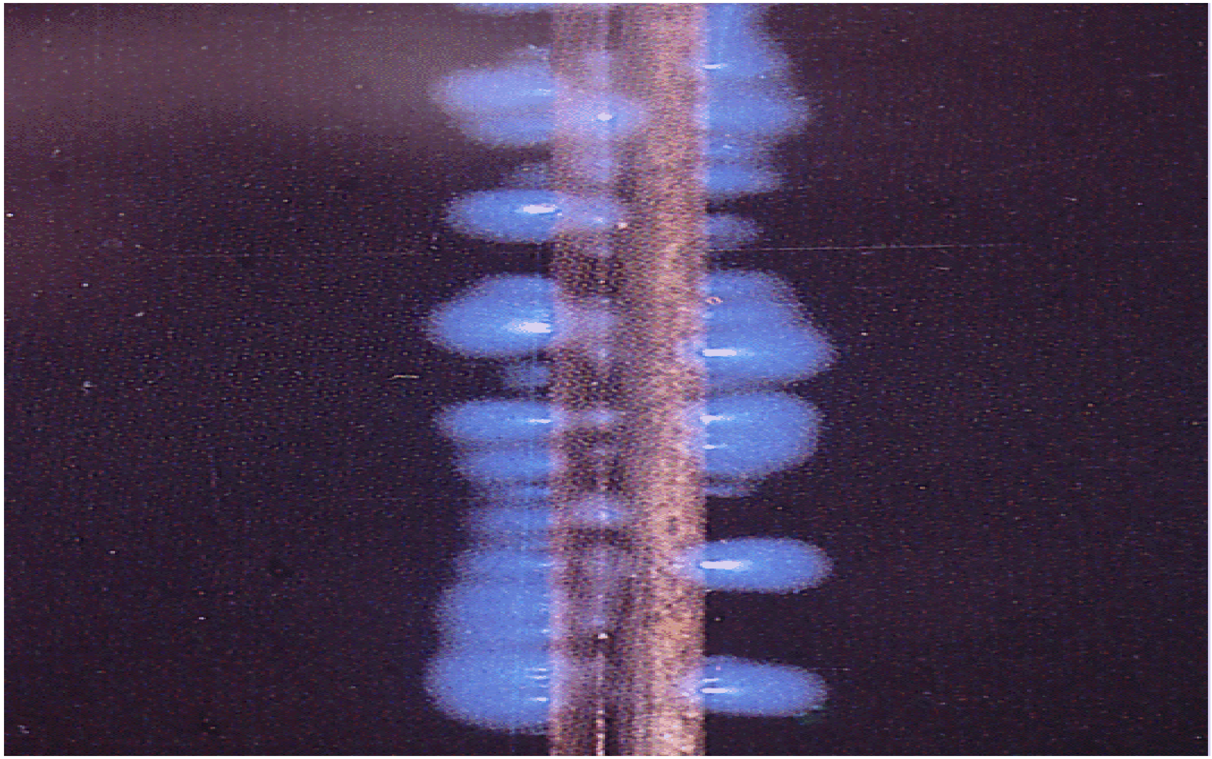
REINHOLD ENVIRONMENTAL Ltd.

2010 APC Round Table & Expo Presentation

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

ESP Advanced Fundamental

By R. F. Ridgeway



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ESP Operation

In the Basic ESP Fundamentals session by Gerry Klemm, you learn how the ESP was designed and expected to operate. Now you are going to get the rest of the story.

ESP Compliance

Most generating facilities have to meet two emissions requirements as part of their air permit to insure the EPA that the ESP is operating properly.

- Opacity Limit
- Particulate Emissions Limit

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ESP Compliance for Opacity

Although we utilize the CEMS (an opacity monitor) as our guide for compliance with the opacity standard, failure to meet the standard in most state has to be based on using EPA Method 9, a visual reading of opacity. Most states use some level of CEMS being out of compliance as a trigger for further action.

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ESP Compliance for Particulate

Compliance with the particulate standard is more involved than with the opacity standard. This requires conducting a particulate emission test typically by an testing contractor using EPA Method 5, 5B or 17. Real time particulate monitors are available, but not widely used and some states have adopted an opacity relationship with particulate to assure compliance with the particulate standard.

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The Call

Most of us get "THE CALL" that the ESP needs attention when the opacity monitor indicates the unit is near or in most cases has exceeded the opacity limit.

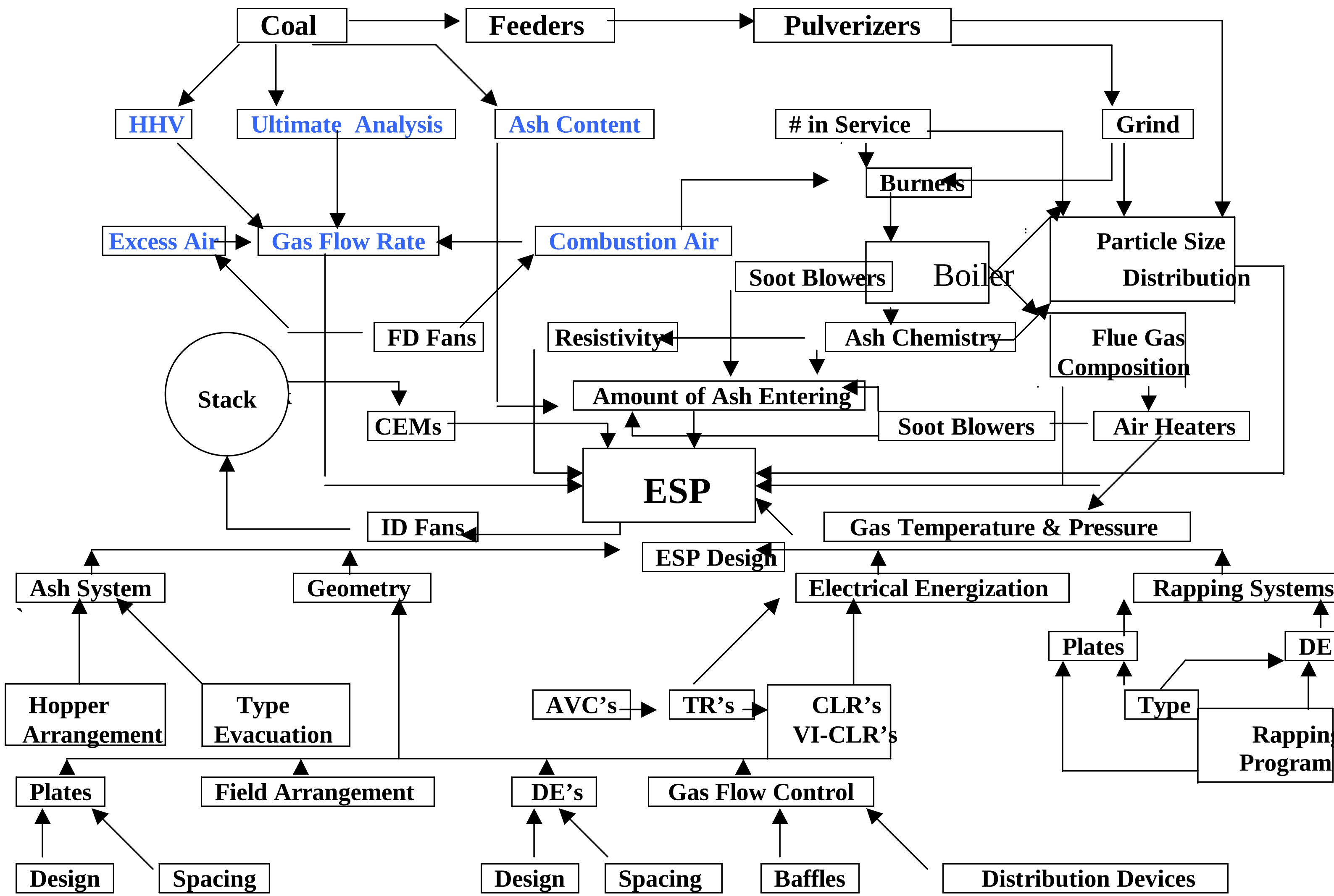
Except for the fly ash removal system (FARS), the ESP is one of the most ignored pieces of equipment in the power plant.

Verify It Is The Right Call

Once you get the call, it is best to verify using a visual observation of the stack that the opacity monitor is telling you the truth.

If the stack serves multiple units, the unit has a wet FGD or it is a night doing a visual is not a option.

What Affects ESP Performance



Compliments of Dr. M Anderson

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Tools to Help with the Call

Since a testing contractor is not readily available to conduct a particulate emissions test, you must rely on other tools to evaluate the ESP.

- Coal Data
- Unit Operating Data
- ESP Data

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Who, What, When, Where, Why

Basic Questions to Ask the Plant When Suspected Problems Occur with Air Pollution Control Equipment

I. Background Information
- A. Where are you calling? (Plant and Unit)
- B. Why are you calling?
- C. Whom did you reach?
- D. What is their position?
- E. When did you call?

II. Generic Operating Information
- A. Load
- B. Curtailments
  - 1. Magnitude
  - 2. Start and end times
  - 3. Reason
- C. Opacity
- D. Total milliamps
- E. Averager KV
- F. Number of grounds/defective T/R sets
  - 1. Reason console(s) are O/S (control problem, defective T/R set, dead ground or close clearance)
  - 2. Locations (if several are O/S)
  - 3. Date consoles was removed from service
  - 4. Date grounds or close clearances were last cleared
- G. Exit gas temps.
  - 1. Economizer/air heater inlet
  - 2. Air heater exit
  - 3. ESP outlet
  - 4. Stack
- H. Coal
  - 1. Flow
  - 2. #/MKBTU
    - a. Ash
    - b. SO_2
    - c. Moisture
- I. Outside Air Temp.

III. Systems
- A. Opacity
  - 1. Visual reading
  - 2. Monitor
    - a. Local reading
    - b. Remote reading
    - c. Calibration
      - i. Date of last calibration
      - ii. Type of calibration (in-place or bench)
- B. Rappers
  - 1. Is ESP being power-off rapped
  - 2. Plate rappers
    - a. Cycle time
    - b. # of rappers O/S
    - c. Location of O/S rappers
  - 3. Wire rappers
    - a. Cycle time
    - b. # of rappers O/S
    - c. Location of O/S rappers
- C. Ash removal
  - 1. # of high hopper
  - 2. Branch line vacuums
    - a. No-load
    - b. Full load
  - 3. Bag filter differentials (if appl.)
- D. Purge air system
  - 1. # of fans I/S
  - 2. Air heaters I/S
- E. SO_3 injection system
  - 1. System leaks
  - 2. SO_2 Flow Stage temp.
  - 3. When was system place I/S after start-up
  - 4. Lance temps.
- F. Steam generator
  - 1. Feedwater flow
  - 2. Heater strings O/S
  - 3. # of pulverizers
    - a. # I/S and location
    - b. Any w/fineness problems
  - 4. % excess air
  - 5. # air heaters I/S
  - 6. Water loss/make-up rate (tube leak indication)
  - 7. Slagging indicators
    - a. Attemperator flow
    - b. Superheater profile
  - 8. Loading cycle of past several days
- G. Start-up
  - 1. ESP energization
    - a. When
    - b. How many fields?
  - 2. F. D. fan rolled
    - a. When?
    - b. Which fan?
  - 3. Oil fire
    - a. Established when
    - b. Which lighters?
  - 4. Coal fire
    - a. Established when
    - b. Which lighters?
  - 5. Opacity thru start-up
  - 6. Any unusual events

NOTE: REFER TO DRAWINGS WHEN EVER POSSIBLE!!!

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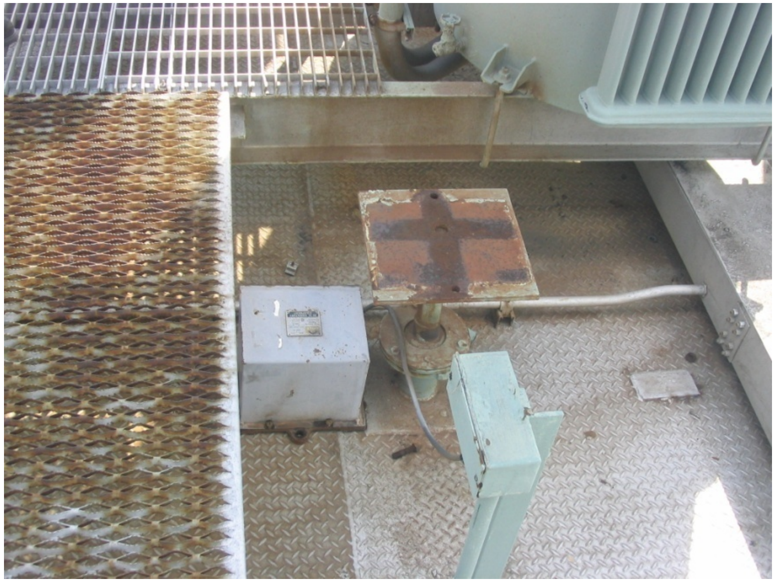
ESP Data

Even though the unit may be on-line, we have a host of data to evaluate the ESP.

- ESP Console Data
- Rapper Data (cycle times & O/S Rappers
- FARS Data (Vacuum Levels, Fill Rates & High Hoppers)
- V-I Curve Data
- Secondary Voltage and Current Waveforms

Visual Rapper Check



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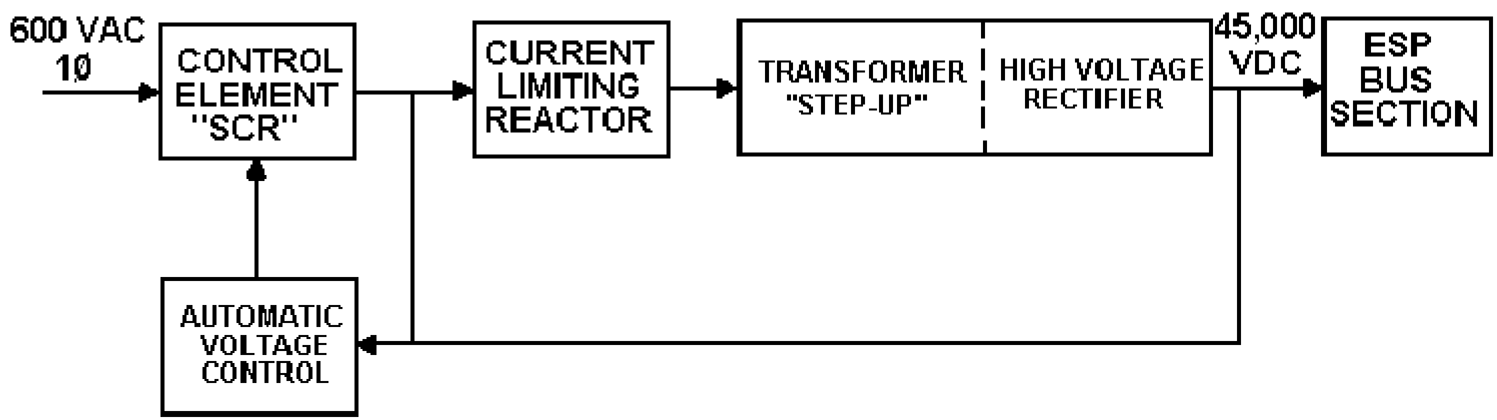
ESP Console Data

The electrical readings from each automatic voltage control, AVC, is typically the most readily available data for you to evaluate the ESP. Although it may be available from some sort of historian, this data can be collected face-to face with your controls.

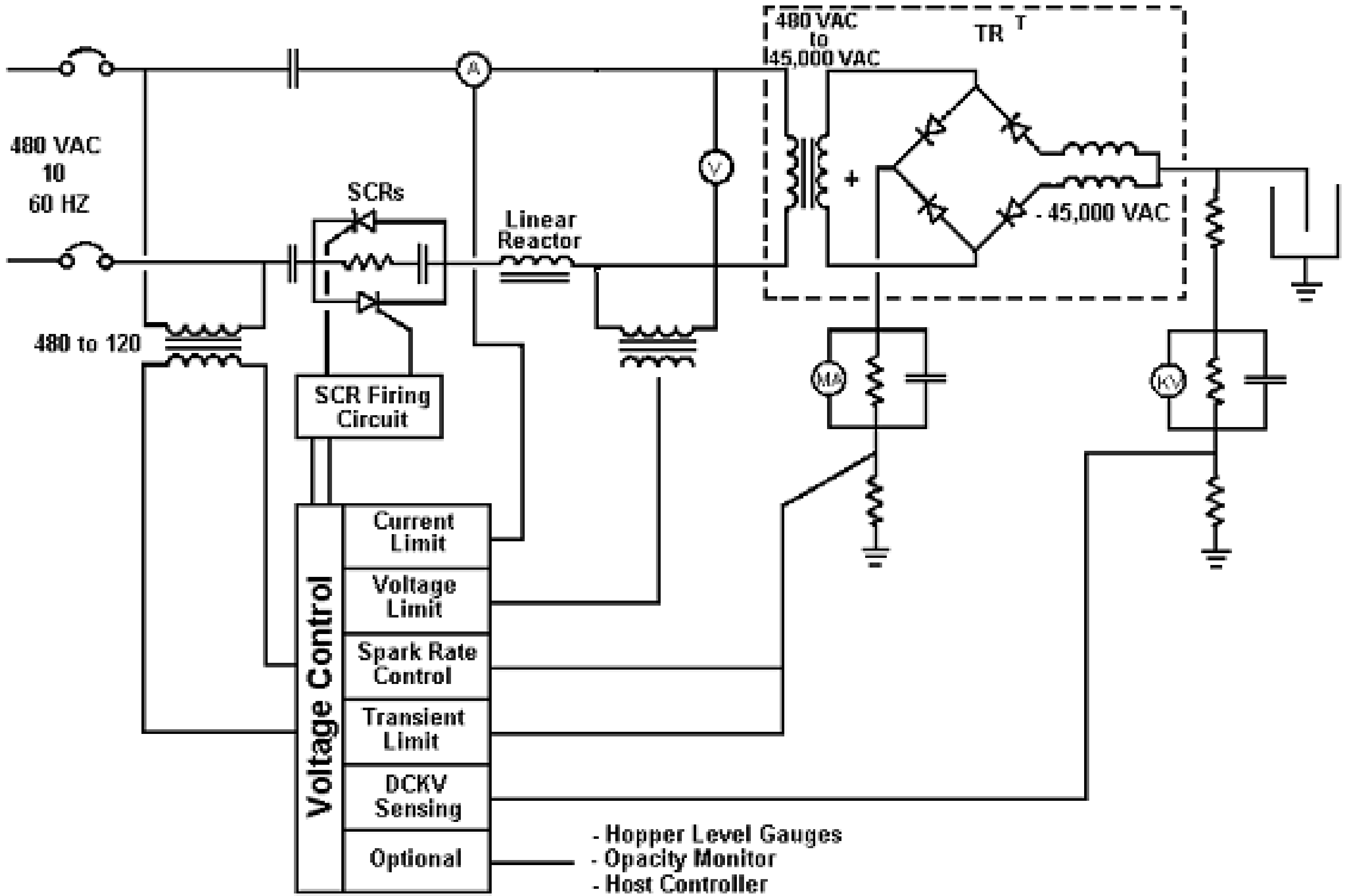
Automatic Voltage Controls

- An automatic voltage control (AVC) serves to maintain the voltage level at the optimum value, even when the dust characteristics and concentration exhibit dynamic behavior.
  - This is achieved by varying the duration that current is applied to the T/R set.

POWER SUPPLY SYSTEM



Simple AVC Circuit



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Terms for Secondary Current

The terms used for a spark cycle are:

Steady state - operation prior to the spark (shown here as current limit)

Spark - a short circuit in side the ESP which disturbed the gases between the wire and plate.

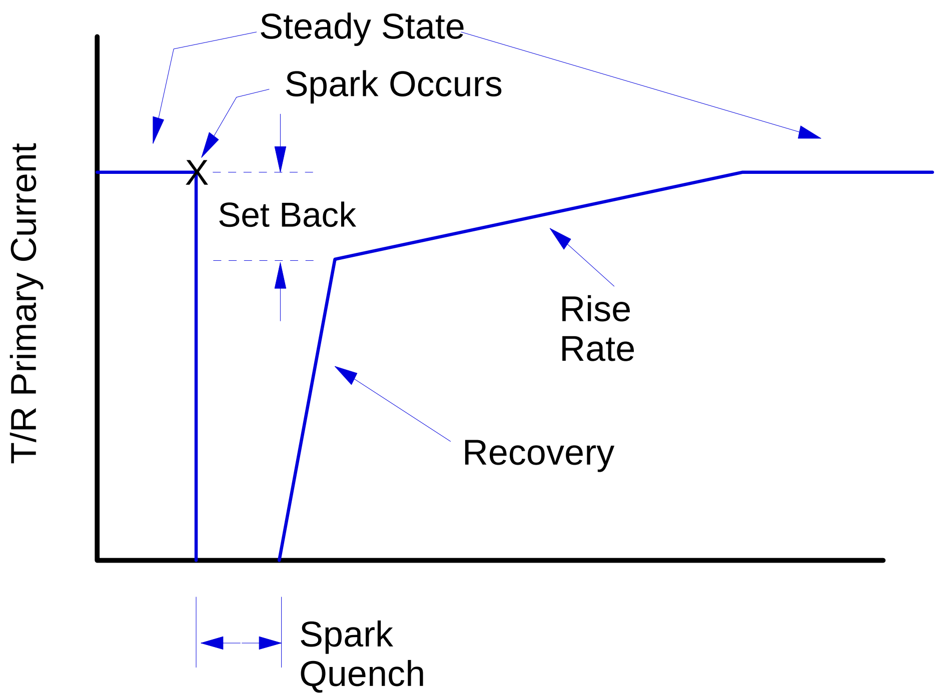
Quench - a period of off time which allows the disturbed gas to be dissipated. (Typically 2 cycles)

Recovery - a series of half cycles where the ESP returns quickly to near prespark conditions. (Typically 4 half cycles)

Set Back / Spark Response - the differential between steady state and recovery operating level. (Typically 3 to 10%)

Slow Ramp / Rise Rate - the period of time it take the control to return to prespark level. The angle is based on **set back** and **spark rate**. Spark rate should never be greater than 60 sparks/minute (typically 10-30 spm for inlet sets and 1-10 spm for outlet sets)

Fast Ramp - a feature on some new controls where the control ramps quickly to induce a spark if one has not occurred based on the preset spark rate. This allows for quicker recovery after an upset inside the ESP.



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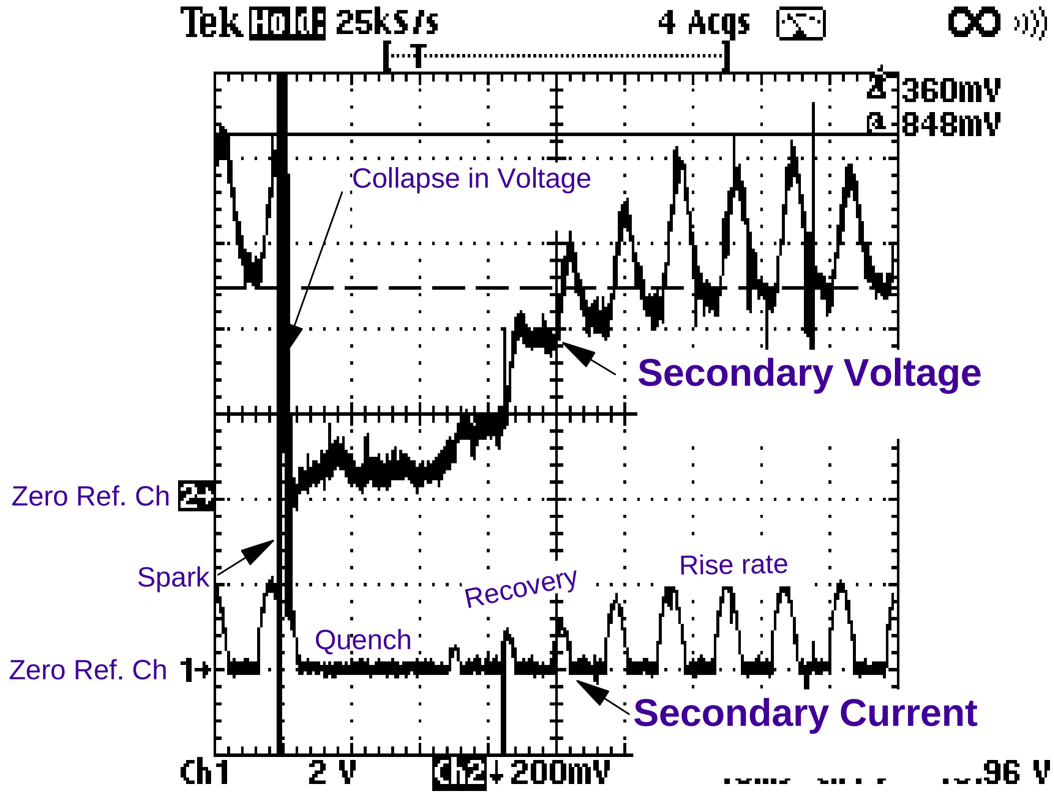
Typical Spark Response

The waveform is a typical trace of a spark response for both secondary voltage (top - shown inverted) and secondary current (bottom). Note the collapse of secondary voltage when the spark occurred. The control quenched and then quickly recovered to a level below the spark point.



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Unit Information

- T-Fire, Burning High Sulfur Coal
- 2 Lungstrom Air Heaters
- 2 ESP Boxes, Weighted Wire, 315 SCA
- 4 Fields (6’,9’,9’,9’)
- 4 T/R Sets per Field
- 16 T/R Sets per Box

Data From Control System

Unit	Amps	Volts	mA	KV	SPM
2NA1	26	285	150	43	29
2NA2	52	313	333	42	10
2NA3	76	275	450	40	14
2NA4	73	245	404	37	14
2NB1	68	320	501	41	22
2NB2	83	274	622	36	11
2NB3	42	193	201	27	20
2NB4	198	346	1400	38	5
2NC1	O/S				
2NC2	27	253	149	39	18
2NC3	41	249	211	39	17
2NC4	41	204	193	31	14
2ND1	41	274	235	40	29
2ND2	76	278	470	34	12
2ND3	77	237	492	31	15
2ND4	164	336	1124	40	8
2SA1	O/S				
2SA2	41	226	252	31	17
2SA3	105	303	700	33	13
2SA4	130	309	836	37	14
2SB1	28	282	157	42	28
2SB2	33	228	175	37	18
2SB3	200	54	1419	6	0
2SB4	65	232	347	35	14
2SC1	56	285	375	36	29
2SC2	63	226	436	30	15
2SC3	116	292	757	35	20
2SC4	179	343	1299	40	14
2SD1	20	227	104	35	29
2SD2	46	266	287	36	17
2SD3	90	317	572	38	18
2SD4	102	285	622	34	14

Rearrange Your Data

Put your data into a form that give a representation of your ESP. This will enable you to analyze the data easily.

ESP Data in a ESP Plan View

2ND1	2NC1	2NB1	2NA1
68	41	O/S	26
320	274		285
501	235		150
41	40		43
22	29		29
2ND2	**2NC2**	**2NB2**	**2NA2**
83	76	27	52
274	278	253	313
622	470	149	333
36	34	39	42
11	12	18	10
2ND3	**2NC3**	**2NB3**	**2NA3**
42	77	41	76
193	237	249	275
201	492	211	450
27	31	39	40
20	15	17	14
2ND4	**2NC4**	**2NB4**	**2NA4**
198	164	41	73
346	336	204	245
1400	1124	193	404
38	40	31	37
5	8	14	14

Amps
Volts
mA
KV
SPM

Gas Flow

2SD1	2SC1	2SB1	2SA1
20	28	O/S	56
227	282		285
104	157		375
35	42		36
29	28		29
2SD2	**2SC2**	**2SB2**	**2SA2**
46	33	41	63
266	228	226	226
287	175	252	436
36	37	31	30
17	18	17	15
2SD3	**2SC3**	**2SB3**	**2SA3**
90	200	105	116
317	54	303	292
572	1419	700	757
38	6	33	35
18	0	13	20
2SD4	**2SB4**	**2SB4**	**2SA4**
102	65	130	179
285	232	309	343
622	347	836	1299
34	35	37	40
14	14	14	14

Evaluate for Bogus Data

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ESP Data Review

	2ND1	2NC1	2NB1	2NA1
Amps	68	41	O/S	26
Volts	320	274		285
mA	501	235		150
KV	41	40		43
SPM	22	29		29
	2ND2	**2NC2**	**2NB2**	**2NA2**
Amps	83	76	27	52
Volts	274	278	253	313
mA	622	470	149	333
KV	36	34	39	42
SPM	11	12	18	10
	2ND3	**2NC3**	**2NB3**	**2NA3**
Amps	42	77	41	76
Volts	193	237	249	275
mA	201	492	211	450
KV	27	31	39	40
SPM	20	15	17	14
	2ND4	**2NC4**	**2NB4**	**2NA4**
Amps	198	164	41	73
Volts	346	336	204	245
mA	1400	1124	193	404
KV	38	40	31	37
SPM	5	8	14	14
	2724	2321	553	1337

Gas Flow ↓

	2SD1	2SC1	2SB1	2SA1
Amps	20	28	O/S	56
Volts	227	282		285
mA	104	157		375
KV	35	42		36
SPM	29	28		29
	2SD2	**2SC2**	**2SB2**	**2SA2**
Amps	46	33	41	63
Volts	266	228	226	226
mA	287	175	252	436
KV	36	37	31	30
SPM	17	18	17	15
	2SD3	**2SC3**	**2SB3**	**2SA3**
Amps	90	200	105	116
Volts	317	54	303	292
mA	572	1419	700	757
KV	38	6	33	35
SPM	18	0	13	20
	2SD4	**2SB4**	**2SB4**	**2SA4**
Amps	102	65	130	179
Volts	285	232	309	343
mA	622	347	836	1299
KV	34	35	37	40
SPM	14	14	14	14
	1585	679	1788	2867

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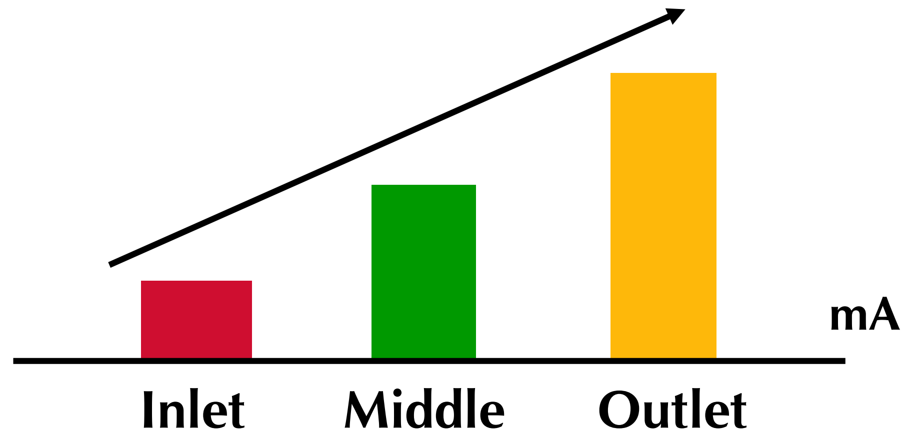
THE FIRST RULE OF PRECIPITATION

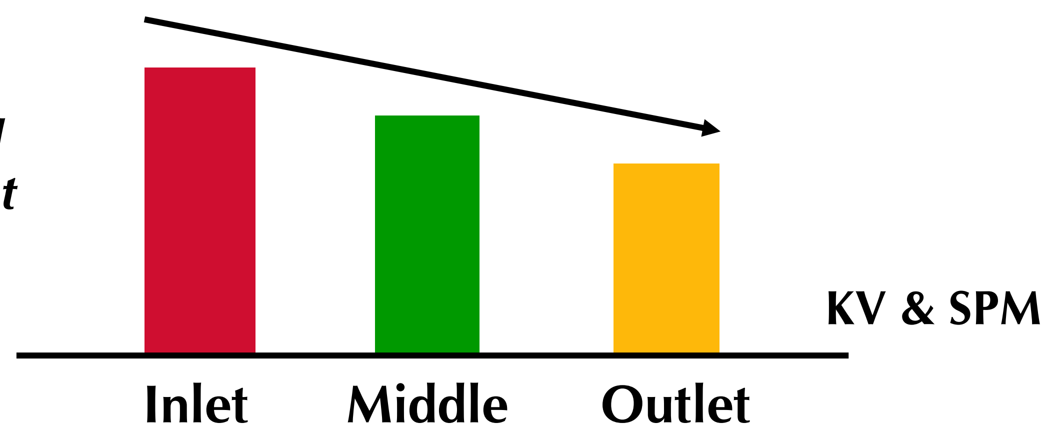
EACH SUCCEEDING FIELD OF A PRECIPITATOR SHOULD HAVE THE SAME OR HIGHER PRECIPITATOR CURRENT (mA), BETTER SAID AS CURRENT DENSITY, THAN THE PRECEDING FIELD.

Space Charge Effects on Meters

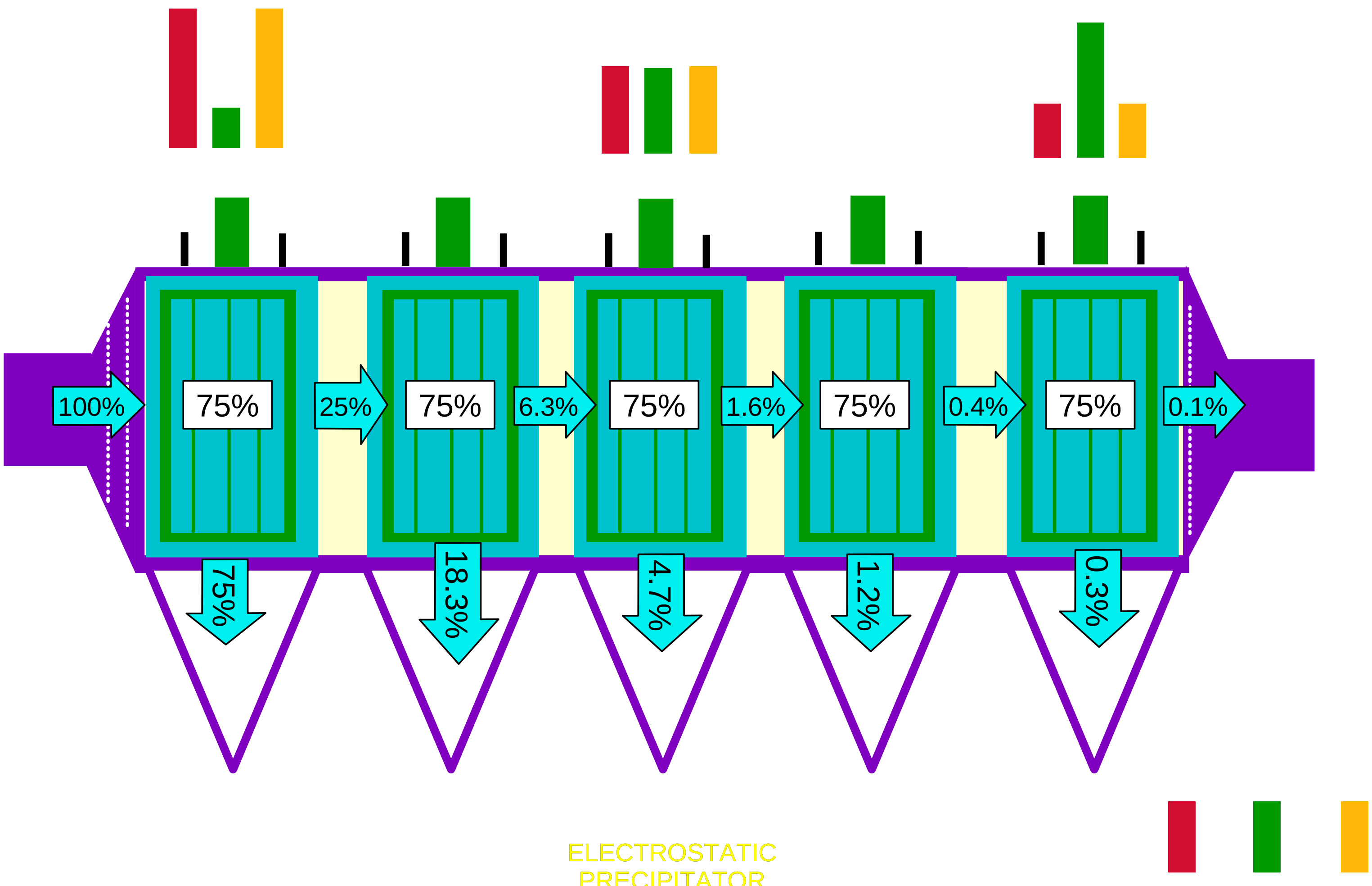
Always look for this trend…



Decreasing KV and SPM from inlet to outlet is not quite as evident



Console Data vs. Collection



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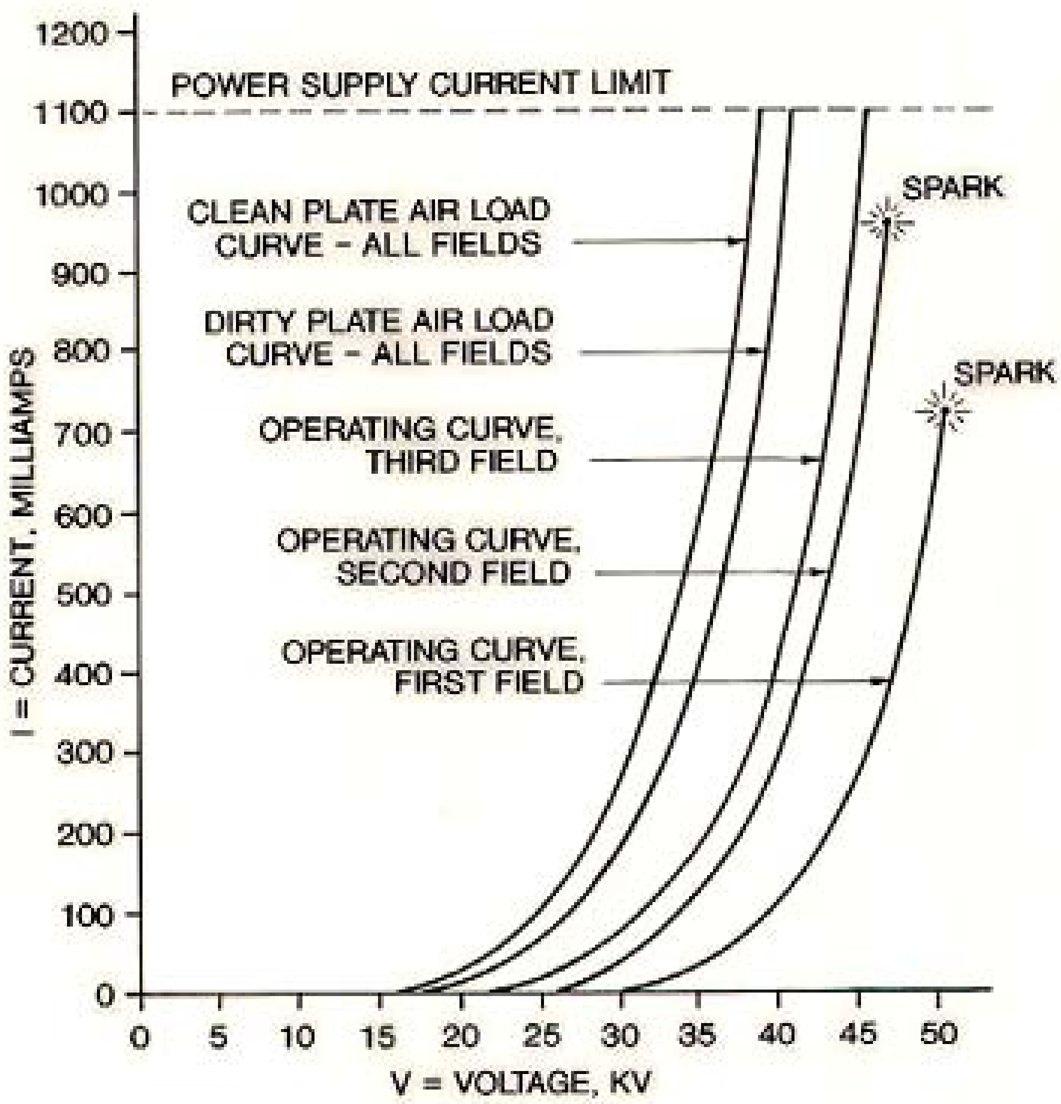
NORMAL PRECIPITATOR CURRENT VOLTAGE CURVES



Increasing Current in Field Progression

	2ND1	2NC1	2NB1	2NA1
Amps	68	41	O/S	26
Volts	320	274		285
mA	**501**	**235**		**150**
KV	41	40		43
SPM	22	29		29
	2ND2	2NC2	2NB2	2NA2
	83	76	27	52
	274	278	253	313
	622	**470**	**149**	**333**
	36	34	39	42
	11	12	18	10
	2ND3	2NC3	2NB3	2NA3
	42	77	41	76
	193	237	249	275
	201	**492**	**211**	**450**
	27	31	39	40
	20	15	17	14
	2ND4	2NC4	2NB4	2NA4
	198	164	41	73
	346	336	204	245
	1400	**1124**	**193**	**404**
	38	40	31	37
	5	8	14	14
	2724	2321	553	1337

Gas Flow ↓

2SD1	2SC1	2SB1	2SA1
20	28	O/S	56
227	282		285
104	**157**		**375**
35	42		36
29	28		29
2SD2	2SC2	2SB2	2SA2
46	33	41	63
266	228	226	226
287	**175**	**252**	**436**
36	37	31	30
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622	**347**	**836**	**1299**
34	35	37	40
14	14	14	14
1585	679	1788	2867

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THE SECOND RULE OF PRECIPITATION

IF THE DUST DOES NOT HAVE A RESISTIVITY PROBLEM, THEN OUTLET FIELDS USUALLY RUN AT FULL CURRENT AND LITTLE OR NO SPARKING.

Ultimate Coal Analysis

As Received % by Weight

	Typical Range	Optimum ESP Operation
Carbon, C	65 - 75	N/A
Hydrogen, H_2	3 - 6	N/A
Oxygen, O_2	4 - 9	N/A
Nitrogen, N_2	1 - 2	N/A
Sulfur, S	0.5 - 2.0	High Value is Better
Moisture, H_2O	2.8 - 12	High Value is Better
Ash	5 - 21	Low Value is Better

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Ash Mineral Analysis

% by Weight

	Typical Range	Optimum ESP Operation
Lithium Oxide, Li_2O	0 - 0.01	High Value is Better
Sodium Oxide, Na_2O	0.5 - 2.5	Greater than 1%
Potassium Oxide, K_2O	0.1 - 5.9	N/A
Magnesia, MgO	0.6 - 1.8	High Value is Better
Lime, CaO	0.9 - 5.8	High Value is Better
Ferric Oxide, Fe_2O_3	3.5 - 10.0	Greater than 6%
Alumina, Al_2O_3	24 - 35	Low Value is Better
Silica, SiO_2	40 - 62	Low Value is Better
Titania, TiO_2	1.1 - 2.3	N/A
Phosphate Pentoxide, P_2O_5	2.8 - 12	N/A
Sulfur Trioxide, SO_3	0.1 - 4.6	High Value is Better

Recommended Fuel Procurement Guidelines for Optimum ESP Operation

Ash Mineral Analysis% by Weight

	Typical Range	Optimum ESP Operation
$Al_2O_3 + SiO_2$	64 - 97	Less than 85%
CaO + MgO	1.5 - 8.0	Greater than 5%

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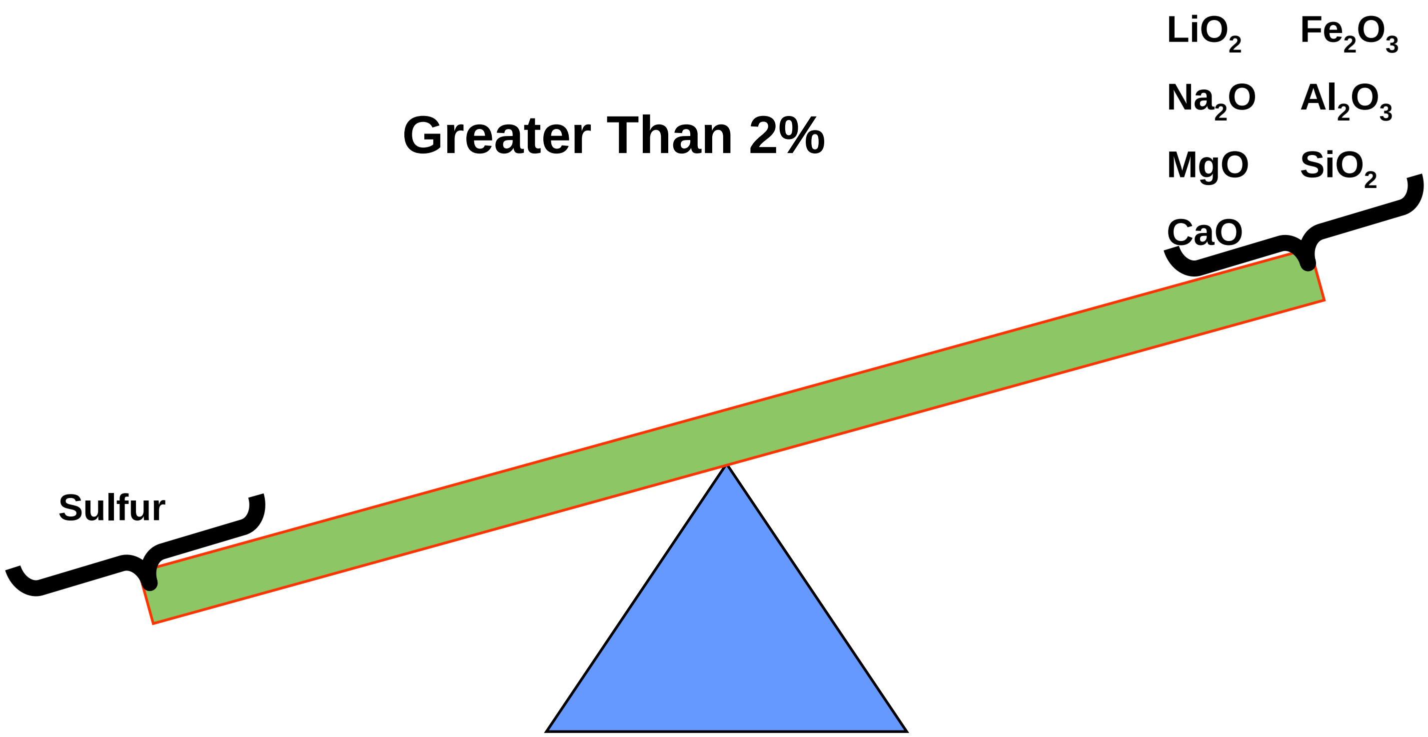
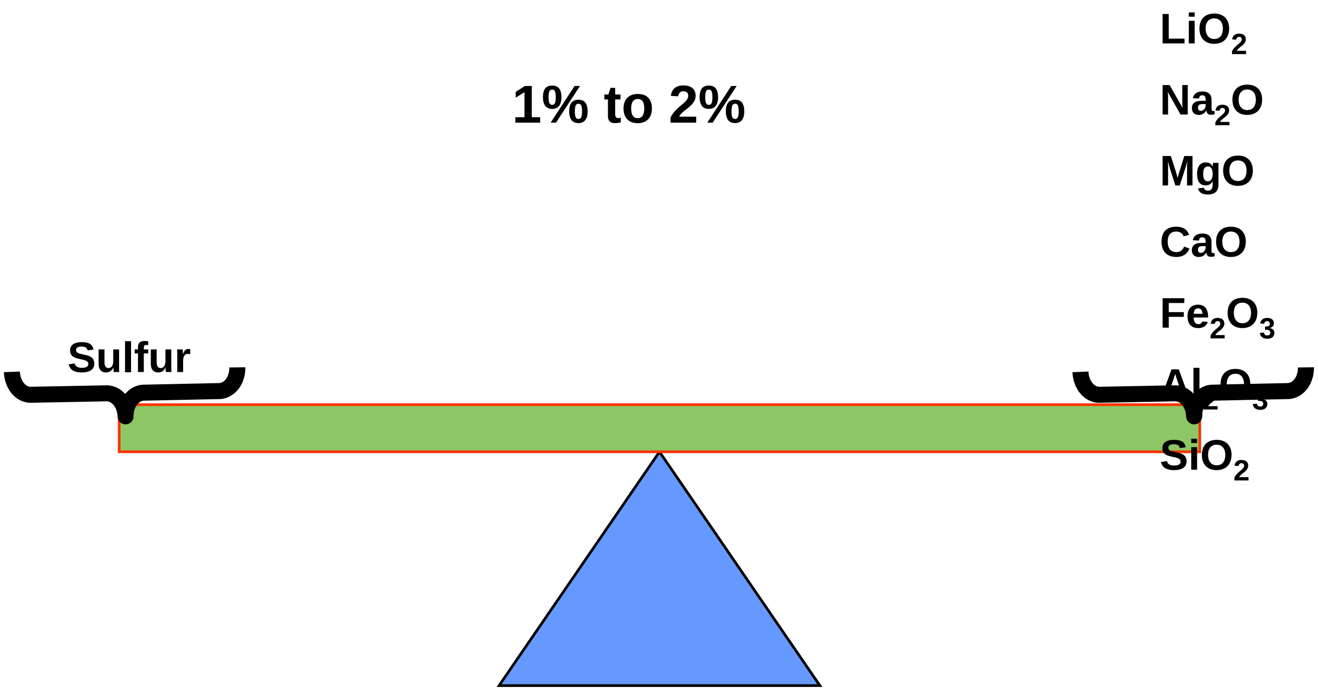
High Sulfur Coal vs. Ash Constituents Sulfur Content >2%

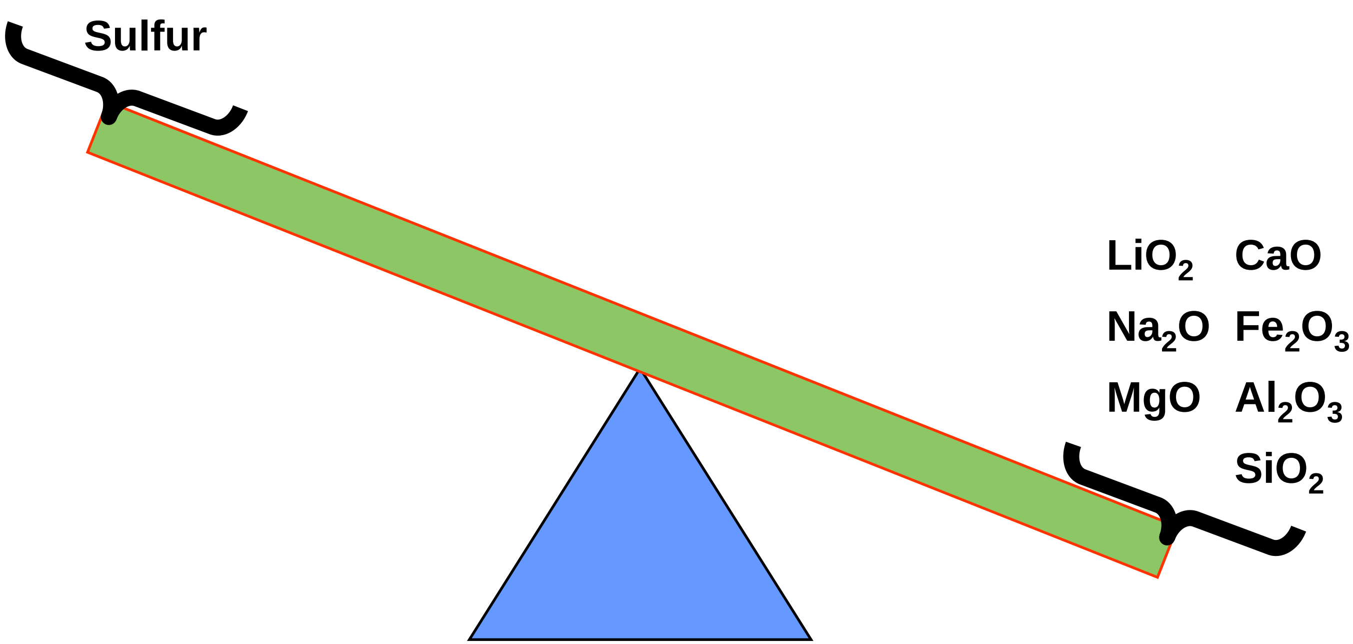


Medium Sulfur Coal vs. Ash Constituents
Sulfur Content 1% to 2%

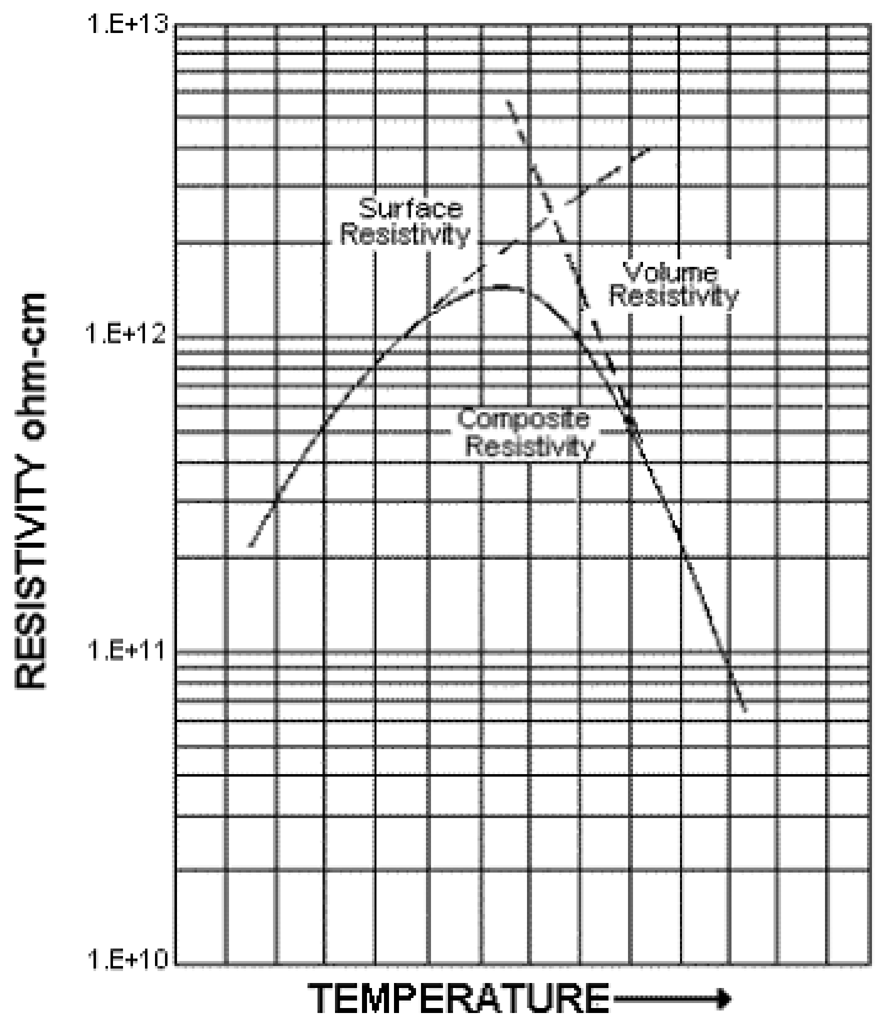


Low Sulfur Coal vs. Ash Constituents
Sulfur Content < 1%

Less Than 1%



Ash Resistivity



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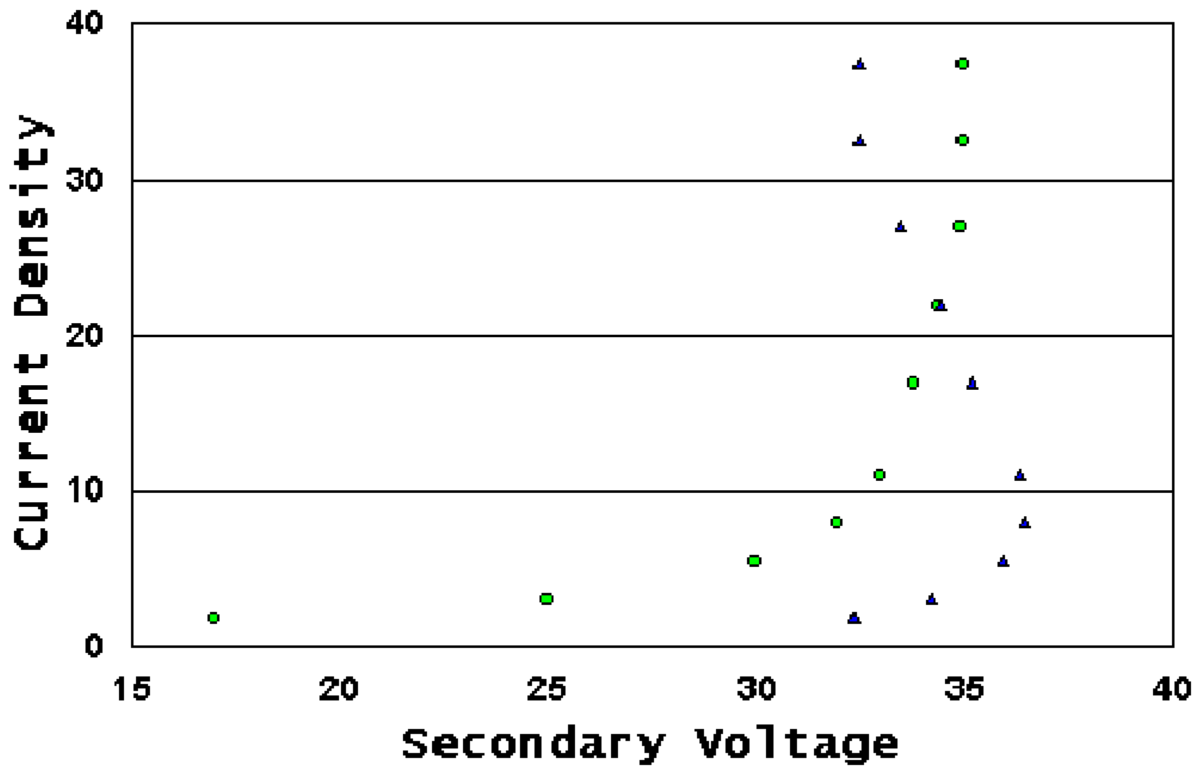
V-I Curves: Typical vs. Back Corona



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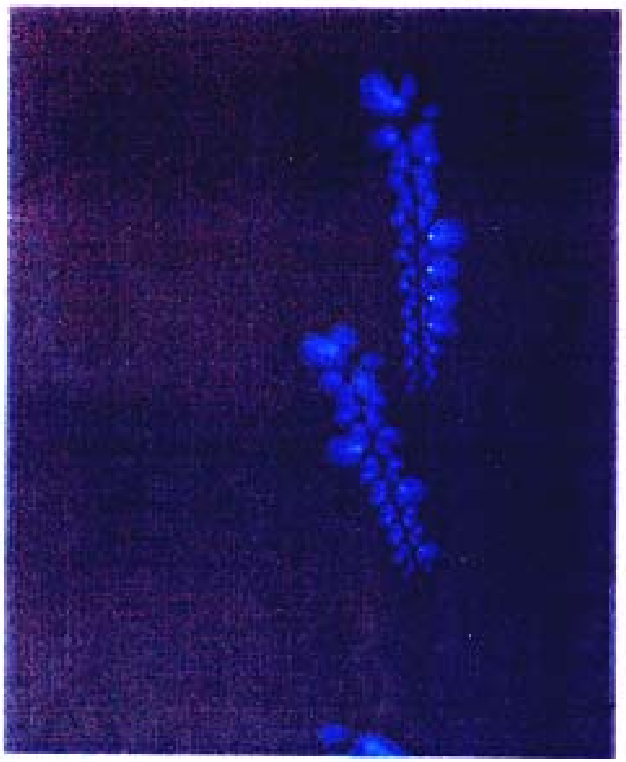
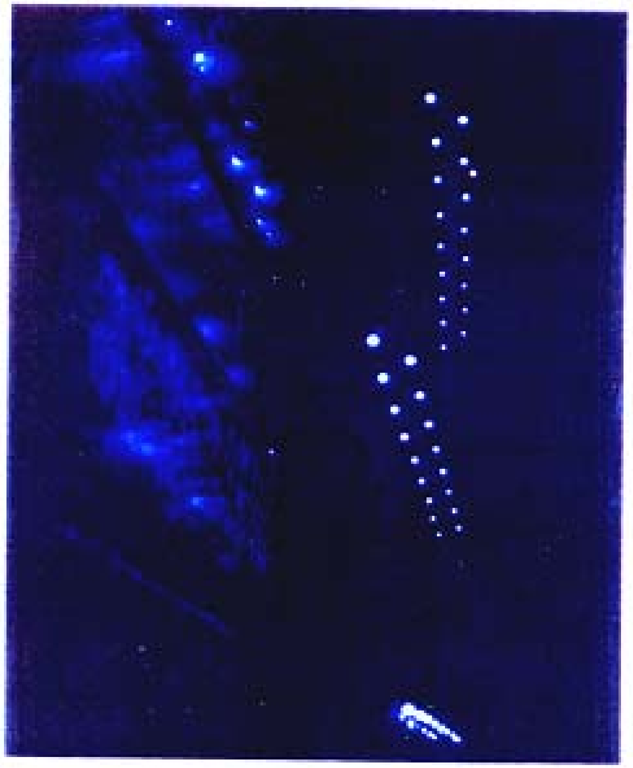
Normal Corona, medium power condition



Back-corona, high power condition



Photos Complements of SCS

THE THIRD RULE OF PRECIPITATION

SINCE SOME ESPS HAVE VARING SIZE ELECTIRCAL BU SECTIONS, CURRENT DENSITIES ARE THE BEST TOOL TO CHECK FOR DUST RESISTIVITY AND TO COMPARE SUCCESSIVE FIELDS' T/R SET CURRENT (mA) VALUES.

Current Density Calculation

First Field

mA x 1000 / (6'L x 30'H x 21 GP x 2 sides) = uA/sqft

Fields 2 thru 4

mA x 1000 / (9'L x 30'H x 21 GP x 2 sides) = uA/sqft

THE FOURTH RULE OF PRECIPITATION

IF THE T/R SET IS NOT SPARKING, THEN THE AVC SHOULD BE PUSHING THAT T/R SET TO ONE OF ITS PRE-SET LIMITS (VOLTS, AMPS, KV, OR mA)

Where a Control Should Operate

- Spark limited
- TR set rating
- SCR Limited (full conduction of the SCRs)
- Artificial Limit (manually or via an EMS)

ESP Data Review

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1400	1124	193	404
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2724	2321	553	1337

Amps
Volts
mA
KV
SPM

Gas Flow ↓

2SD1	2SC1	2SB1	2SA1
20	28	O/S	56
227	282		285
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29	28		29
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17	18	17	15
2SD3	**2SC3**	**2SB3**	**2SA3**
90	200	105	116
317	54	303	292
572	1419	700	757
38	6	33	35
18	0	13	20
2SD4	**2SB4**	**2SB4**	**2SA4**
102	65	130	179
285	232	309	343
622	347	836	1299
34	35	37	40
14	14	14	14
1585	679	1788	2867

THE FIFTH RULE OF PRECIPITATION

T/R SETS IN THE SAME RELATIVE FIELD POSITION SHOULD RUN AT THE SAME POWER LEVELS, BOTH VOLTAGE (kV) AND CURRENT (mA)

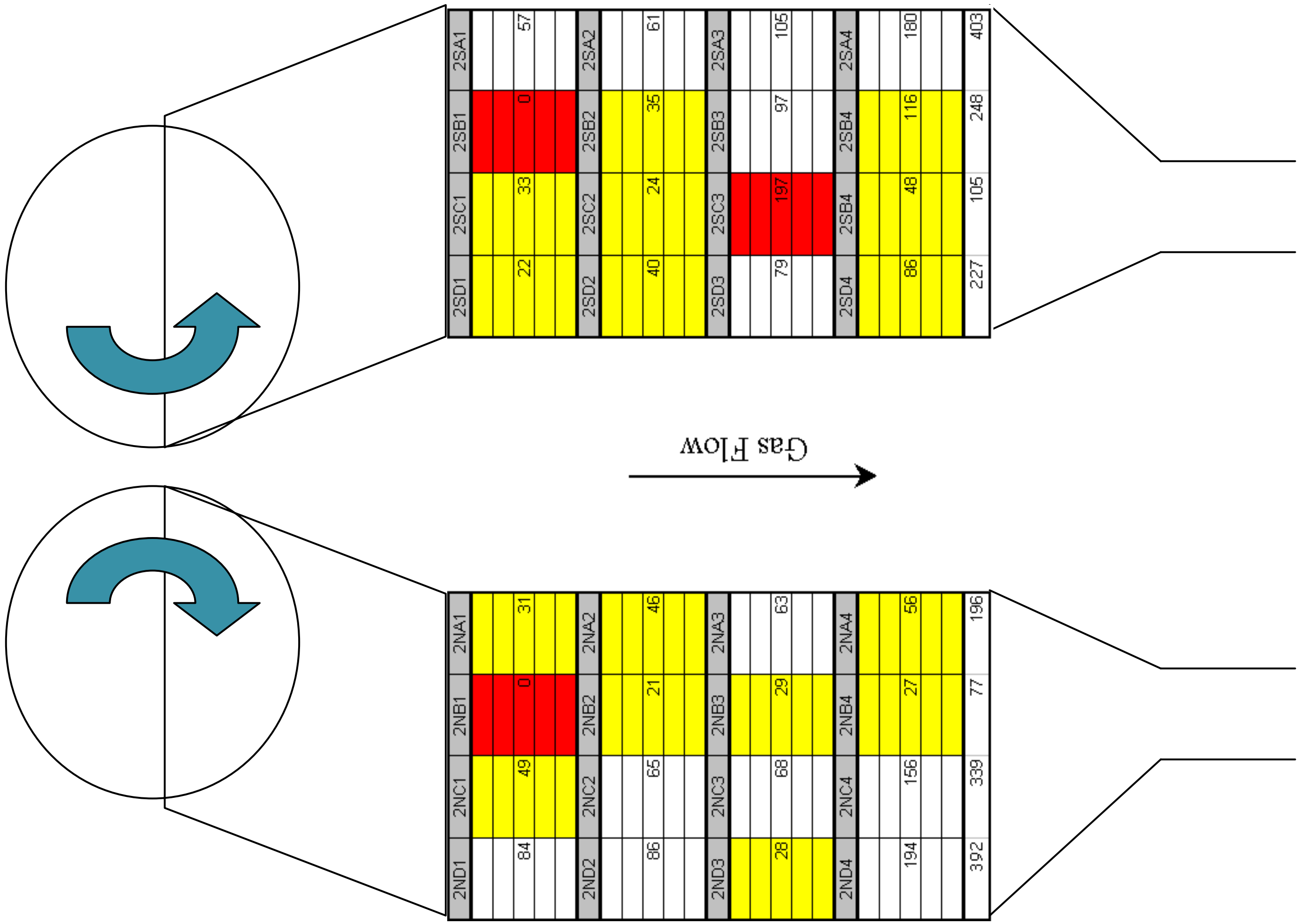
Field Comparison of Current Densities

2ND1	2NC1	2NB1	2NA1
53	31	0	20
2ND2	2NC2	2NB2	2NA2
55	41	13	29
2ND3	2NC3	2NB3	2NA3
18	43	19	40
2ND4	2NC4	2NB4	2NA4
123	99	17	36
249	215	49	125

Gas Flow

2SD1	2SC1	2SB1	2SA1
14	21	0	36
2SD2	2SC2	2SB2	2SA2
25	15	22	38
2SD3	2SC3	2SB3	2SA3
50	125	62	67
2SD4	2SB4	2SB4	2SA4
55	31	74	115
144	67	158	256

Physical Factor Effecting Performance



Mechanical Factors Affecting Performance

- Poor Electrode Alignment
- Vibrating or Swinging Electrodes
- Distorted Collecting Plates
- Excessive Ash Deposits on Electrodes
- Full Hoppers
- Air Inleakage
- Ash Deposits on Gas Distribution Devices
- Gas Sneakage Through Hoppers and Around ESP Zones

Operational Factors Affecting Performance

- Coal Quality
- Improper T/R Control Adjustment
- Excessive Gas Flow Through Precipitator
- Process Upsets
  - Tube Leaks
  - Plugged Air Heater
  - Shut-Downs and Start-Ups
  - Improper Adjustment of Rapper Intensity or Frequency

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THE END

- ANY QUESTIONS?

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