

Reinhold Environmental Ltd.



2008 APC Round Table
& Expo Presentation

July 13-15, 2008, in Savannah, GA

Advanced Electrostatic Precipitator Diagnostics

GE Energy

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imagination at work

Does This ESP Have A Problem?

*****AVERAGE VALUES*****

Unit	Amps	Volts	MA	KV	S/M
#3-1A1	26	285	150	43.0	29
#3-2A1	52	313	333	42.4	10
#3-3A1	76	275	450	39.5	14
#3-4A1	73	245	404	35.7	14
#3-5A1	68	320	501	41.1	22
#3-6A1	83	274	622	35.8	11
#3-7A1	64	193	350	26.8	20
#3-8A1	198	346	1400	37.7	5
#3-1A2	***	***	****	****	***
#3-2A2	27	253	149	38.5	18
#3-3A2	41	249	211	38.6	17
#3-4A2	41	204	193	30.9	14
#3-5A2	41	274	235	39.8	29
#3-6A2	67	278	470	34.1	12
#3-7A2	77	237	492	30.6	15
#3-8A2	164	336	1124	39.6	8
#3-1B1	***	***	****	****	***
#3-2B1	41	226	252	31.4	17
#3-3B1	105	303	700	33.3	13
#3-4B1	130	309	836	36.9	14
#3-5B1	28	282	157	42.4	28
#3-6B1	33	228	175	36.7	18
#3-7B1	71	312	419	35.8	17
#3-8B1	65	232	347	34.8	14
#3-1B2	56	285	375	36.0	29
#3-2B2	63	226	436	30.1	15
#3-3B2	116	292	757	34.7	20
#3-4B2	179	343	1299	39.8	14
#3-5B2	20	227	104	34.7	29
#3-6B2	46	266	287	35.9	17
#3-7B2	90	317	572	38.0	18
#3-8B2	102	285	622	34.1	14

How Can One Easily Tell?

*****AVERAGE VALUES*****

Unit	Amps	Volts	MA	KV	S/M
#3-1A1	26	285	150	43.0	29
#3-2A1	52	313	333	42.4	10
#3-3A1	76	275	450	39.5	14
#3-4A1	73	245	404	35.7	14
#3-5A1	68	320	501	41.1	22
#3-6A1	83	274	622	35.8	11
#3-7A1	64	193	350	26.8	20
#3-8A1	198	346	1400	37.7	5
#3-1A2	***	***	****	****	***
#3-2A2	27	253	149	38.5	18
#3-3A2	41	249	211	38.6	17
#3-4A2	41	204	193	30.9	14
#3-5A2	41	274	235	39.8	29
#3-6A2	67	278	470	34.1	12
#3-7A2	77	237	492	30.6	15
#3-8A2	164	336	1124	39.6	8
#3-1B1	***	***	****	****	***
#3-2B1	41	226	252	31.4	17
#3-3B1	105	303	700	33.3	13
#3-4B1	130	309	836	36.9	14
#3-5B1	28	282	157	42.4	28
#3-6B1	33	228	175	36.7	18
#3-7B1	71	312	419	35.8	17
#3-8B1	65	232	347	34.8	14
#3-1B2	56	285	375	36.0	29
#3-2B2	63	226	436	30.1	15
#3-3B2	116	292	757	34.7	20
#3-4B2	179	343	1299	39.8	14
#3-5B2	20	227	104	34.7	29
#3-6B2	46	266	287	35.9	17
#3-7B2	90	317	572	38.0	18
#3-8B2	102	285	622	34.1	14



This Leads Us to...

A Step by Step Analysis for Diagnosing a Misbehaving ESP

That data was for an ESP that had:

(2) Boxes, American Style ESP

(4) Fields

(4) T-R Sets Per Field

(16) T-R Sets Per Box

(2) Lungstrom Air Heaters

Burning High Sulfur Coal

First Step:

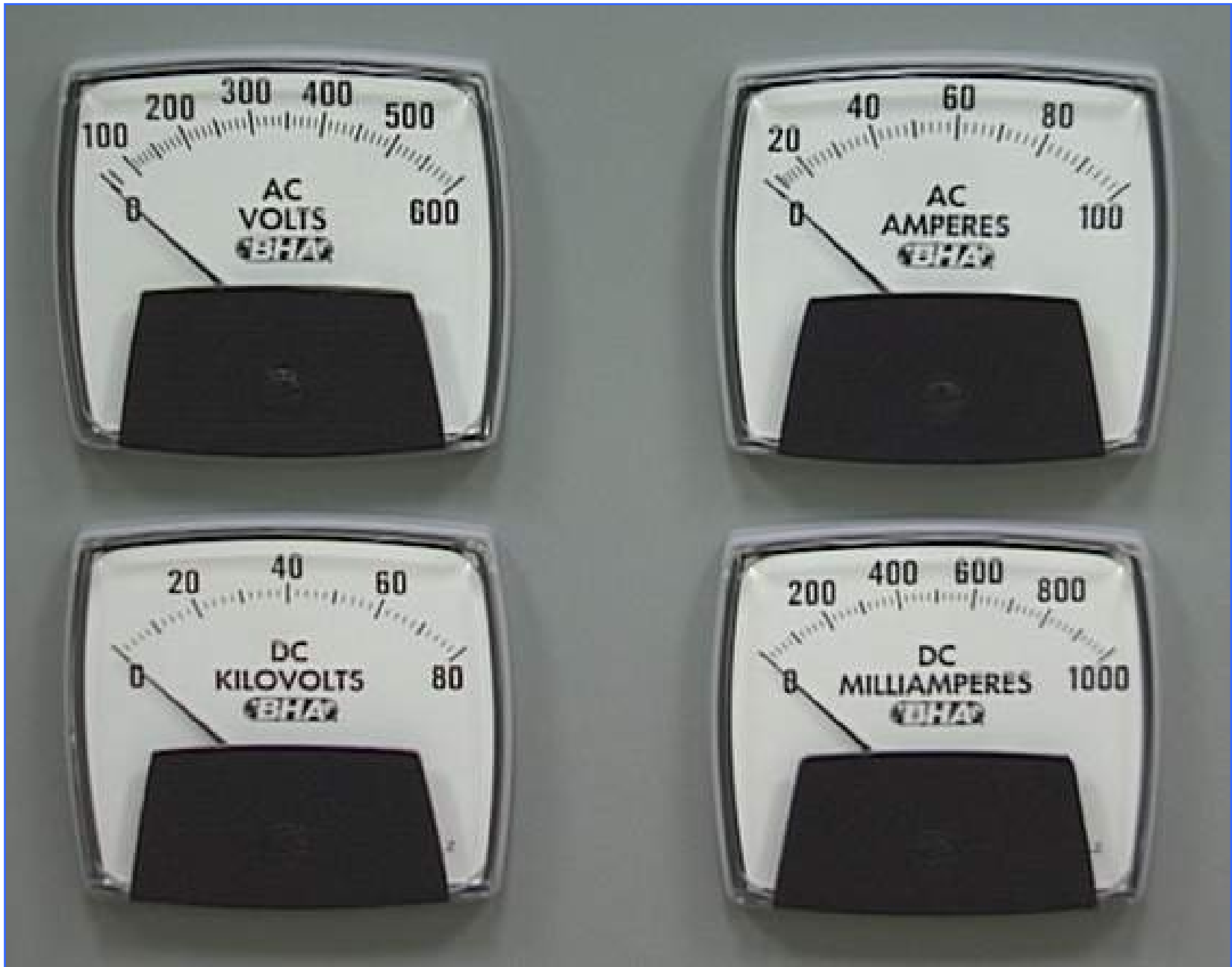
Put T-R Set Data into an ESP Plan View

4B2	4B1	8B2	8B1	T/R SETS	4A2	4A1	8A2	8A1
3B2	3B1	7B2	7B1		3A2	3A1	7A2	7A1
2B2	2B1	6B2	6B1		2A2	2A1	6A2	6A1
1B2	1B1	5B2	5B1		1A2	1A1	5A2	5A1

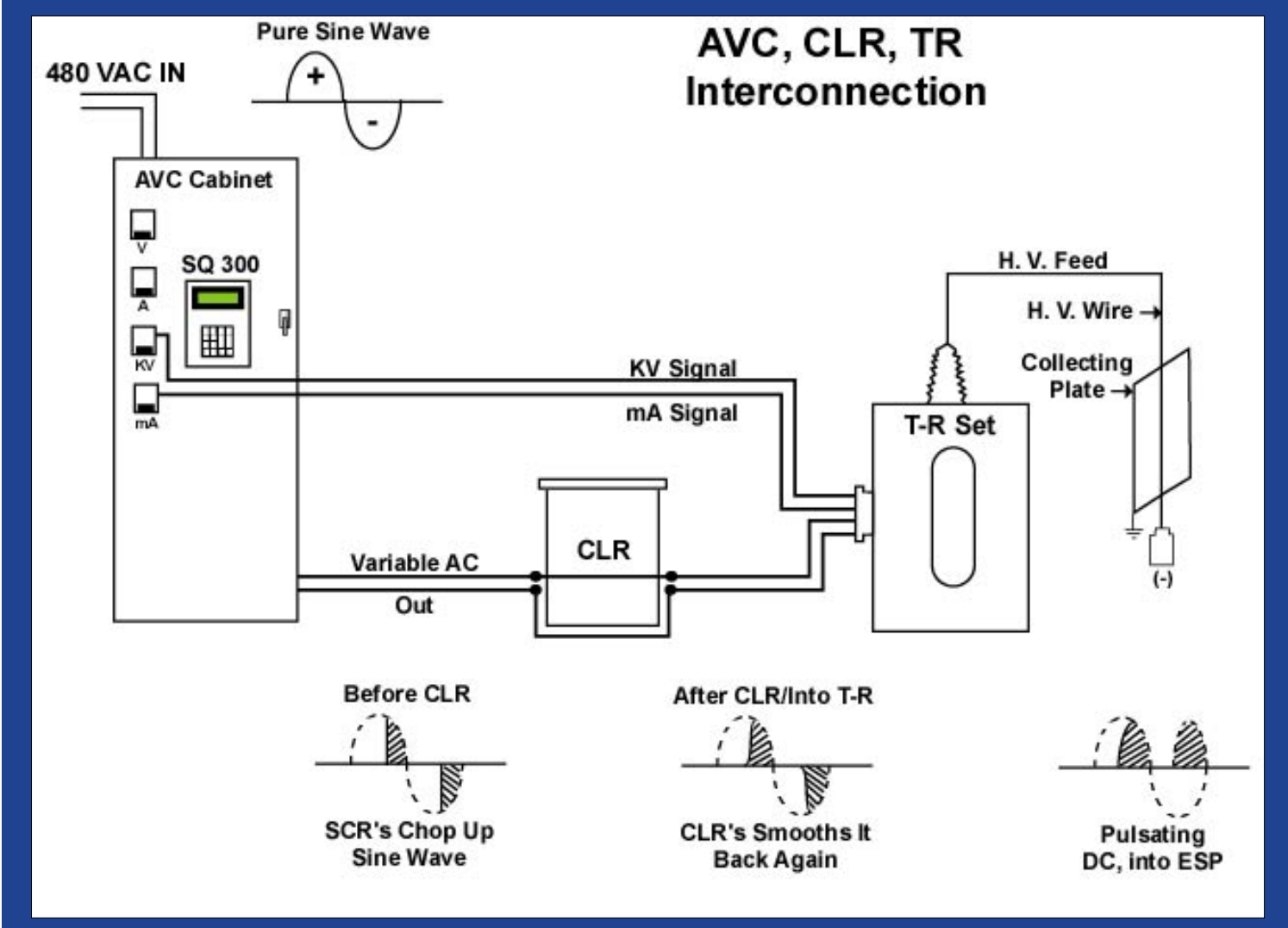
Next show your meter readings.

But what AVC meters should you use?

Gas Flow

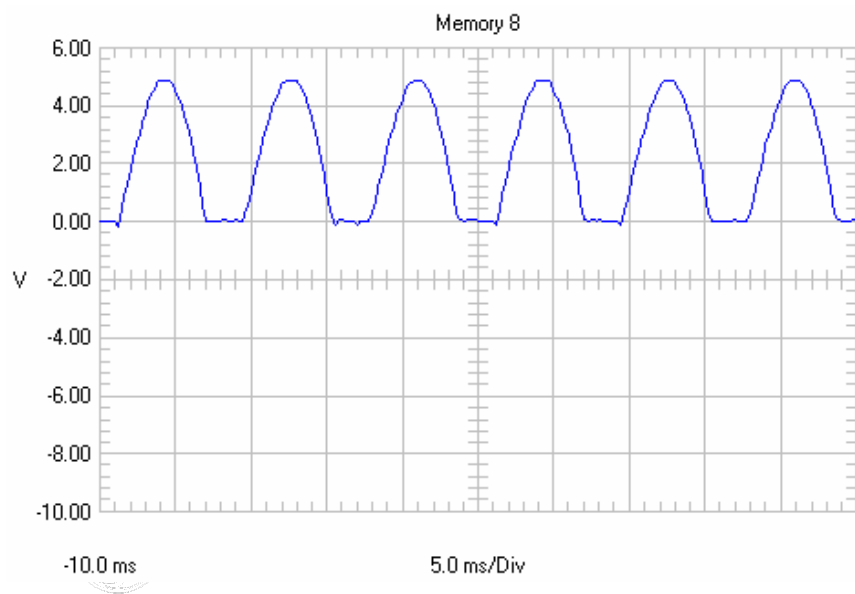


AVC CABINET, CLR, & T/R SET



What Is the Best AVC Meter to Use to Evaluate an ESP Field?

The Milliamp Meter



Put Data in an ESP View

4B2	4B1	8B2	8B1	T/R SETS	4A2	4A1	8A2	8A1
3B2	3B1	7B2	7B1		3A2	3A1	7A2	7A1
2B2	2B1	6B2	6B1		2A2	2A1	6A2	6A1
1B2	1B1	5B2	5B1		1A2	1A1	5A2	5A1
1299	836	622	347	MILLIAMP	193	404	1124	1400
757	700	572	419		211	450	492	350
436	252	287	175		149	333	470	622
375	OFF	104	157		OFF	150	235	501



Gas Flow


**Which Meter
Next?**

The Spark Meter



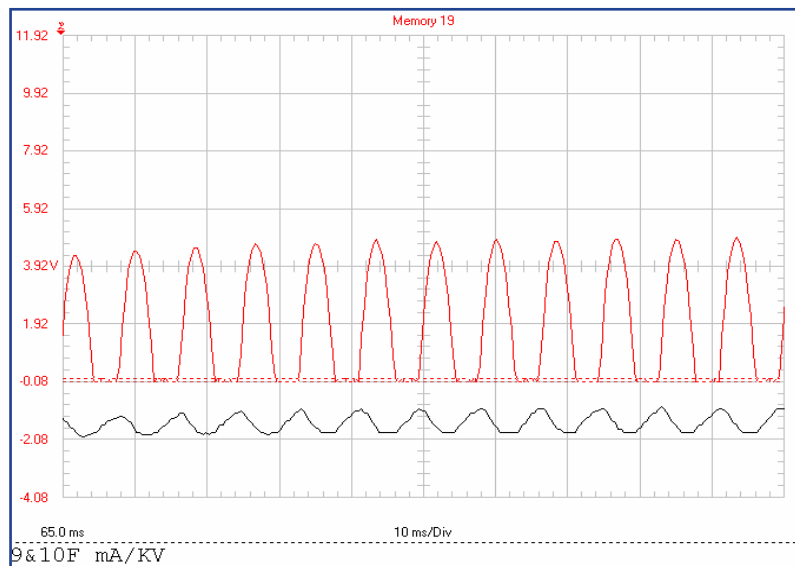
Put Data in an ESP View

4B2	4B1	8B2	8B1	T/R SETS	4A2	4A1	8A2	8A1
3B2	3B1	7B2	7B1		3A2	3A1	7A2	7A1
2B2	2B1	6B2	6B1		2A2	2A1	6A2	6A1
1B2	1B1	5B2	5B1		1A2	1A1	5A2	5A1
1299	836	622	347	MILLIAMP	193	404	1124	1400
757	700	572	419		211	450	492	350
436	252	287	175		149	333	470	622
375	OFF	104	157		OFF	150	235	501
14	15	15	14	SPM	14	11	6	1
18	13	18	17		12	11	16	20
22	18	14	17		14	11	15	11
30	OFF	30	27		OFF	28	27	25


Gas Flow

What About the KV Meter?

It can be very important, but very tricky.
More will be discussed later.



Step 2

If a T/R set is not sparking, then its AVC should be pushing that T/R set to one of its pre-set, healthy limits (volts, amps, KV, ma, or firing angle).

I'll explain what is meant by "healthy" in a minute

Again, know the ratings of the T/R sets on the ESP being reviewed.

Walk up to the roof of the ESP and look at the nameplate on the T/R set

HV KV	LV CONN	MA RATING	TRANS
<u>45</u>	14-12	<u>1800</u>	CLASS
55	14-11	1473	1 PH
FULL WAVE RECTIFIER BRIDGE			
MAX. AMBIENT		65 °C	TRANS &
KVA	115.5	40 °C RISE	TANK &
LV:	<u>440 VOLTS</u>		FLUID
	<u>262.4 AMPS</u>		
HV:	53460 V	2.16 A	45 KV
	65340 V	1.77 A	SERIAL
MAXIMUM TANK PRESSURE 15 P			
SUITABLE FOR OUTDOOR SERVICE AN			

The diagram shows a transformer with LV and HV windings. The LV winding has terminals 12, 11, and 14. The HV winding has terminals 7 and 3. A full-wave rectifier bridge is connected to the HV winding. The LV winding is connected to a power source. The HV winding is connected to a load through a bridge rectifier.

One T/R Running with “No” Sparking, but it is not at Secondary Current Limit,

1600	1600	1600	1600	T/R SIZE	1600	1600	1600	1600
1400	1400	1400	1400		1400	1400	1400	1400
1250	1250	1250	1250		1250	1250	1250	1250
950	950	950	950		950	950	950	950
1299	836	622	347	MILLIAMP	193	404	1124	1400
757	700	572	419		211	450	492	350
436	252	287	175		149	333	470	622
375	OFF	104	157		OFF	150	235	501
14	15	15	14	SPM	14	11	6	1
18	13	18	17		12	11	16	20
22	18	14	17		14	11	15	11
30	OFF	30	27		OFF	28	27	25

What Limit is it at?

Check to see if T/R is at limit. The mA values on the previous page were average values. Looking closer we find

VALUES	AMPS	VOLTS	mA	KV	SPM
T-R RATING	214	480	1600	45	
ACTUAL	215	365	1517	39.7	1
AVERAGE	198	246	1400	37.7	5

VALUES	AMPS	VOLTS	mA	KV	SPM
T-R RATING	214	480	1600	45	
ACTUAL	215	365	1517	39.7	1
AVERAGE	198	246	1400	37.7	5

Yes, the T/R is primary amp limited

Examples of AVC 's at a Limit



imagination at work

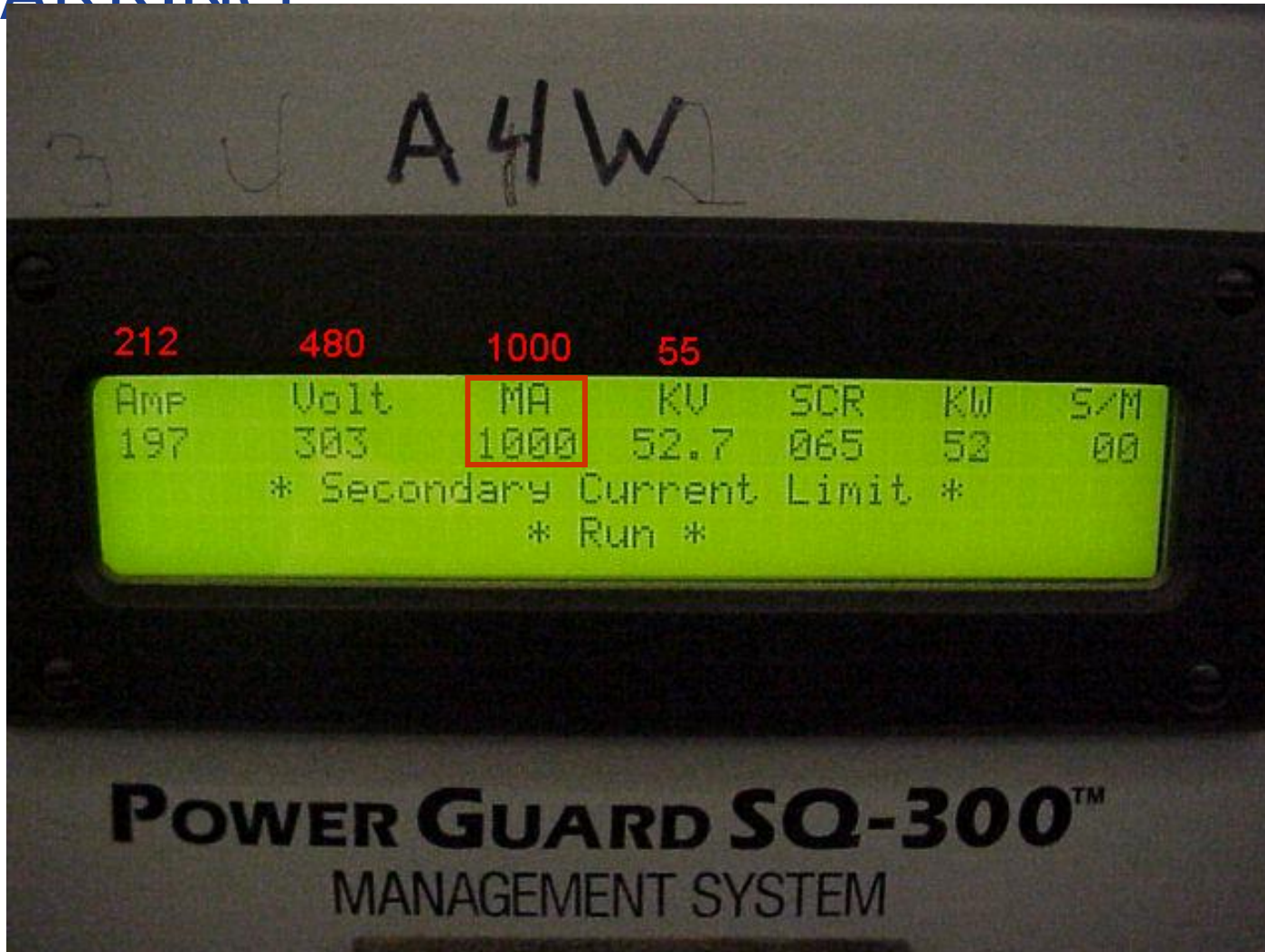
AVC SPARK LIMITED – DOING IT'S JOB



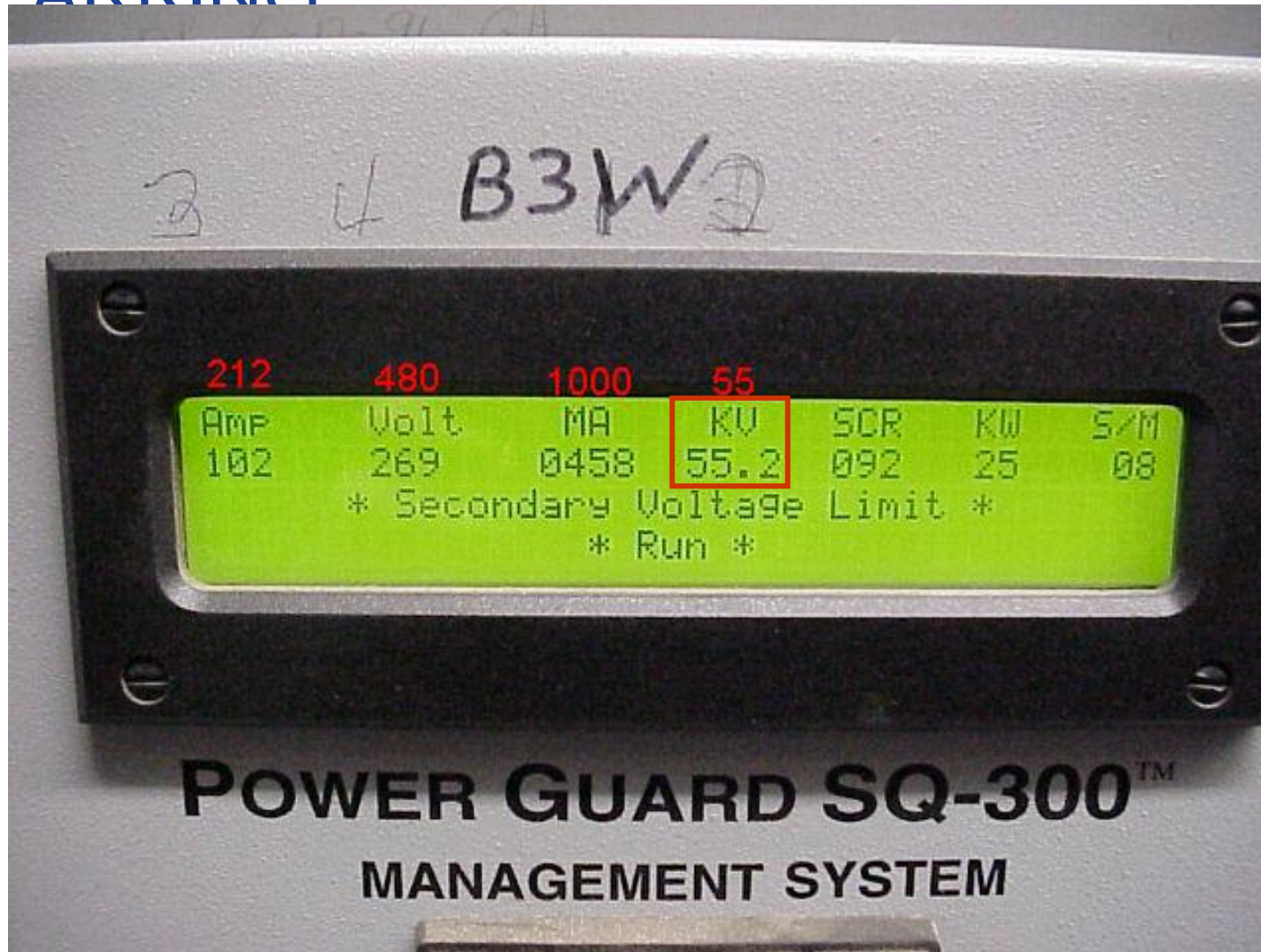
T/R Current Limited with Sparking



T-R CURRENT LIMITED WITHOUT SPARKING



T-R VOLTAGE LIMITED WITH SPARKING



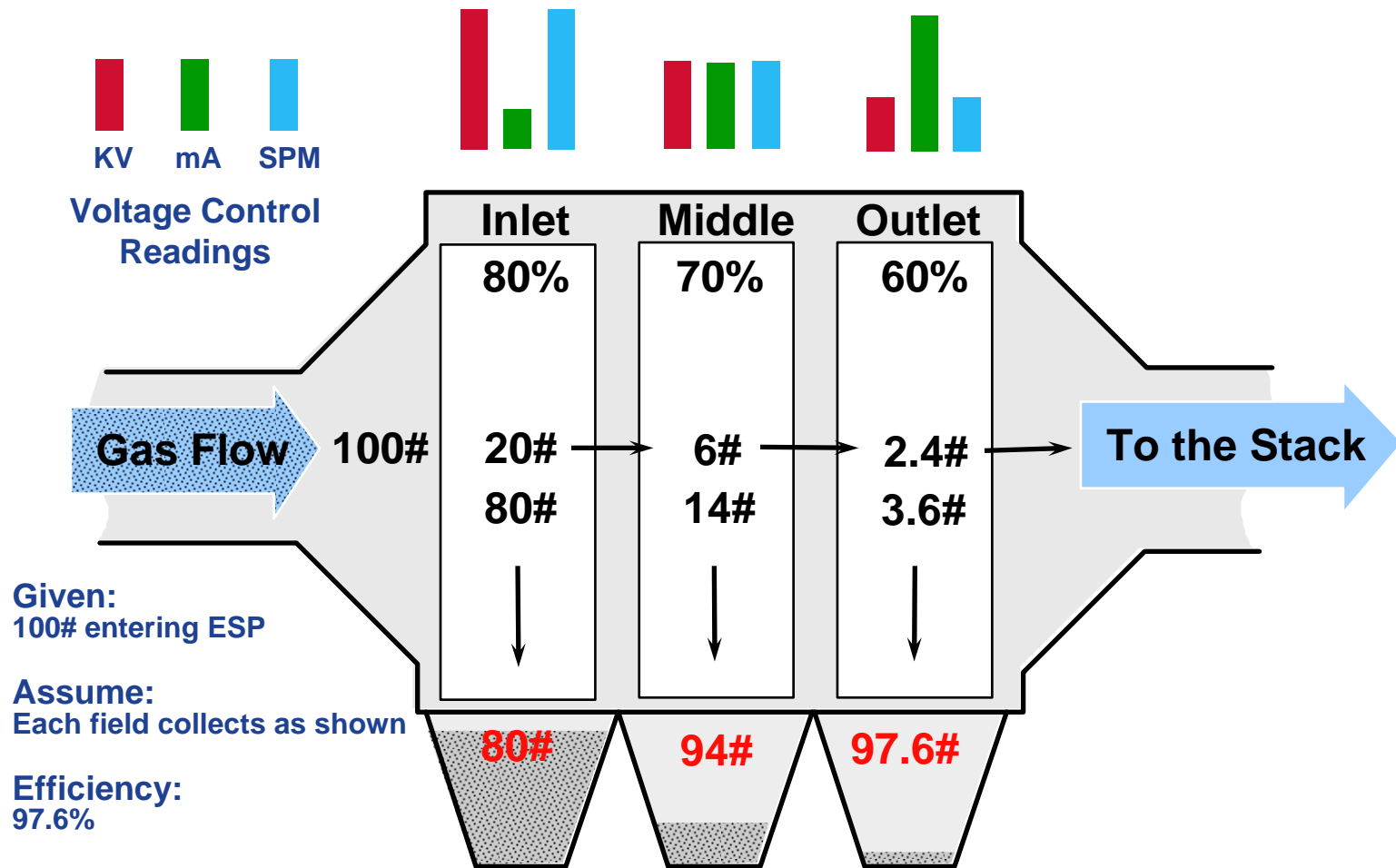
What is meant by “Healthy Limits?”

- Primary or Secondary Limit is not healthy when accompanied by a Primary Voltage level < 90 VAC or a Secondary level < 12 KV. It usually indicates a short circuit.
- Secondary Voltage Limit is not healthy when there is very little Secondary Current. It usually indicates an open circuit.
- Neither condition is aiding in particle capture

Step 3

3. Each succeeding field of a precipitator should have the same or higher precipitator current (mA), better said as current density, than the preceding field.

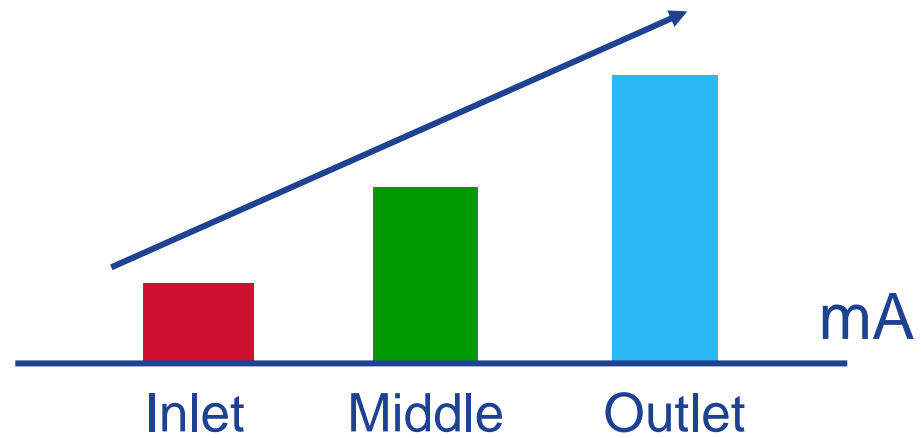
Incremental Collection Efficiency and Secondary Operating Conditions



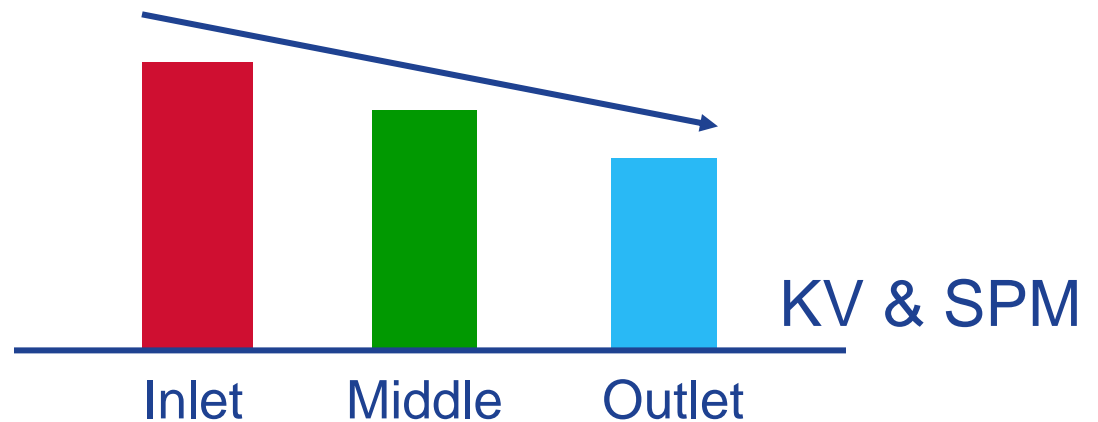
Values shown are to represent relationship only...not necessarily actual conditions

Space Charge Effects on Meters

Always look for this trend...



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



Applying Step 3, we get:

 Gas Flow


1299	836	622	347	MILLIAMP	193	404	1124	1400
757	700	572	419		211	450	492	350
436	252	287	175		149	333	470	622
375	OFF	104	157		OFF	150	235	501

At first glance, probably not enough “bad” sets to cause the high opacity

Step 4

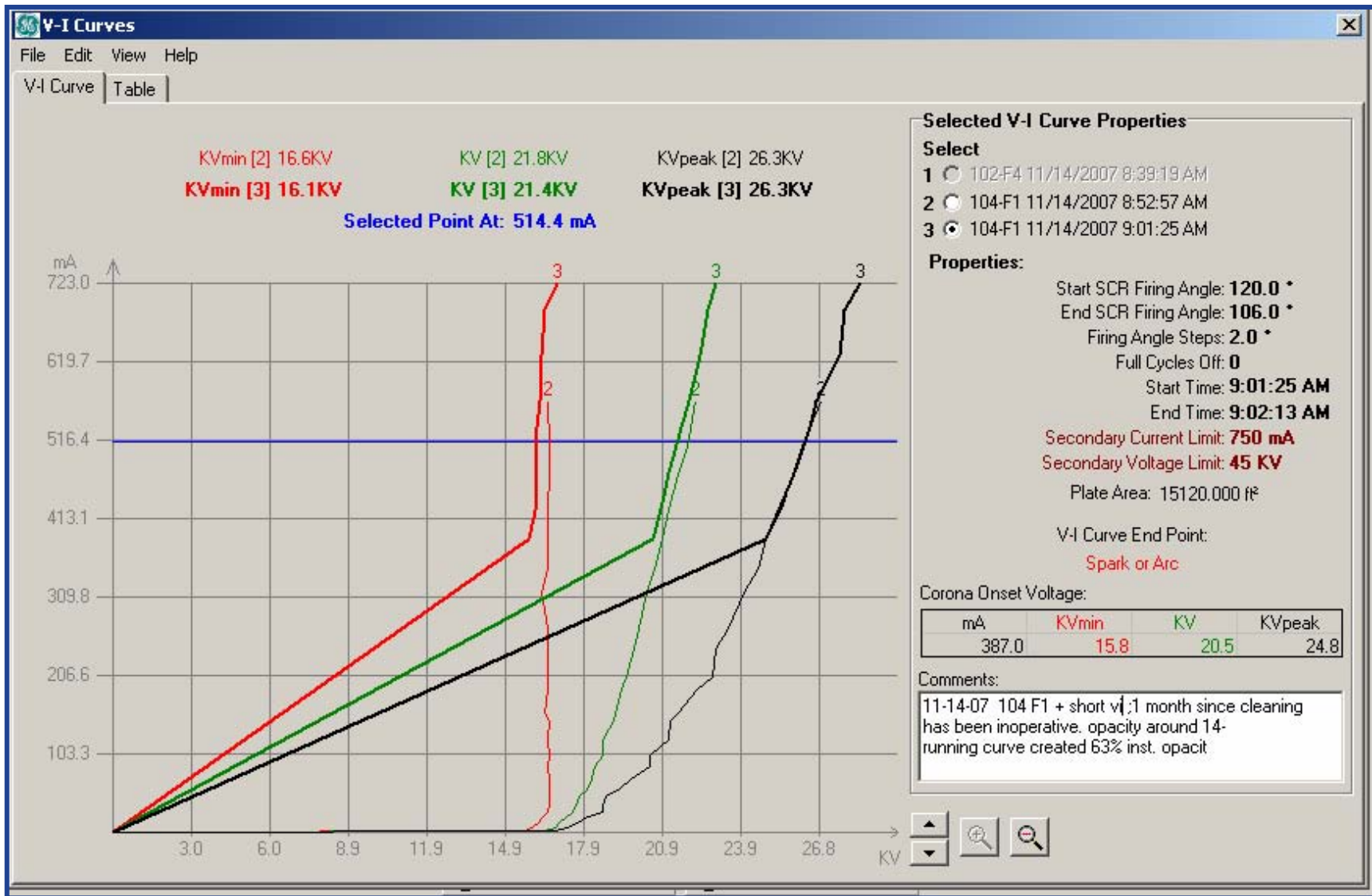
4. If the dust is not highly resistive, then outlet fields usually run at full current and little or no sparking.

But These Outlet Fields Are Sparking. Should This Happen With High Sulfur

1600	1600	1600	1600	T/R SIZE	1600	1600	1600	1600
1400	1400	1400	1400		1400	1400	1400	1400
1250	1250	1250	1250		1250	1250	1250	1250
950	950	950	950		950	950	950	950
1299	836	622	347	MILLIAMP	193	404	1124	1400
757	700	572	419		211	450	492	350
436	252	287	175		149	333	470	622
375	OFF	104	157		OFF	150	235	501
14	15	15	14	SPM	14	11	6	1
18	13	18	17		12	11	16	20
22	18	14	17		14	11	15	11
30	OFF	30	27		OFF	28	27	25

Maybe the dust is resistive?
This one is tricky!

Wouldn't Hurt to Run a Couple of Quick V-I Curves



Curve 2 is the full VI Curve, Curve 3 is a “Quick – Curve”

Unfortunately, No V-i Curves
Were Run at the Time for
This ESP. So, Let's See
What Else Might Be Helpful.



imagination at work

Step 5

5. Current densities are the best tool to check for dust resistivity and to compare successive fields' current (mA) values.

Current Density

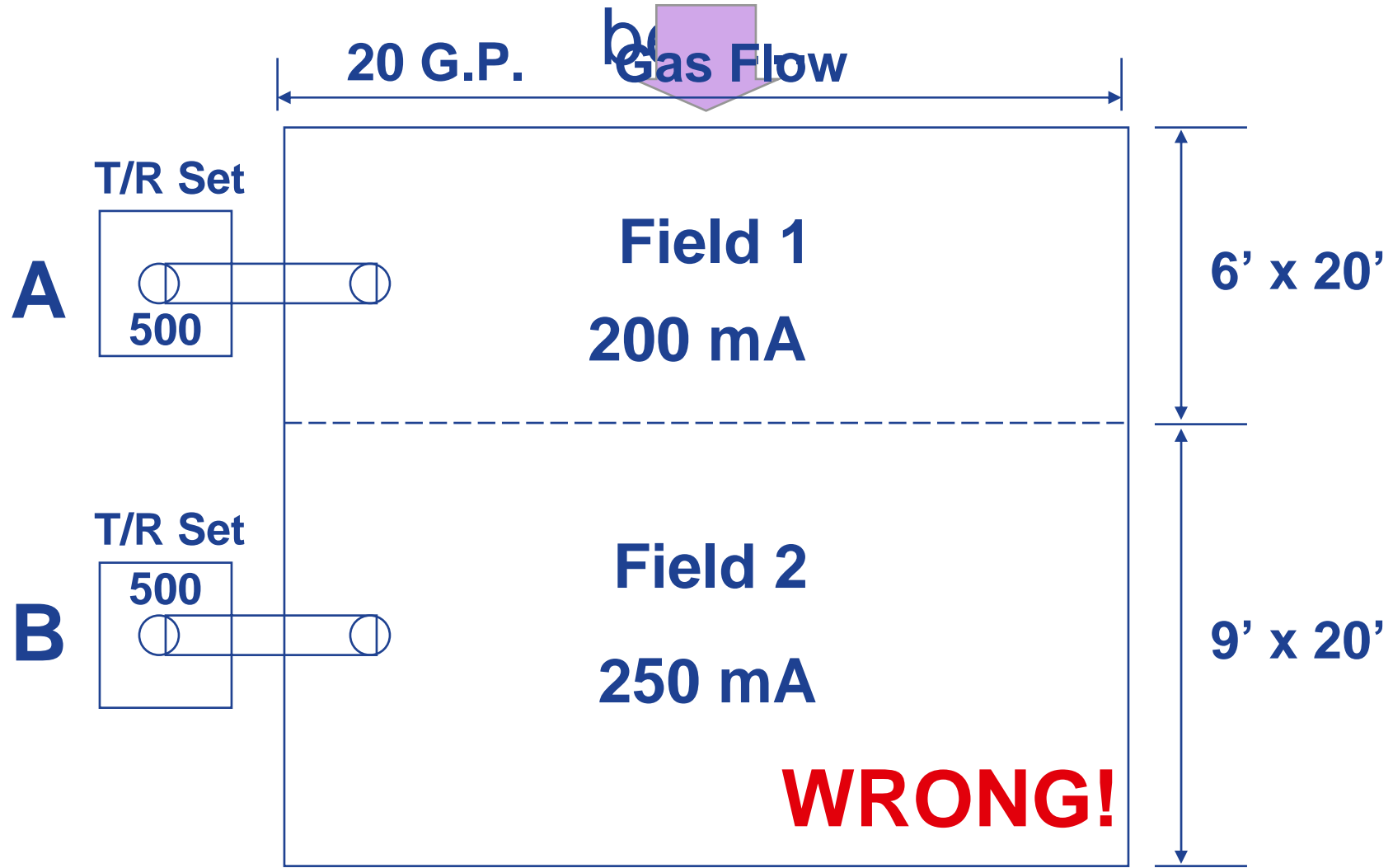


imagination at work

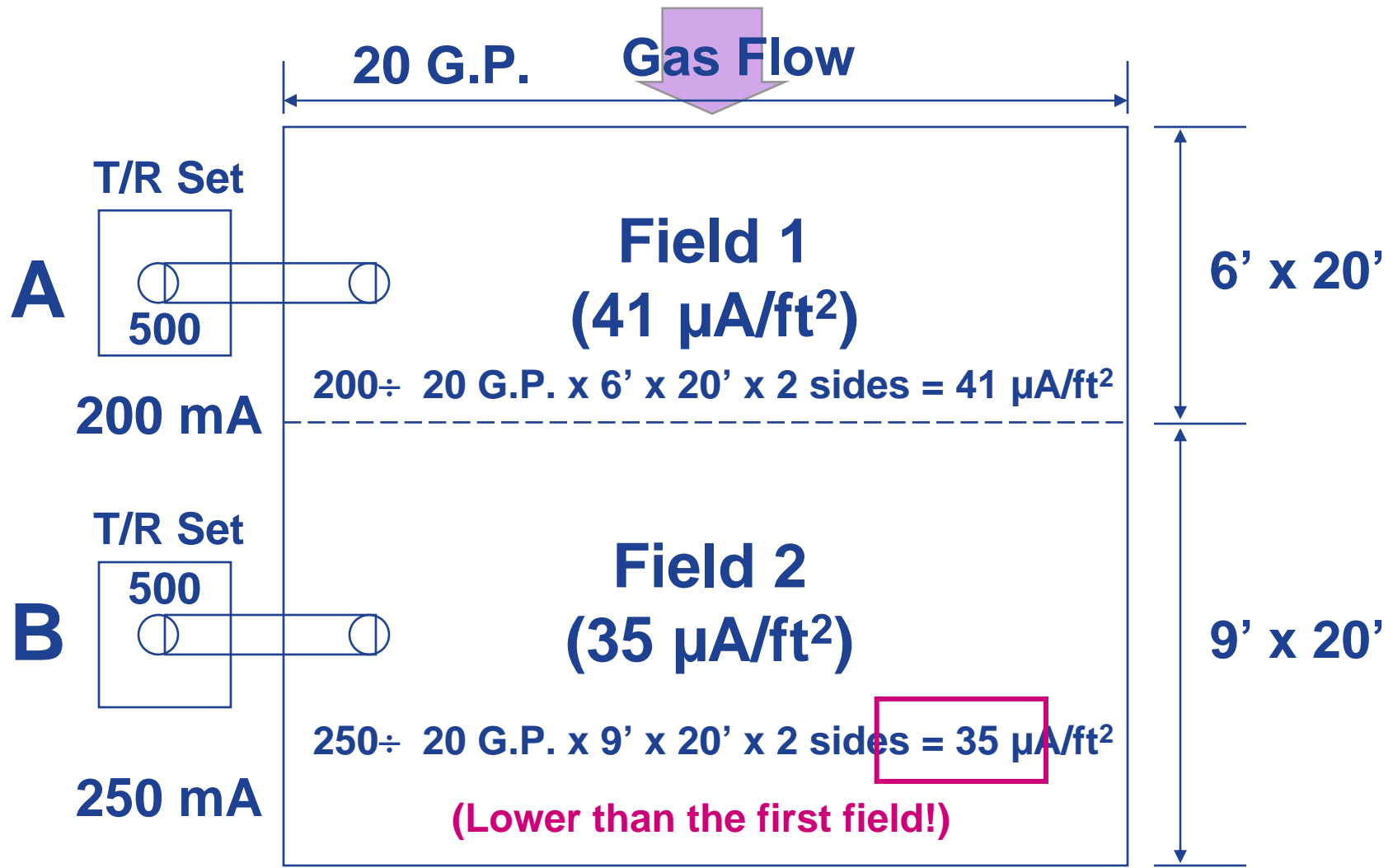
Current Density

1. Enables A true comparison of ESP current for T/R sets not energizing the same square feet of collecting plates.
2. Generally accepted values for low and high resistivity dust, can aid in troubleshooting.

Based on what we learned in Step 3, this ESP is OK. However, that would



Current Density



I. Current Densities (for very conductive dust)

In general, typical range of values for current density for a four field **American ESP**

Field Number	Current Density ($\mu\text{A}/\text{ft}^2$)
1	15 - 25
2	25 - 40
3	40 - 60
4	60 - 80

I. Current Densities (for conductive dust)

~~In general~~, typical range of values for current density for a four field **European ESP** where T-R sets may not be sized to provide more than $40\mu\text{A}/\text{ft}^2$

Field Number	Current Density ($\mu\text{A}/\text{ft}^2$)
1	10 - 20
2	20 - 30
3	30 - 40
4	30 - 40

II. Current Densities (for high resistivity dust)

Typical values of current density for high resistivity but no Back Corona.

Field Number	Current Density ($\mu\text{A}/\text{ft}^2$)
1	7 - 25
2	7 - 25
3	7 - 25
4	7 - 25

(Accompanied by sparking in all fields)

Converting to Densities we get:

1299	836	622	347	MILLIAMP	193	404	1124	1400
757	700	572	419		211	450	492	350
436	252	287	175		149	333	470	622
375	OFF	104	157		OFF	150	235	501
109	70	52	29	DENSITY	16	34	95	118
64	59	48	35		18	38	41	29
37	21	24	15		13	28	40	52
32	OFF	9	13		OFF	13	20	42



Evaluating Densities We Get:

1299	836	622	347	MILLIAMP	193	404	1124	1400
757	700	572	419		211	450	492	350
436	252	287	175		149	333	470	622
375	OFF	104	157		OFF	150	235	501
109	70	52	29	60 - 80	16	34	95	118
64	59	48	35	40 - 60	18	38	41	29
37	21	24	15	25 - 40	13	28	40	52
32	OFF	9	13	15 - 25	OFF	13	20	42



There appears to be a pattern here. Why?



Other Examples of Usefulness of Current Densities at other Installations





imagination at work

Just based on readings, you might think everything is okay! But that is not the

case

11.63 X 24'	520mA	150mA	220mA	240mA		
11.63 X 24'	180mA	110mA	90mA	80mA		
	14g.p. @9"	24g.p. @9"	24g.p. @9"	14g.p. @9"		
						
		315 ⁰ F		294 ⁰ F		
	A PREHEATER (CW ROTATION)		B PREHEATER (CCW ROTATION)			

Converting to Current Densities, it is a Different Story

					RANGE
11.63 X 24'	22SPM 66.6MICRO AMPS	23SPM 11.2MICROAMPS	24SPM 16.4MICROAMPS	18SPM 30.7MICRO AMPS	20 TO 35 MICRO-AMPS
11.63 X 24'	23SPM 23.0MICRO AMPS	24SPM 8.2MICROAMPS	18SPM 6.7MICROAMPS	22SPM 10.2MICRO AMPS	10 TO 20 MICRO-AMPS
	14g.p. @9"	24g.p. @9"	24g.p. @9"	14g.p. @9"	
					
		315 ⁰ F		294 ⁰ F	
	A PREHEATER (CW ROTATION)		B PREHEATER (CCW ROTATION)		

Misled by a 4 Field, 2 Chamber ESP

AVC	AMPS	VOLTS	mA	KV	SPM
4A1	6	226	60	34	58
4A2	12	244	83	32	40
4A3	36	287	217	32	21
4A4	22	256	164	26	50
AVC	AMPS	VOLTS	mA	KV	SPM
4B1	8	219	72	33	57
4B2	34	227	245	12	46
4B3	34	262	264	16	33
4B4	72	336	459	37	31

Converting to Current Densities, it is a Different Story



AVC	mA	DENSITY	NORMAL	DENSITY	mA	AVC
4B1	72	4.5	10 - 20	3.8	60	4A1
4B2	245	10.3	20 - 30	3.5	83	4A2
4B3	264	11.1	30 - 45	9.1	217	4A3
4B4	459	29.0	50 - 70	10.4	164	4A4

Back to Our Story



imagination at work

Step3 vs. Step 5 Comparison

1299	836	622	347	MILLIAMP	193	404	1124	1400
757	700	572	419		211	450	492	350
436	252	287	175		149	333	470	622
375	OFF	104	157		OFF	150	235	501

Step 3

Notice how many more “substandard” fields are identified by applying Step 5

109	70	52	29	60 - 80	16	34	95	118
64	59	48	35	40 - 60	18	38	41	29
37	21	24	15	25 - 40	13	28	40	52
32	OFF	9	13	15 - 25	OFF	13	20	42

Step 5

Get the point?



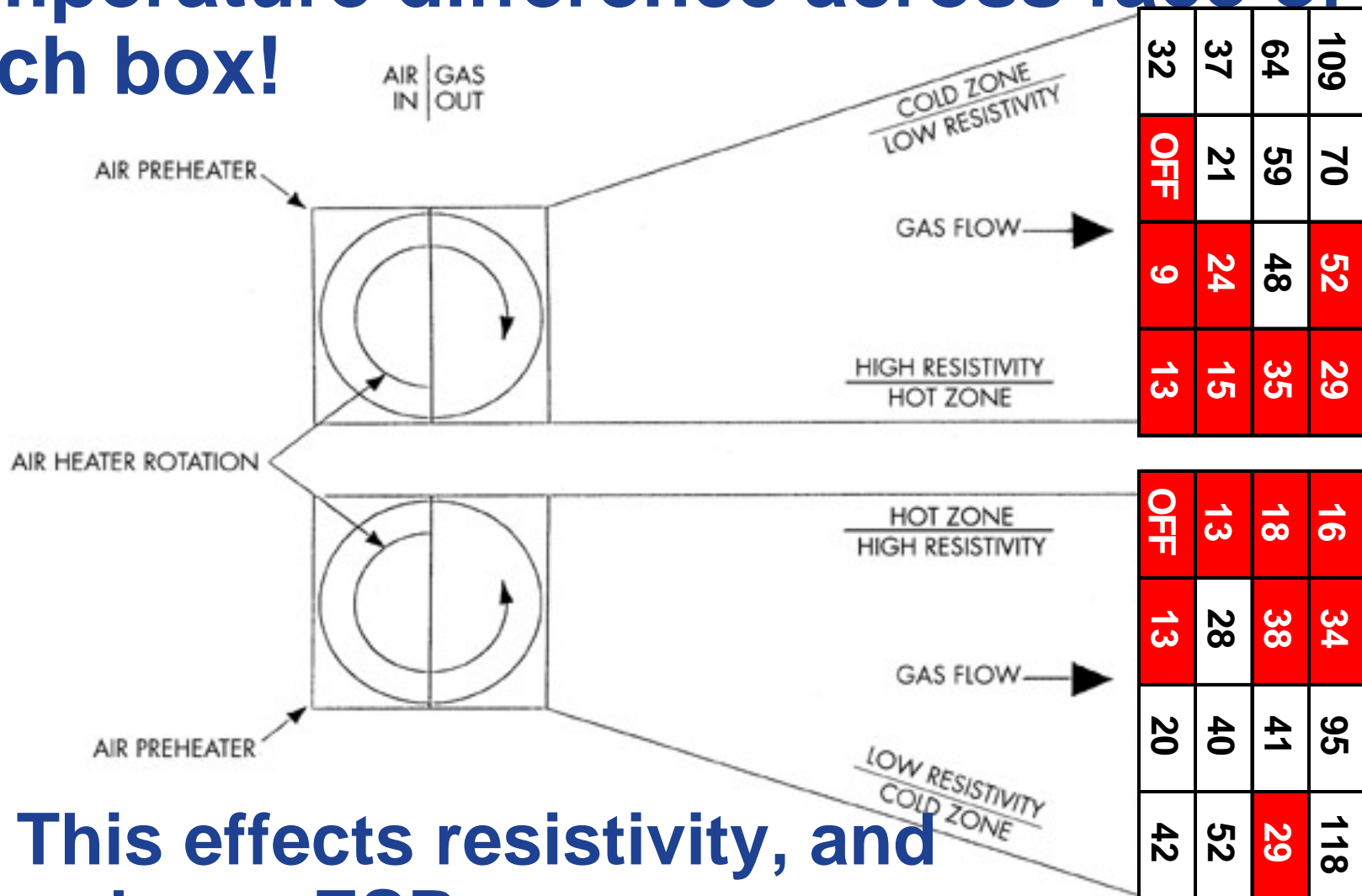
Looking at things again:

1299	836	622	347	MILLIAMP	193	404	1124	1400
757	700	572	419		211	450	492	350
436	252	287	175		149	333	470	622
375	OFF	104	157		OFF	150	235	501
109	70	52	29	60 - 80	16	34	95	118
64	59	48	35	40 - 60	18	38	41	29
37	21	24	15	25 - 40	13	28	40	52
32	OFF	9	13	15 - 25	OFF	13	20	42



There appears to be a pattern here. Why?

Air-Preheaters produce 60° temperature difference across face of each box!



This effects resistivity, and reduces ESP power

Step 6

6. T/R sets in the same relative field position should run at the same power levels, both voltage (kV) and current (mA)

Applying Step 6 we get:

1299	836	622	347	MILLIAMP	193	404	1124	1400
757	700	572	419		211	450	492	350
436	252	287	175		149	333	470	622
375	OFF	104	157		OFF	150	235	501

Step 6 can achieve the same results as a density review and is simpler, but not as precise because it is subjective.

With just numbers, we were nowhere.

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Time = Thu 1998/03/05 2:11pm Page 1 of 3

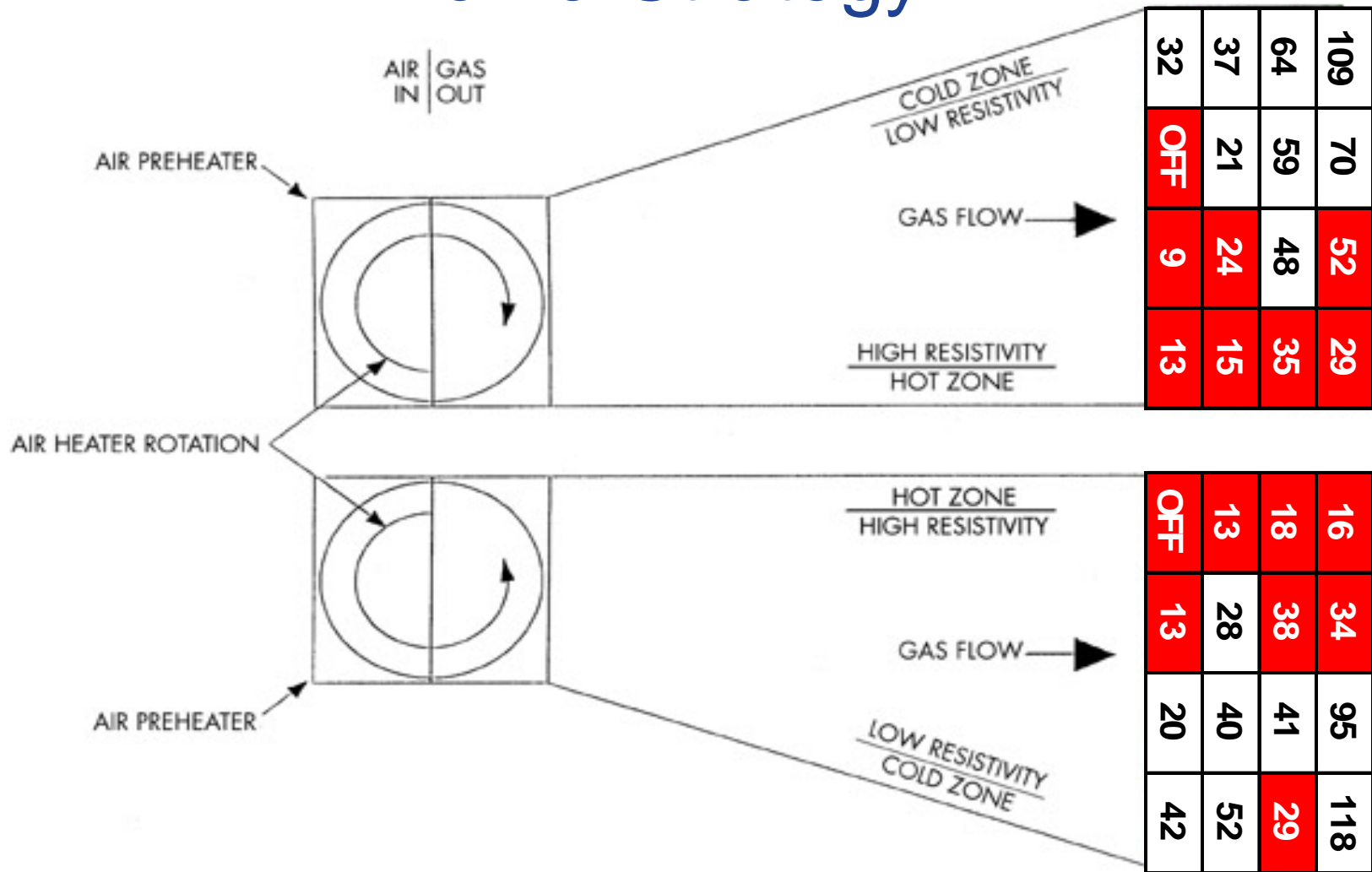
PrecipTech, Inc.
Power Guard Management System
DAC Version 2.9014
SQ-300 AVC

*****Supplemental Printout*****

*****CURRENT VALUES*****
```

Unit	Amps	Volts	MA	KV	S/M	Status
#3-1A1	22	254	126	39.2	28	Running
#3-2A1	58	346	379	45.0	11	Running
#3-3A1	60	248	324	37.5	11	Running
#3-4A1	76	252	415	36.1	11	Running
#3-5A1	83	357	652	44.5	25	Running
#3-6A1	115	334	909	41.4	11	Running
#3-7A1	59	185	312	25.9	20	Running
#3-8A1	215	365	1517	39.7	1	Running
#3-1A2	***	***	****	****	***	No Response
#3-2A2	16	194	71	33.2	14	Running
#3-3A2	35	236	166	38.1	12	Running
#3-4A2	37	207	173	31.9	14	Running
#3-5A2	39	265	217	39.6	27	Running
#3-6A2	60	263	375	33.3	15	Running
#3-7A2	55	210	308	26.6	16	Running
#3-8A2	144	312	924	38.1	6	Running
#3-1B1	***	***	****	****	***	No Response
#3-2B1	36	217	213	30.6	18	Running
#3-3B1	165	399	1229	42.2	13	Running
#3-4B1	84	206	782	30.4	15	Running
#3-5B1	26	266	150	39.7	27	Running
#3-6B1	23	200	102	35.3	17	Running
#3-7B1	115	377	758	41.3	17	Running
#3-8B1	76	249	415	36.0	14	Running
#3-1B2	55	276	355	35.1	30	Running
#3-2B2	49	207	296	28.1	22	Running
#3-3B2	112	291	719	34.8	18	Running
#3-4B2	192	373	1339	41.6	14	Running
#3-5B2	12	173	55	29.7	30	Running
#3-6B2	97	373	687	44.7	14	Running
#3-7B2	111	345	743	38.1	18	Running
#3-8B2	79	251	438	31.2	15	Running

Now After Applying 6 Steps, We Can Plan a Strategy.



Questions?

Thank you.



imagination at work