REINHOLD ENVIRONMENTAL Ltd.

2016 APC-Wastewater Round Table & Expo Presentation

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Understanding Your ESP. Why Does it Not Perform?

2016 APC-Wastewater Round Table

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Is This ESP Performing Properly?

(This is a single chamber, four field, weighted wire ESP with conventional TR sets.)

Good Dust					*AVC Readings*
AVC	AMPS	VOLTS	mAMPS	KV	SPM
1	60	365	300	43	30
2	90	350	500	38	30
3	240	345	1390	40	10
4	240	310	1450	39	0

First, Check How Each AVC is Operating

Good Dust					*AVC Readings*
AVC	AMPS	VOLTS	mAMPS	KV	SPM
1	60	365	300	43	30
2	90	350	500	38	30
3	240	345	1390	40	10
4	240	310	1450	39	0

First Step: You Must Know Each T-R Sets' Ratings

	Good Dust					*AVC Readings*
	AVC	AMPS	VOLTS	mAMPS	KV	SPM
RATINGS →	1&2 T-R	120	400	750	45	30
OPERATING VALUES →	1	60	365	300	43	30
	2	90	350	500	38	30
RATINGS →	3&4 T-R	240	400	1500	45	30
OPERATING VALUES →	3	240	345	1390	40	10
	4	240	310	1450	39	0

Voltage Controls Should Either be Spark Rate Limited or Nameplate Limited

Good Dust					*AVC Readings*
AVC	AMPS	VOLTS	mAMPS	KV	SPM
1&2 T-R	120	400	750	45	30
1	60	365	300	43	30
2	90	350	500	38	30
3&4 T-R	240	400	1500	45	30
3	240	345	1390	40	10
4	240	310	1450	39	0

SPARK RATE LIMITED (SPM values of 30 for AVC 1 and 2)

PRIMARY CURRENT LIMITED (AMPS values of 240 for AVC 3 and 4)

The AVC Has Two Jobs to Execute

1. Control Power to the TR set after a spark.
2. **In the absence of sparking, push the T/R set to its limit(s)**

Second: ESP Current Should Increase from Inlet to Outlet Fields, if the Fields are the Same Size

Good Dust — ***AVC Readings***

AVC	AMPS	VOLTS	mAMPS	KV	SPM
1&2 T-R	120	400	750	45	30
1	60	365	300	43	30
2	90	350	500	38	30
3&4 T-R	240	400	1500	45	30
3	240	345	1390	40	10
4	240	310	1450	39	0

SPARK RATE LIMITED

PRIMARY CURRENT LIMITED

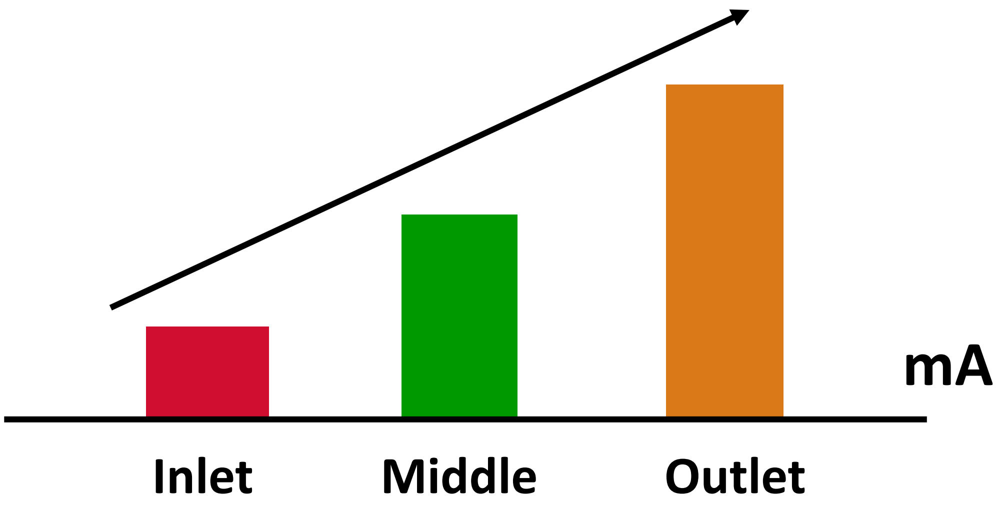
Second, Check ESP Current From Inlet to Outlet. How Much it will Increase from Field to Field is Slightly Complicated. Keep it Simple.

Good Dust					AVC Readings
AVC	AMPS	VOLTS	mAMPS	KV	SPM
1	60	365	300	43	30
2	90	350	500	38	30
3	240	345	1390	40	10
4	240	310	1450	39	0

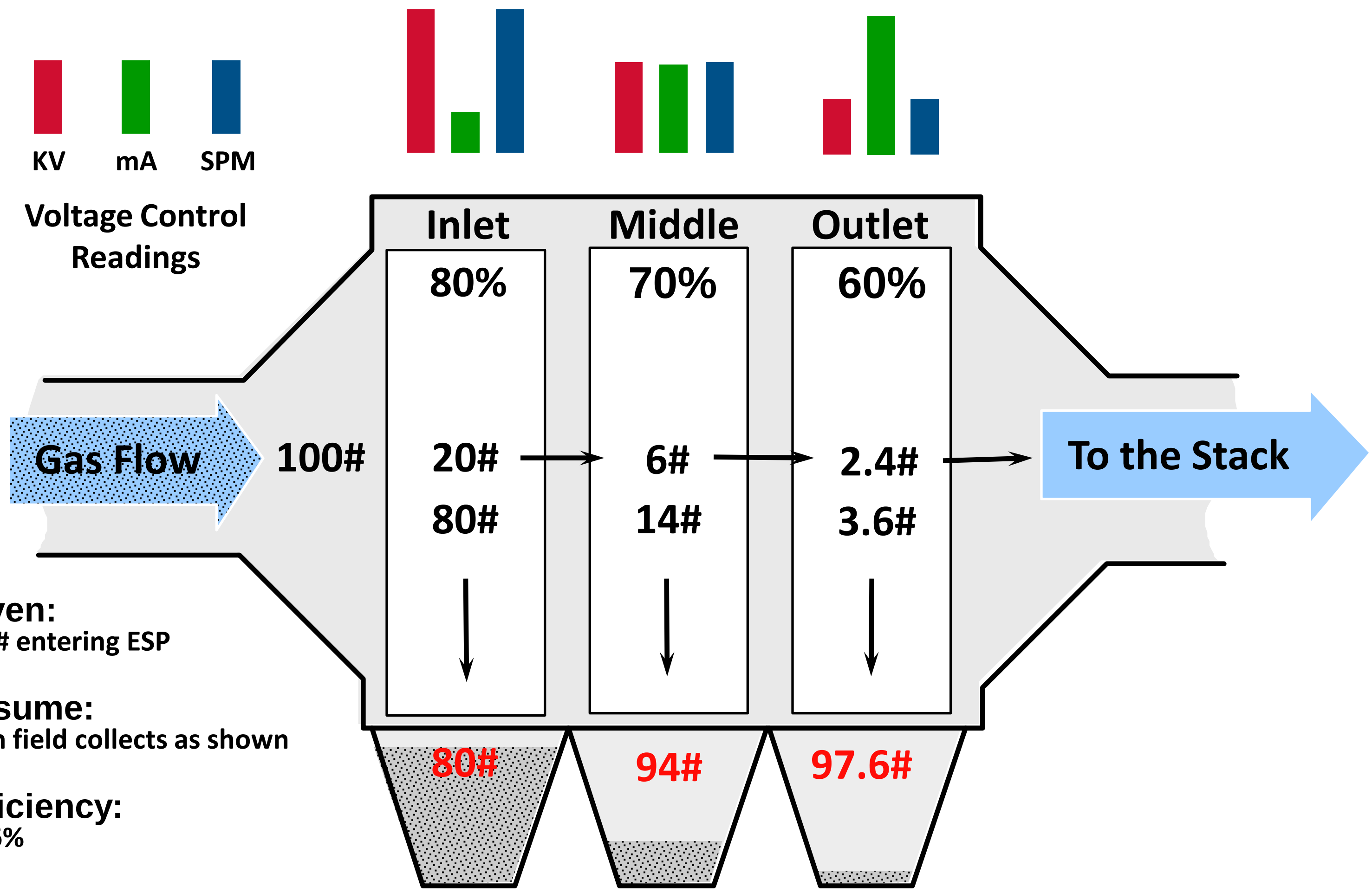
Here, the ESP current is increasing from inlet to outlet. The ESP is behaving.

Typical Trends for all ESPs
(ESP current increases from inlet to outlet)

Always look for this trend, IF THE FIELDS ARE THE SAME SIZE



Incremental Collection Efficiency and Secondary Operating Conditions



Given:
100# entering ESP

Assume:
Each field collects as shown

Efficiency:
97.6%

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

Third, Sparking Usually Decreases From Inlet To Outlet, But Not Always.

Good Dust					AVC Readings
AVC	AMPS	VOLTS	mAMPS	KV	SPM
1	60	365	300	43	30
2	90	350	500	38	30
3	240	345	1390	40	10
4	240	310	1450	39	0

Is Anything Wrong With This ESP?

(Same ESP design as previous example.)

Good Dust					*AVC Readings*
AVC	AMPS	VOLTS	mAMPS	KV	SPM
1&2 T-R	120	400	750	45	30
1	60	365	300	43	30
2	32	265	170	32	40
3&4 T-R	240	400	1500	45	30
3	220	325	1270	39	28
4	240	310	1450	39	0

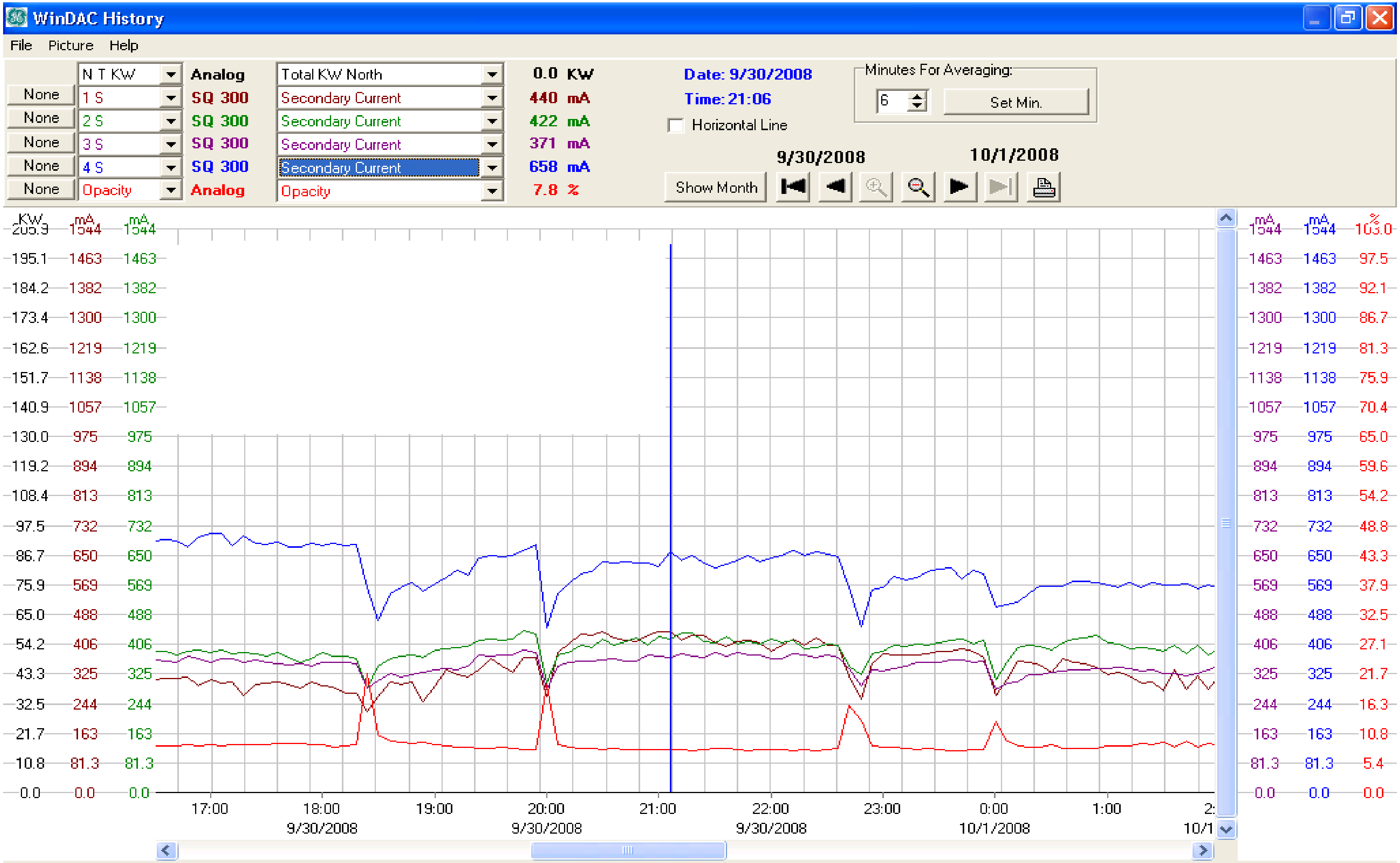
Correct, Field 2 is not running properly. It is seriously exceeding its spark limit and its ESP current is lower than the upstream field. What could be the reason?

Good Dust					AVC Readings
AVC	AMPS	VOLTS	mAMPS	KV	SPM
1&2 T-R	120	400	750	45	30
1	60	365	300	43	30
2	32	265	170	32	40
3&4 T-R	240	400	1500	45	30
3	220	325	1270	39	28
4	240	310	1450	39	0

Is it a Process Problem, or an ESP Problem?

Good Dust					***AVC Readings***
AVC	AMPS	VOLTS	mAMPS	KV	SPM
1	60	365	300	43	30
2	32	265	170	32	40
3	220	325	1270	39	28
4	240	310	1450	39	0

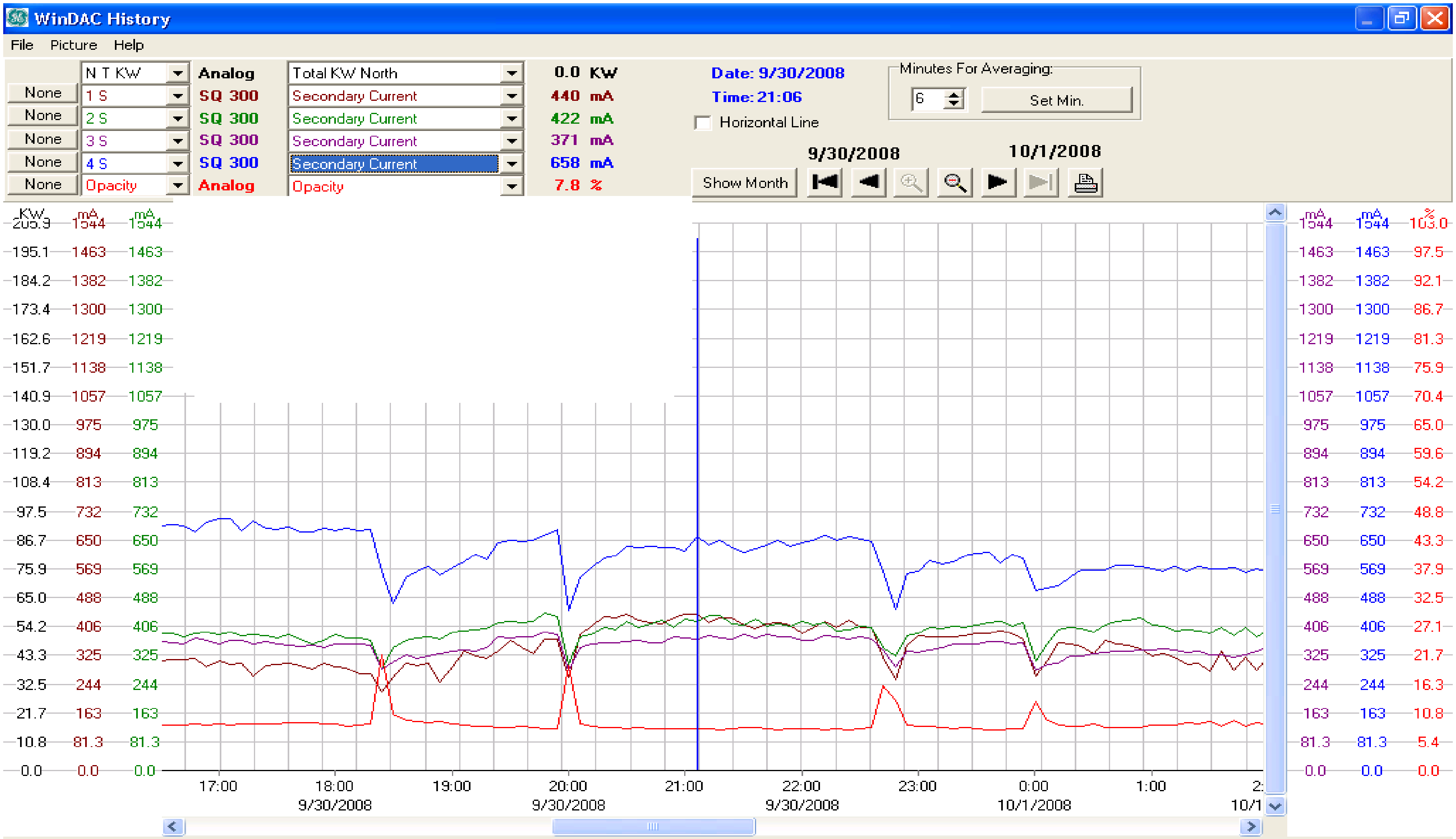
Example: Process or ESP Problem?



Is it a Process Problem, or an ESP Problem?

1. **If it is process, usually fields 2 thru 4 will *each* be affected.**
2. **If it's an ESP problem, then *only that field* with the problem will be affected.**

The mA Meter is the Best Barometer to Detect Problems. Much Better than the KV Meter. KV is too Subtle.



Two Different Sized TR Sets. Which is Helping Its ESP, More? The One Operating at 1000mA or the One at 550mA?

TR SET		VOLT	AMP	mA	KV	KW	SPM
1	RATING	480	328	2000	55	110	30
	OPERATING VALUE	320	155	1000	39	39	29
		VOLT	AMP	mA	KV	KW	SPM
2	RATING	400	120	750	45	33.75	30
	OPERATING VALUE	330	85	550	36	19.8	31

TR Set #2 is the Winner! This Introduces the Concept of Current Density.

TR SET		VOLT	AMP	mA	KV	KW	SPM	AREA TR ENERGIZES	CURRENT DENSITY
1	RATING	480	328	2000	55	110	30	50,000	40.0
	OPERATING VALUE	320	155	1000	39	39	29	50,000	20.0
		VOLT	AMP	mA	KV	KW	SPM	AREA TR ENERGIZES	CURRENT DENSITY
2	RATING	400	120	750	45	33.75	30	10,000	75.0
	OPERATING VALUE	330	85	550	36	19.8	31	10,000	55.0

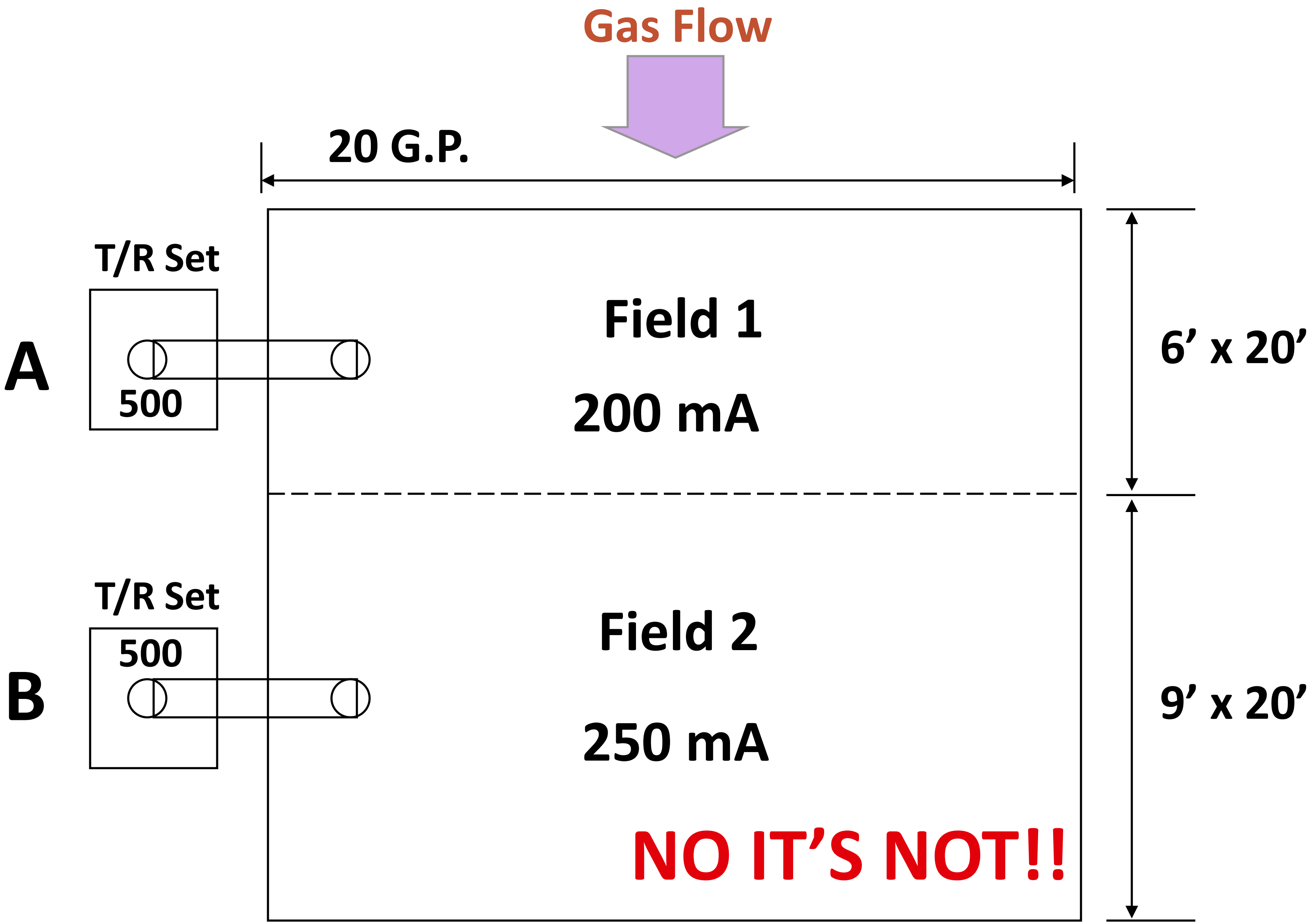
TR Set #2 has almost 3 times (55 vs 20 uA/ft^2) the current per square foot as TR Set #1!!!

And that is what the ESP cares about, how much current it is getting per square foot.

Current Density

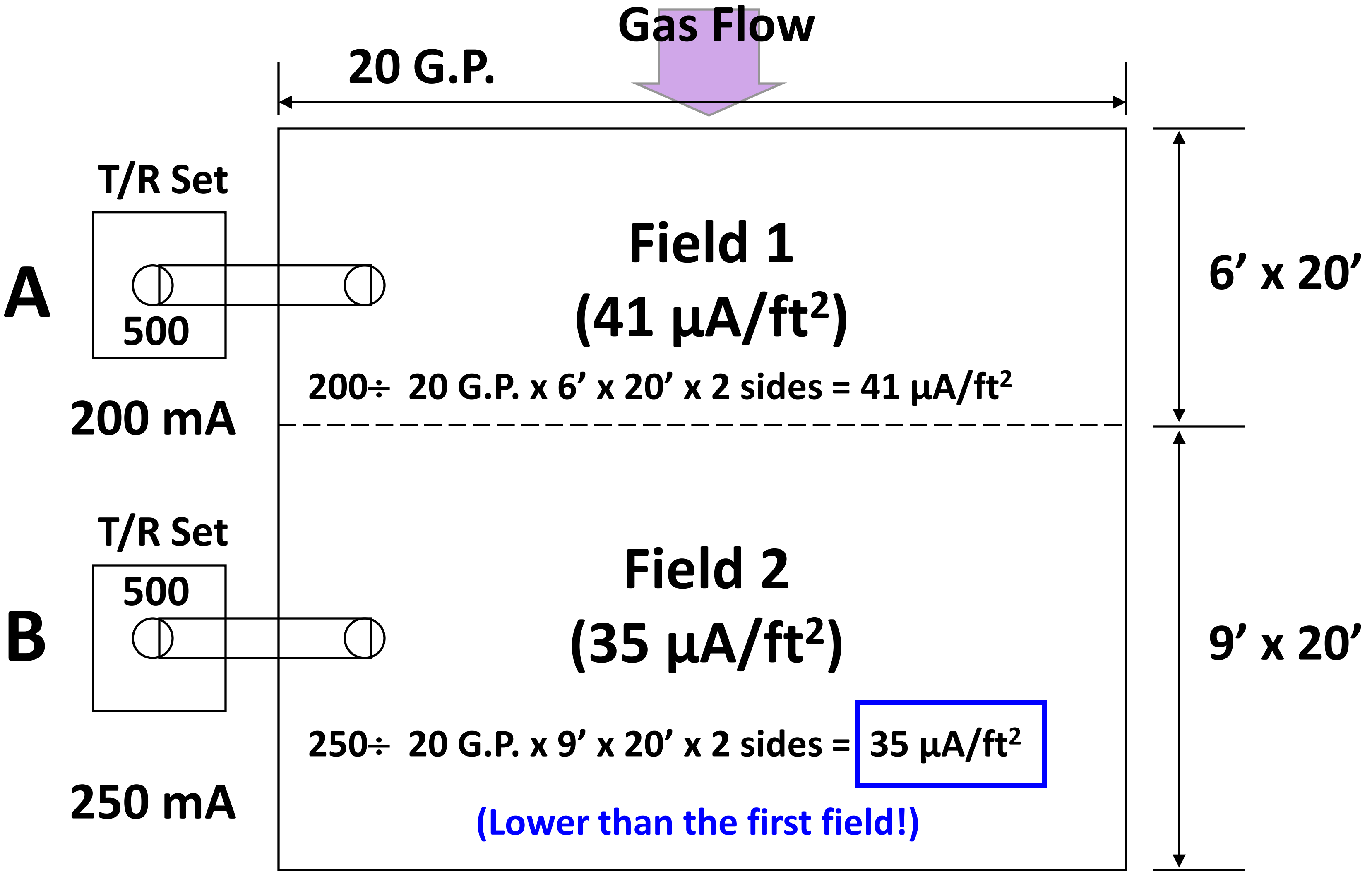
1. **Enables a true comparison of ESP current for T/R sets not energizing the same area of collecting plates.**
2. **Generally accepted values for low and high resistivity dust, can aid in troubleshooting.**

Is This Two-Field ESP Running Properly?



NO IT’S NOT!!

Because the fields are different sizes, there is more current per square foot in the inlet than the outlet. That doesn't follow the rules.



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 ($\mu A/ft^2$)
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 40μA/ft^2

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

(Accompanied by sparking in all fields)

Example of Using Current Densities to Expose Why an ESP is Sick. (Green = Good, Red = Bad)

T-R LOCATION UNITS	T-R NAME	AREA ENRGZ'D FT^2	GAS PASS WIDTH IN.	DENSITY RANGE	SECONDARY CURRENT mA	CURRENT DENSITY uA/FT^2	SECONDARY VOLTAGE KV	SECONDARY POWER KW	SPARK RATE SPM
1A	1W	10,962	6.25		230	21.0	27.1	6.2	58
1B	1C	10,962	6.25	10-20	200	18.2	30.6	6.1	0
1C	1E	10,962	6.25		140	12.8	27.4	3.8	45
2A	2W	10,962	6.25		170	15.5	26.1	4.4	54
2B	2C	10,962	6.25	20-30	130	11.9	12	1.6	0
2C	2E	10,962	6.25		250	22.8	4.8	1.2	0
3A	3W	10,962	6.25		80	7.3	25.9	2.1	52
3B	3C	10,962	6.25	30-50	40	3.6	35.9	1.4	0
3C	3E	10,962	6.25		170	15.5	31.6	5.4	34
TOTAL		98658			1410			32.266	243

SHOW T-R NAMES IN LOCATION, HERE:								W/ FT^2	0.33
		1	2	3	4	GAS PSG		W/1000ACFM	84.5
	WEST	1W	2W	3W		58@6.25"		TOTAL DENSITY	14.3
	CENTER	1C	2C	3C		58@6.25"	?/??/???? PM TEST		#/MMBtu
	EAST	1E	2E	3E		58@6.25"		TOTAL	
	TR SIZE	1000mA	1000mA	1000mA				FLTERABLE	
FIELD DIMENSION		4.5X21'	4.5X21'	4.5X21'				CNDNSBLE	

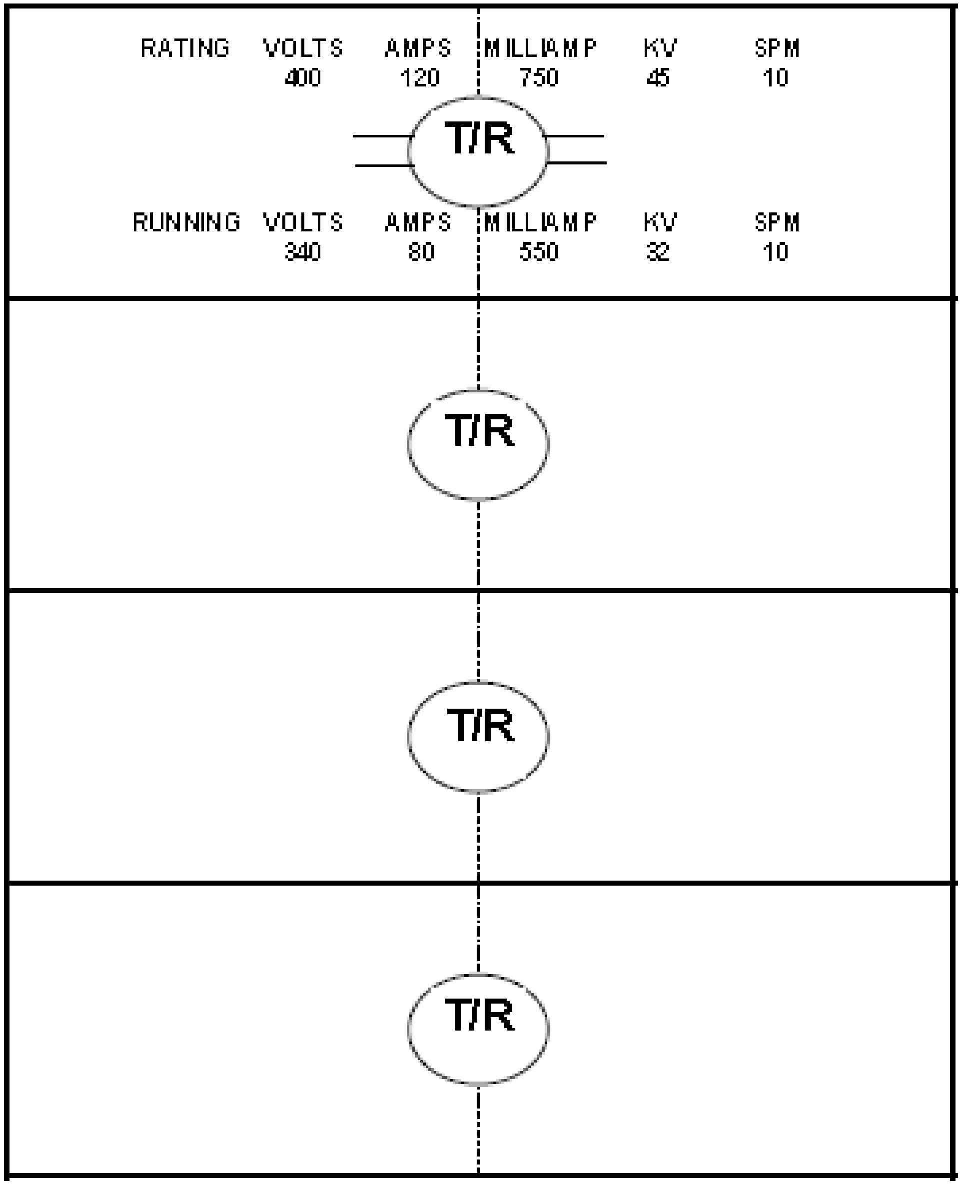
T-R Evaluation

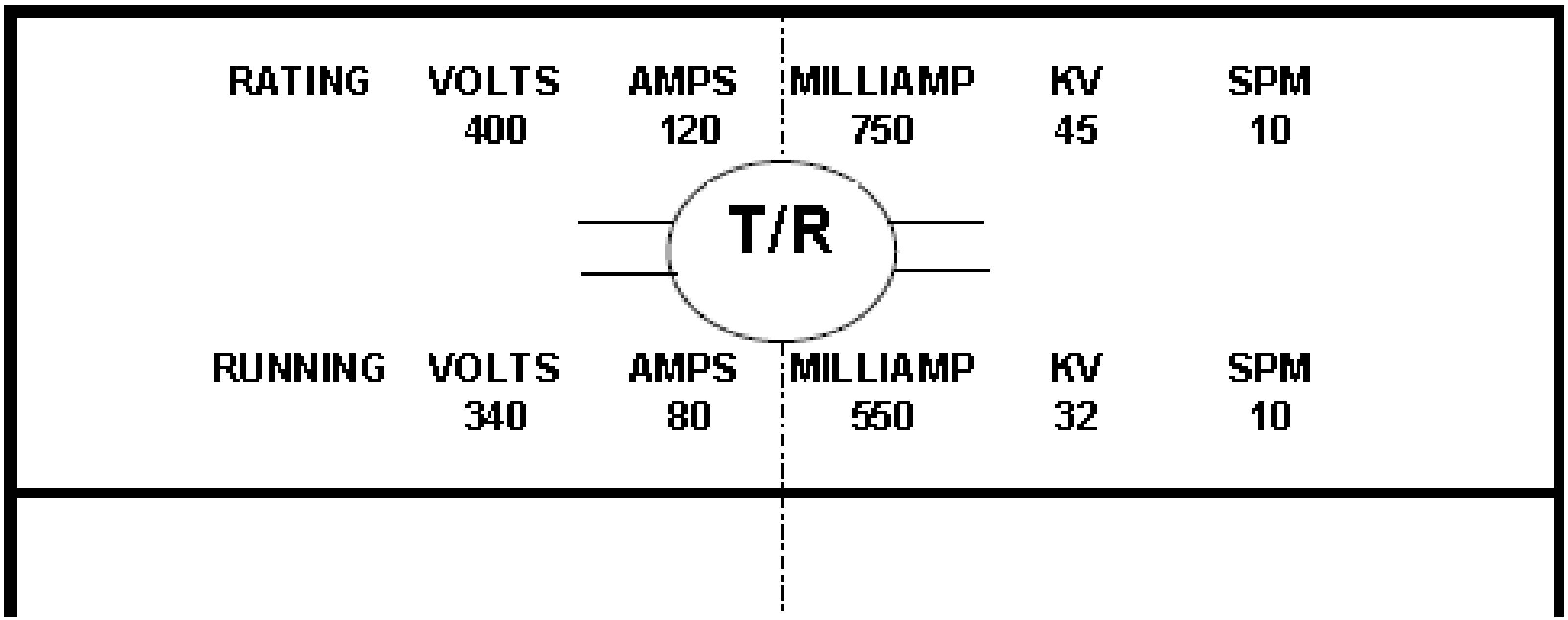
- In general, 18,000 ft^2 per TR set or less
- For best ESP performance, attempt to size TR set to run at 70 – 100% of full load
- Based on current density, for conductive dust, use 30, 40, 50, and 70 microamps per square foot for fields 1 – 4, respectively.

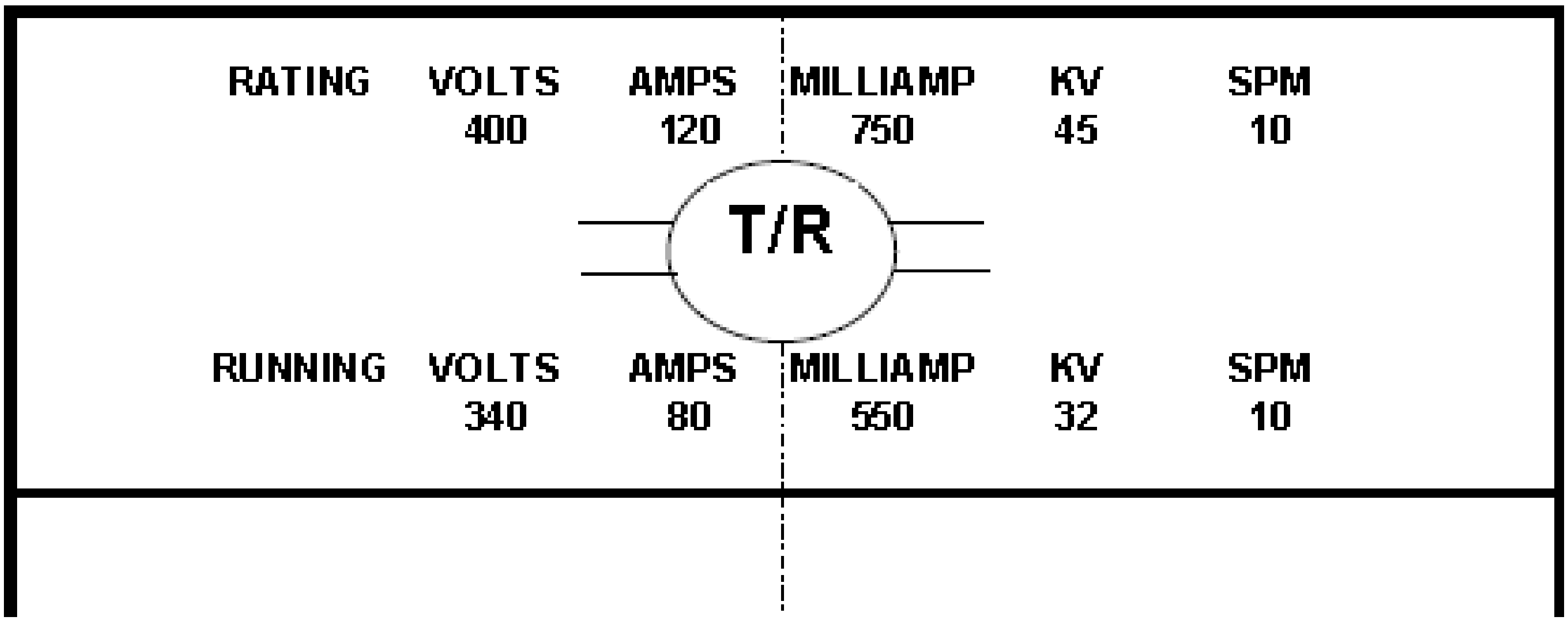
T-R Sets

Could the efficiency of this ESP be increased by replacing this T-R with a bigger one?

(closer view next slide)




RATING
VOLTS 400
AMPS 120
MILLIAMP 750
KV 45
SPM 10
T/R
RUNNING
VOLTS 340
AMPS 80
MILLIAMP 550
KV 32
SPM 10

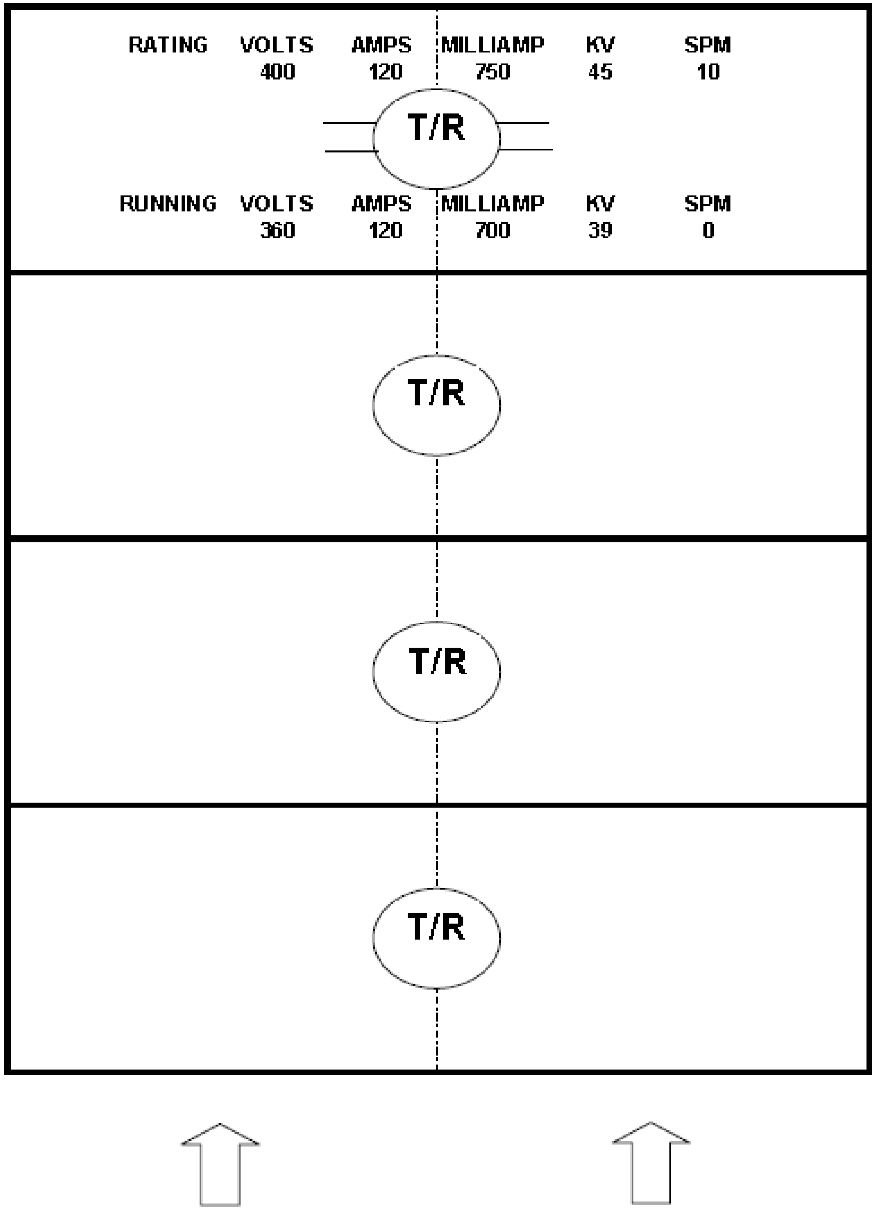


Most probably not. The bigger T-R would still be limited by the 32KV sparkover voltage and produce less than 550mA because of the poor form factor. Bigger is not always better.

T-R Sets

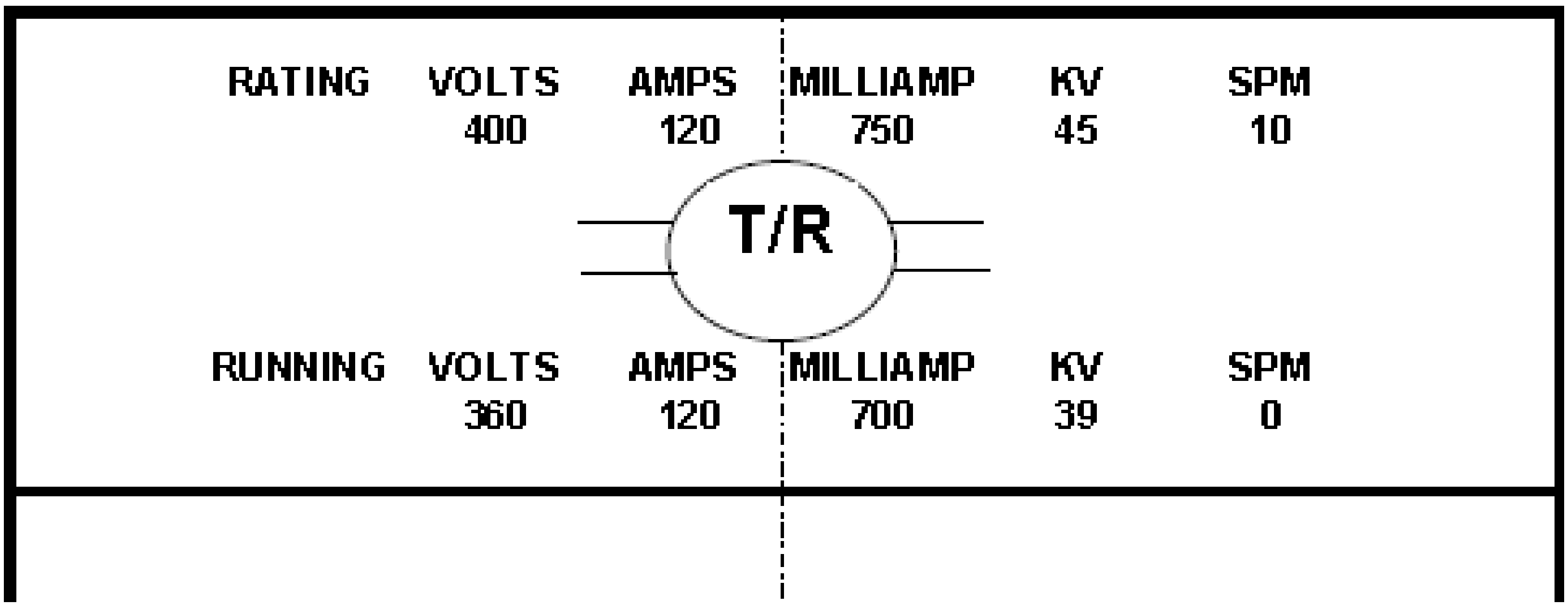
Could the efficiency of this ESP be increased by replacing this T-R set?

(closer view next slide)



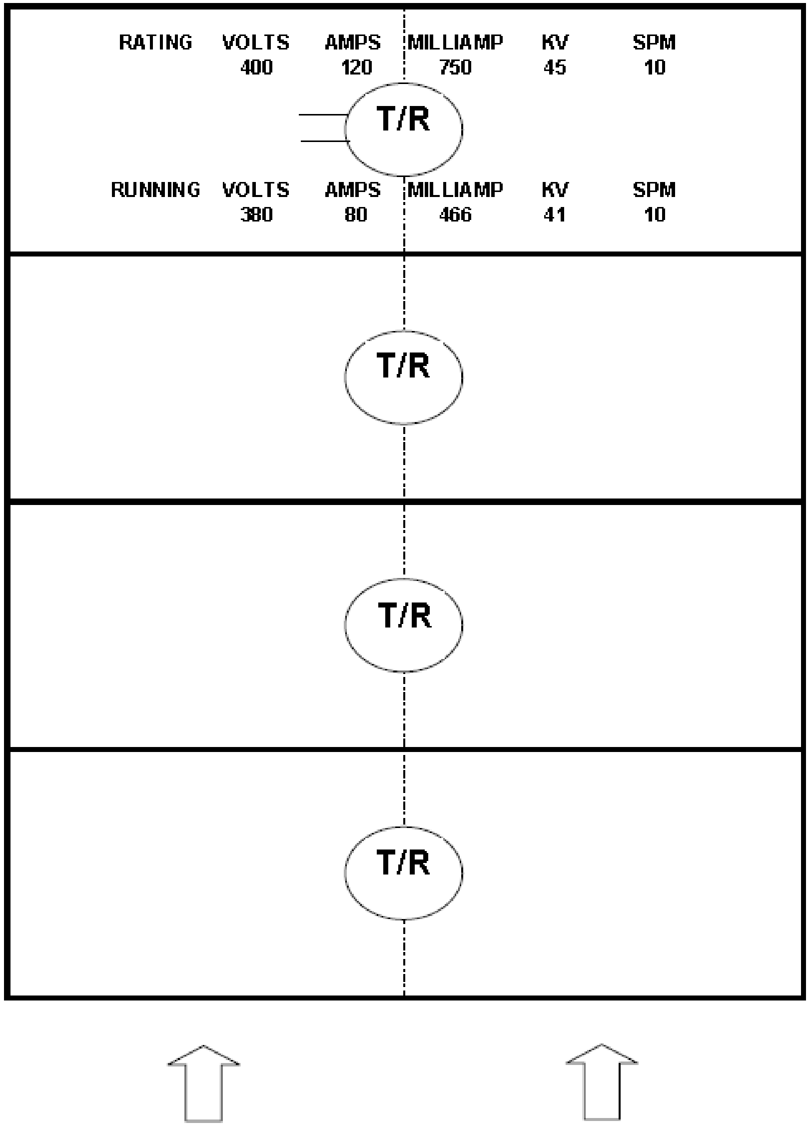
Could the efficiency of this ESP be increased by replacing this T-R set?

(Closer View)

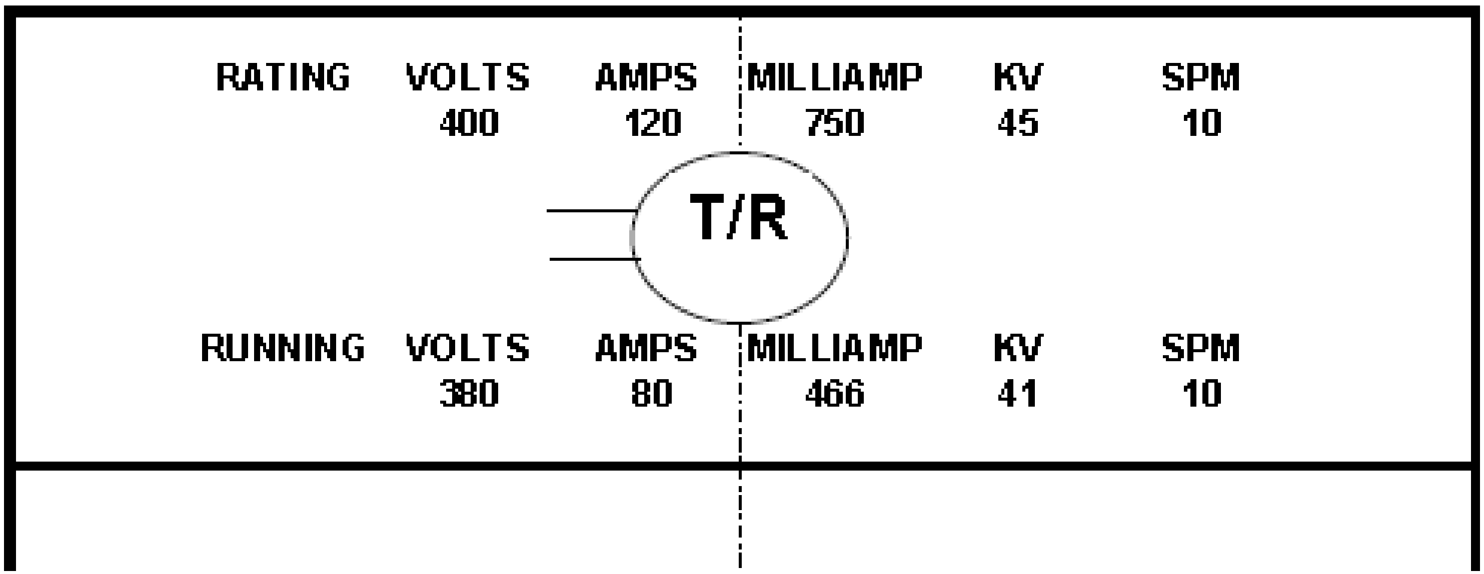


Possibly.

Experiment by energizing one bushing at a time and see what the results are for each bus section.

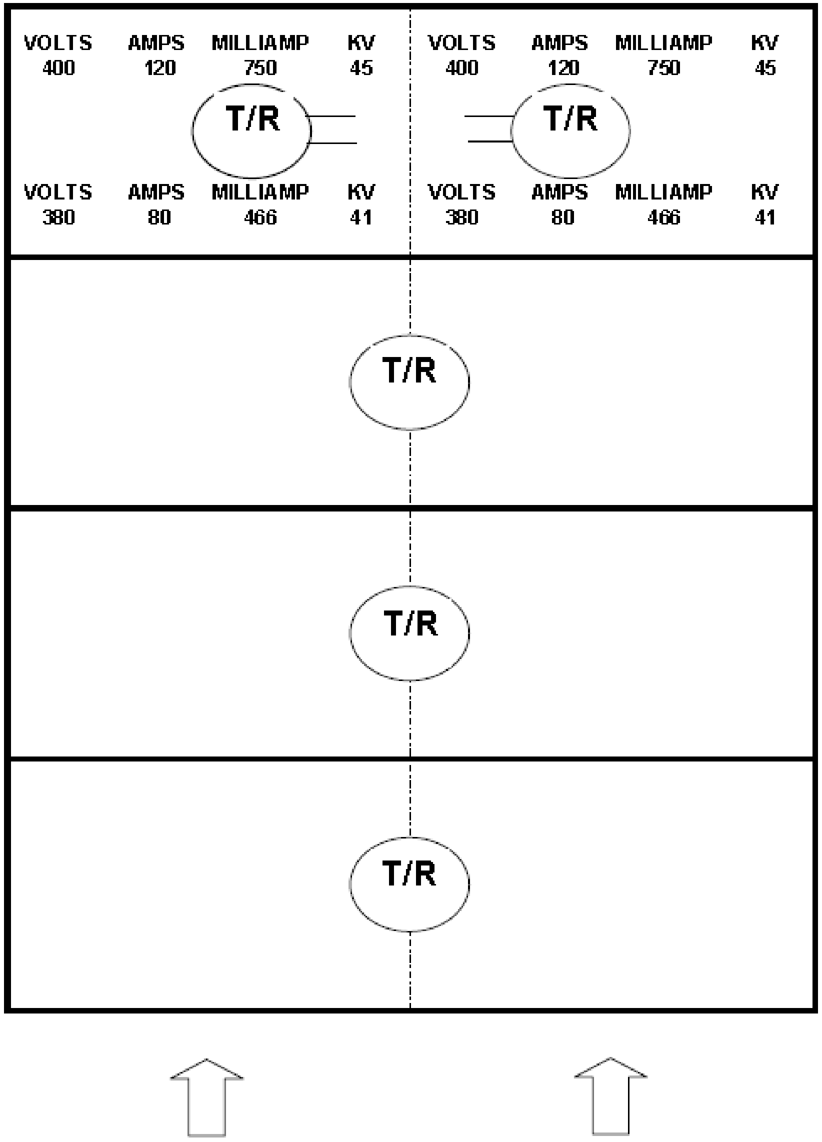


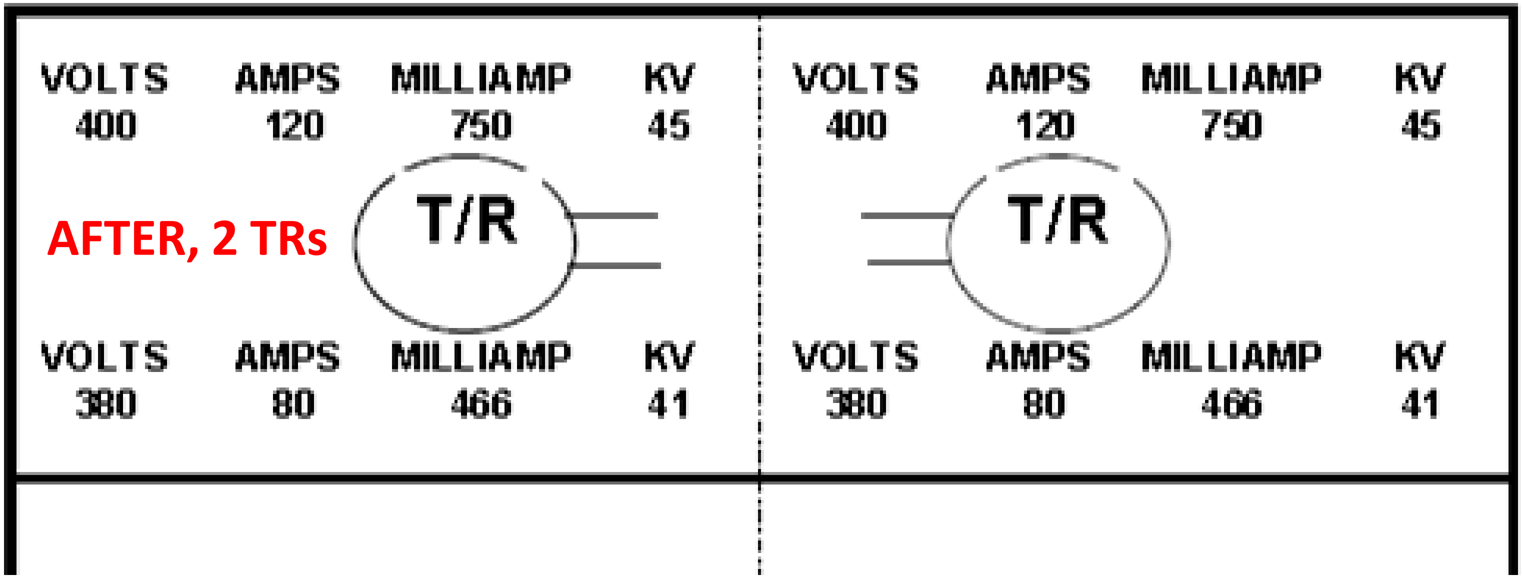
Results with Just One of the Two T-R Set Sections Energized.

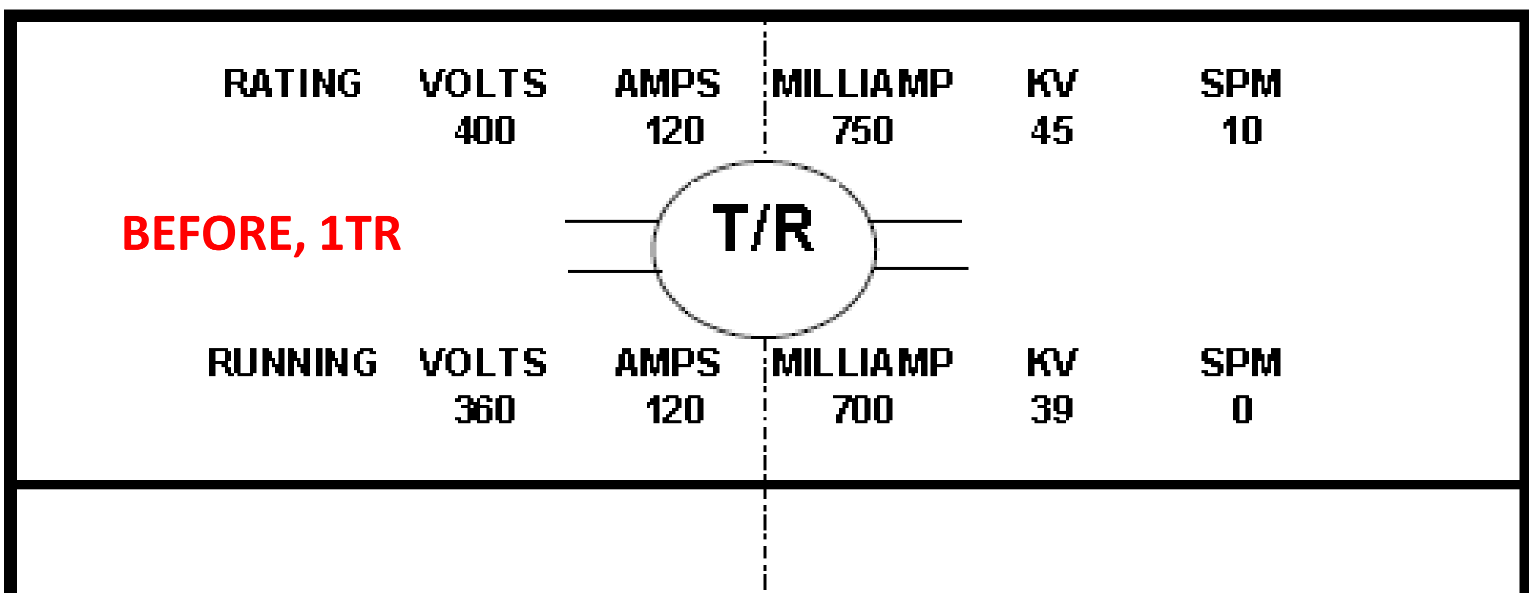


When the T-R was energizing both sections, each section got 700mA/2 = 350mA/section. Here, one section alone runs at 466mA, much more total power. This section of the ESP is capable of powering-up.

Your experiment shows that adding a second T-R would be the best way. More power means higher efficiency if you are on the straight part of the curve

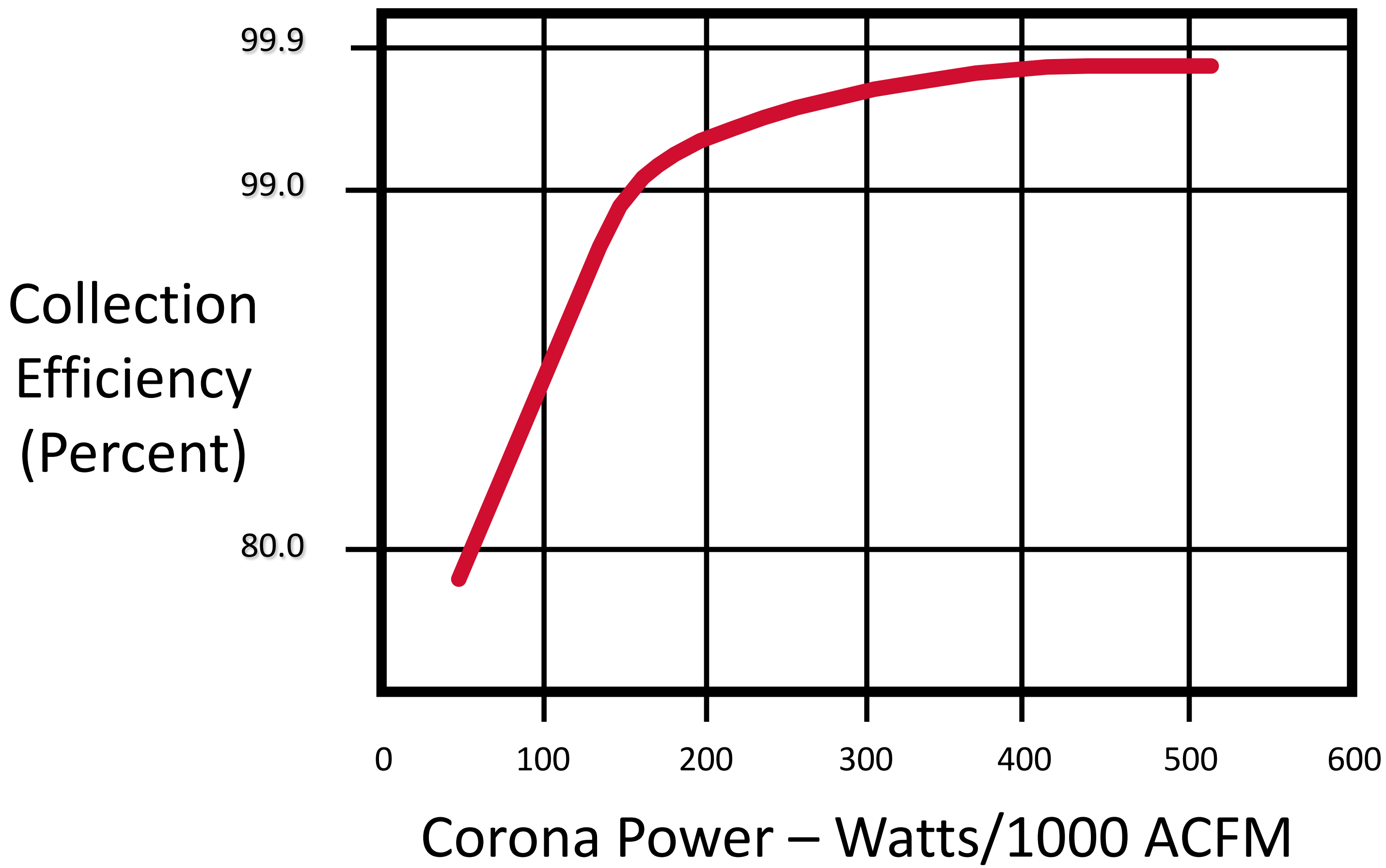


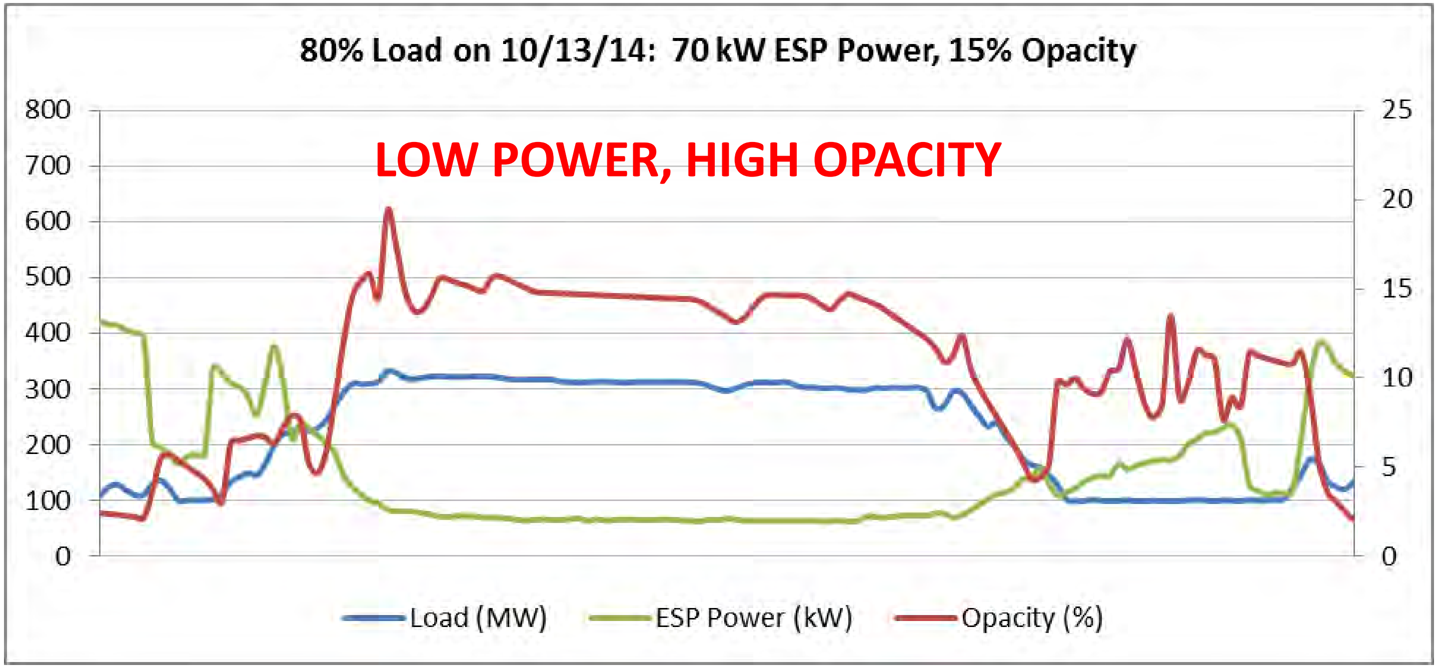

AFTER, 2 TRs
VOLTS 400
AMPS 120
MILLIAMP 750
KV 45
T/R
VOLTS 380
AMPS 80
MILLIAMP 466
KV 41
VOLTS 400
AMPS 120
MILLIAMP 750
KV 45
T/R
VOLTS 380
AMPS 80
MILLIAMP 466
KV 41

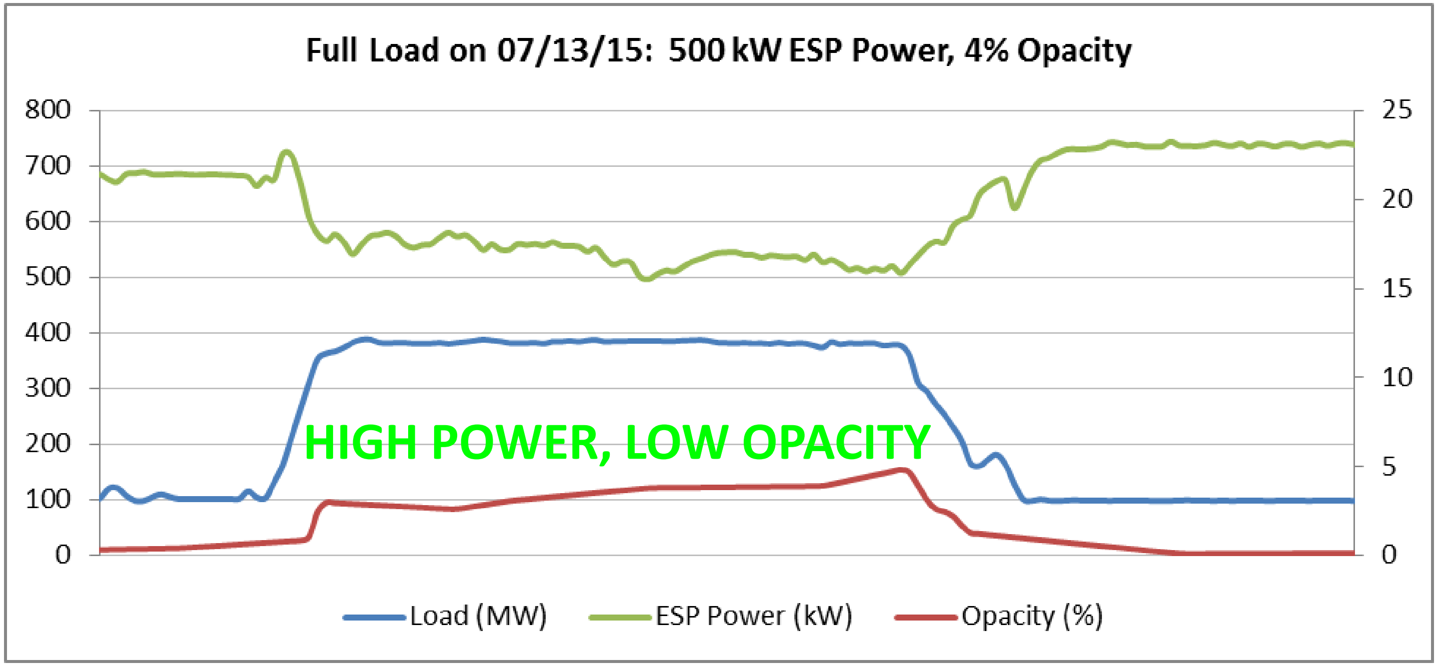

BEFORE, 1TR
RATING
VOLTS 400
AMPS 120
MILLIAMP 750
KV 45
SPM 10
T/R
RUNNING
VOLTS 360
AMPS 120
MILLIAMP 700
KV 39
SPM 0

Efficiency vs. Specific Corona Power

Everyone should be trending the total power (kW) at which their ESP operates.







Example of Role ESP Power (kW) can have on Opacity.

To Achieve Higher ESP Power, the ESP Must Be in Good Shape

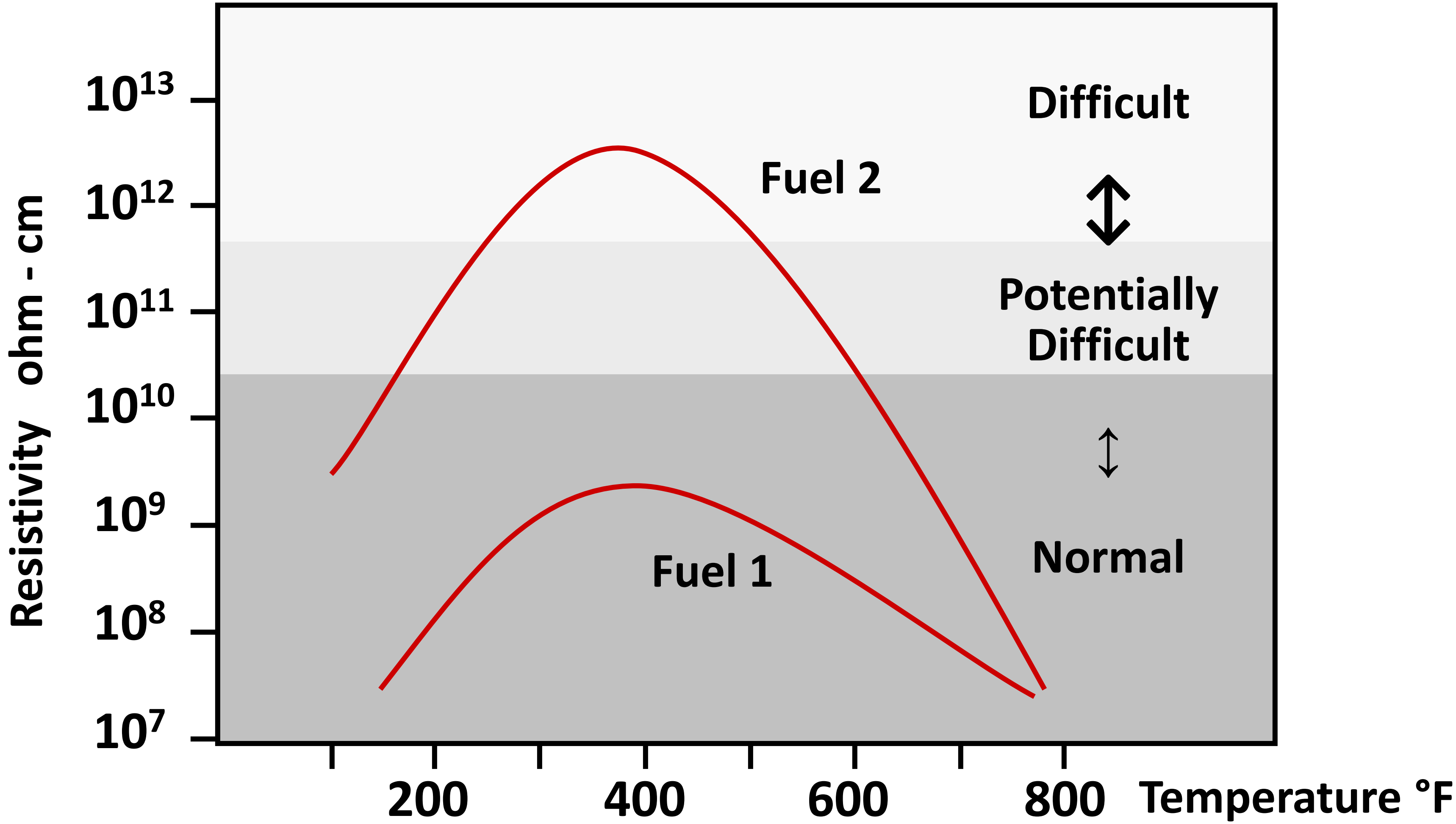
1. New power supplies alone, won’t always cut it.
2. Warped plates/electrode alignment
3. Gas flow balance and distribution
4. Ineffective rapping system
5. T- sets undersized or energize too large an area
6. Air inleakage
7. Temperature maldistribution

Fuel Impact on ESP Performance

Most difficult ash for an ESP

1. Low sulfur (S) in the coal < 1.0%. Increases ash resistivity.
2. Low sodium (Na_2O) in ash < 1.2%. Lower sodium increases ash resistivity, even on cold-side ESPs. A definite must for hot-side ESPs.
3. Low iron (Fe_2O_3) in ash < 5.0%. Increases ash resistivity.
4. Combined content of silica (SiO_2) and alumina (Al_2O_3) in ash > 80%. Both increase ash resistivity.
5. Combined content of calcium (CaO) and magnesium (MgO) in ash > the iron (Fe_2O_3) content. Both increase ash resistivity.

Particulate Resistivity – Good Dust vs. Bad Dust



Besides fuels, flue gas temperature has a strong effect on ash resistivity

Sorbents and the ESP

- Fuel switching to a low chlorine coal
- Dry sorbent injection of a calcium-based or sodium-based compound
  - Both sorbents will add to the amount of dust going to the ESP (inlet loading)
  - Sorbents may affect the dust resistivity
  - Sodium-based sorbents tend to decrease resistivity
  - Calcium-based sorbents tend to increase resistivity

How to Deal with ESP Problems

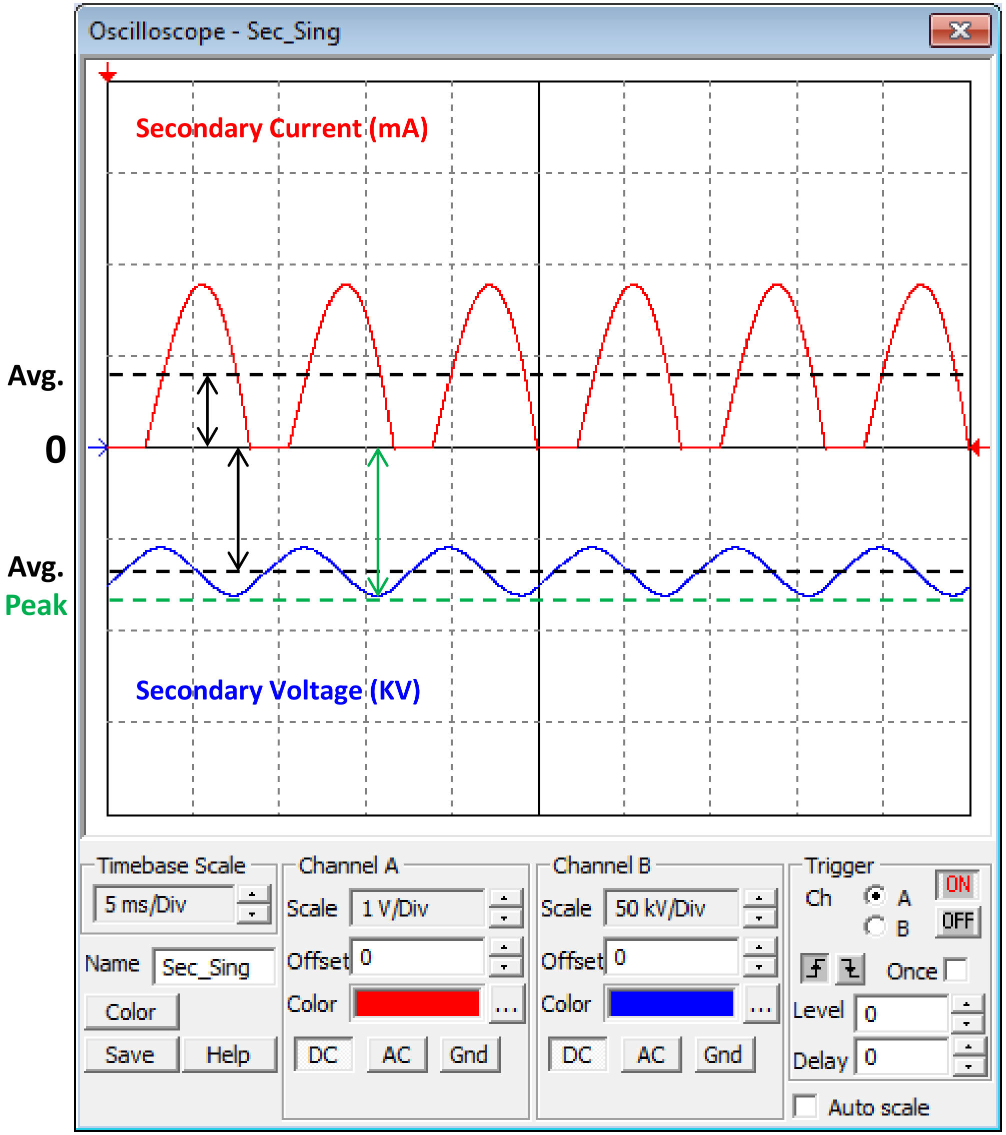
- Check and realign internals, as necessary, to restore electrical clearances to OEM specifications.
- Replace the ESP internals with new collecting plates and rigid discharge electrodes
- Increase the electrical sectionalization.
- Change out conventional, high ripple power supplies, to low ripple devices.
- Perform a model study to check for non-uniform gas flow and/or gas sneakage.
- Perform field studies to check for rapping re-entrainment.
- Rapping is your friend. Develop, if possible and if permitted, a good “power off” rapping program.

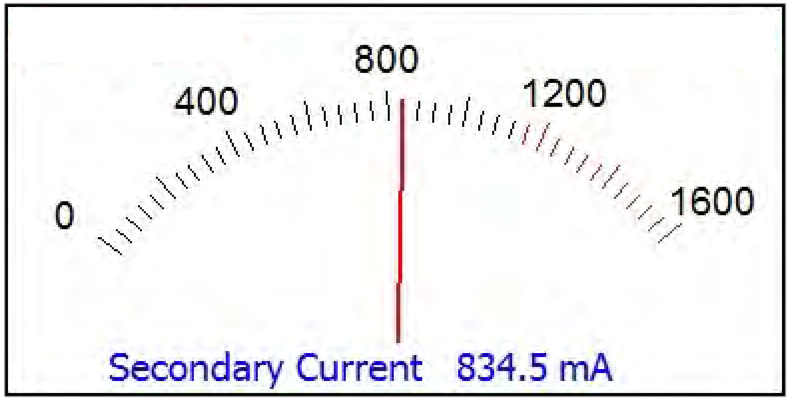
How to Deal with ESP Problems

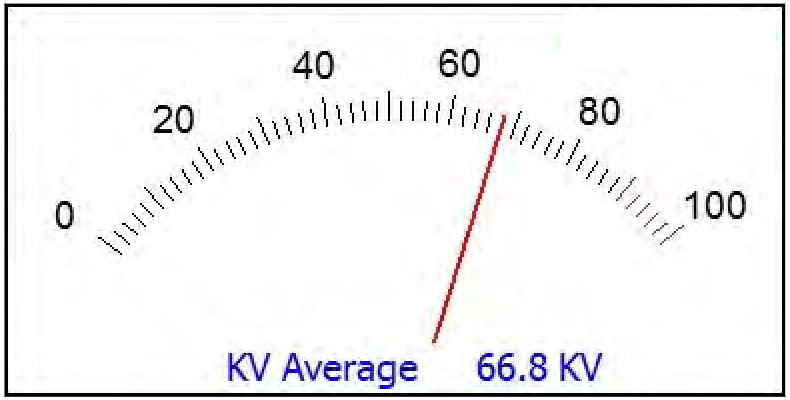
Low Ripple Power Supplies

- Change out conventional, high ripple power supplies, to low ripple devices
- Note, the emphasis is on the amount of ripple in the DC kV waveform and not the frequency
- The following slides emphasize why

Single-Phase Power – Supply Ripple in the kV



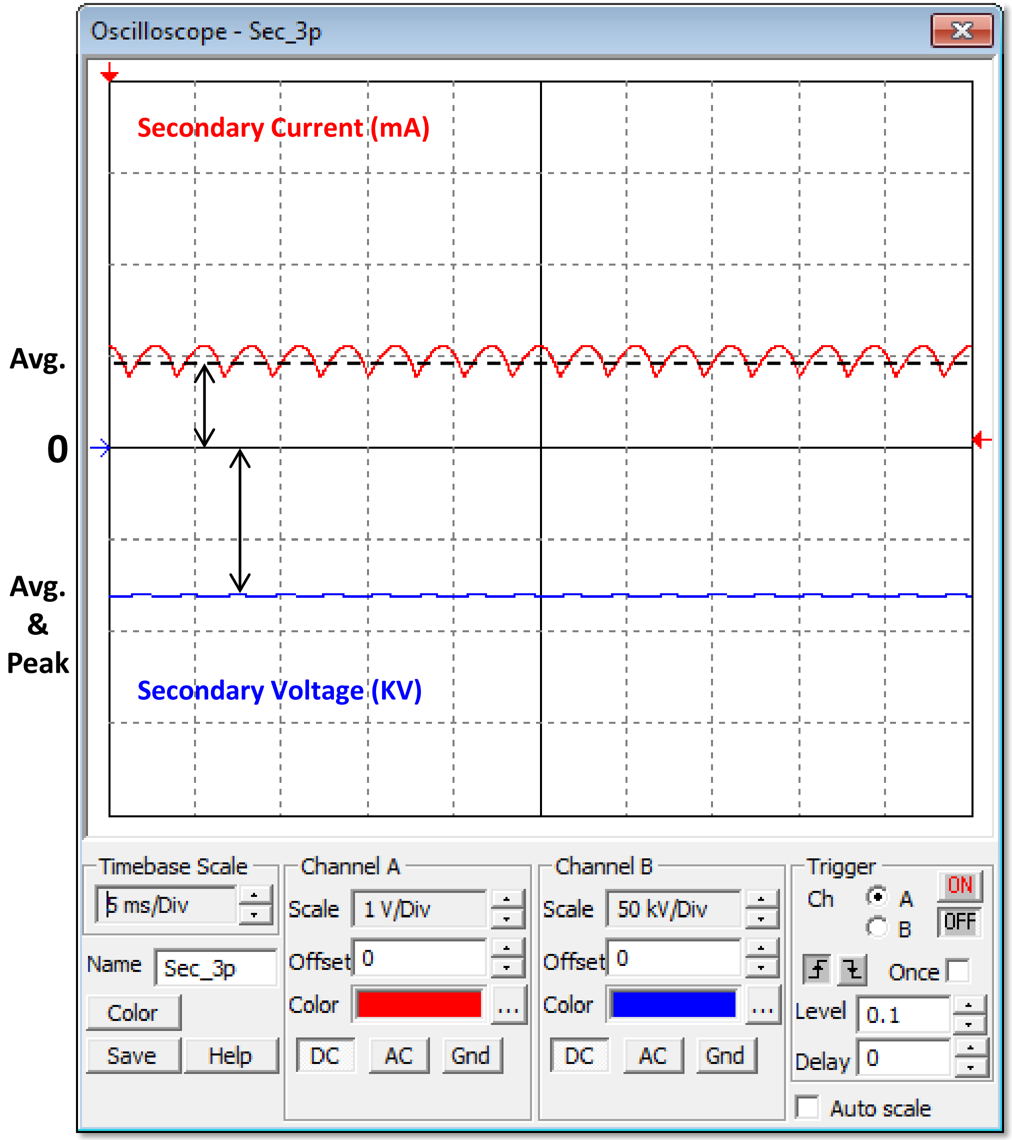


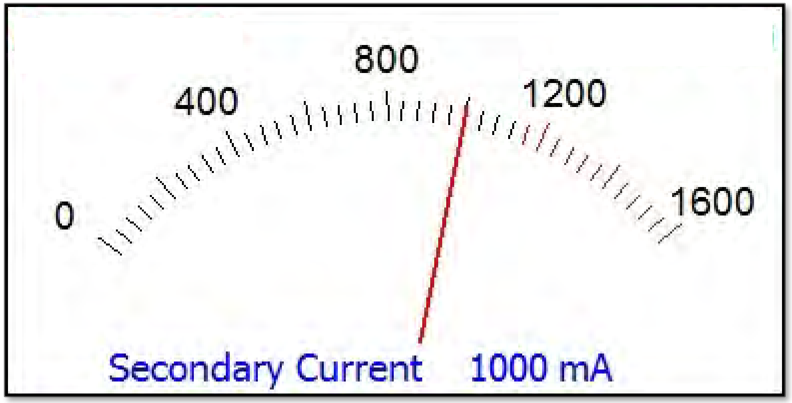


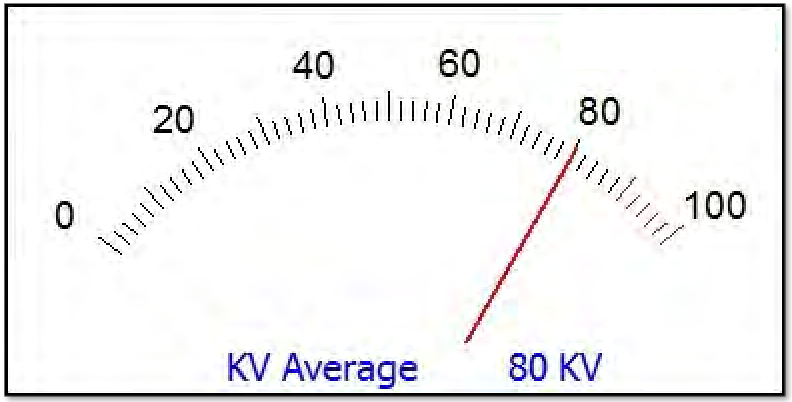
Peak to Avg. Voltage Ratio = 1.2

ω ≈ β * 67 KV Avg. * 80 KV Peak

3-Ph. Power Supply – Very Little Ripple in the kV







Peak to Avg. Voltage Ratio = 1.0

ω ≈ β * 80 KV Avg. * 80 KV Peak

Understanding Your ESP.
Why does it not Perform?

Questions?

Thank you.