GE Energy

BHA ESP Control Systems

Presented to:
Cinergy/Reinhold Users

Terry Farmer-Product Leader
11/16/2005

imagination at work

Key Components of the System

- SQ-300 Automatic Voltage Control
- WinDAC Data Acquisition and Control Software
- PRC-100 Rapper Control System
- Remote Diagnostics and Optimization

SQ-300® Automatic Voltage Controls

- Installation
- Delivering the Power
- Information is Power
- Troubleshooting

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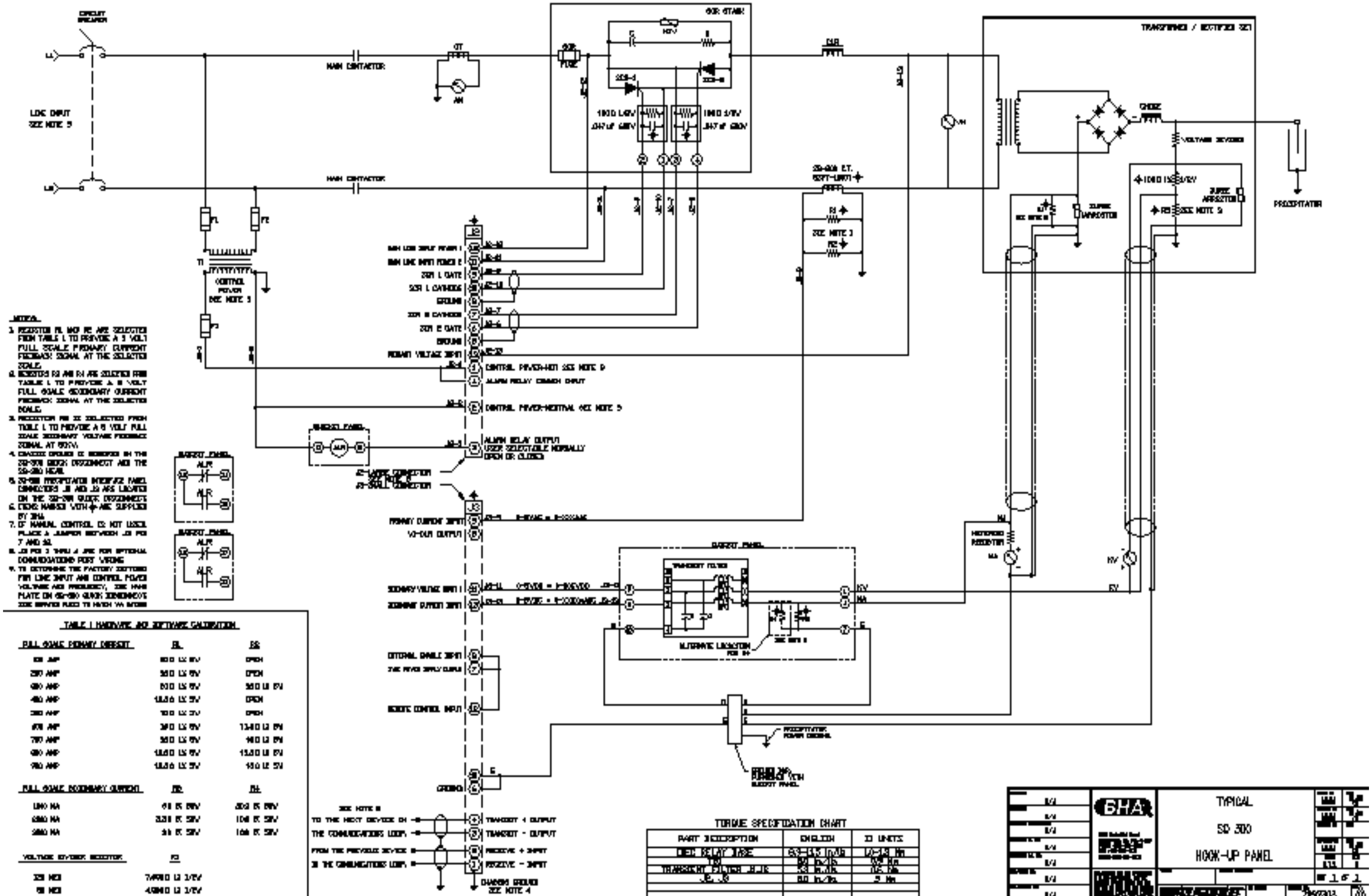
Installation Discussion Points

1. 90-95% of all of our sales are retrofit.
2. Good as is drawings are key.
3. Make a decision on reuse or rewire.
4. Typically, SCRs, breakers, contactors, alarm control circuitry and meters can be reused.
5. The SQ-300 comes with all necessary interface components. Scaling resistors, feedback filter boards and current transformer.
6. Once the control is mounted and the resistors are installed, there is no calibration required.
7. Retrofit or as-built drawings are generated each time

SQ-300® Automatic Voltage Controls



SQ-300® Automatic Voltage Controls

- A few representative installations

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- A few representative installations

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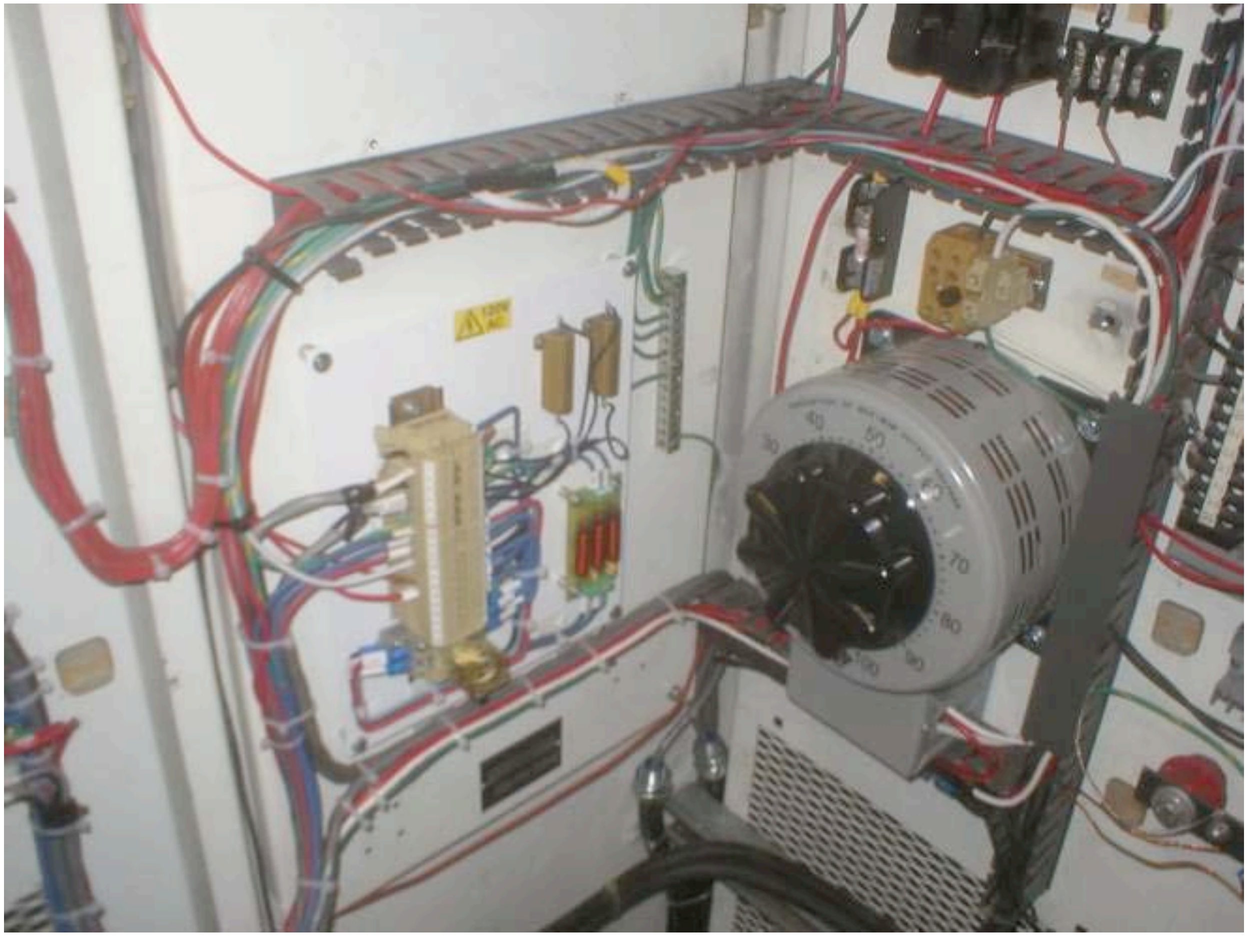

SQ-300® Automatic Voltage Controls

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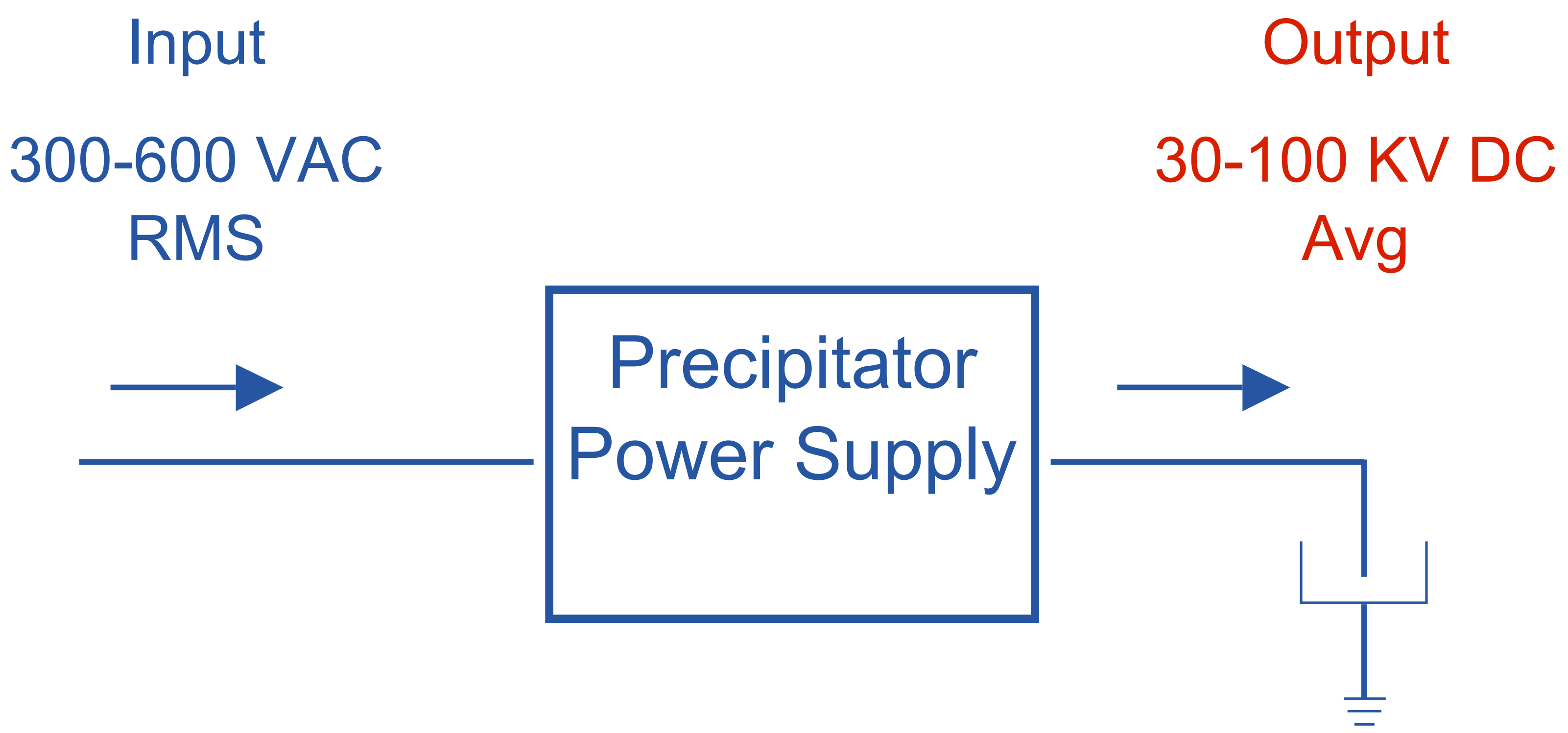
GE Proprietary

SQ-300® Automatic Voltage Controls

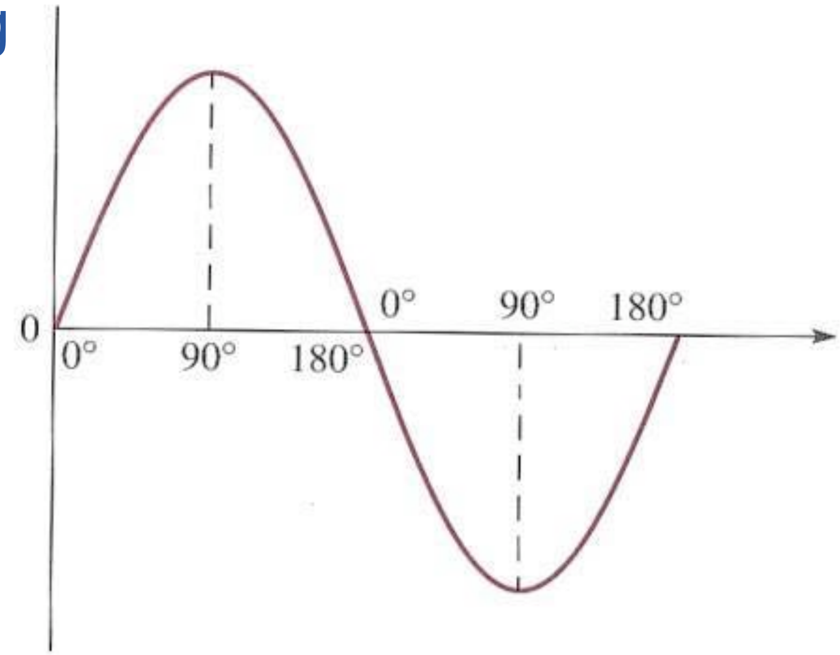


SQ-300® Automatic Voltage Controls

When the SQ-300 AVC starts to run, it ramps up power by starting at 180° and slowly decreases the firing angle towards 0°.

This continues until a spark, arc or T/R set limit is reached.

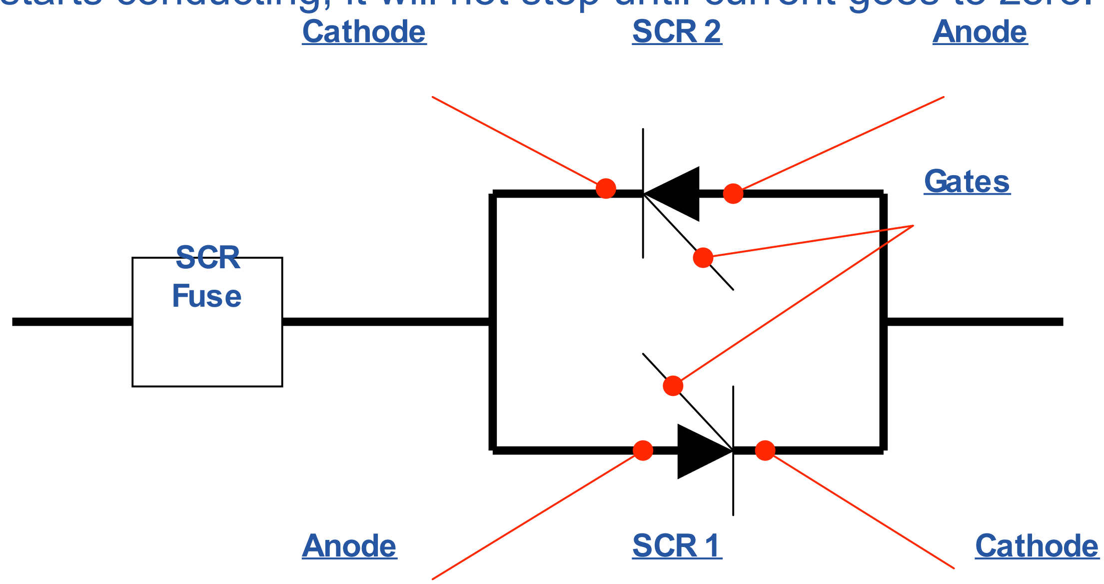
By controlling the SCRs, an SQ-300 AVC can control power to the T/R set.



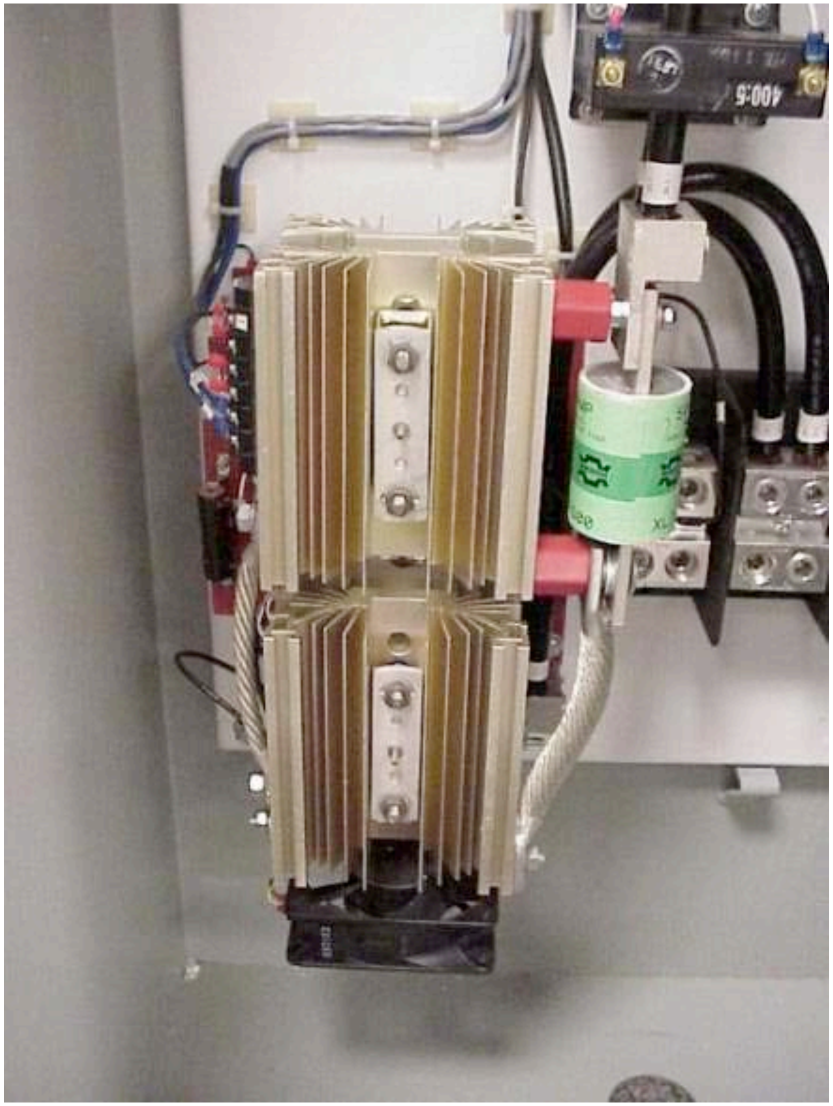
SQ-300® Automatic Voltage Controls

<u>The SCR Stack</u>
The SCR (Silicon Controlled Rectifier) stack is the device used to control power going to the primary of a TR set. The SCR Stack is composed of two inverse parallel SCRs. In general terms, it is called a “Switching” power supply. This configuration allows for controlling of an AC waveform on both the positive and negative half-cycles.

In order for an SCR to turn on, it must be forward biased and a gate signal applied from the SQ-300 AVC. Therefore when one SCR is forward biased, the other is reversed biased. Once an SCR starts conducting, it will not stop until current goes to zero.

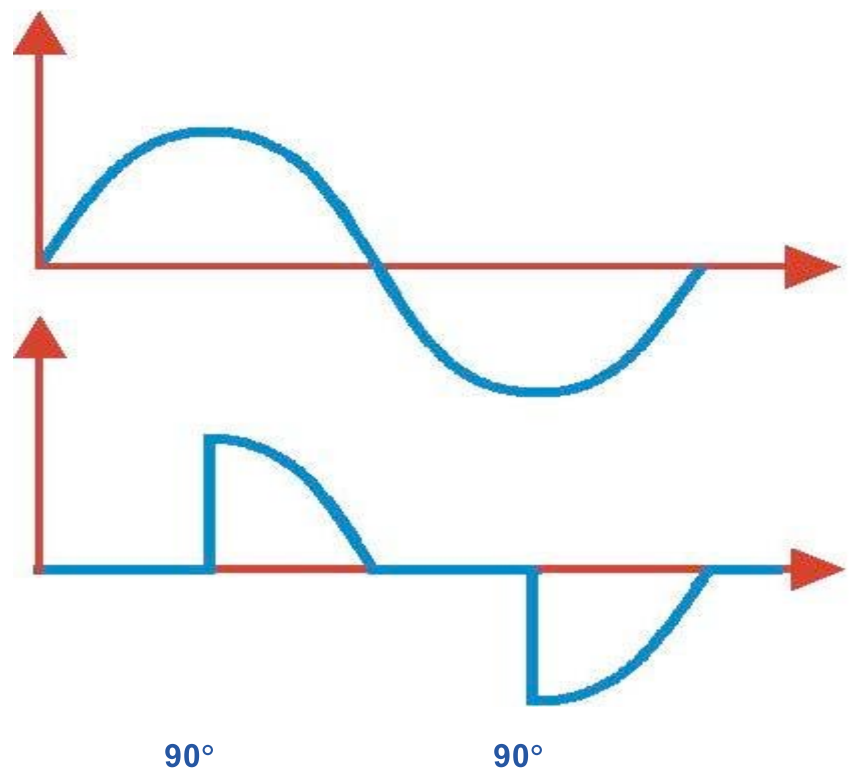


SQ-300® Automatic Voltage Controls



SQ-300® Automatic Voltage Controls

- The diagram would represent the waveform with the SCRs turning on at 90 °.
- If this waveform were applied to the T/R set, very inefficient operation would occur.
- Output power from the T/R set would be greatly reduced.



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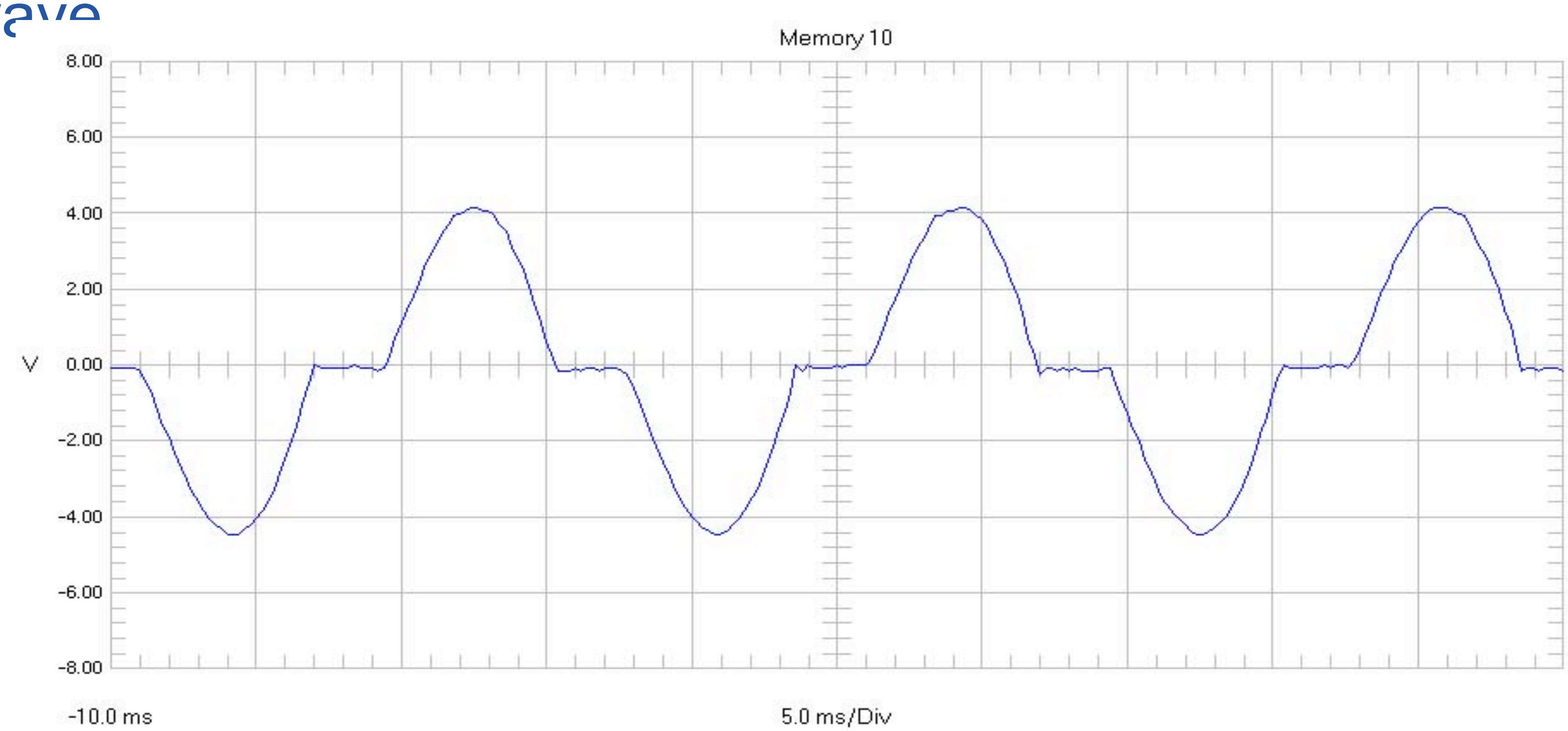
To increase the efficiency of the T/R set, a device called a CLR (current limiting reactor) is used. A CLR is an inductor. Recall that the property of an inductor is to oppose a change in current. Because of this property, the shape of the current waveform is changed and it starts looking more like a sine wave



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- CLRs are typically designed to be 50% of the impedance (inductance) of the T/R set. This allows for the best waveshape when the T/R set is at its rated limits.
- However, for a field that is not reaching its rated limits due to sparking, sizing the CLR based upon T/R limits would actually be detrimental.
- Since the field is running below rated limits, more impedance (inductance) is needed to shape the waveform to look more like sine wave.

SQ-300® Automatic Voltage Controls

- The value we look at to determine the shape of the waveform is called Form Factor.
- A pure AC waveform has a form factor of 1.11. Since we have a switching power supply (the SCR stack), the best form factor we can ever achieve is 1.20.
- With the control running at a form factor of 1.2, we have the best efficiency we can get, thereby the most power out of the TR set.

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One More Thing:

- The CLR has another function; it limits the current in the primary circuit when a spark occurs in the ESP.
- When a spark occurs, current increases dramatically.
- Without the CLR, and its property of inductance (to oppose a change in current), the current would increase to a point were it would blow fuses and trip breakers.

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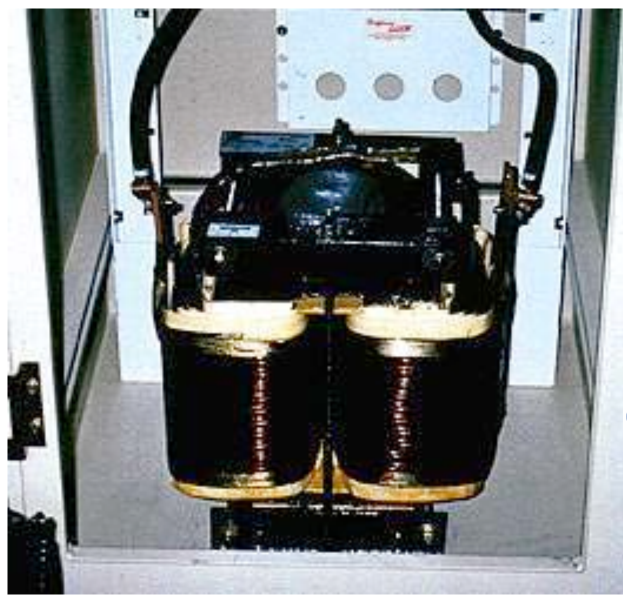
CLR

VI/CLR



CLR

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- The T/R set is divided up into two sections, the Transformer section and the Rectifier section.
- The Transformer section steps up the AC voltage from the primary to a very high AC voltage on the secondary.
- The Rectifier then converts the high voltage AC to high voltage DC (Direct Current) which in turn is applied to the precipitator field.
- Direct currents can fluctuate with time but will NEVER change polarity (cross zero).

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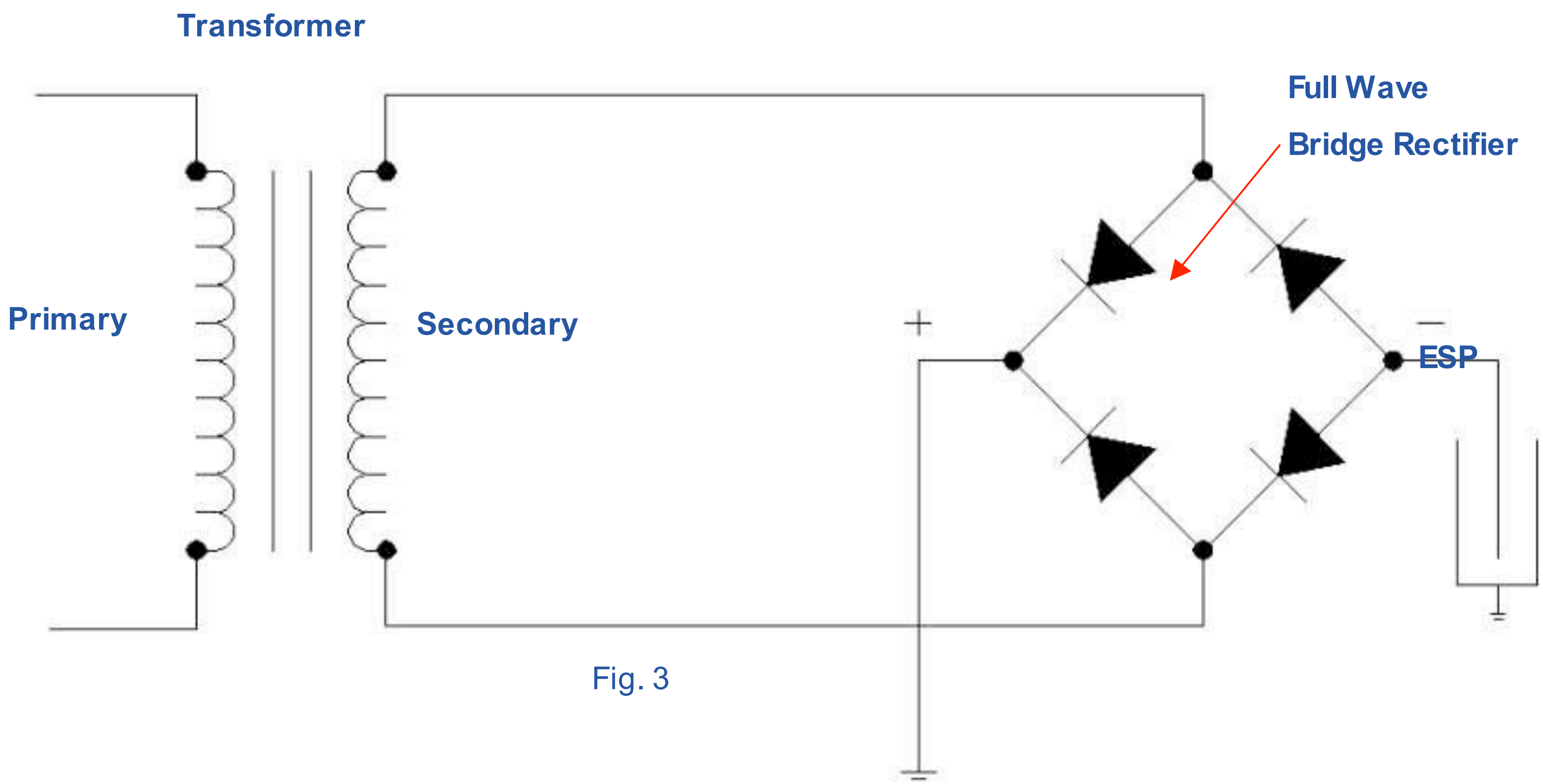

Fig. 3

Although the Bridge rectifier is shown as four diodes, it actually is not. Each diode represents hundreds of diodes in parallel.

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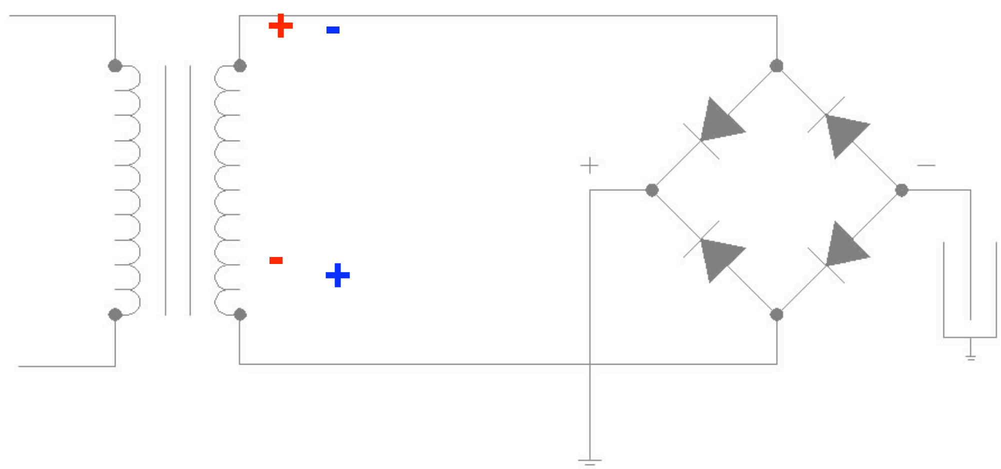
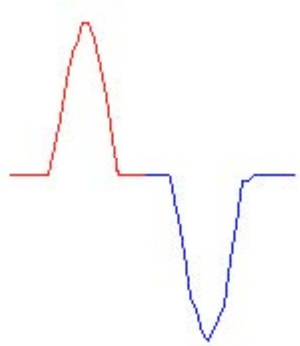
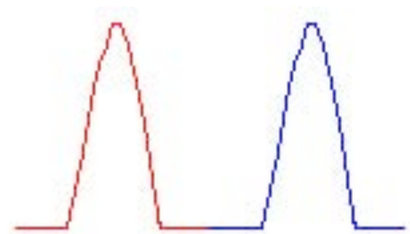
In order to understand how this device changes AC into DC, we must follow how the current flows through the circuit.



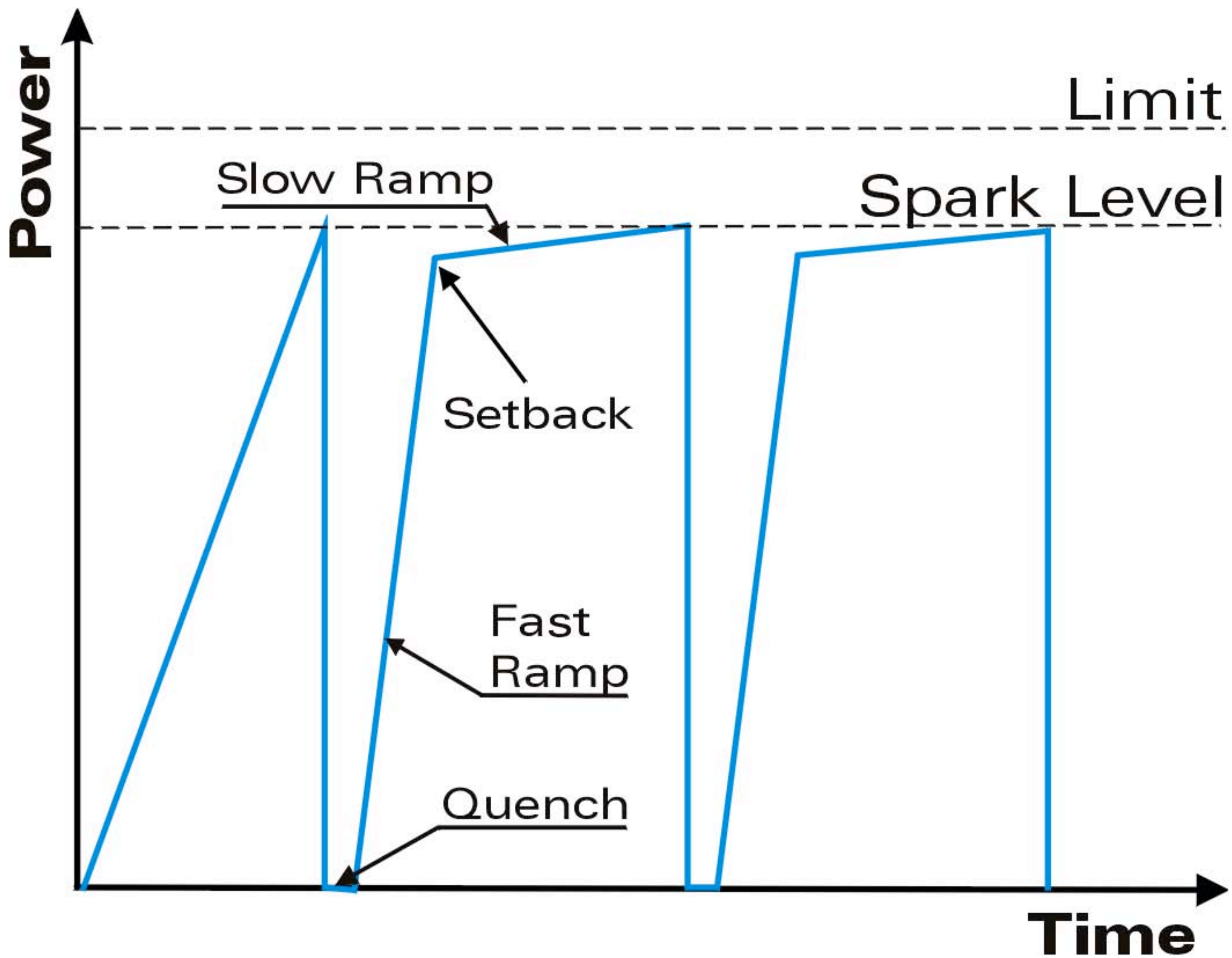
Input to the rectifier



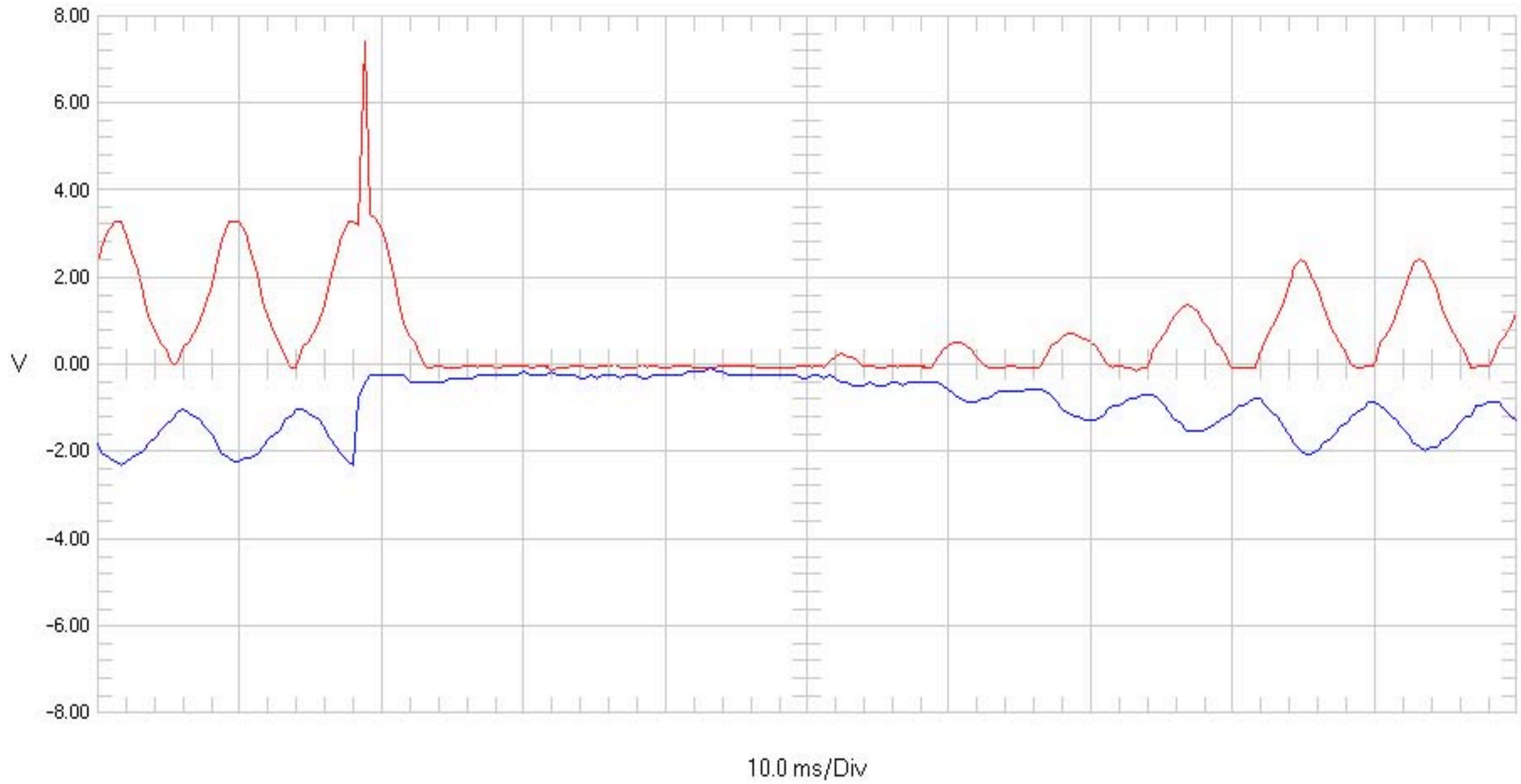
Output from the rectifier



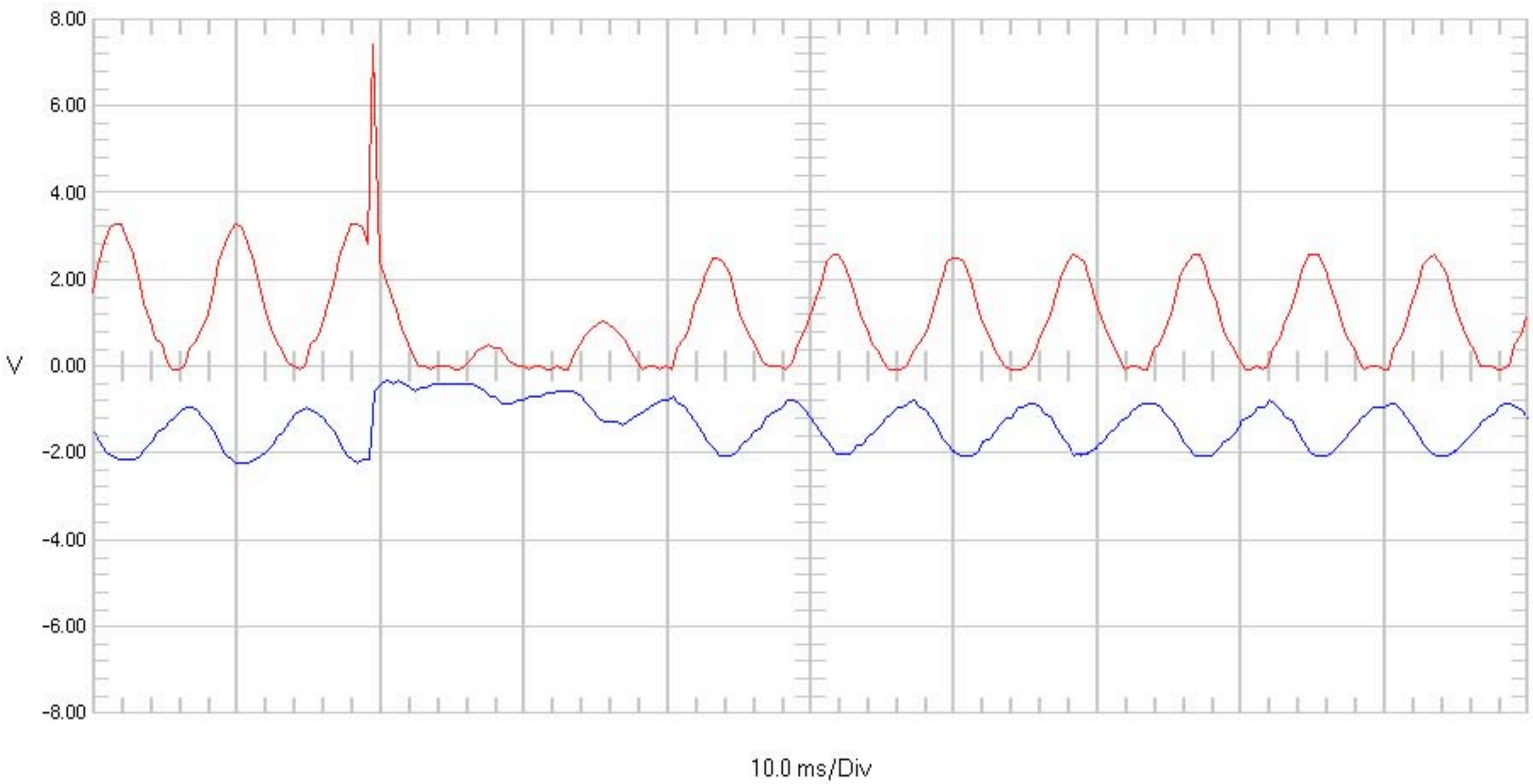
Typical AVC Response



Spark Response - Secondary Current and Voltage Waveforms



Spit Spark Response - Secondary Current and Voltage Waveforms



SQ-300® Automatic Voltage Controls

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Main Status Display
Updates at Spark, Arc or Limit

Main Power Off - Contactor not pulled in

Main Status Display
Updates at Spark, Arc or Limit

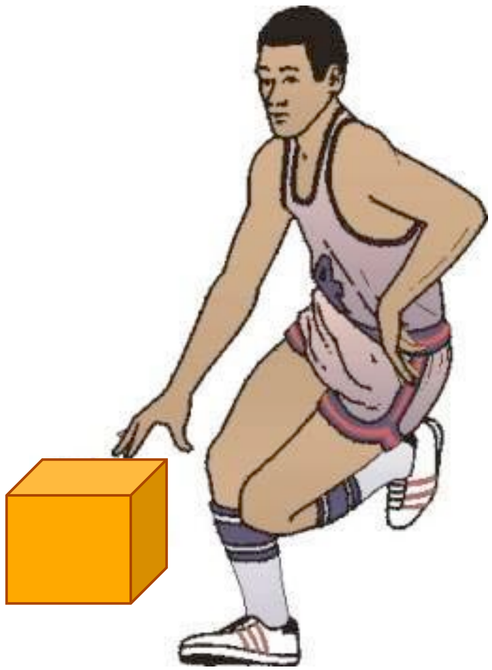
SQ-300 Halted - Contactor is pulled in but the SCRs are not Firing

Main Status Display
Updates at Spark, Arc or Limit

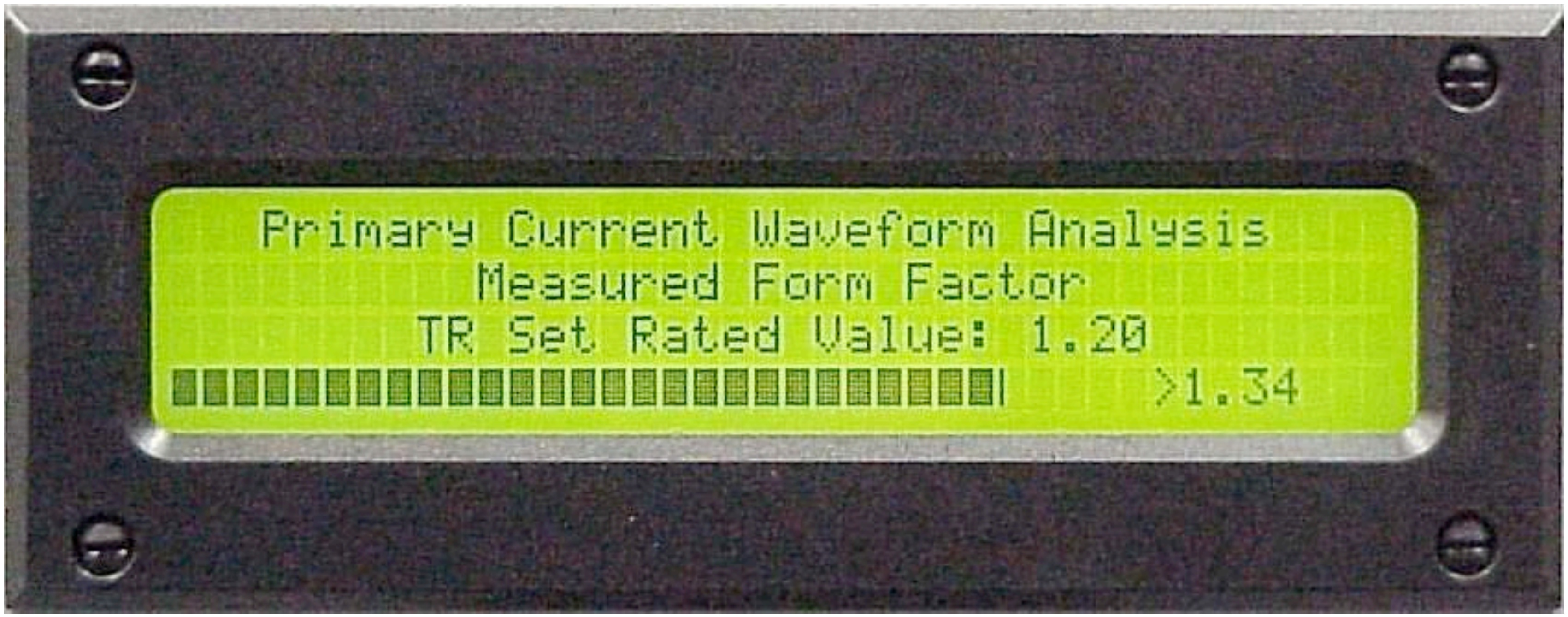
Run - SCRs are firing and the Control is Operating at a Spark or Limit

The Shape of Precipitator Waveforms

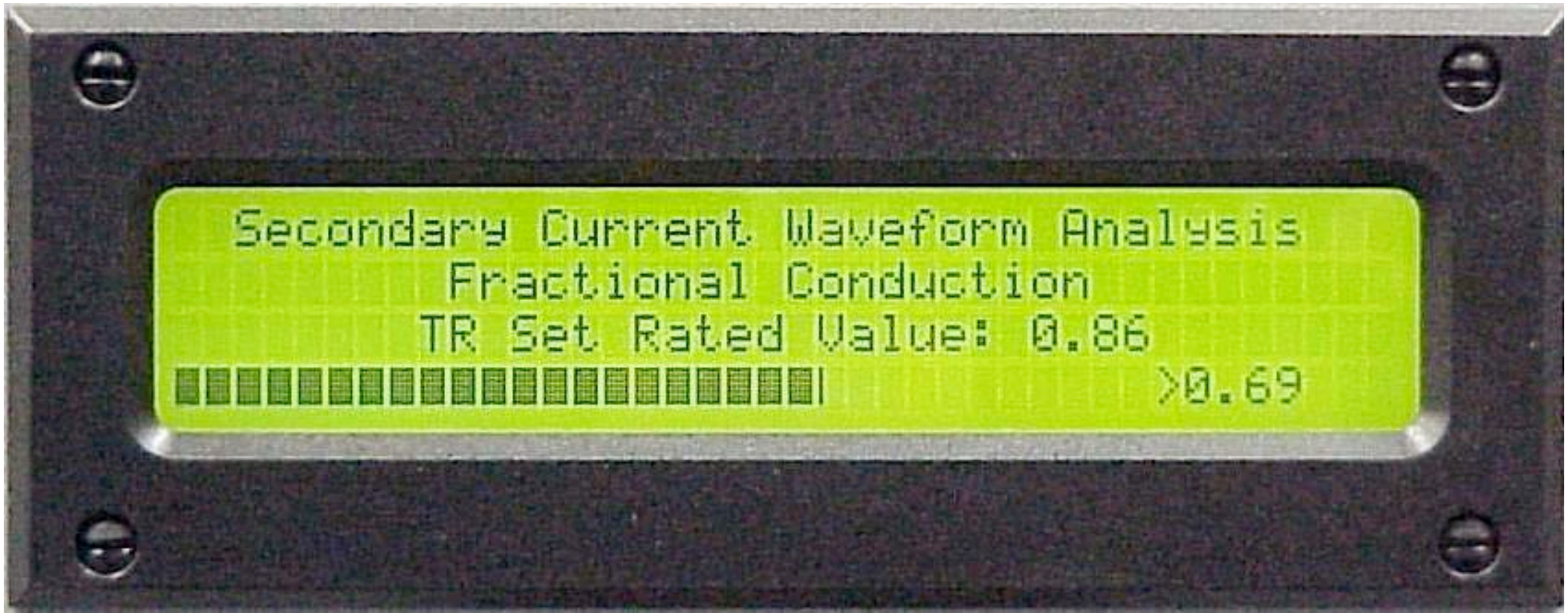
Shape Matters!



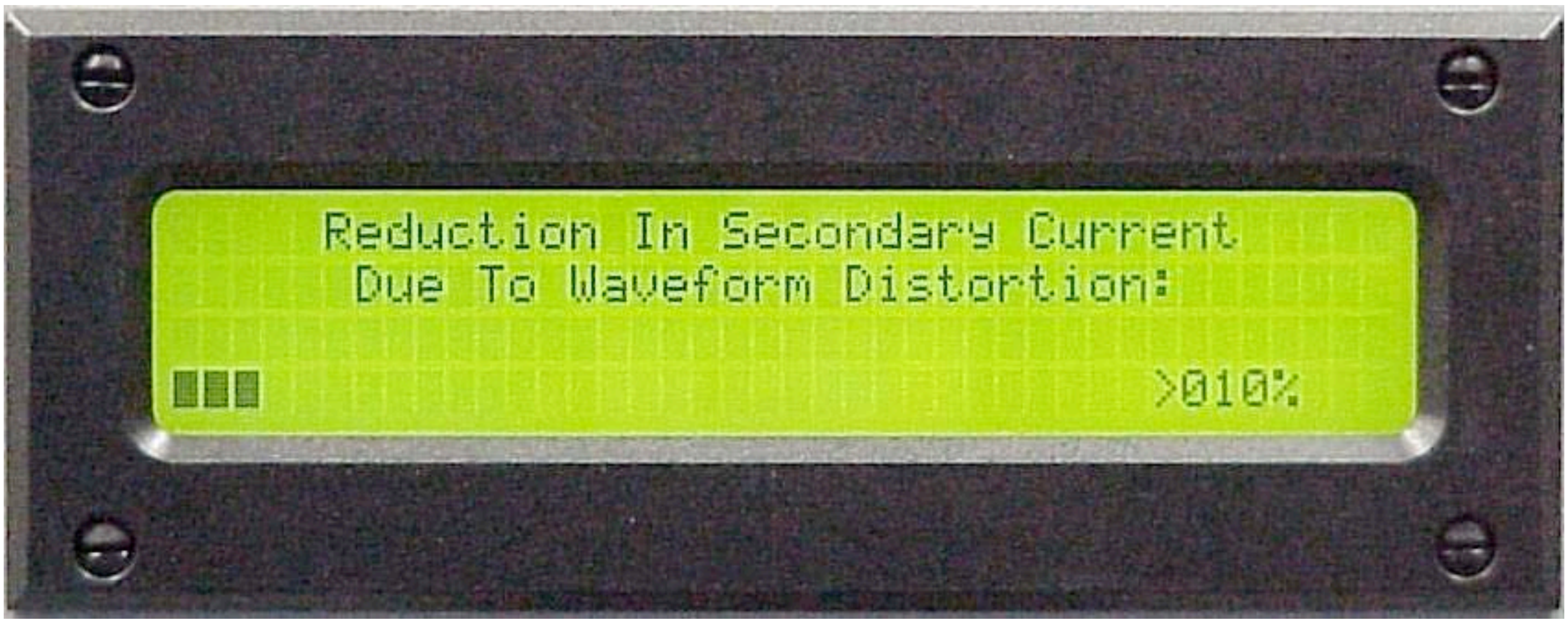
Primary Form Factor
=RMS Current / AVG Current



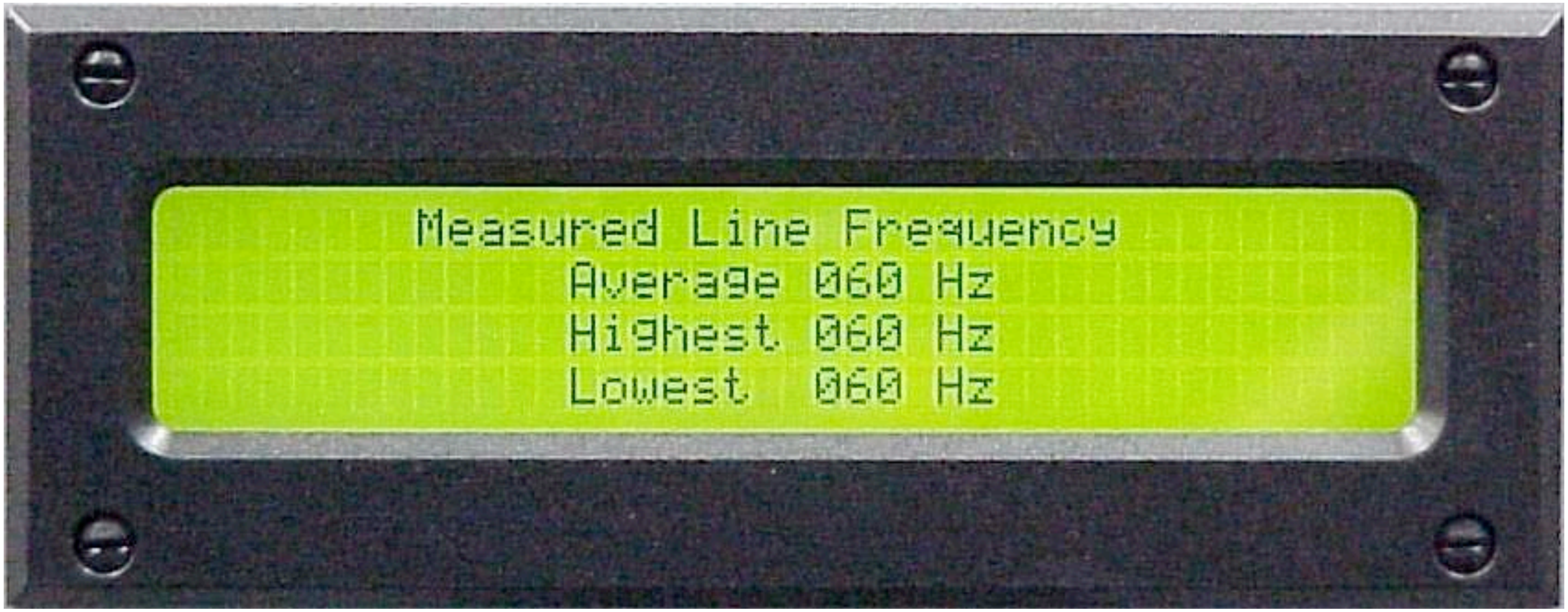
Secondary Fractional Conduction = Time on / 8.33 msec (60 hz)



Waveform Distortion Shows Efficiency



Line Frequency



SQ-300® Automatic Voltage Controls

- Installation
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- Troubleshooting

There are two main areas where we troubleshoot :

- Control Level
- System Level

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Control Level Troubleshooting

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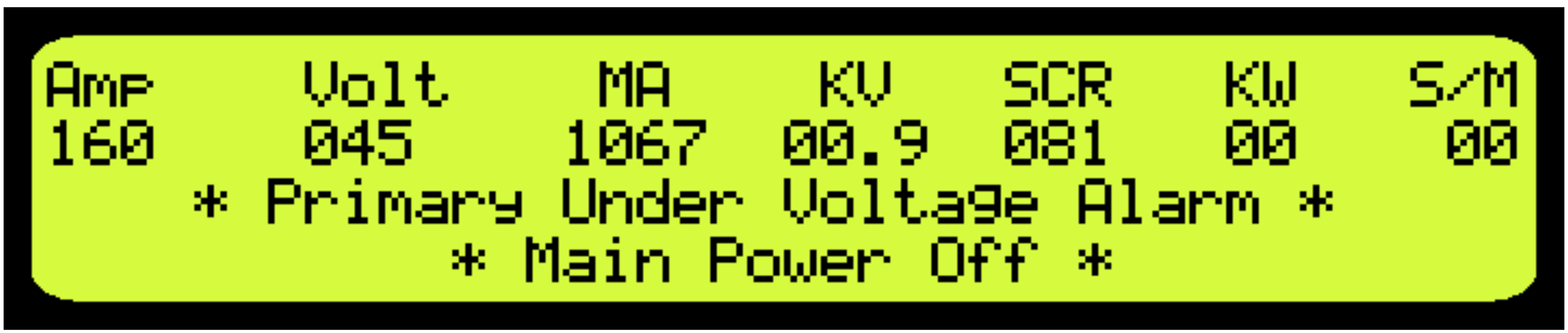
TR Namplate Values
(for this exercise)

Primary Current	160 Amps
Primary Voltage	480 Volts
Secondary Current	1200 mA
Secondary Voltage	45 kV

First Indication

Second Indication



Short

Mechanical Checks for Shorts

- T/R Set output bushing dirty, tracked or broken
- Bus duct stand-off insulator dirty, tracked or broken
- Bus duct through-put insulator dirty, tracked or broken
- HV frame support insulator dirty, tracked or broken
- Broken wire or RDE in shorted field, or adjacent field
- Construction/maintenance debris in field (welding rod, metal tools, temporary brackets, etc)
- Grounding strap left in place

Close Clearance

Mechanical Checks for Close Clearances

- HV hanger rod at roof penetration/corona shield
- Misaligned HV frame to collecting system. Wires or RDEs too close to plates.
- HV wires too close to side or mid-height spacer bars
- Lower HV frames swinging (anti-sways broken).
- Broken wire (intermittent as it swings about). SCR firing angle will usually swing wildly in this case
- Construction/maintenance debris in field

First Indication

Second Indication

Restart Control --->

First Indication

Second Indication

Tracked Insulator

SCRs Not Firing

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System Level Troubleshooting

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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
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#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
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#3-1B1	***	***	****	****	***
#3-2B1	41	226	252	31.4	17
#3-3B1	105	303	700	33.3	13
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#3-5B1	28	282	167	42.4	28
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#3-6B2	46	266	287	35.9	17
#3-7B2	90	317	572	38.0	18
#3-8B2	102	285	622	34.1	14

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

This leads us to…

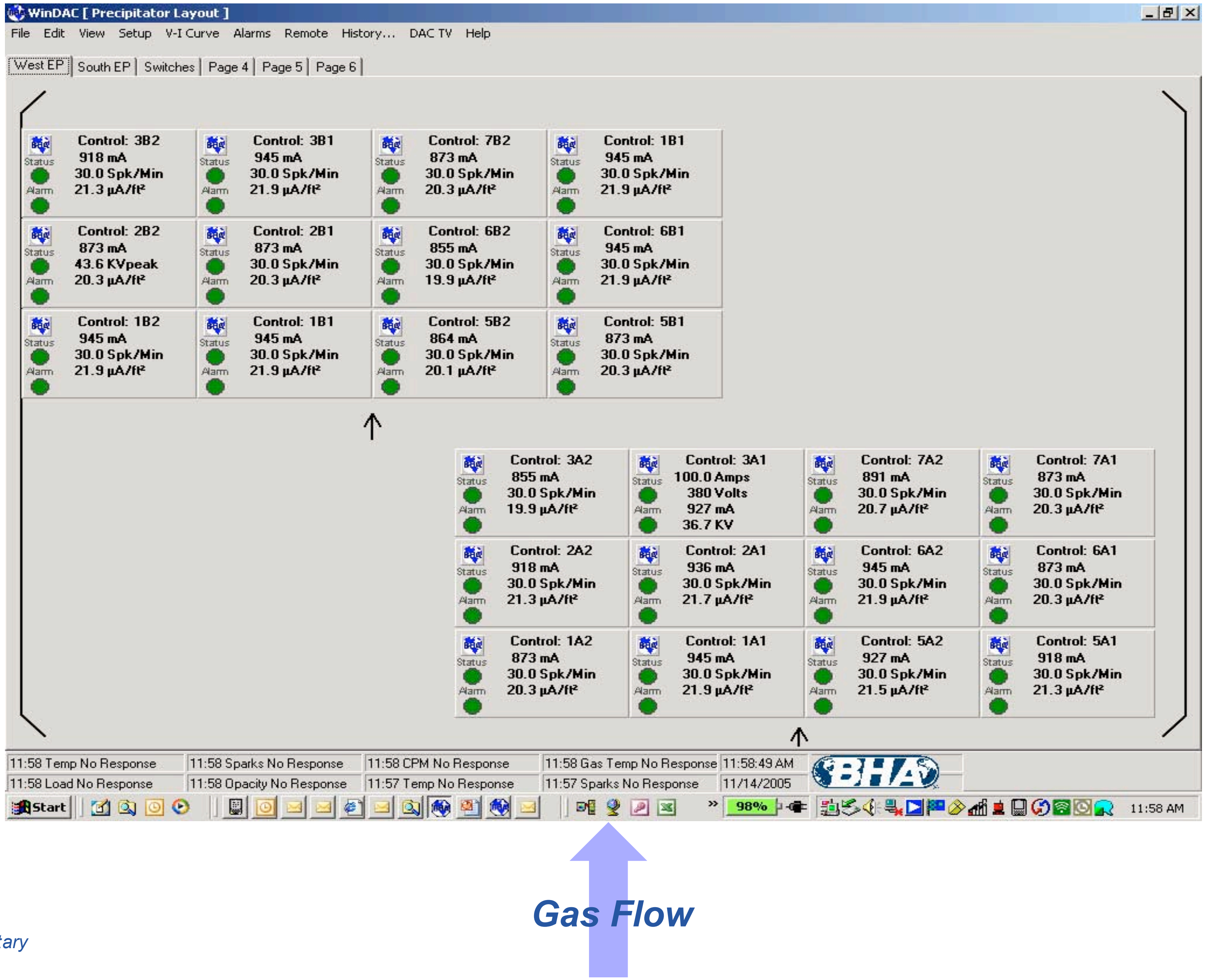
5 Easy Rules for ESP Performance Evaluation

Not a rule,
but a recommendation:

Put your data in a form you can easily visualize

imagination at work

Put T-R Sets in an ESP View



The First Rule of Precipitation

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

Applying Rule 1, 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, not too bad!

The Second Rule of Precipitation

2. If the dust does not have a resistivity problem, then outlet fields usually run at full current and little or no sparking.

A Lot of Sparking Going On!

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!

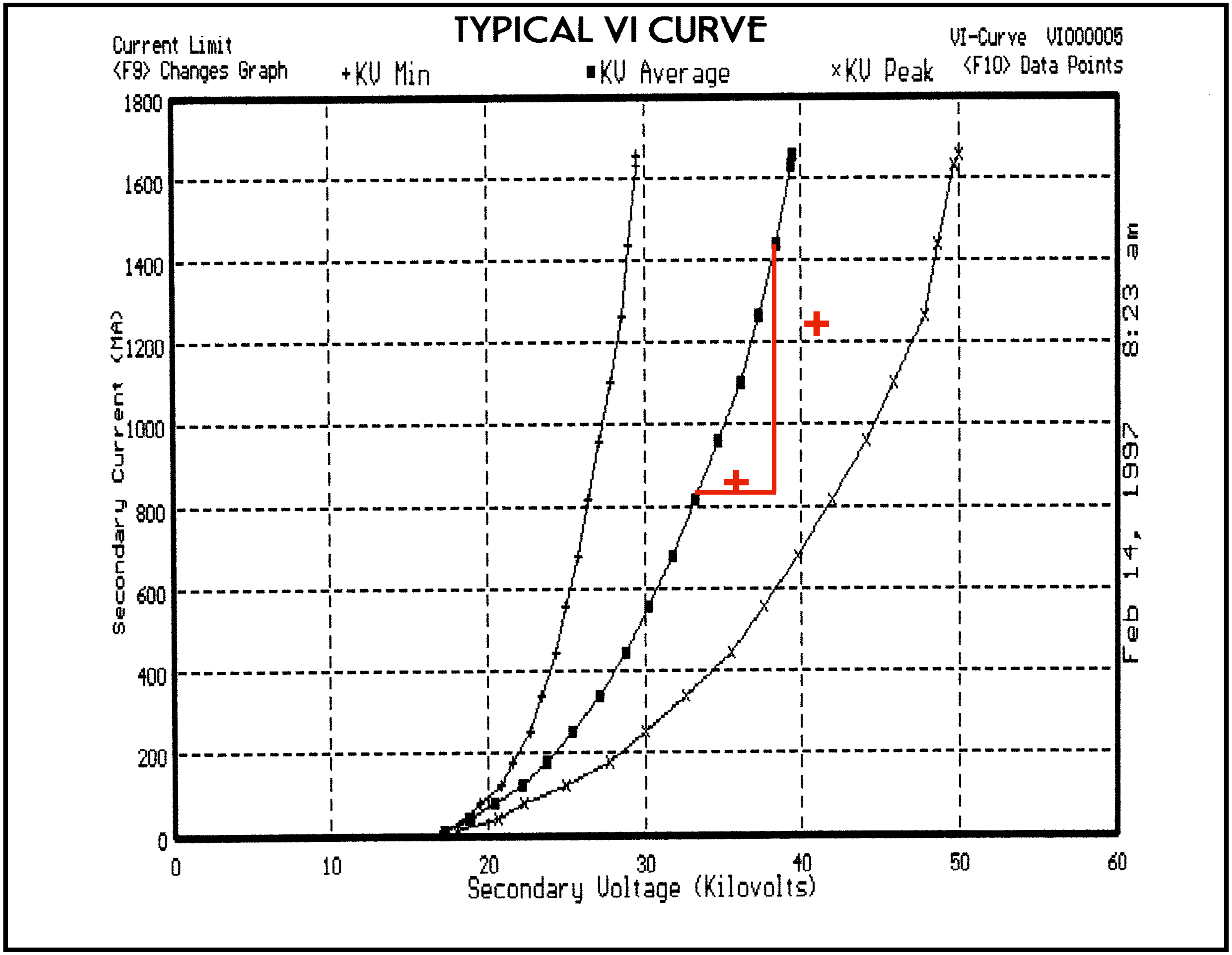
Wouldn’t hurt to run a couple of quick V-I curves

These are quick tests for resistivity. A full curve may be prohibitive because of opacity spiking.

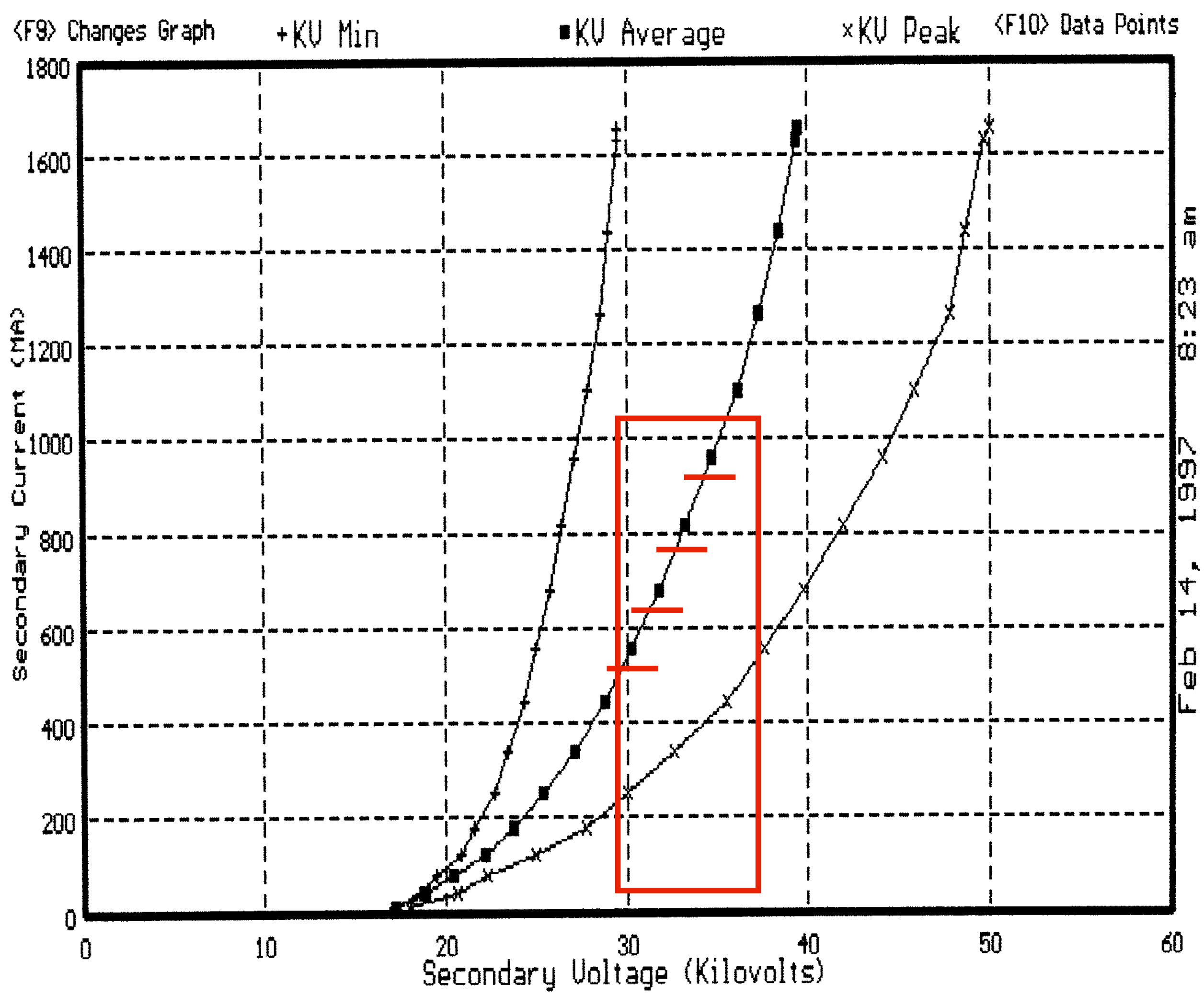
V-I Curves and their Interpretation

(The ESP Stethoscope)

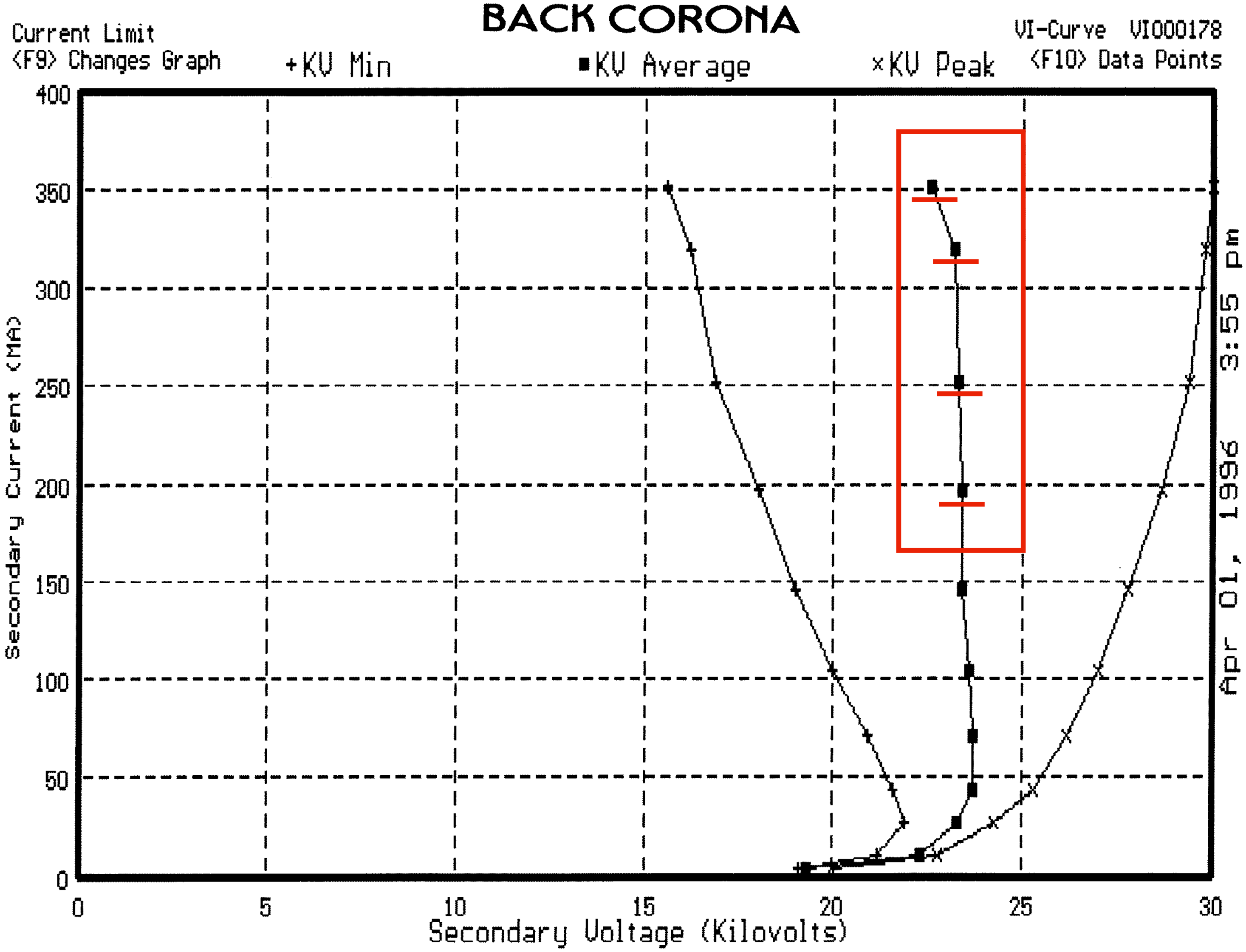
imagination at work


TYPICAL VI CURVE
Current Limit
<F9> Changes Graph
+KV Min
■KV Average
×KV Peak
VI-Curve VI000005
<F10> Data Points
Secondary Current (MA)
1800
1600
1400
1200
1000
800
600
400
200
0
0
10
20
30
40
50
60
Secondary Voltage (Kilovolts)
Feb 14, 1997 8:23 am

Quick V-I Curve



BACK CORONA



Current Limit
<F9> Changes Graph
+KV Min
■KV Average
×KV Peak
VI-Curve VI000178
<F10> Data Points
Secondary Current (MA)
Secondary Voltage (Kilovolts)
Apr 01, 1996 3:55 pm
400
350
300
250
200
150
100
50
0
0
5
10
15
20
25
30

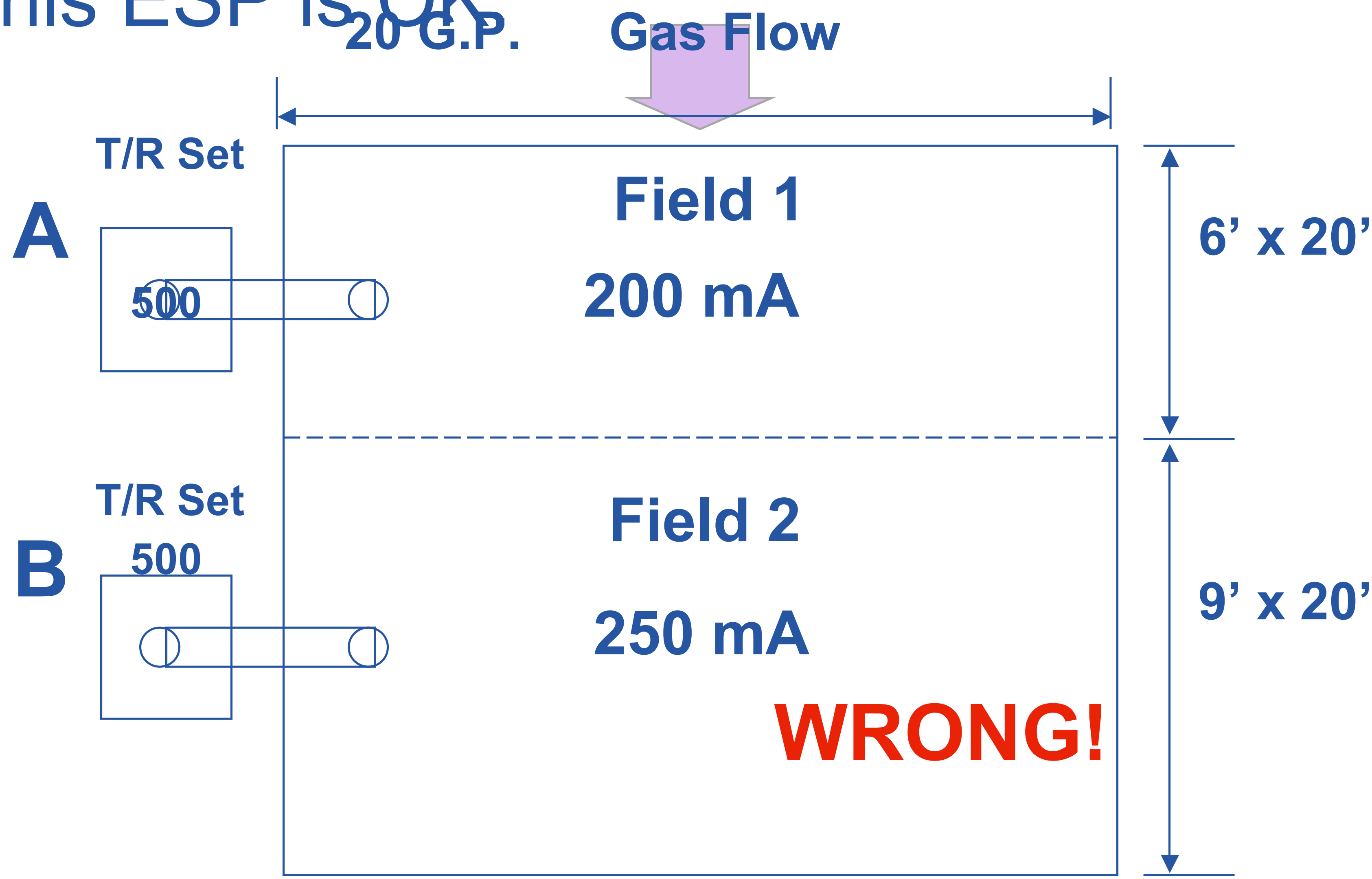
The Third Rule of Precipitation

3. Current densities are the best tool to check for dust resistivity and to compare successive fields' T/R set current (mA) values.

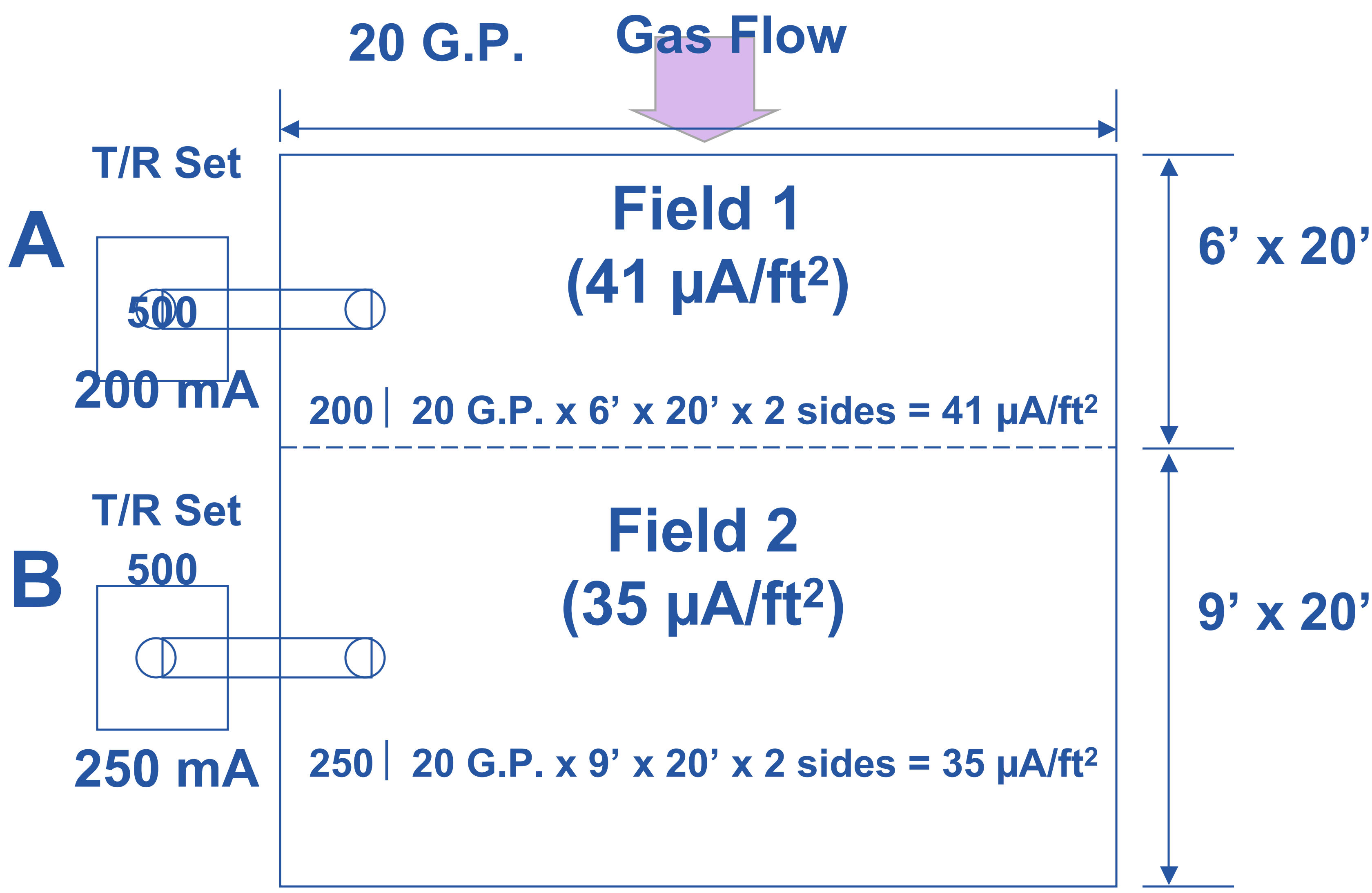
Current Density

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 Rule 1, this ESP is OK



Current Density



I. Current Densities (for conductive dust)

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

Field Number	Current Density ($\mu A/ft^2$)
1	10 - 20
2	15 - 35
3	35 - 50
4	50 - 80

II. Current Densities (for high resistivity dust)

Typical values for current density for a four field ESP. 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)

III. Current Densities (stable back corona dust)

Actual values for stable back corona dust for a four field ESP.

Field Number	Current Density ($\mu A/ft^2$)
1	21
2	27
3	19
4	72

Don't be fooled!

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

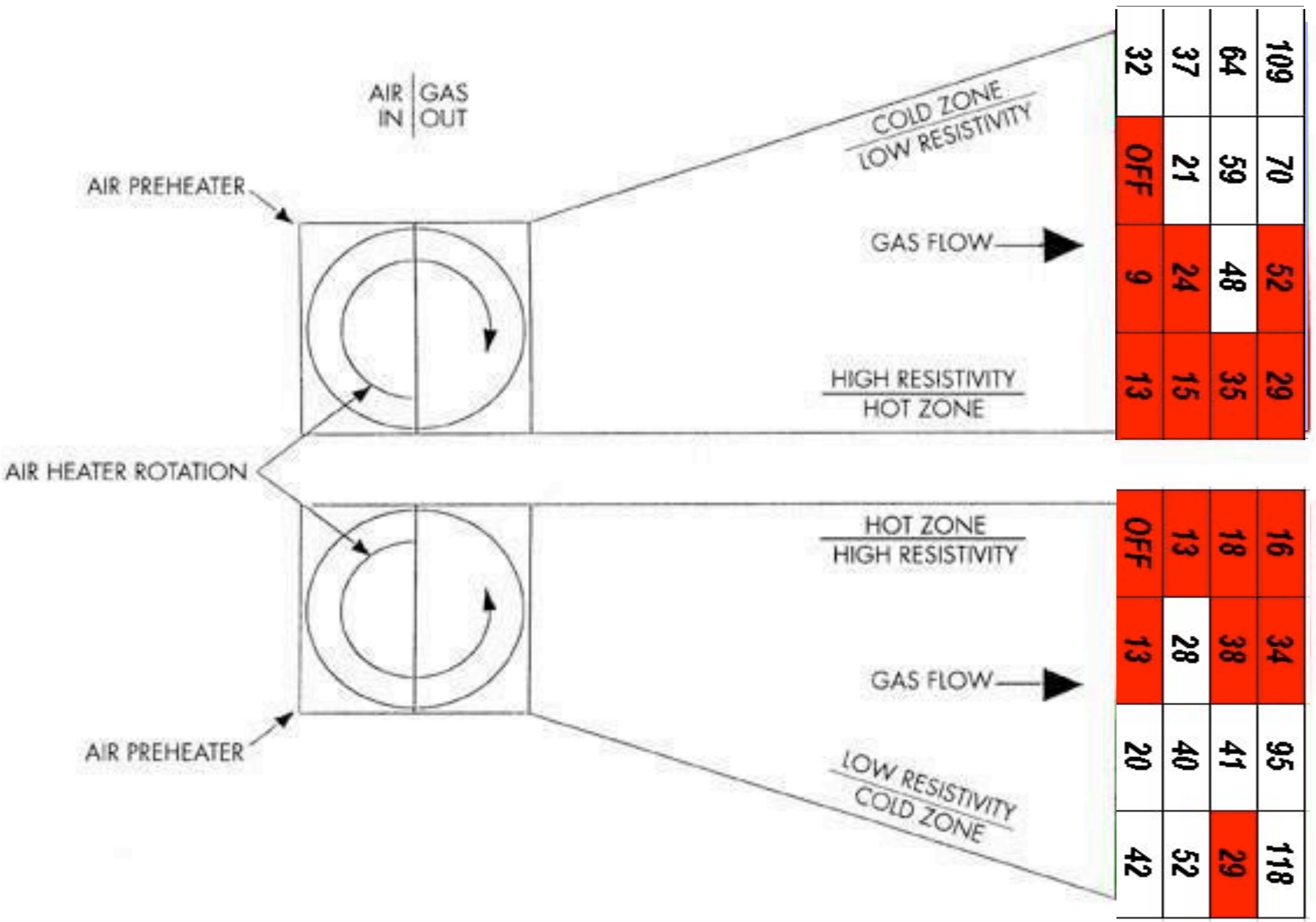
Evaluating Densities We Get:

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?

Graphic Visualization

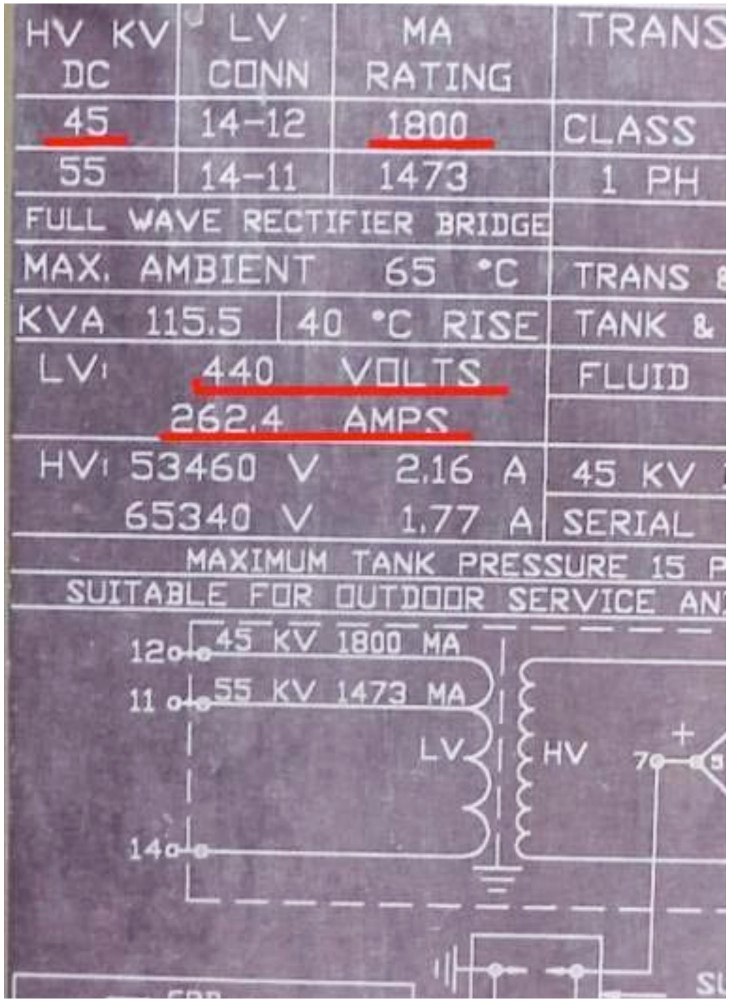


The Fourth Rule of Precipitation

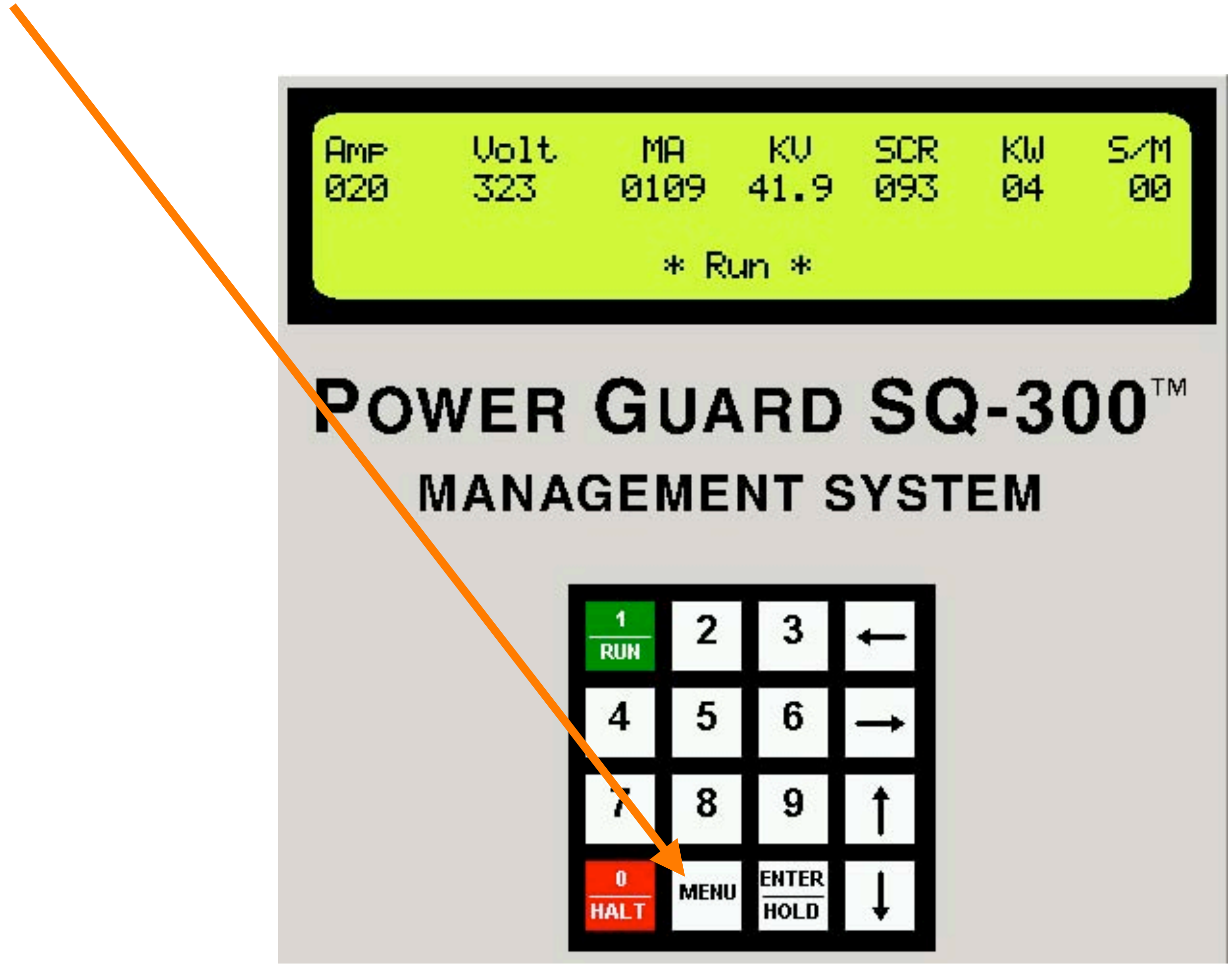
4. If the T/R set is not sparking, then the AVC should be pushing that T/R set to one of its pre-set limits (volts, amps, KV, or mA)

Hard Way

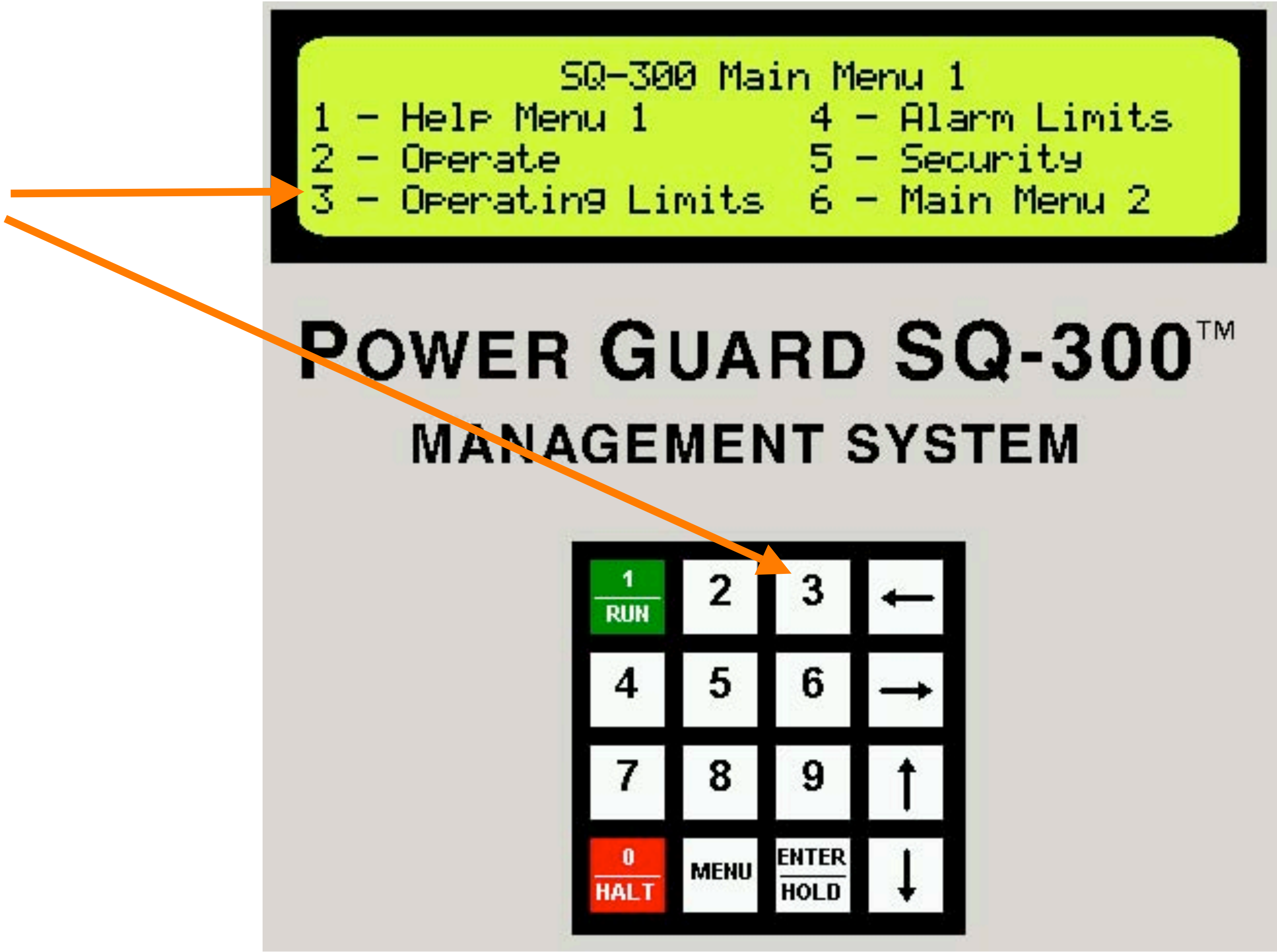
Walk up to the roof of the ESP and look at the nameplates on the T/R sets



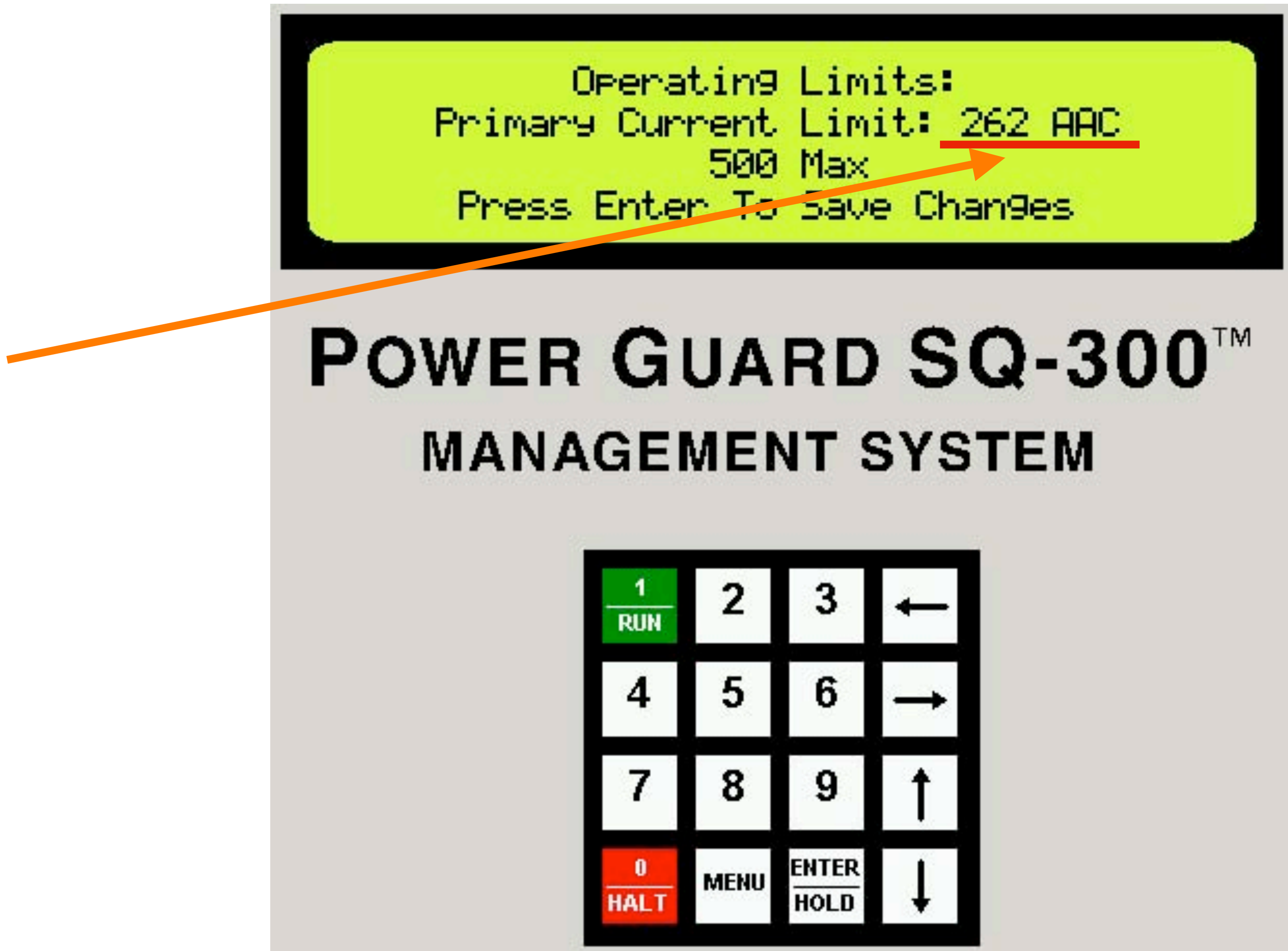
Press the Menu Button



Press 3, “Operating Limits”



Read What the T/R Ratings Are



One T/R Running with "No" Sparking

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

Is it at a limit?

The Fifth Rule of Precipitation

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

9A,10A, 16A RUNNING PROPERLY. 13A JUST SLIGHTLY OFF. SEEING HOW THESE RUN ENABLE AN ANALYTICAL REVIEW OF 15A

Applying Rule 5 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

Rule 5 can achieve the same results as a density review and is simpler, but not as precise.

With just numbers, we were nowhere.

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

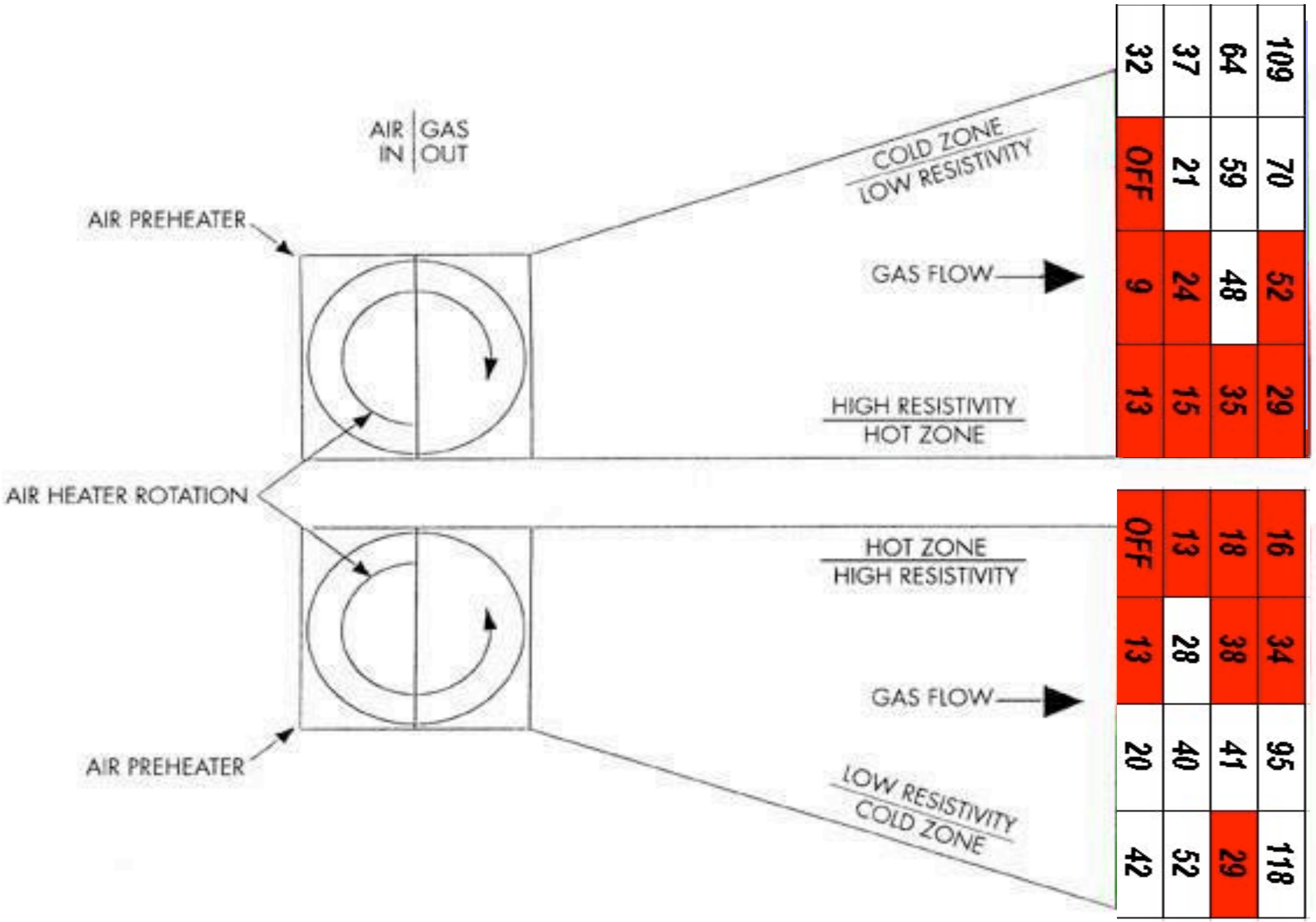
PrecipTech, Inc.
Power Guard Management System
DAC Version 2.9014
SQ-300 AVC

*******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 we can plan a strategy.



PRC-100® Equipment & Basic Operation

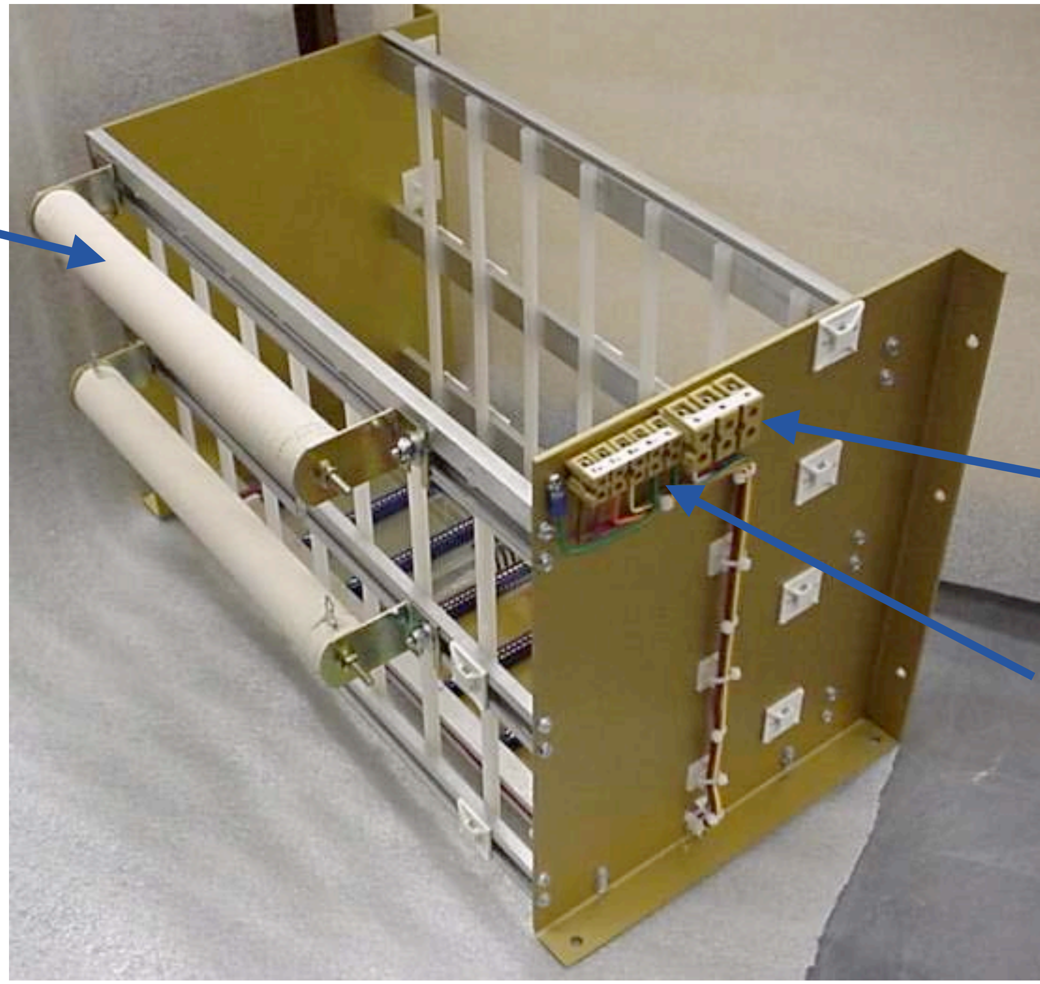
imagination at work

Introduction

Operational equipment for the PRC-100®

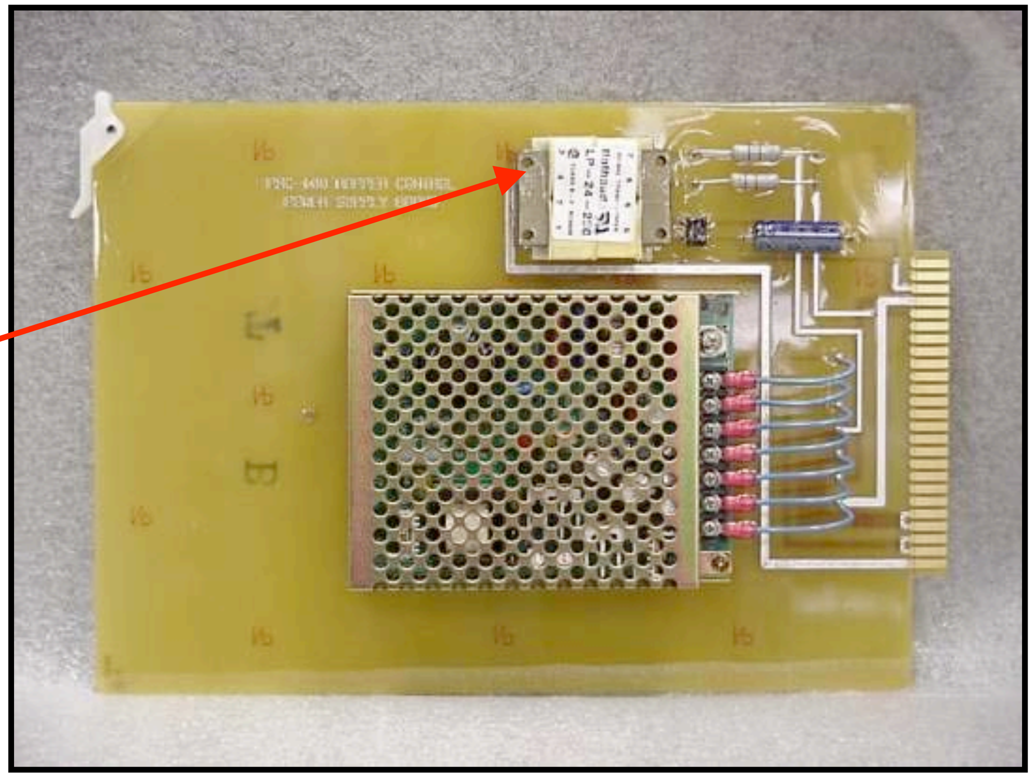
- Card cage & back plane
- Control cards
- WinRAP® interface
- Troubleshooting

7 Position Card Cage



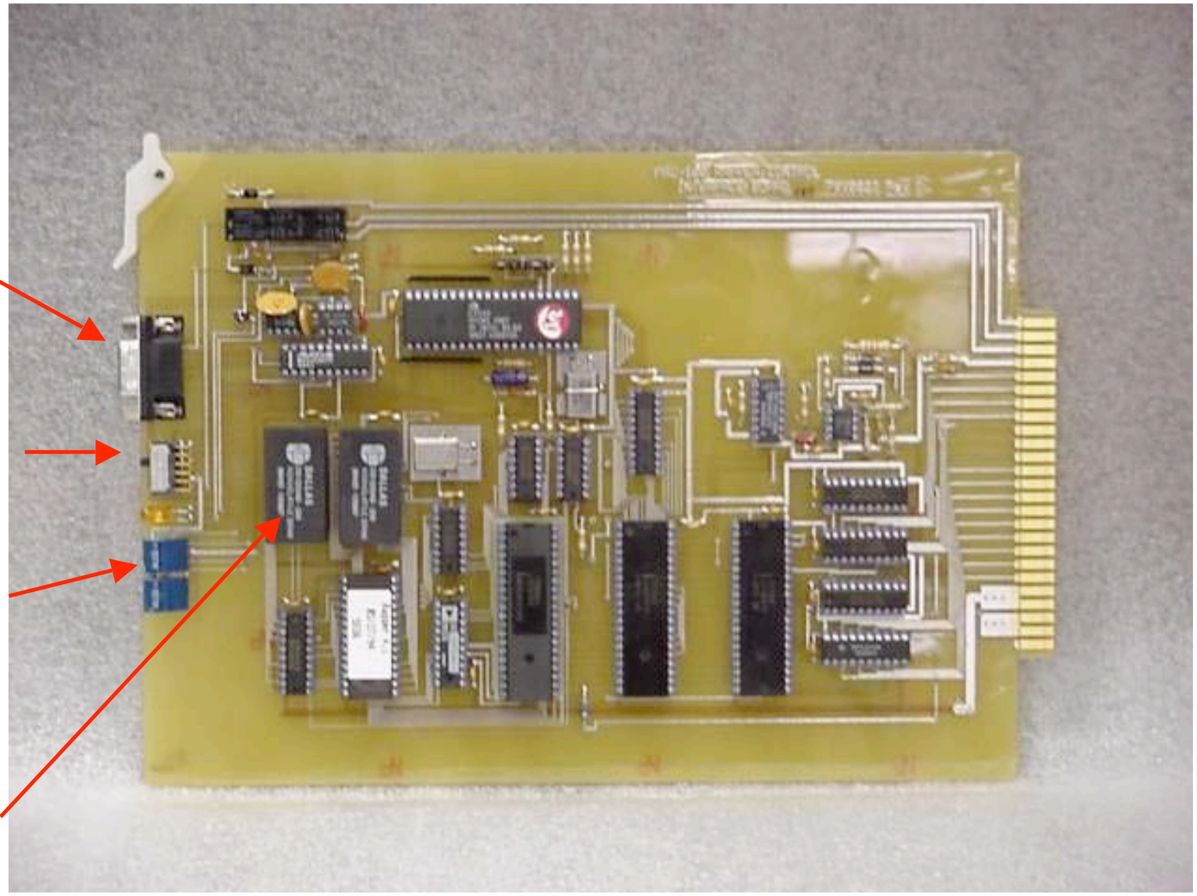
Power Supply Card

Zero Cross



Supplies +/- 5-12 VDC,
Detects “Zero Crossing”

Interface Board



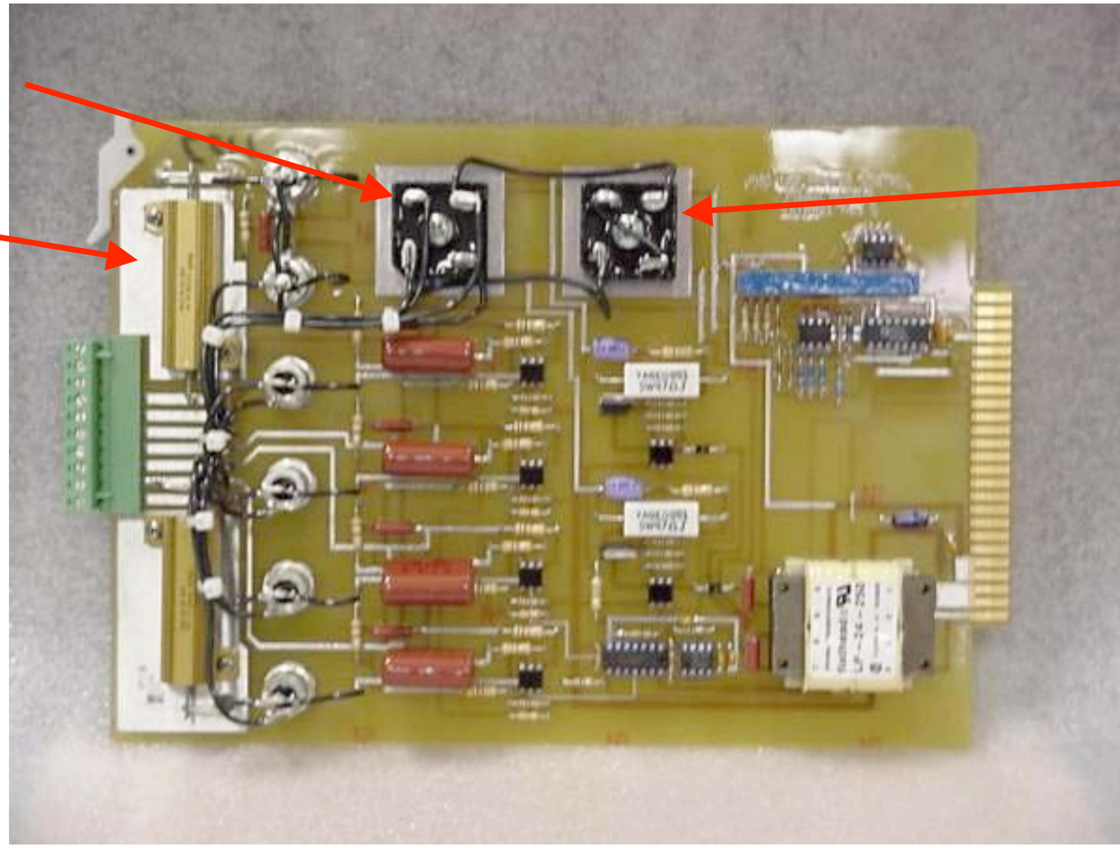
Local/remote communications,
Default memory & program,
Specific hex address

Power Module Board

AC/DC Rectifier

Current Sensing

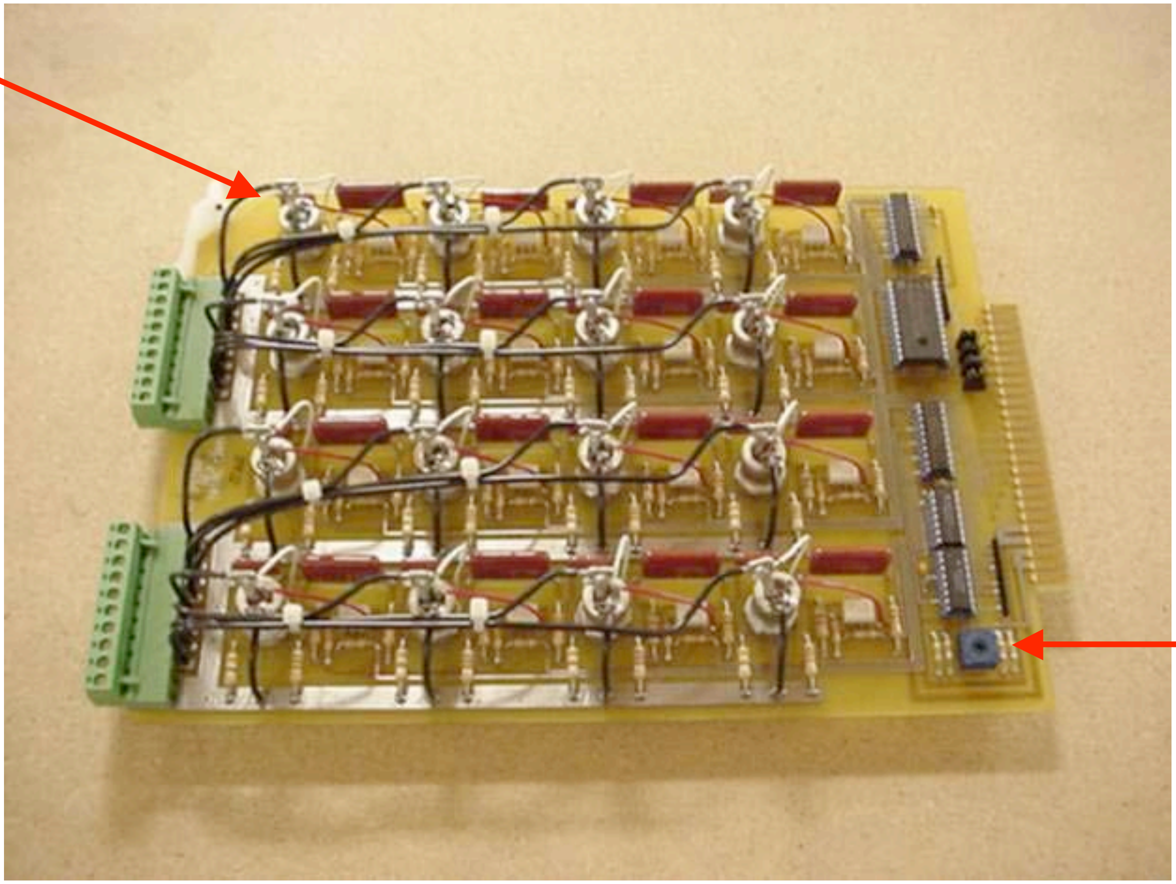
Absorbs Inductive Kick



Supplies voltage, AC or DC for rapper boards, Current sensing, absorbs transient kicks, Color tab=scaling

Triac Board

Triac

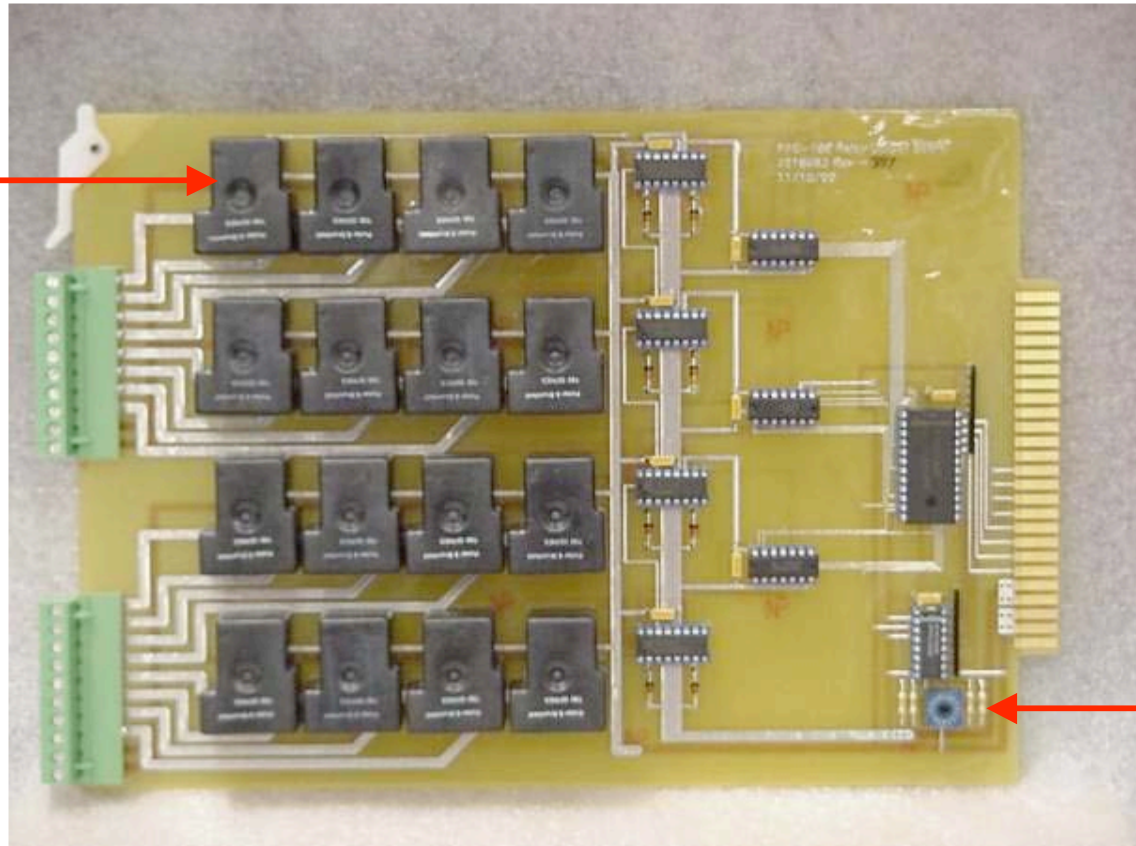


Hex Address

16 outputs/board, DC rappers,
Specific hex address

Relay Output Board

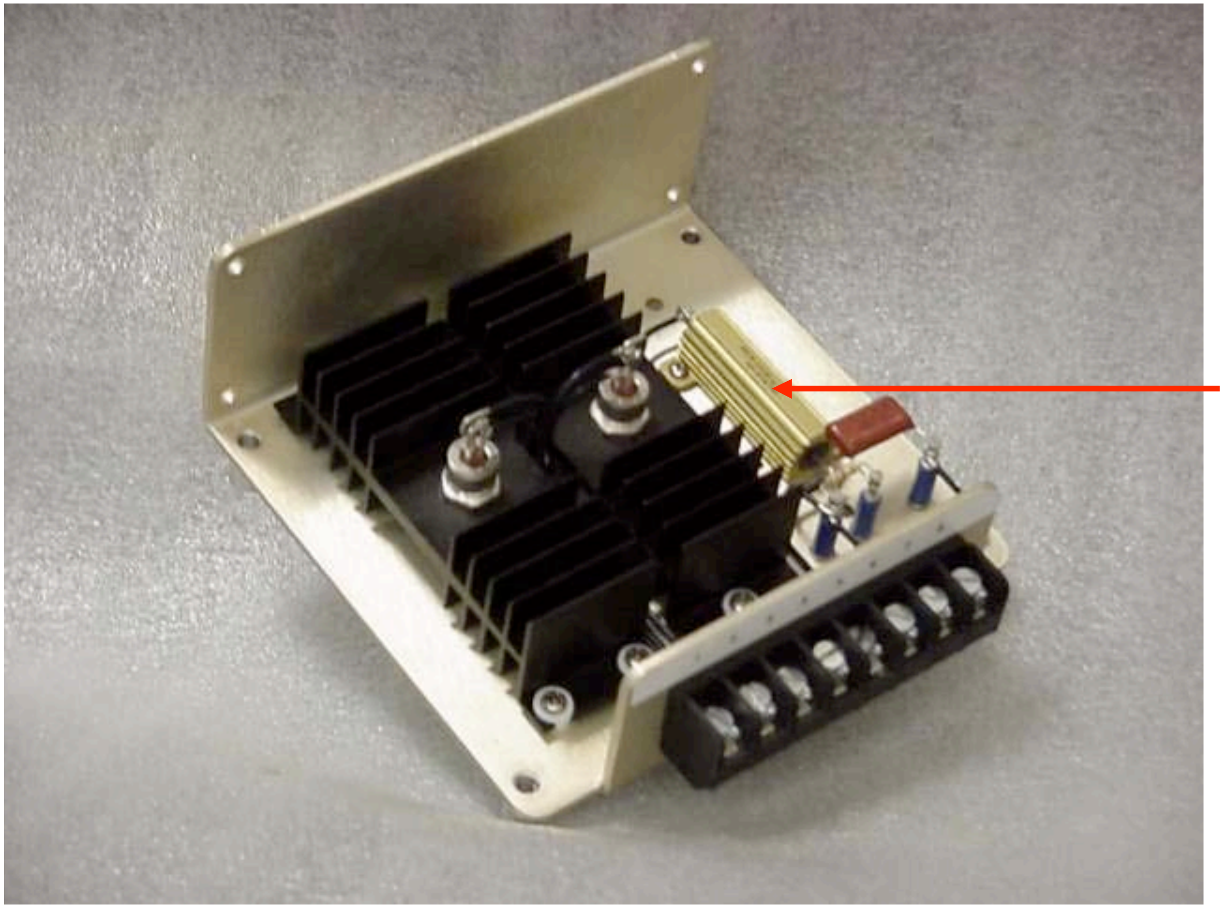
Relay



Hex Address

16 output/board, AC vibrators,
Specific hex address

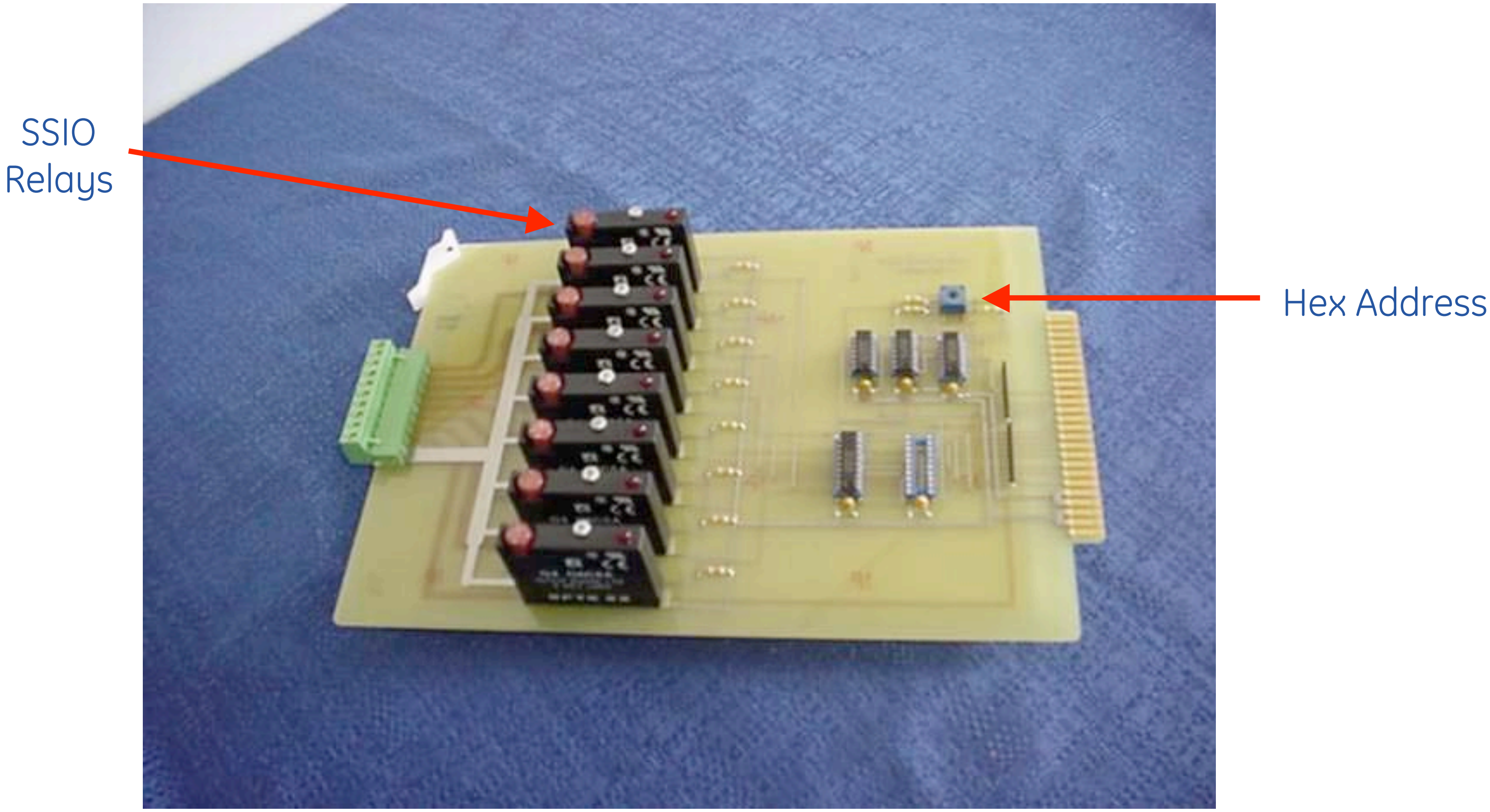
External Power Driver



Current Sensing
Resistor

AC Vibrators, Current Sensing.
Needed due to long on times

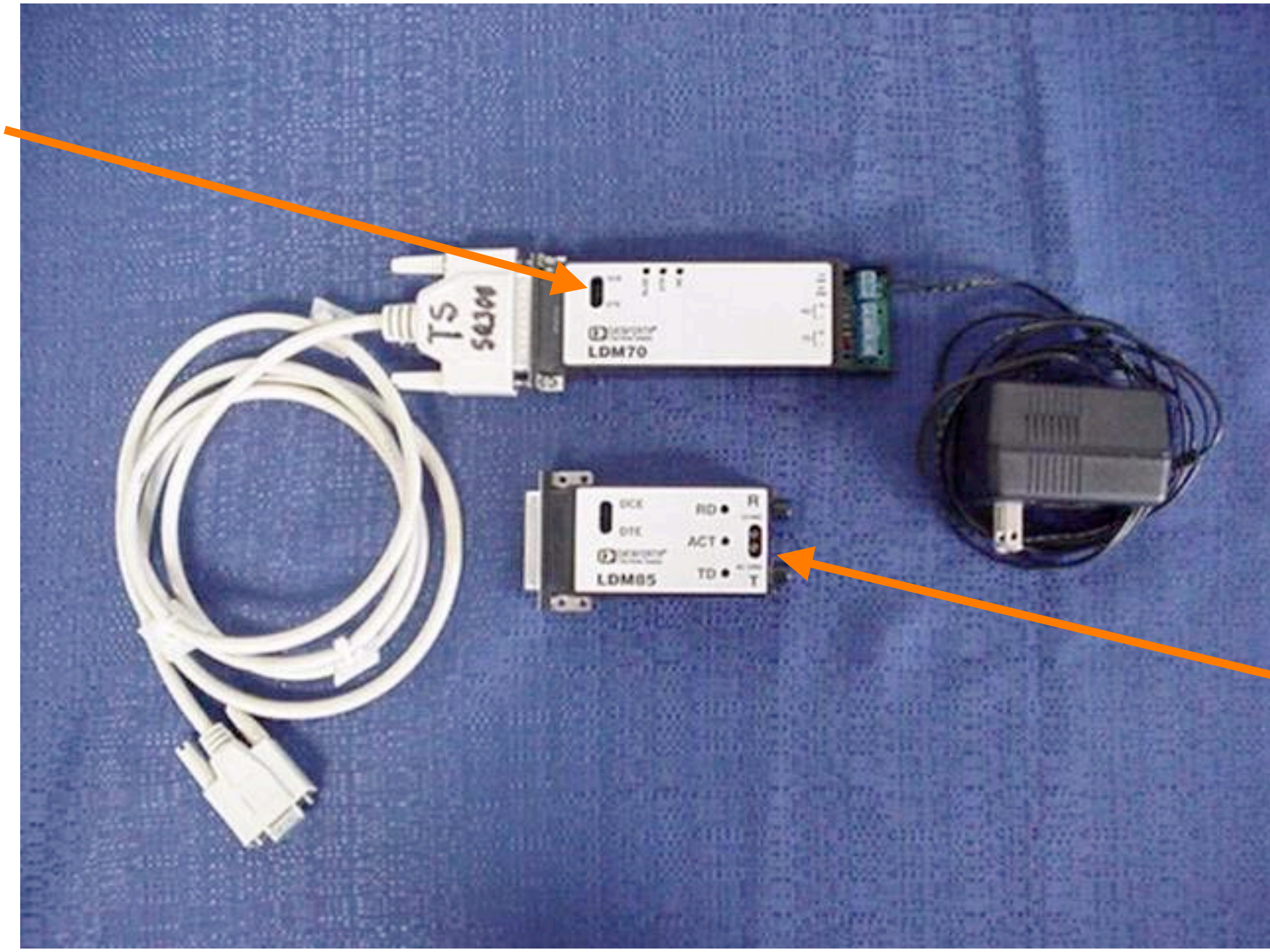
Solid State Output Board



8 outputs/board, tumbling hammer motors,
Acoustic horn timers, specific hex address

WinRAP Interface

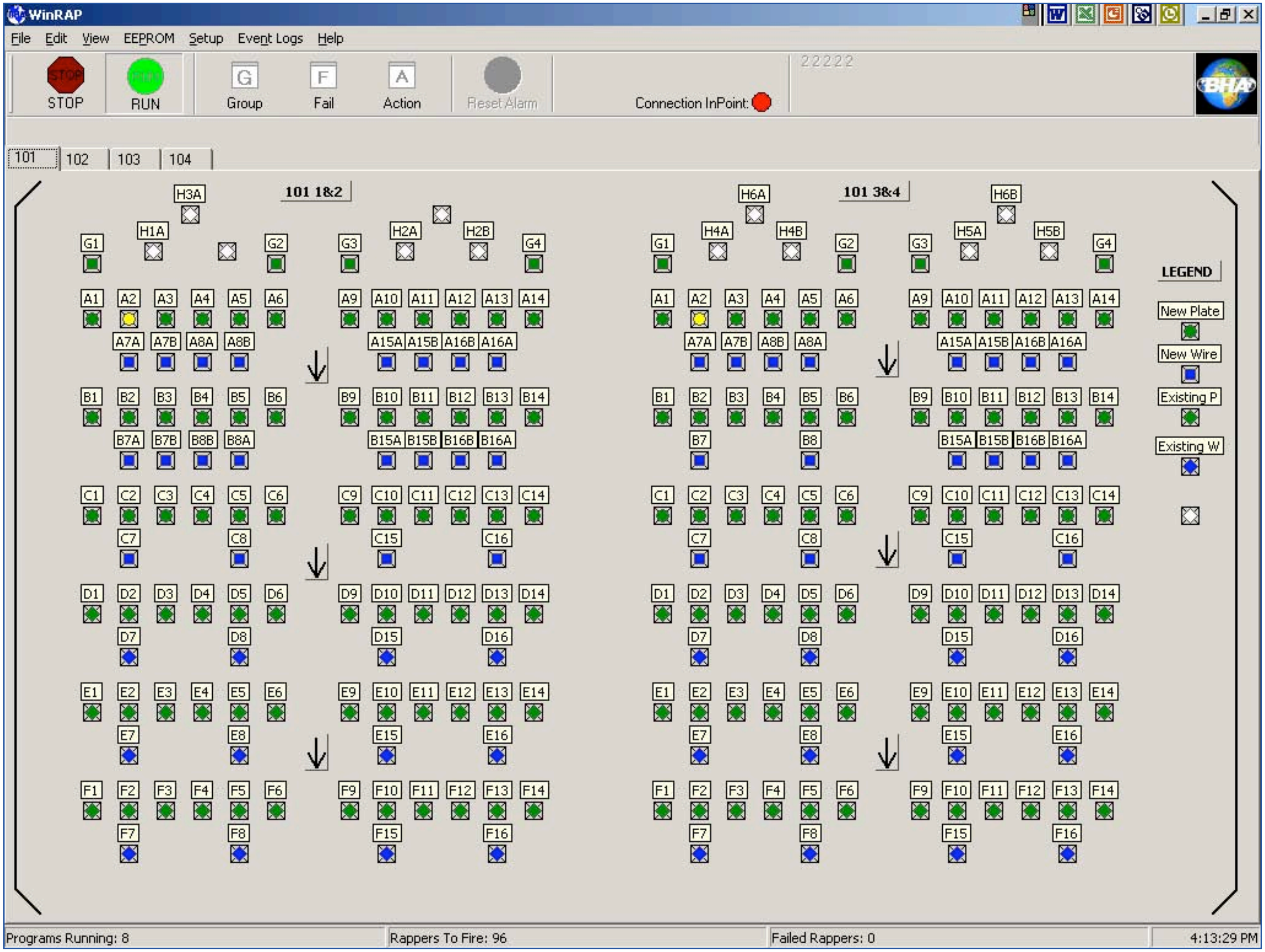
Standard Wiring



Fiber Optics

LDM-70 & LDM-85

WinRAP Interface



Automation

- IRAP
- Digital Inputs
- DCS/PI Data Inputs
- Sequence Manager
- Syncrorap
- Power Off/Power Down

PRC-100

These are the rapper failure modes:

- Short
- Open
- Communication Error

There can be multiple reasons for each failure mode.

Short:

1. Rapper shorted to ground.
2. How many rappers are shorting?
3. Are they all associated with one IFB or TRIAC card?
4. What is the actual current draw?

Open:

1. Rapper coil is open.
2. How many rappers are opening?
3. Are they all associated with one IFB or TRIAC card?
4. What is the actual current draw?

Communication Error:

1. Are all rappers in communications error?
2. Are they all associated with one IFB?

Remote Precipitator Optimization

imagination at work

What is Remote Optimization?

Experienced GE Technicians

Using a computer / phone line

Monitoring Your Precipitator

In Real Time

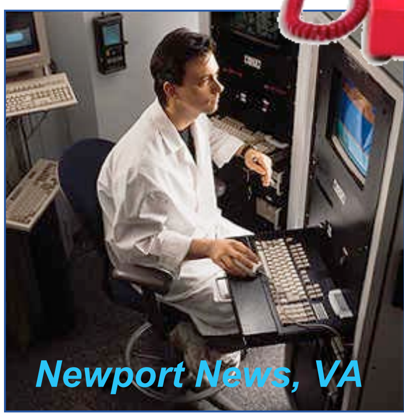
<u>Diagnosing</u> equipment and process problems

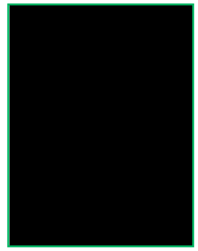
BEFORE THEY BECOME SERIOUS

Without actually traveling to your facility

How Does it Work?

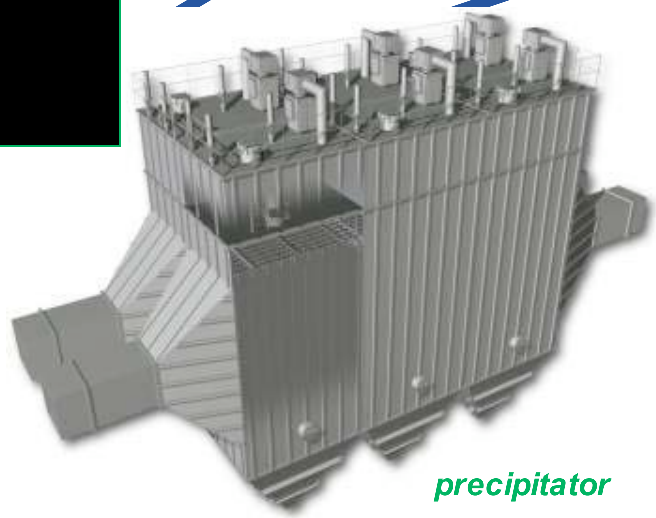
Using a simple phone line . . .



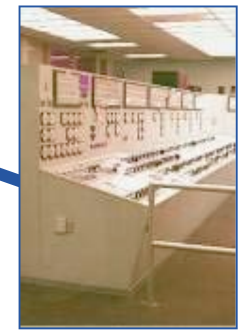


fuel blend

boiler



precipitator



control room

emissions

. . . GE Energy can remotely access operational info for your precipitator (through the ESP control system). This data can be used to find problem & underperforming areas of <u>your entire process</u>

Why Use Remote Optimization?

- Early detection - identify precipitator/process problems before they become serious
- Observe system performance in real time (as problems occur) and solve problems faster
- BHA technicians can adjust rapper and voltage controls (if given access) to maximize performance
- Remote Diagnostics can also assess other critical parameters, including damper positioning, temperatures, carbon monoxide levels, fan currents, boiler or kiln loads, any digital or analog input

Questions?

Thank you.

imagination at work