Worldwide Pollution Control Association

FirstEnergy ESP Seminar

November 27th – 28th, 2007

WPCA

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Flue Gas Conditioning

WPCA

November 27, 2007

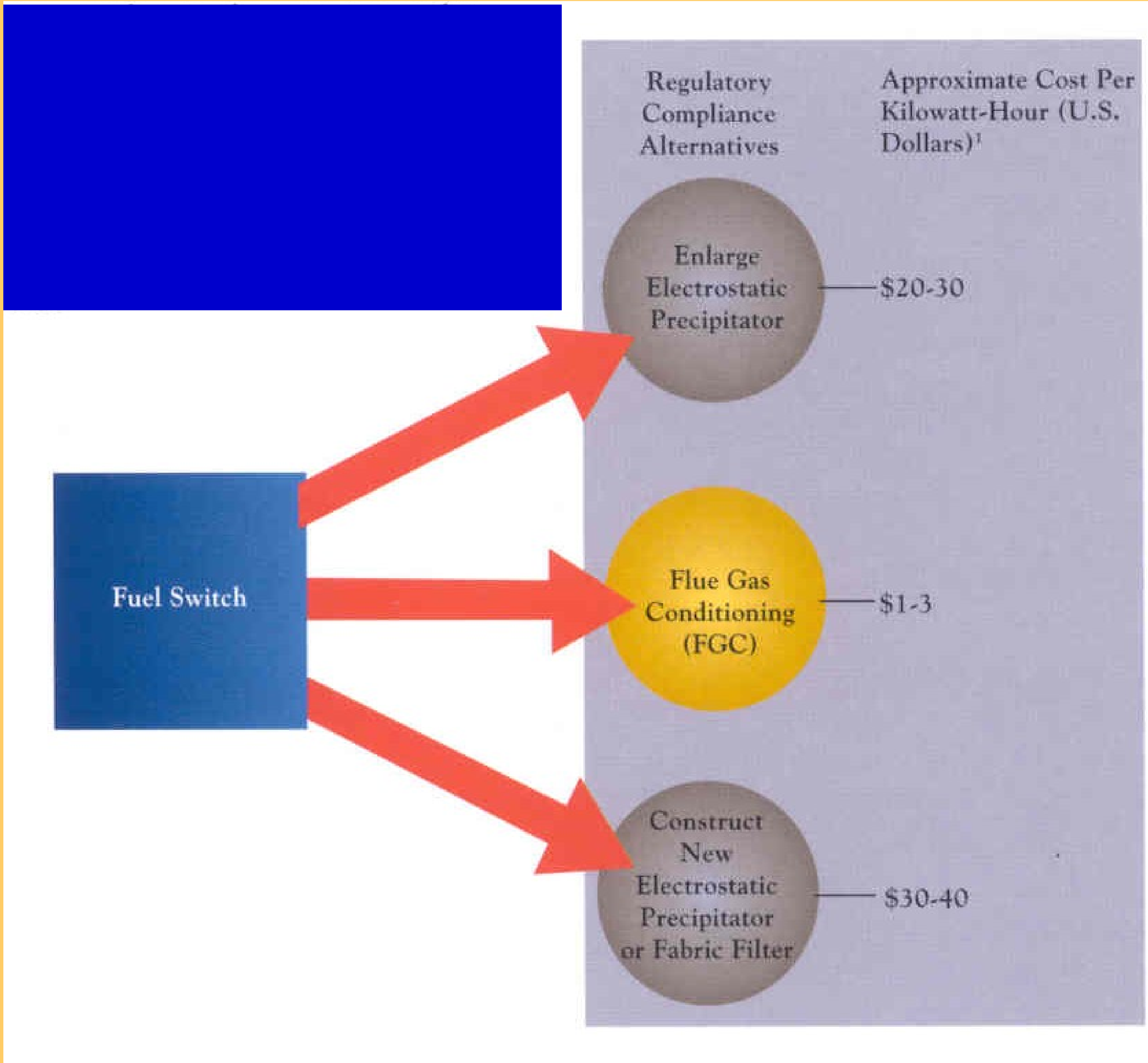
William Hankins
VP Sales

Outline

- What is SO3 FGC
- Basics of an Electrostatic Precipitator
- Ash Resistivity
- SO3 Process
- Design Principles

SO3 FGC Background

- Sulfur Trioxide Flue Gas Conditioning
- Corrects Ash Resitivity to Improve performance of Electrostatic Precipitators (ESPs)
- Small amount injected upstream of ESP
- Approximately 1500 units worldwide
- Commercialized by Wahlco in early 1970's


Regulatory Compliance Alternatives
Approximate Cost Per Kilowatt-Hour (U.S. Dollars)[1]
Fuel Switch
Enlarge Electrostatic Precipitator
$20-30
Flue Gas Conditioning (FGC)
$1-3
Construct New Electrostatic Precipitator or Fabric Filter
$30-40

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Sulfur Emissions

Typical Sulfur Oxide Emissions from Coal-Burning Boilers

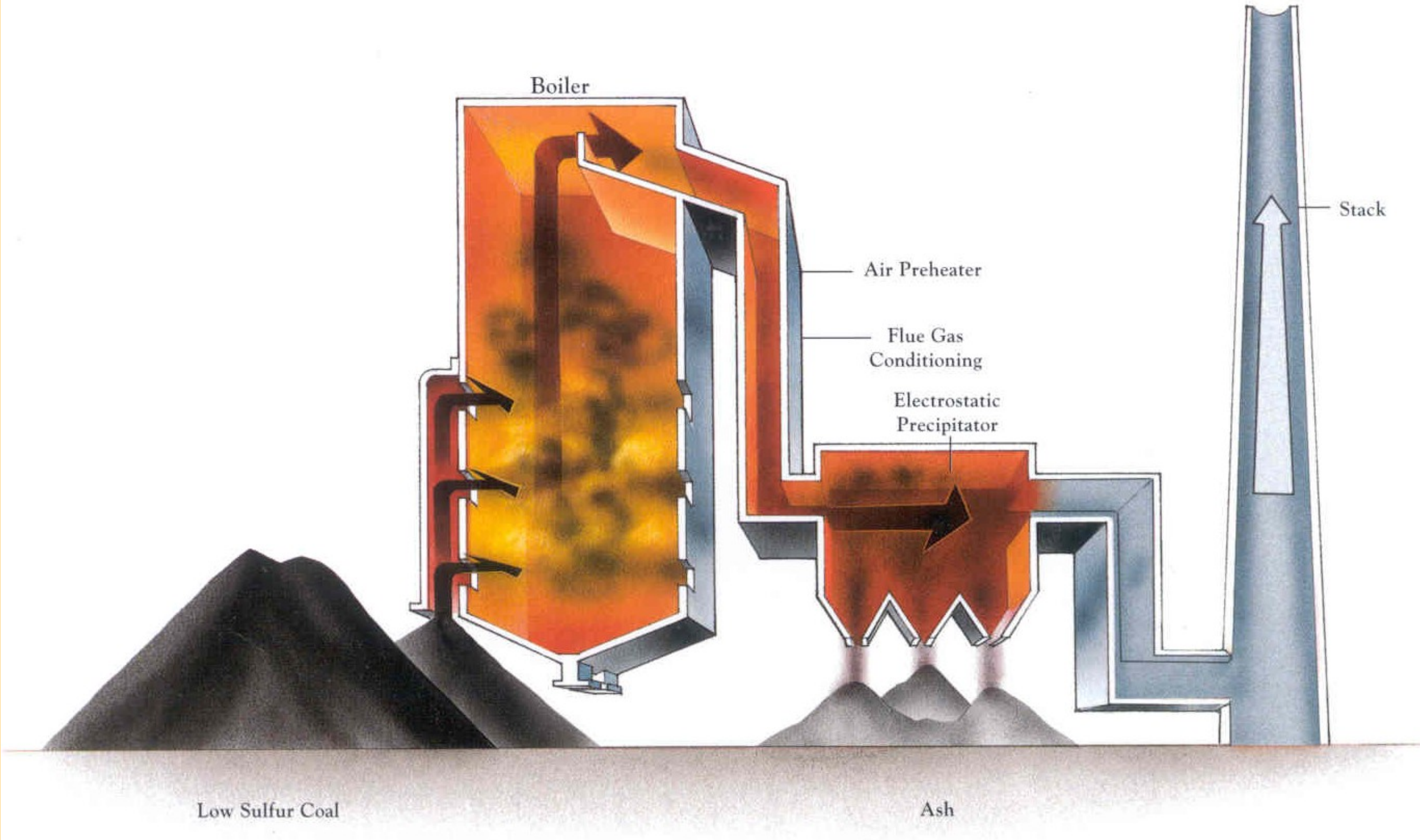
Sulfur Oxides PPMV		3.5% Sulfur Content	0.5% Sulfur Content	0.5% Sulfur & FGC
Entering Precipitator	SO_2	2600	370	371
	SO_3	26	4	10
Entering Stack	SO_2	2600	370	375
	SO_3	7	4	4

Flue gas conditioning does not increase emission levels of sulfur oxides (SO_2 or SO_3).

Sulfur Trioxide

- Toxic highly reactive gas
- Combines with water vapor to form sulfuric acid mist
- Gas above 500 deg F
- Generally produced by burning sulfur and catalytic oxidation of Sulfur Dioxide gas
- Typical inject 5 to 15 ppm in Flue Gas ~ 20 to 300 lb/hr sulfur - 50 to 800 mW

Flue Gas Conditioning Basics



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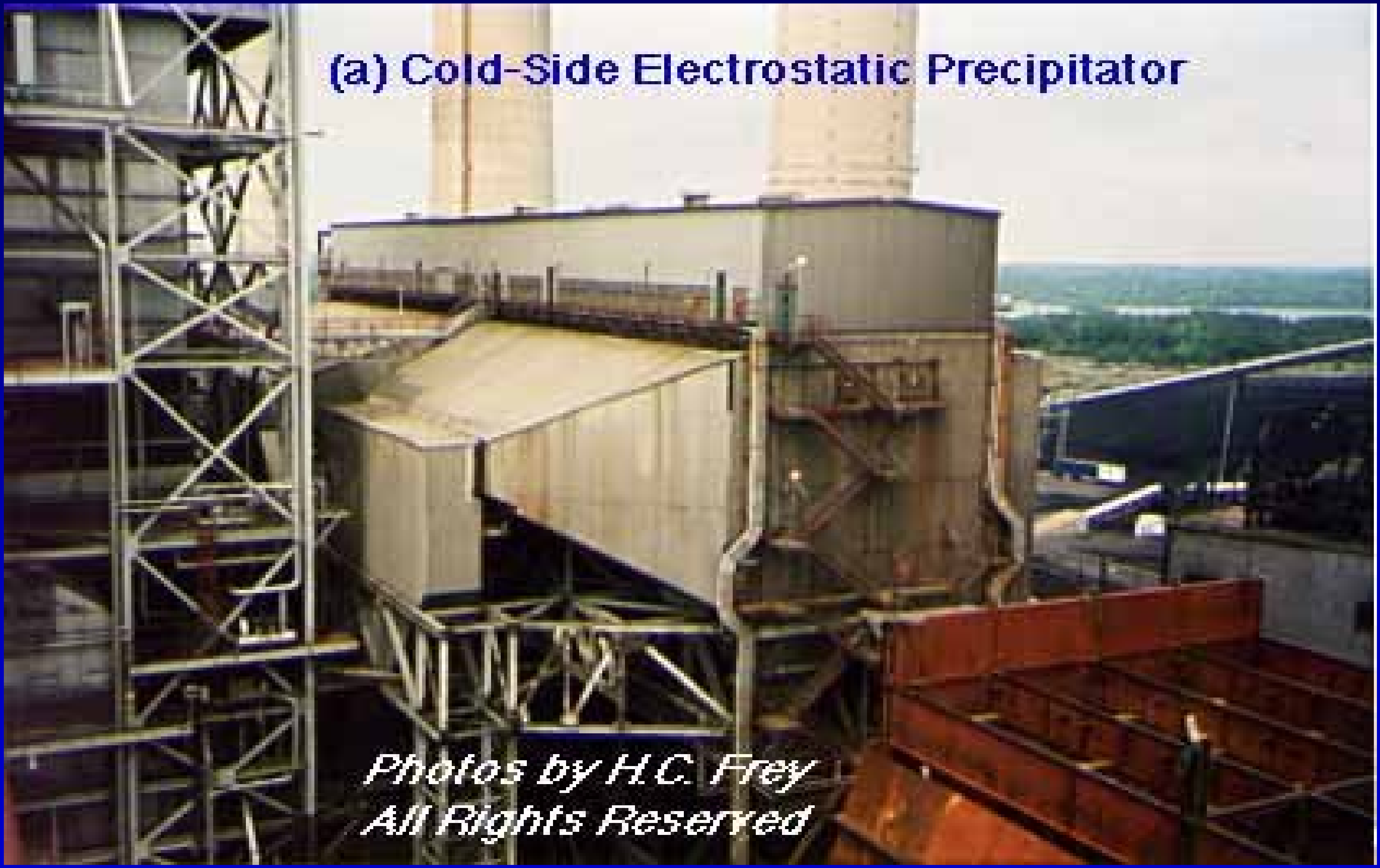
Typical ESP


(a) Cold-Side Electrostatic Precipitator
Photos by H.C. Frey
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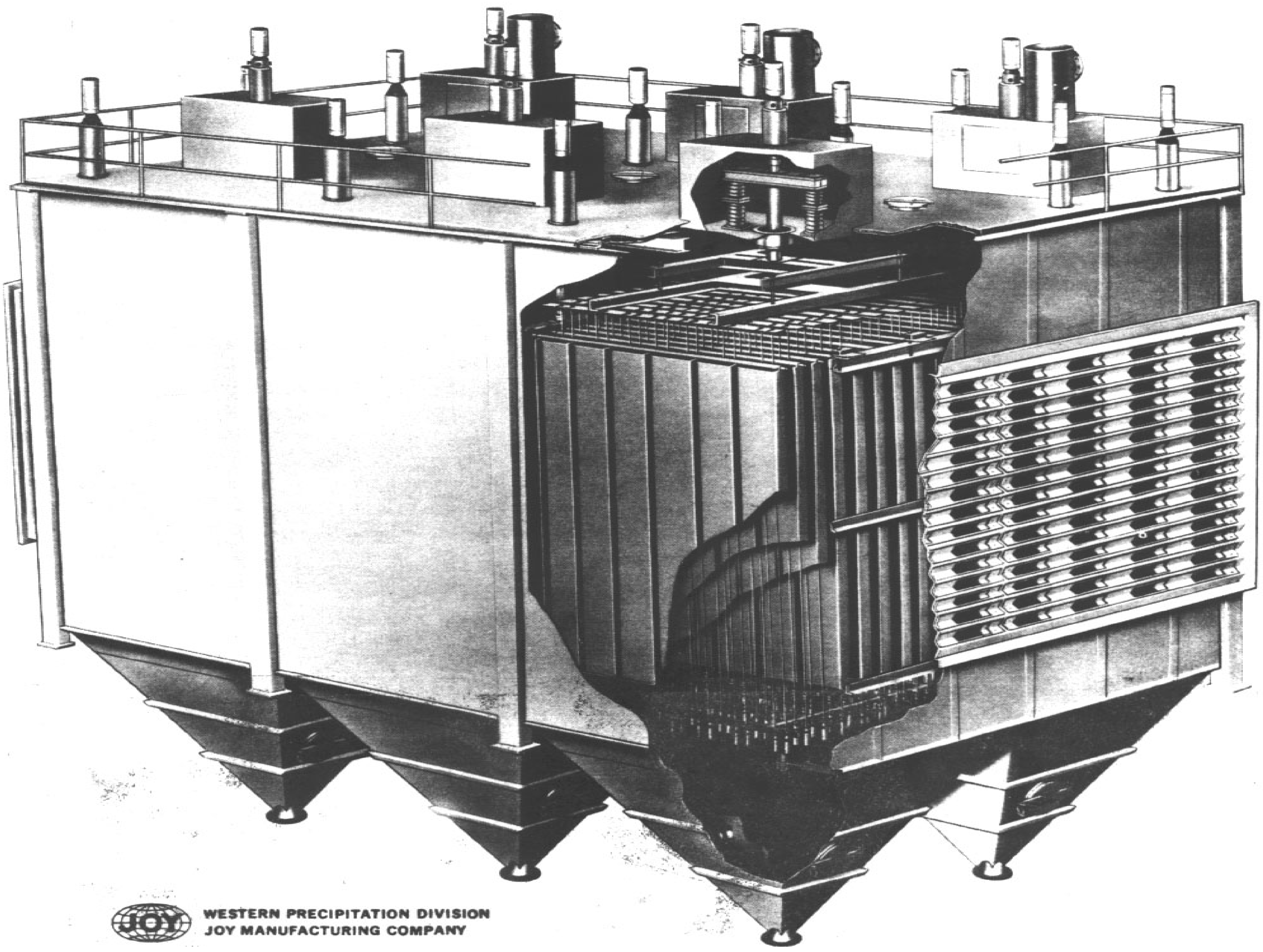
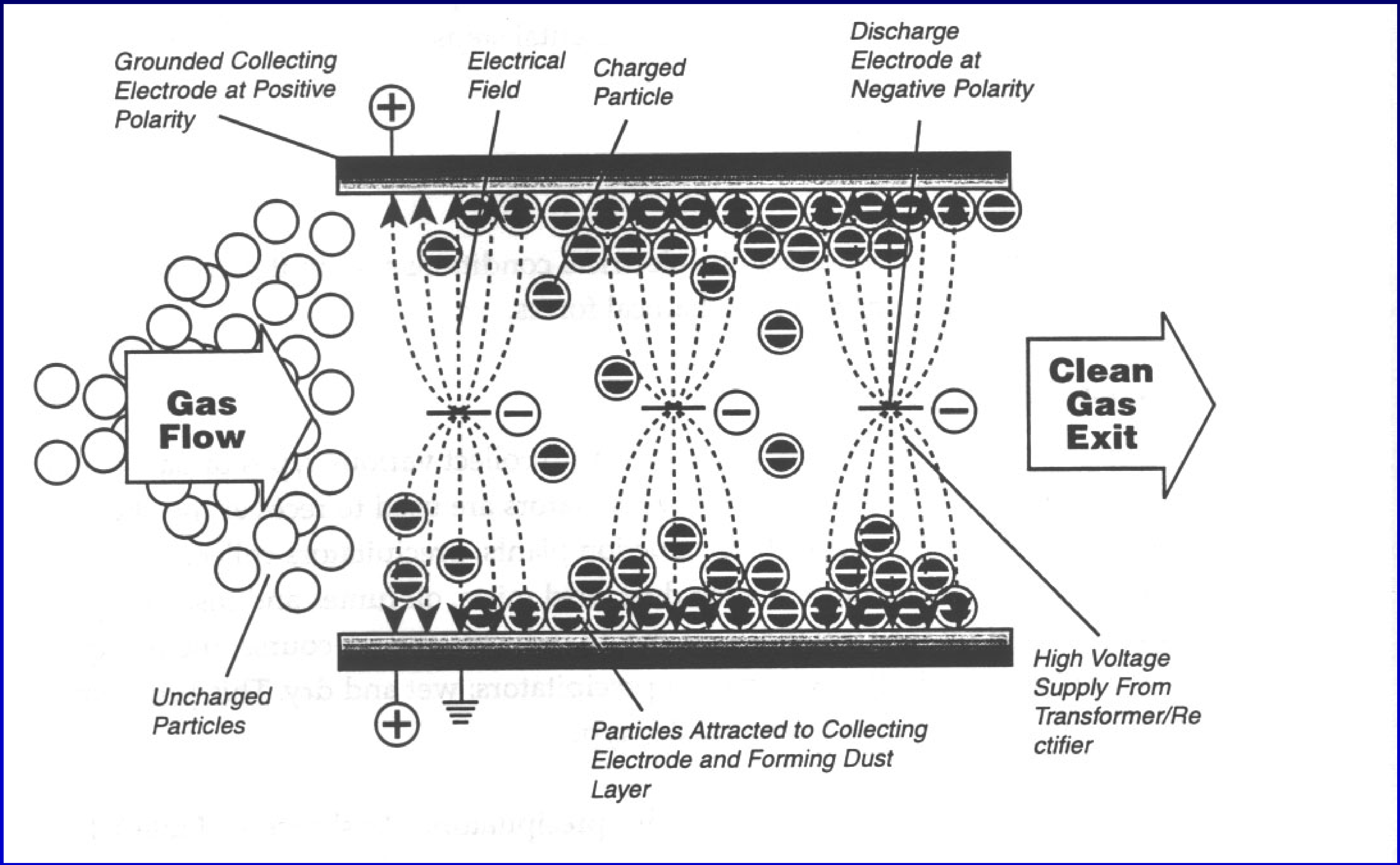


WESTERN PRECIPITATION DIVISION
JOY MANUFACTURING COMPANY

ESP Principles

- Charge the Particles
- Migration of Charged Particles to Collecting Plates
- Move the Collected Material to the Hopper for Removal

Dust Collection



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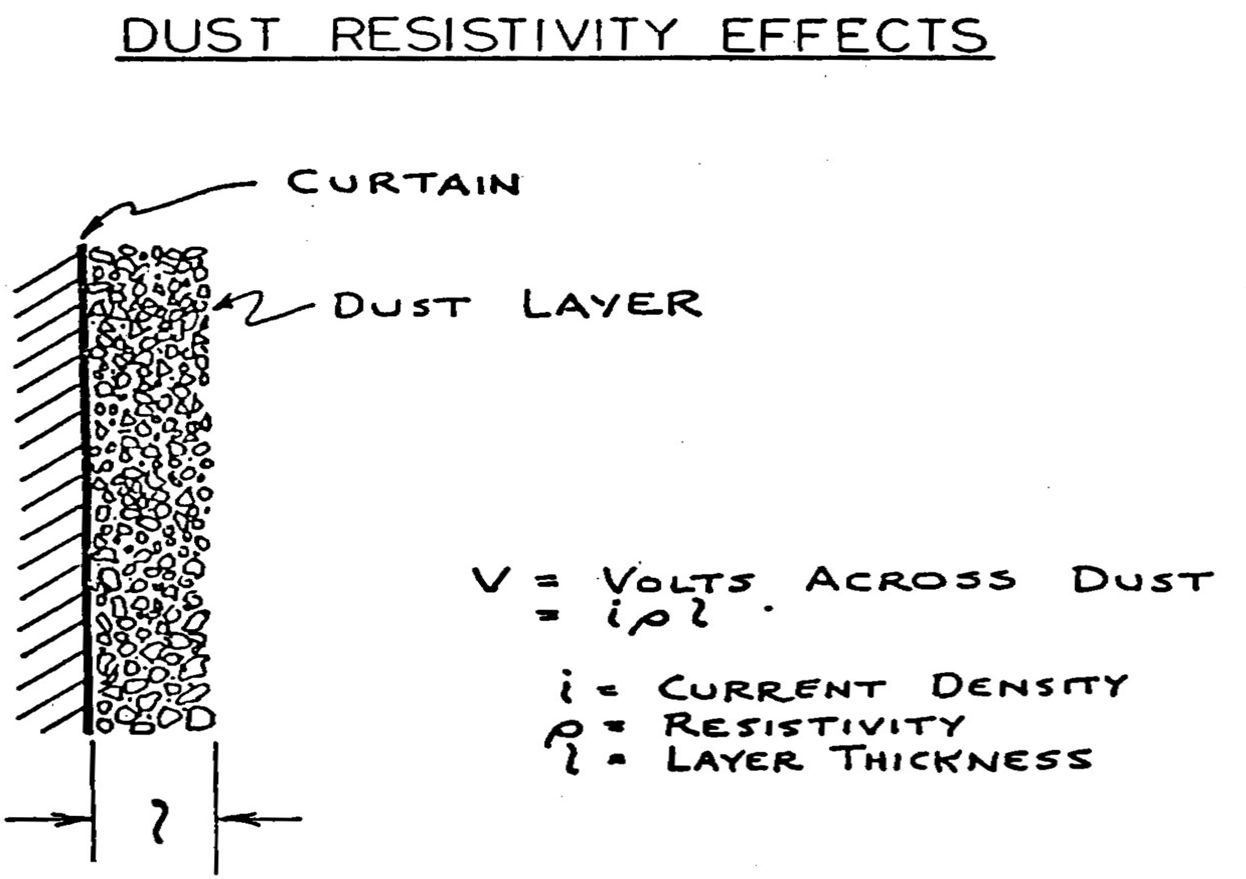
Dust Layer on Plates



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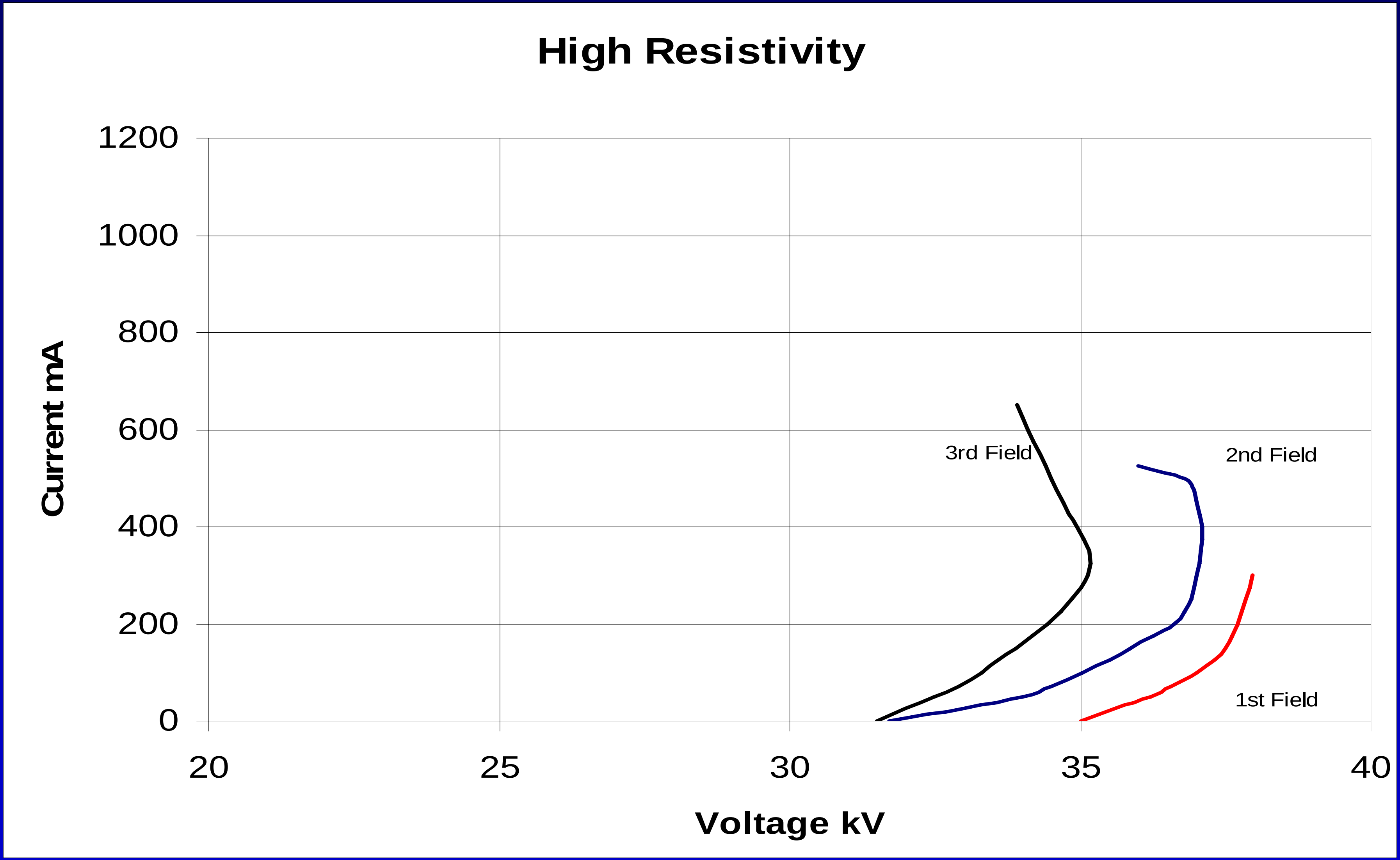
Sulfur Trioxide FGC

- SO_3 Reacts with moisture in flue gas
- Absorbed on surface of fly ash
- Improves surface conductance of ash
- Lowers the surface resistivity

Ash Resistivity

- Surface Conduction
- Volume Conduction
- Optimum is between
  - 1 x 10^8 ohm- cm
  - And
  - 1 x 10^{10} ohm – cm
- Ash measured in Laboratory in Oven and High voltage Cell
- Computer model developed based on Ash Analysis

VI Curves



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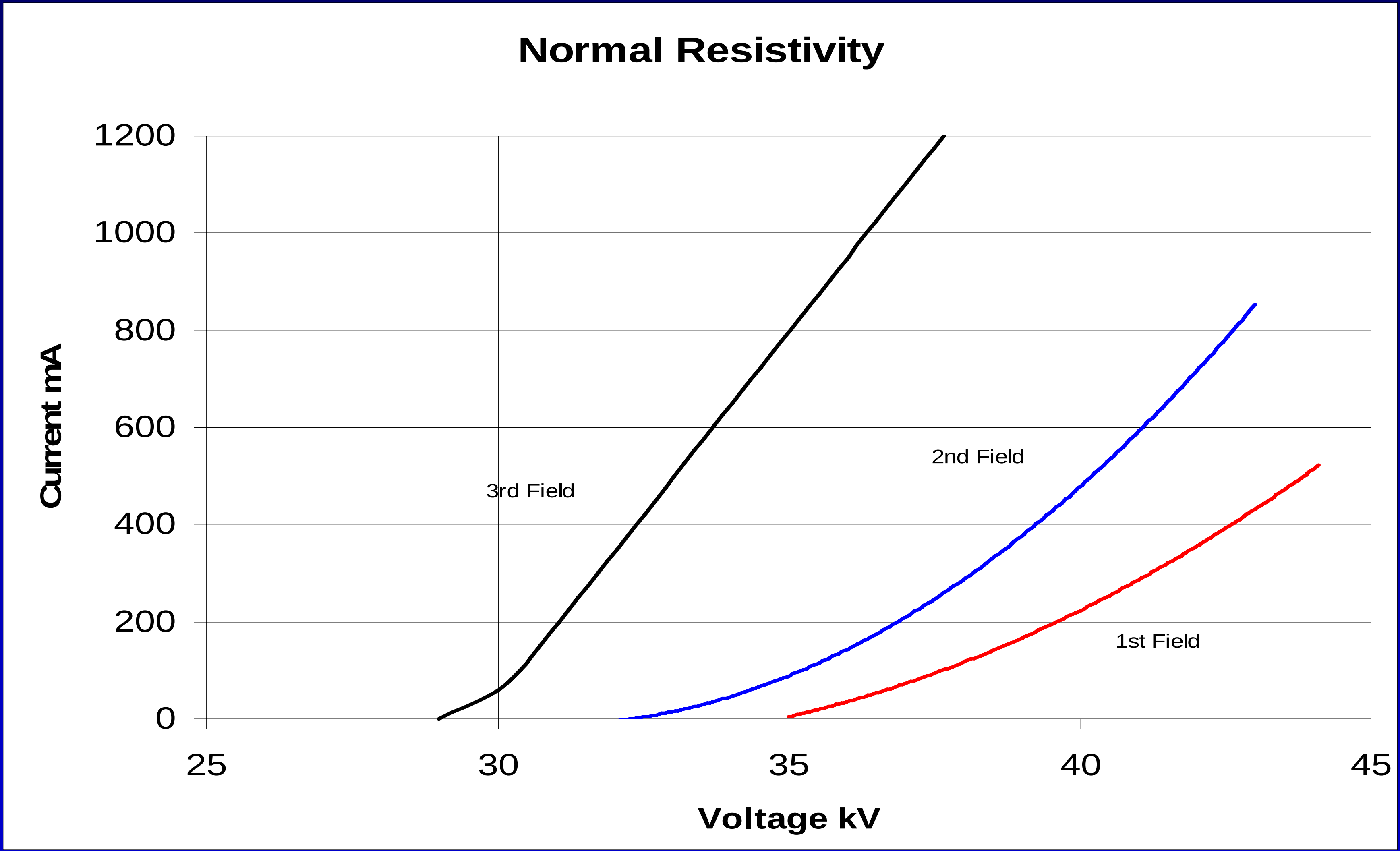
VI Curves



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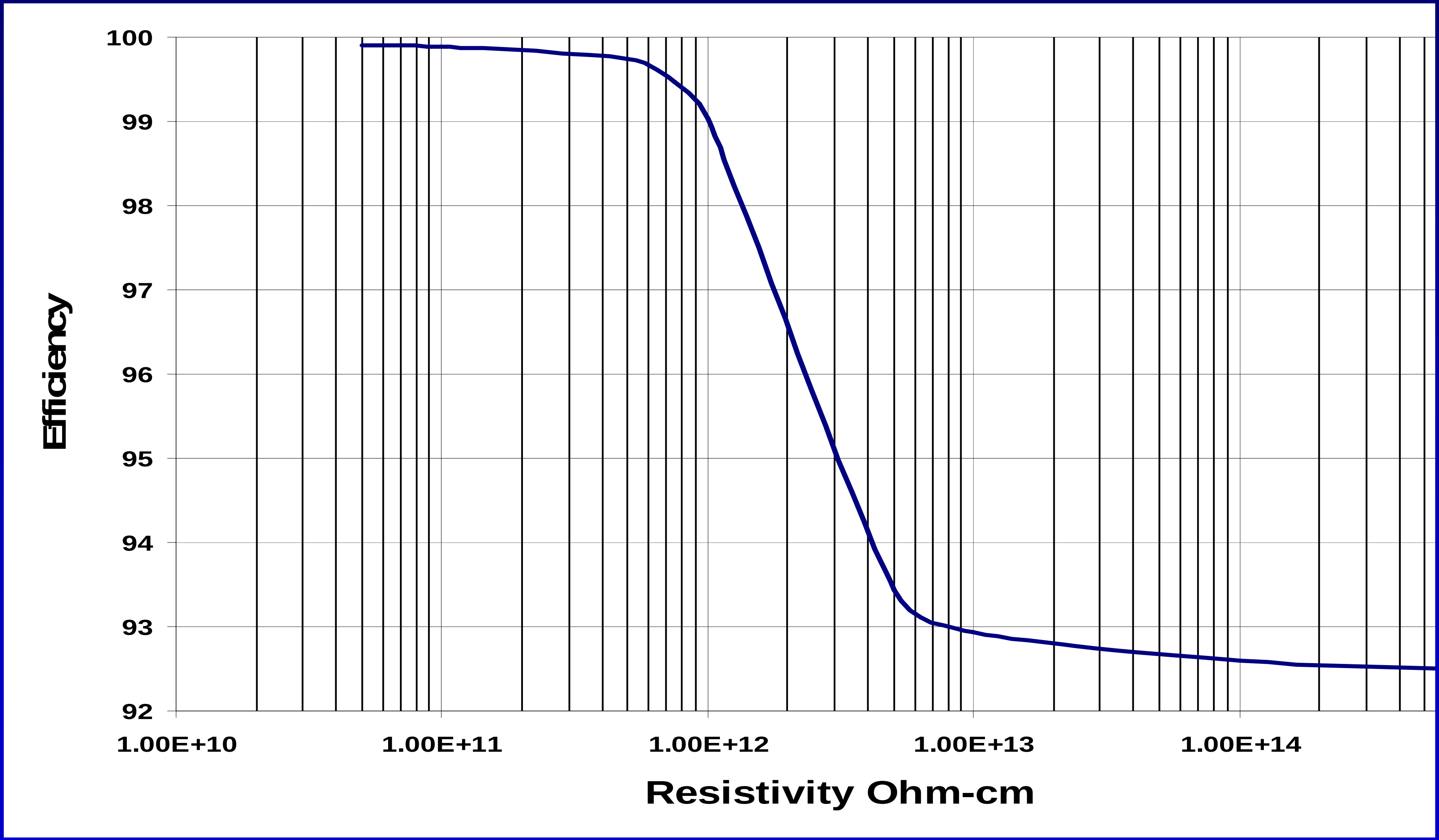
ESP Efficiency vs. Resistivity for SCA 325 ft2/1000 acfm



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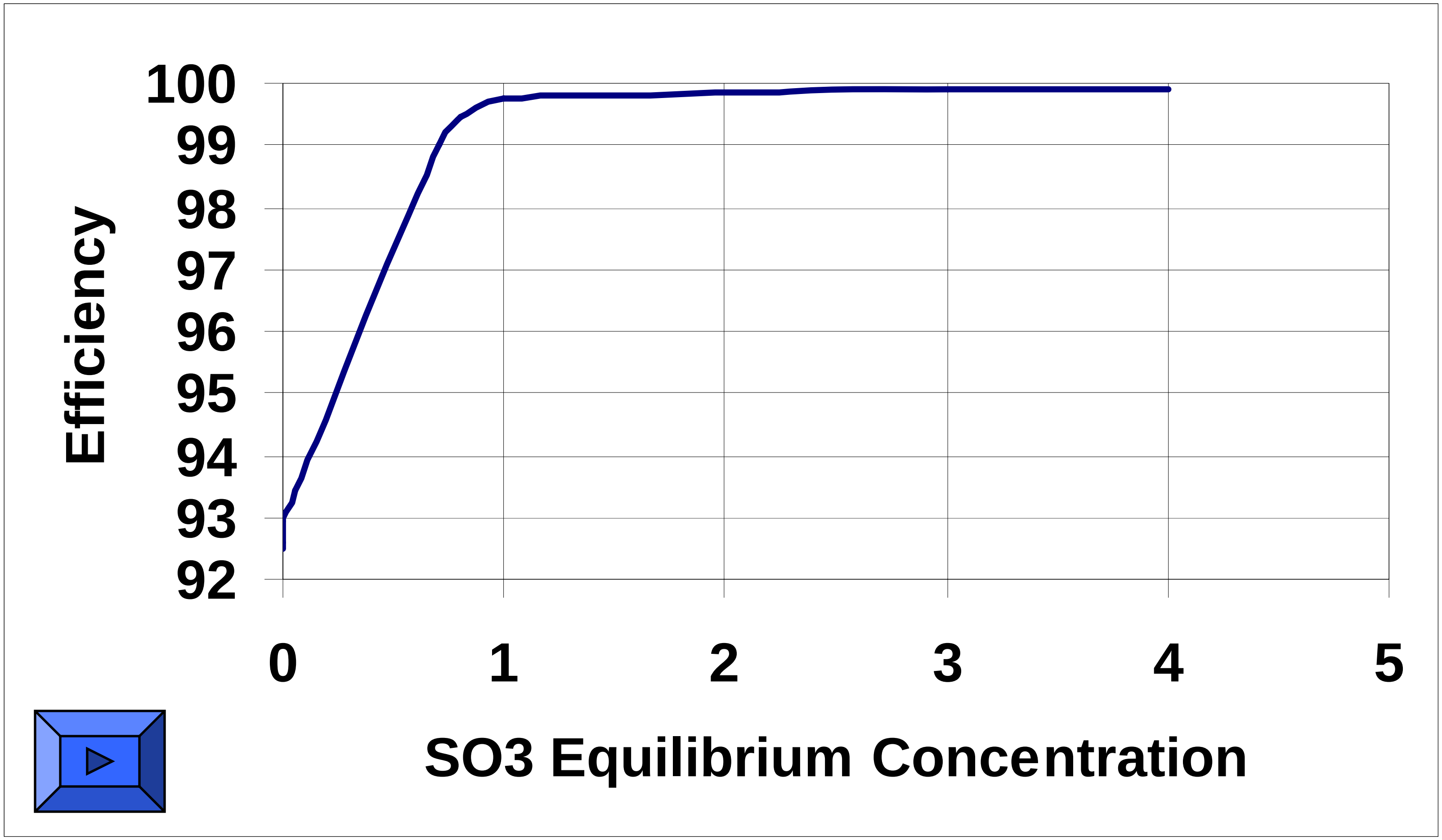
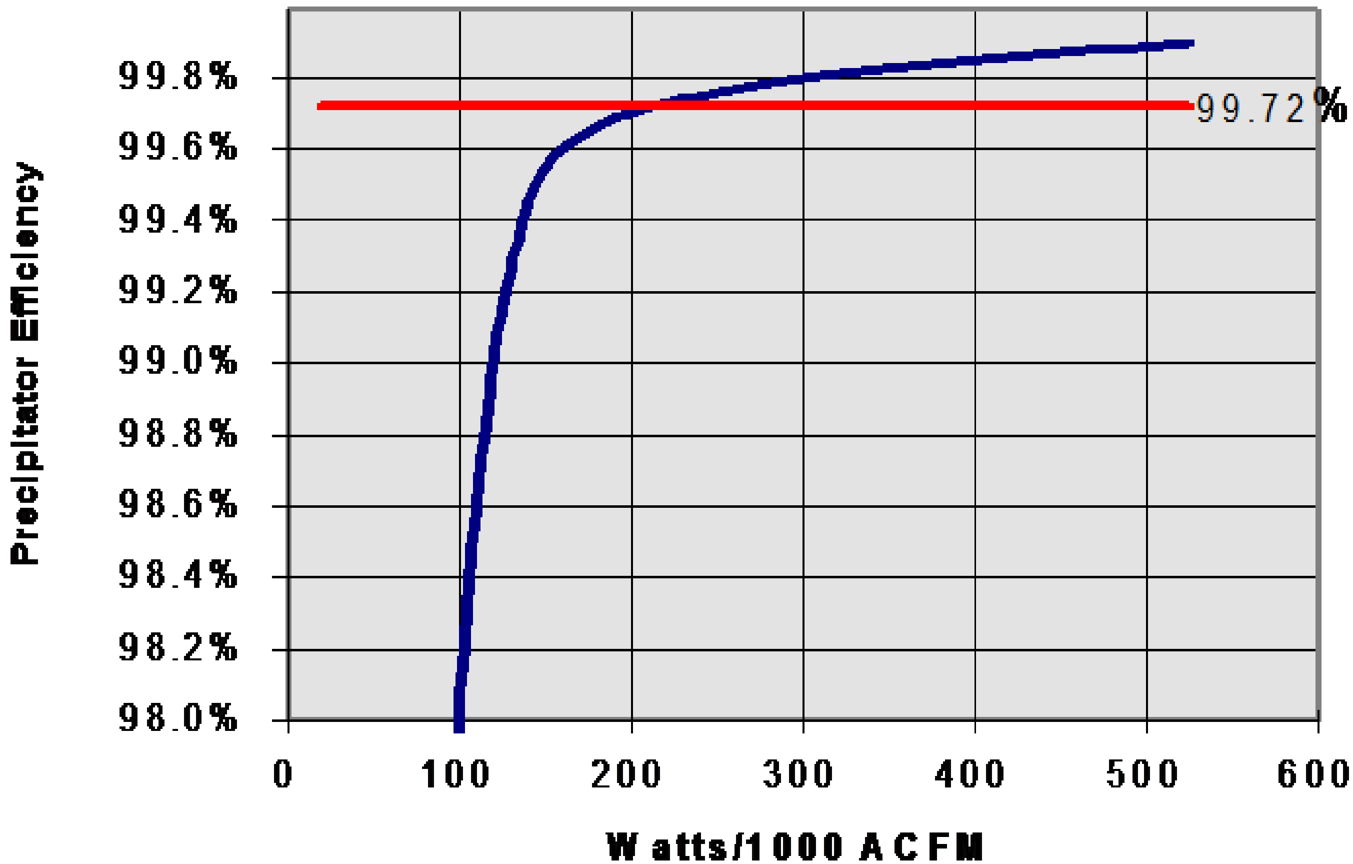
Precipitator Efficiency vs. SO_3 for ESP of 325 SCA

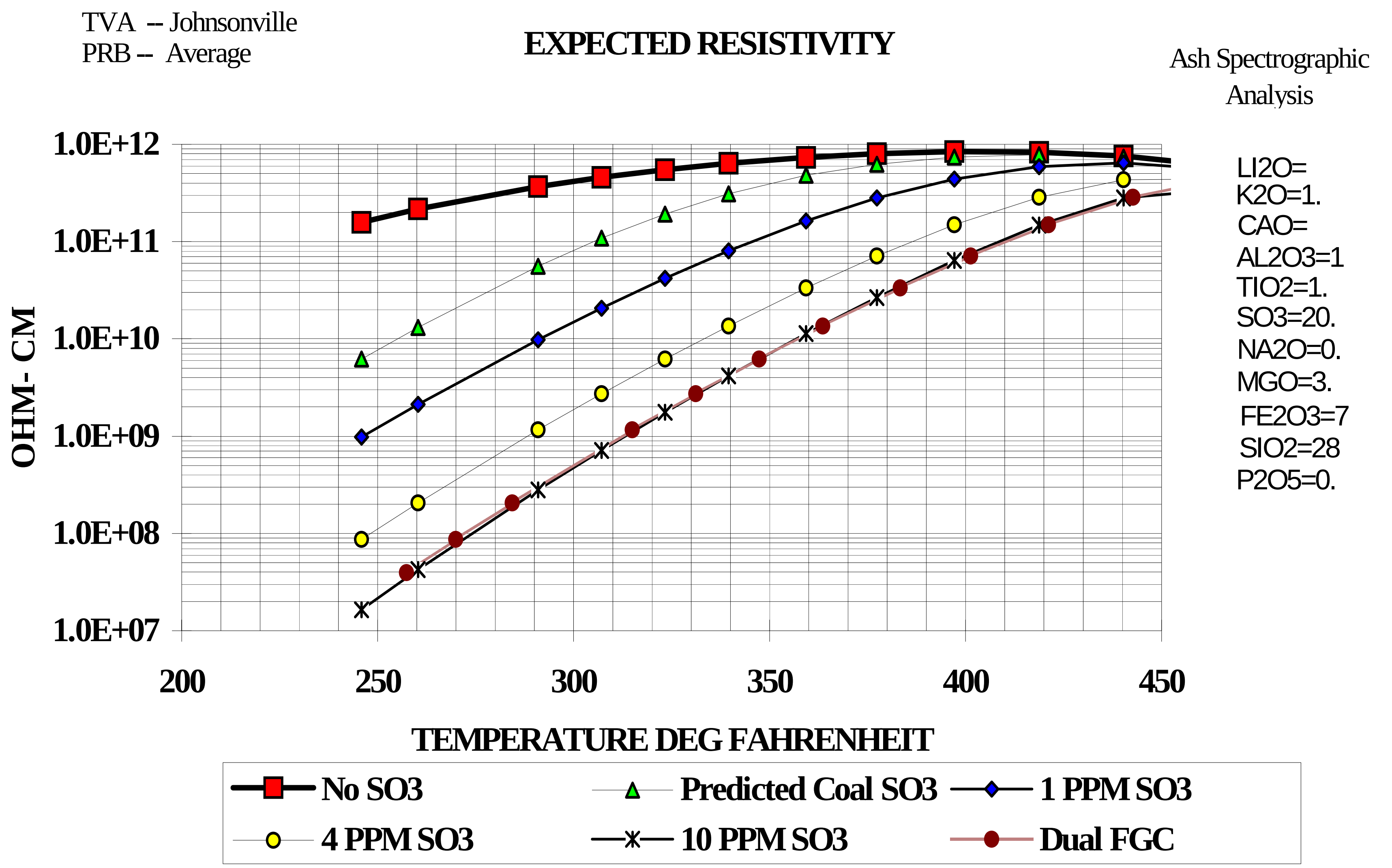


Precipitator Efficiency vs. Power



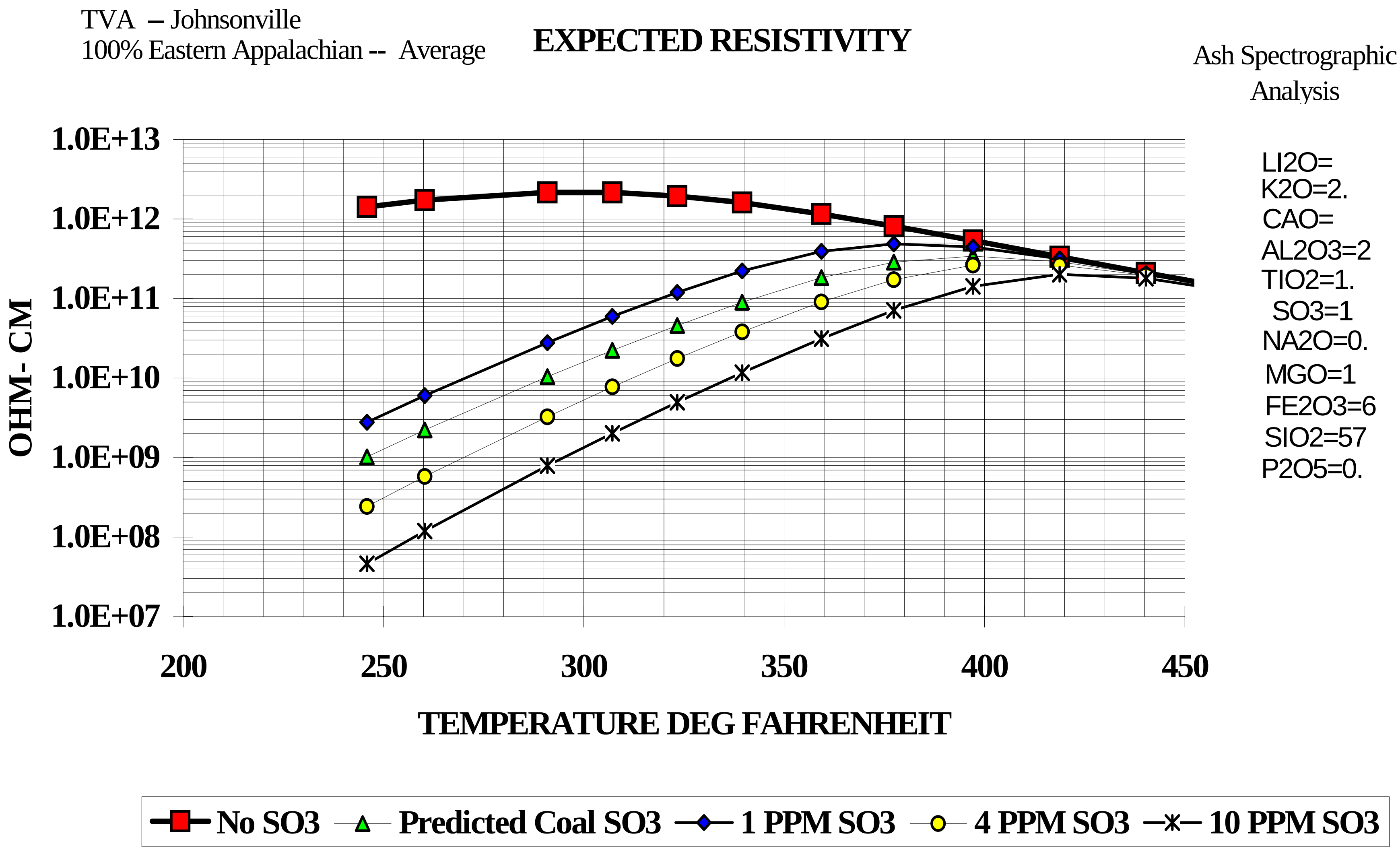
EPRI CS2908

PRB

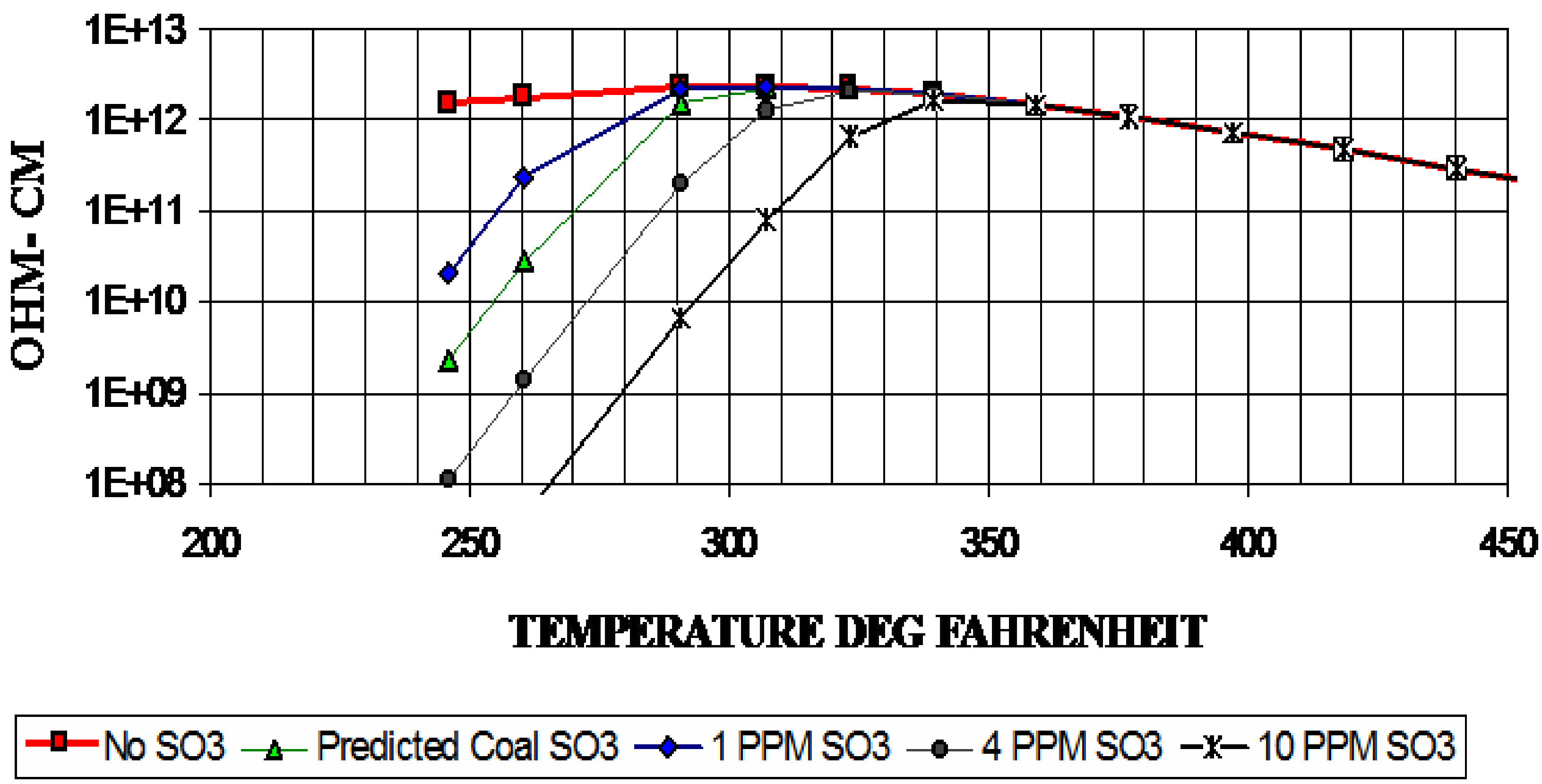


TVA -- Johnsonville
PRB -- Average
EXPECTED RESISTIVITY
Ash Spectrographic Analysis
1.0E+12
1.0E+11
1.0E+10
1.0E+09
1.0E+08
1.0E+07
OHM- CM
200
250
300
350
400
450
TEMPERATURE DEG FAHRENHEIT
LI2O=
K2O=1.
CAO=
AL2O3=1
TIO2=1.
SO3=20.
NA2O=0.
MGO=3.
FE2O3=7
SIO2=28
P2O5=0.
No SO3
Predicted Coal SO3
1 PPM SO3
4 PPM SO3
10 PPM SO3
Dual FGC

Appalachian 'Average'



Low Alkali


1E+13
1E+12
1E+11
1E+10
1E+09
1E+08
OHM- CM
200
250
300
350
400
450
TEMPERATURE DEG FAHRENHEIT
No SO3
Predicted Coal SO3
1 PPM SO3
4 PPM SO3
10 PPM SO3

Dual Conditioning

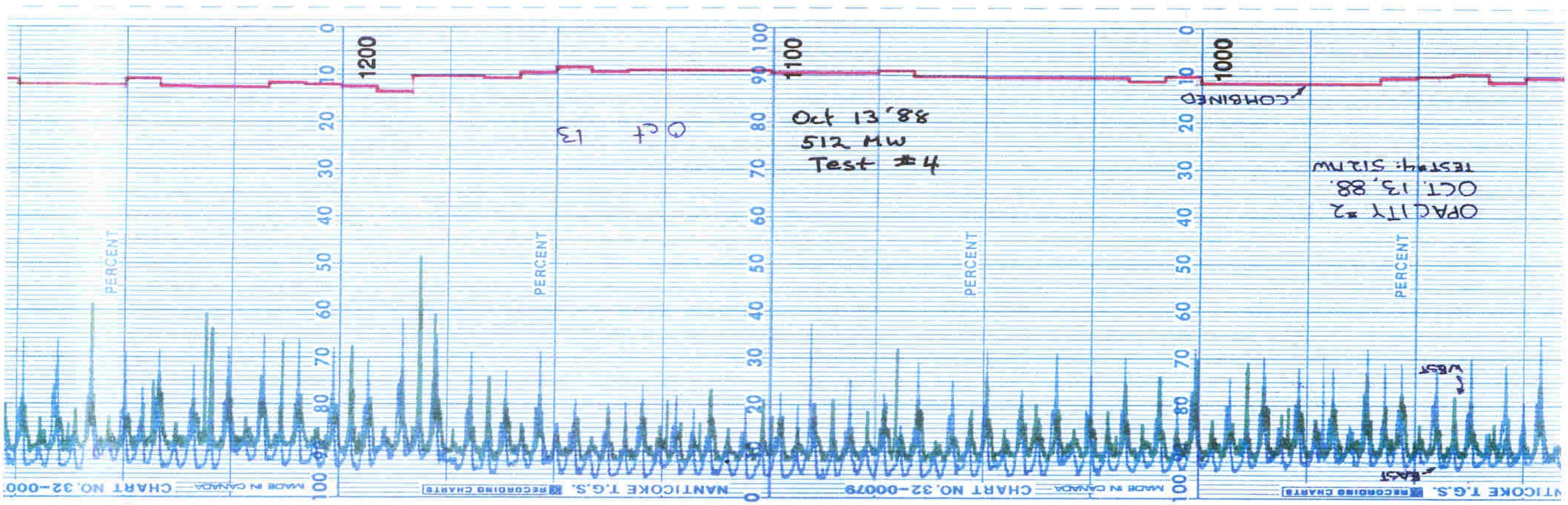
- Inject both SO_3 and Ammonia independently
- Ammonia improves attachment of SO_3
- Extend performance at higher temperatures
- Reduces precipitator ash reentrainment

Nanticoke Dual FGC Results

- SO3 – Opacity reduced from 22 to 15%
- With Dual FGC opacity 8%
- Substantial increase in Particle Size
- Dramatic reduction in rapper spikes
- Reduction in opacity baseline
- No hopper ash removal problems encountered

Nanticoke Regular Coal – No FGC

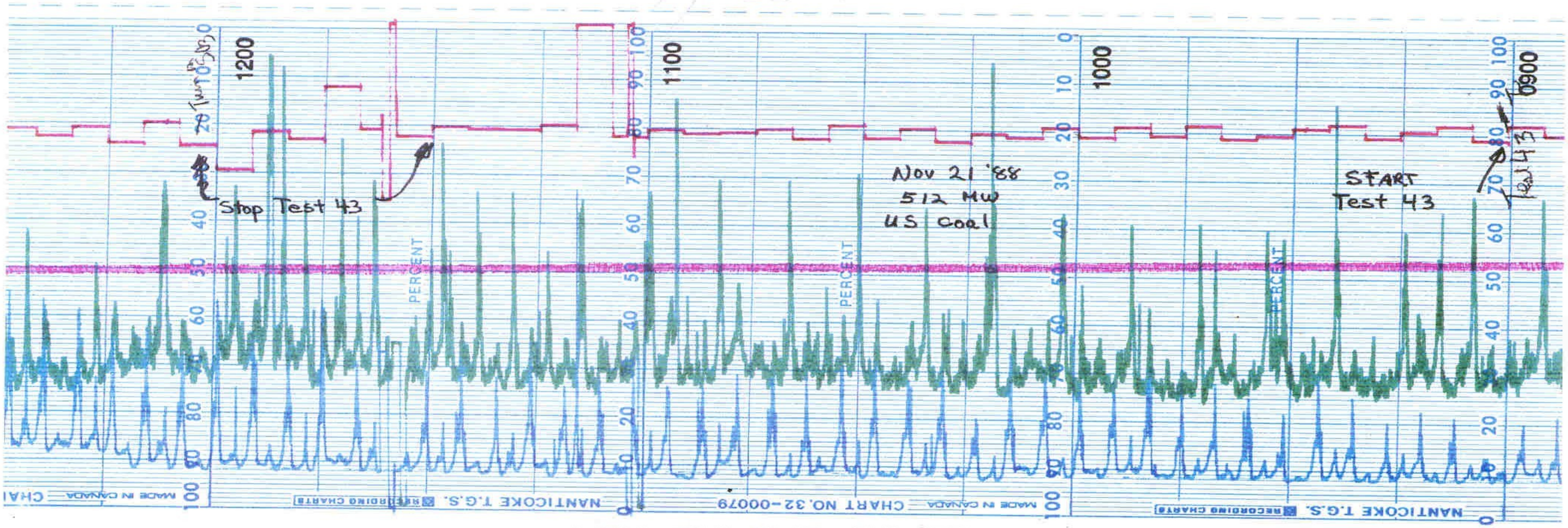
NANTICOKE UNIT 2
OPACITY



REGULAR 50/50
TEST 4
SO3 OFF
NH3 OFF

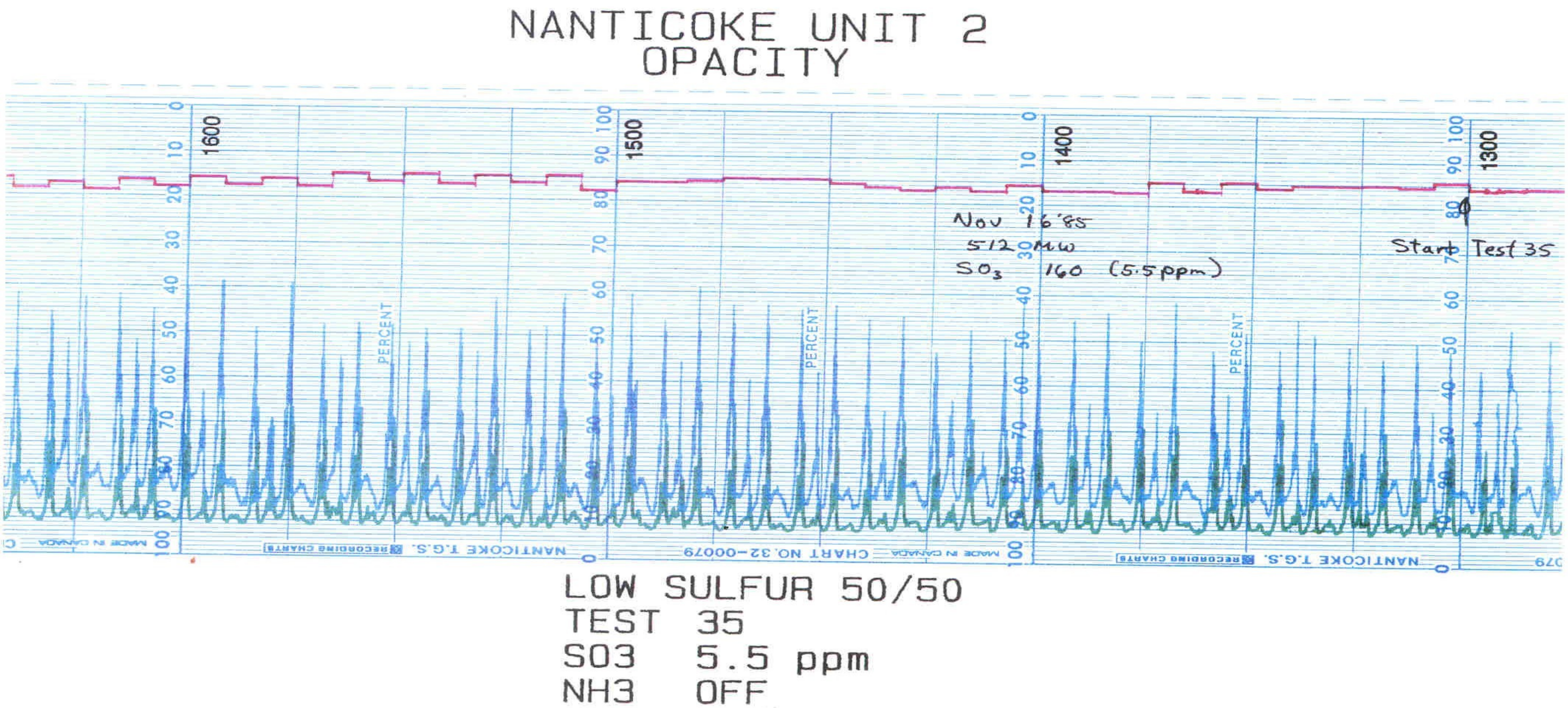
Nanticoke No FGC

NANTICOKE UNIT 2
OPACITY



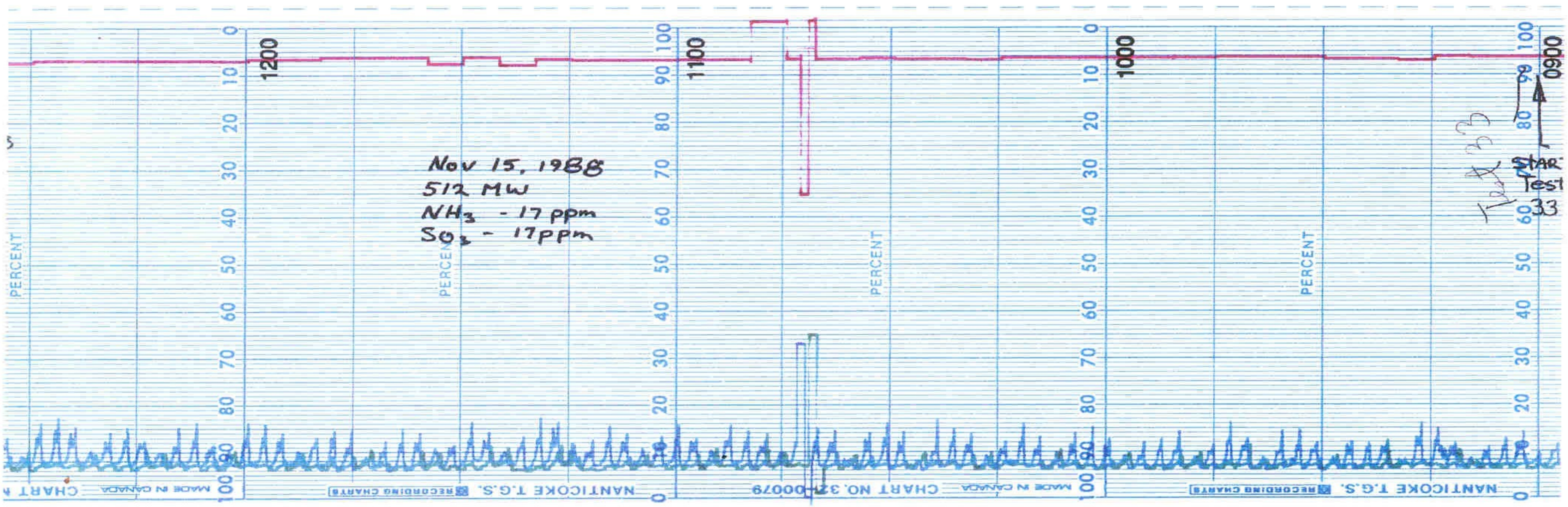
LOW SULFUR 50/50
TEST 43
SO3 OFF
NH3 OFF

Nanticoke SO3 Only



Nanticoke Dual FGC

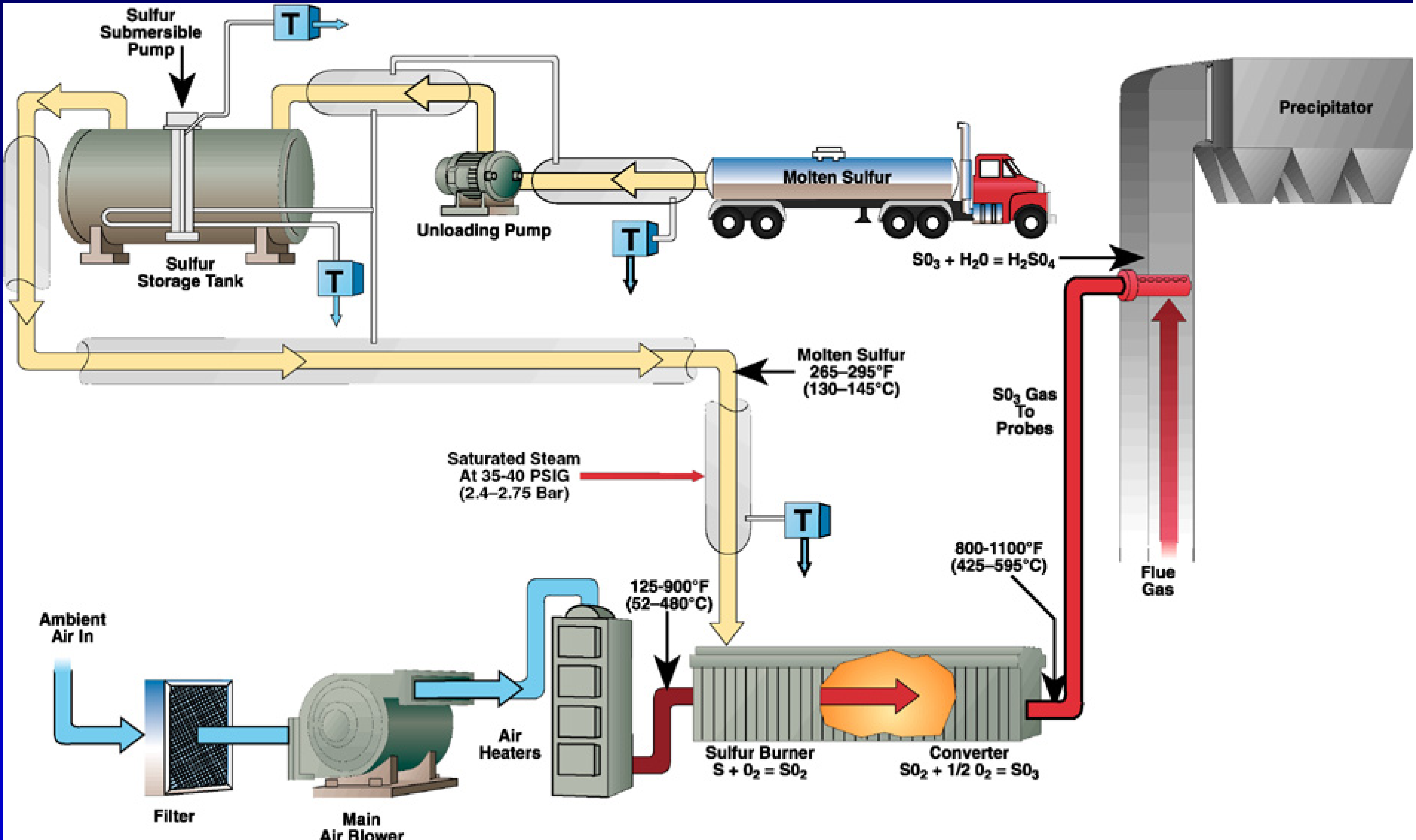
NANTICOKE UNIT 2
OPACITY



LOW SULFUR 50/50
TEST 33
SO3 17 ppm
NH3 17 ppm

Equipment Design Issues

SO3 Flue Gas Conditioning



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Critical Design Principles

- Injection into Flue Gas
  - Must remain above Dew Point
    - Piping Heat Loss Issues
    - Energy Consumption
  - Proper Distribution
- SO3 Converter Inlet Temperature
  - Conversion Efficiency
  - Catalyst Life
- Burner Issues
  - Sulfur Purity
  - Complete Combustion

Injection Location Criteria

- Achieve > 1 second residence time
- Nozzle Spacing < 1/10th Mixing Distance
- Hot Gas Piping not excessive length
- Accessible Location
- Hot Side / Cold Side

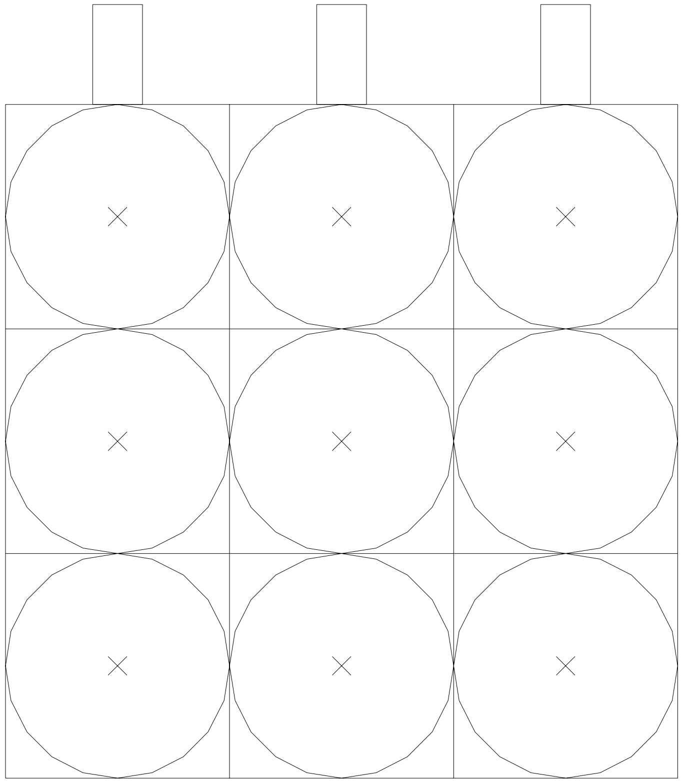
Injector Sizing Principles

- Achieve Uniform Distribution
- Mixing
- Maintain Adequate Injection temperatures
- Maintain Injection velocities

Injector and Nozzle Spacing

- Inject into Centroid of Square Equal Areas
- Adequate Injection Points
- Minimize Number of Injectors
- Injectors Usually about 3 feet apart

Square Duct Injector Spacing



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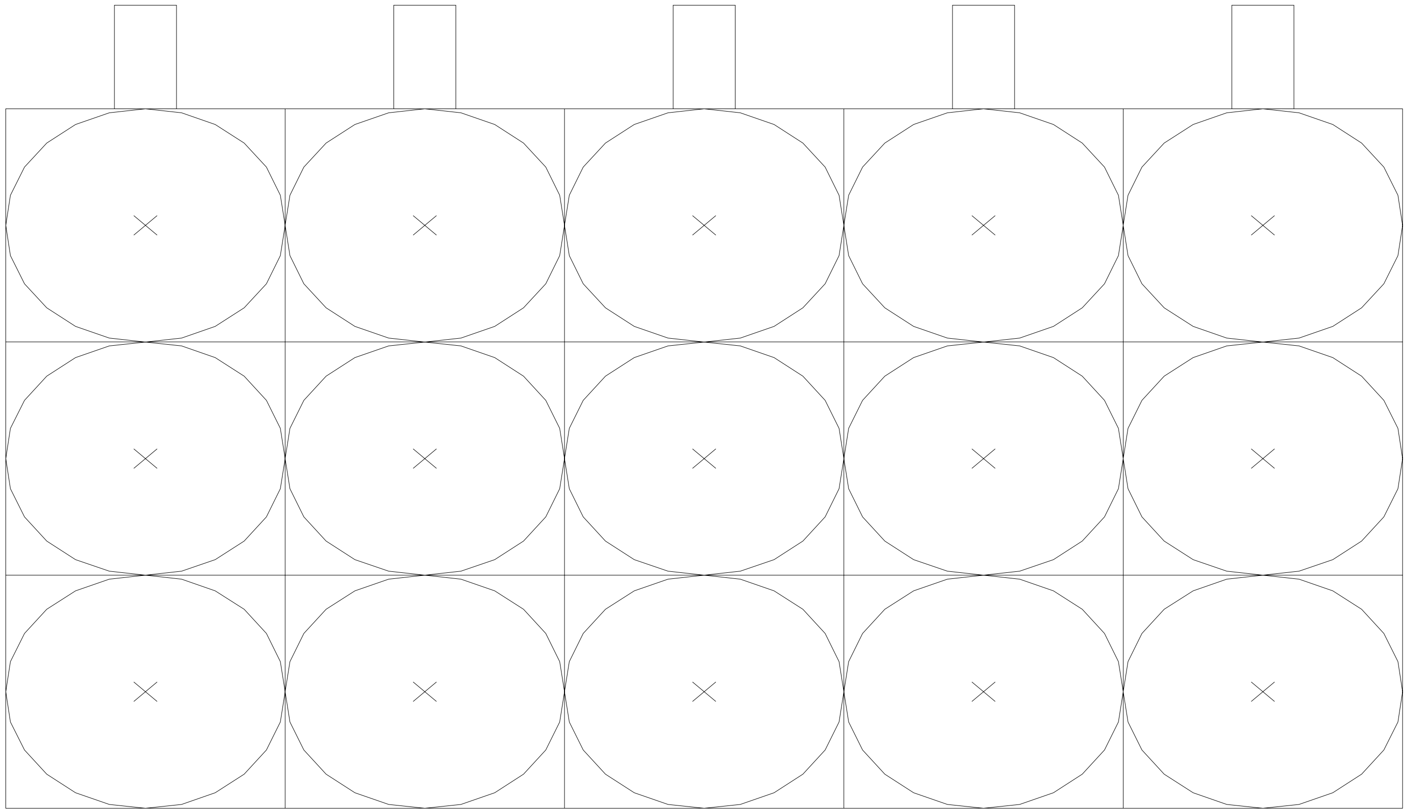
Rectangular Duct Injector Spacing



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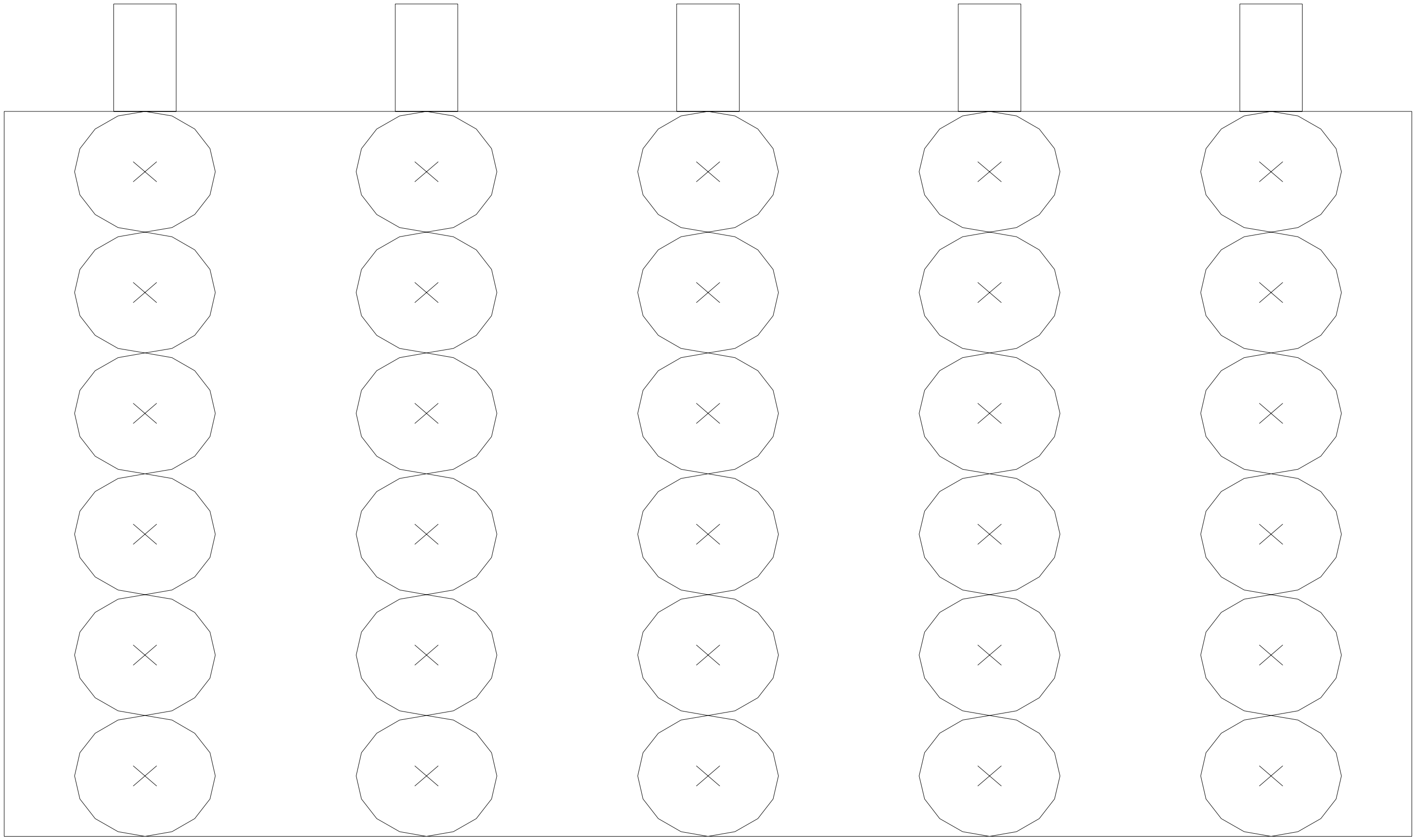
Improper Nozzle Spacing



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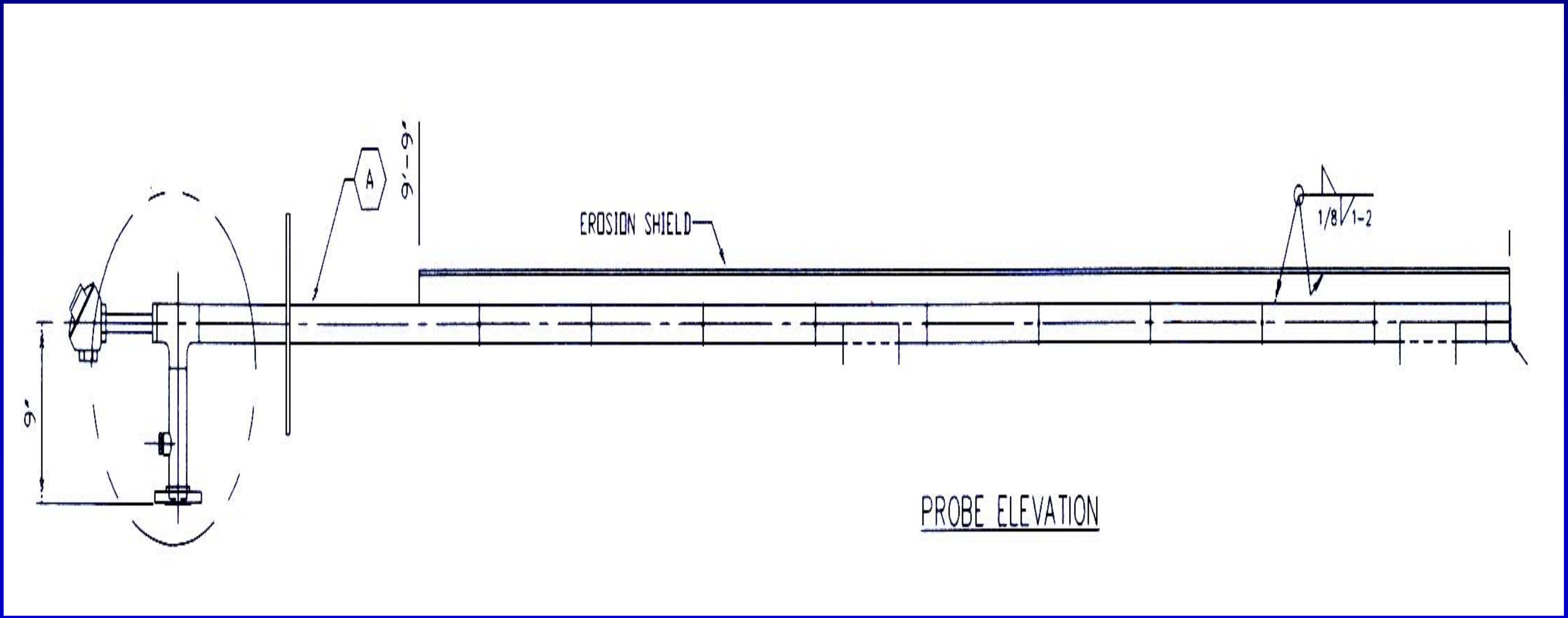
Hot Side Injector



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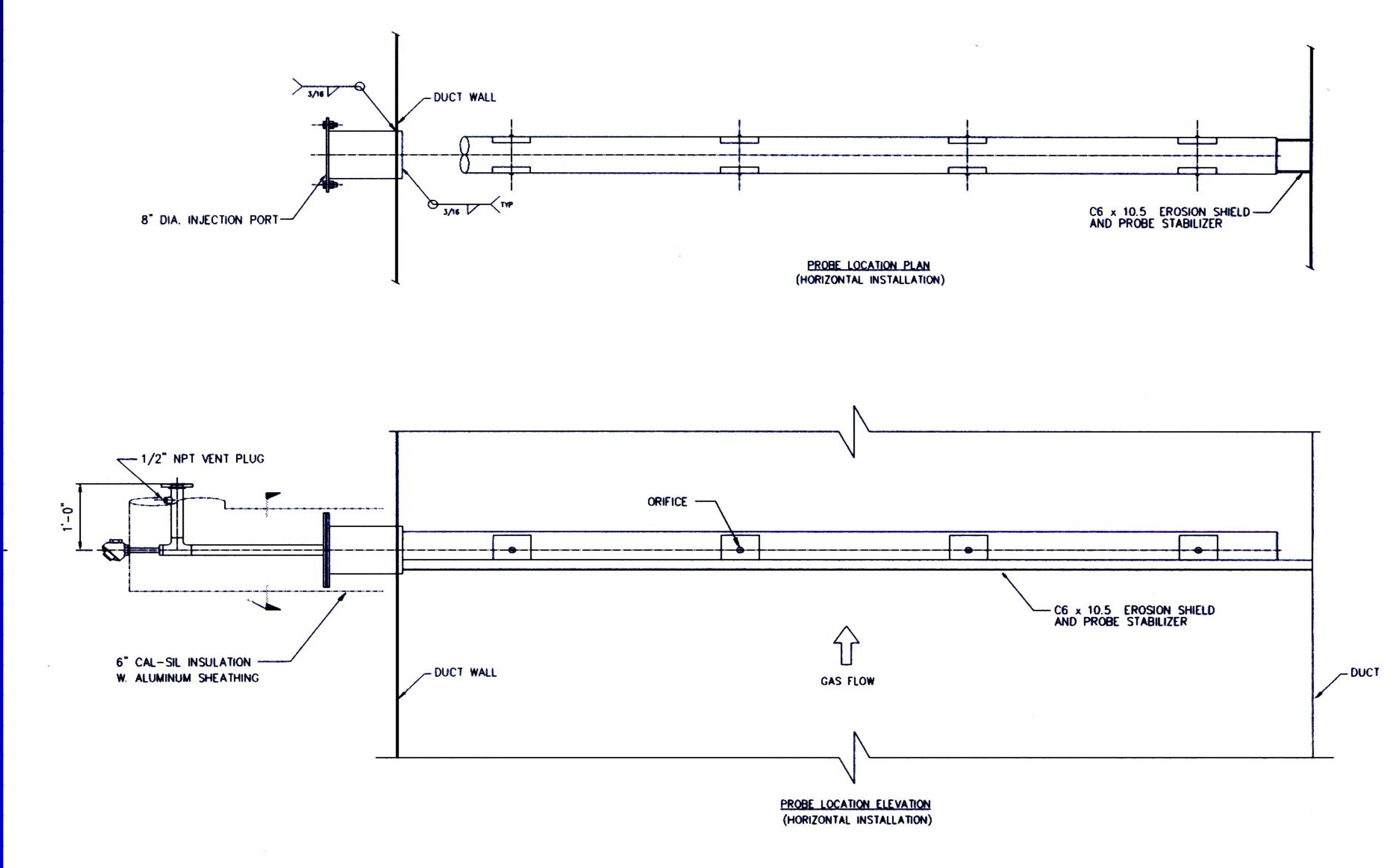
Typical 'Old Style' Design



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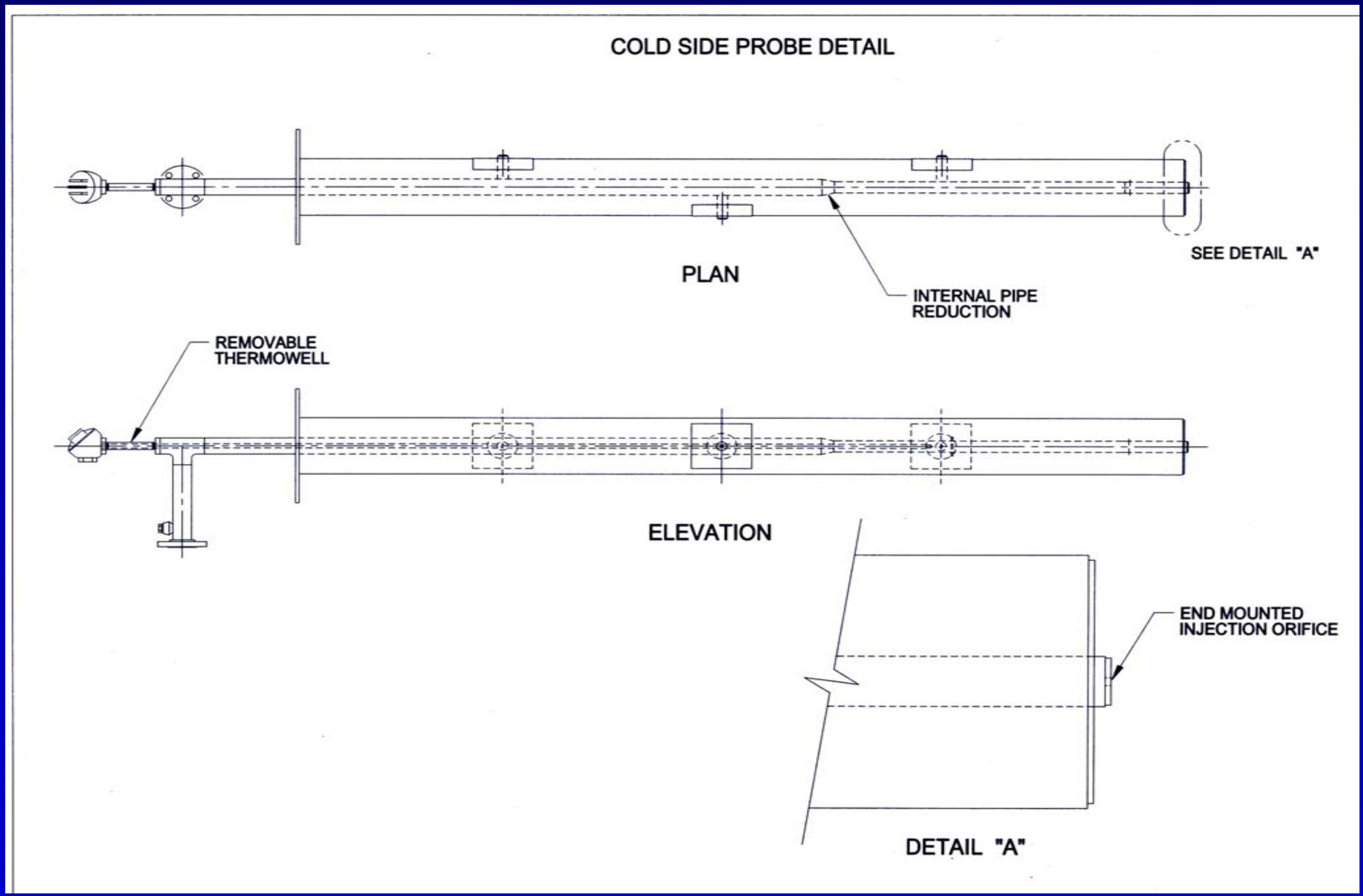
Injector Plugging Factors

- Injector Gas Flow
- Injector Temperature
- Duct Temperature
- Injector Length
- Injector Type
- Number and Size of Injector Nozzles

Improvements in Design

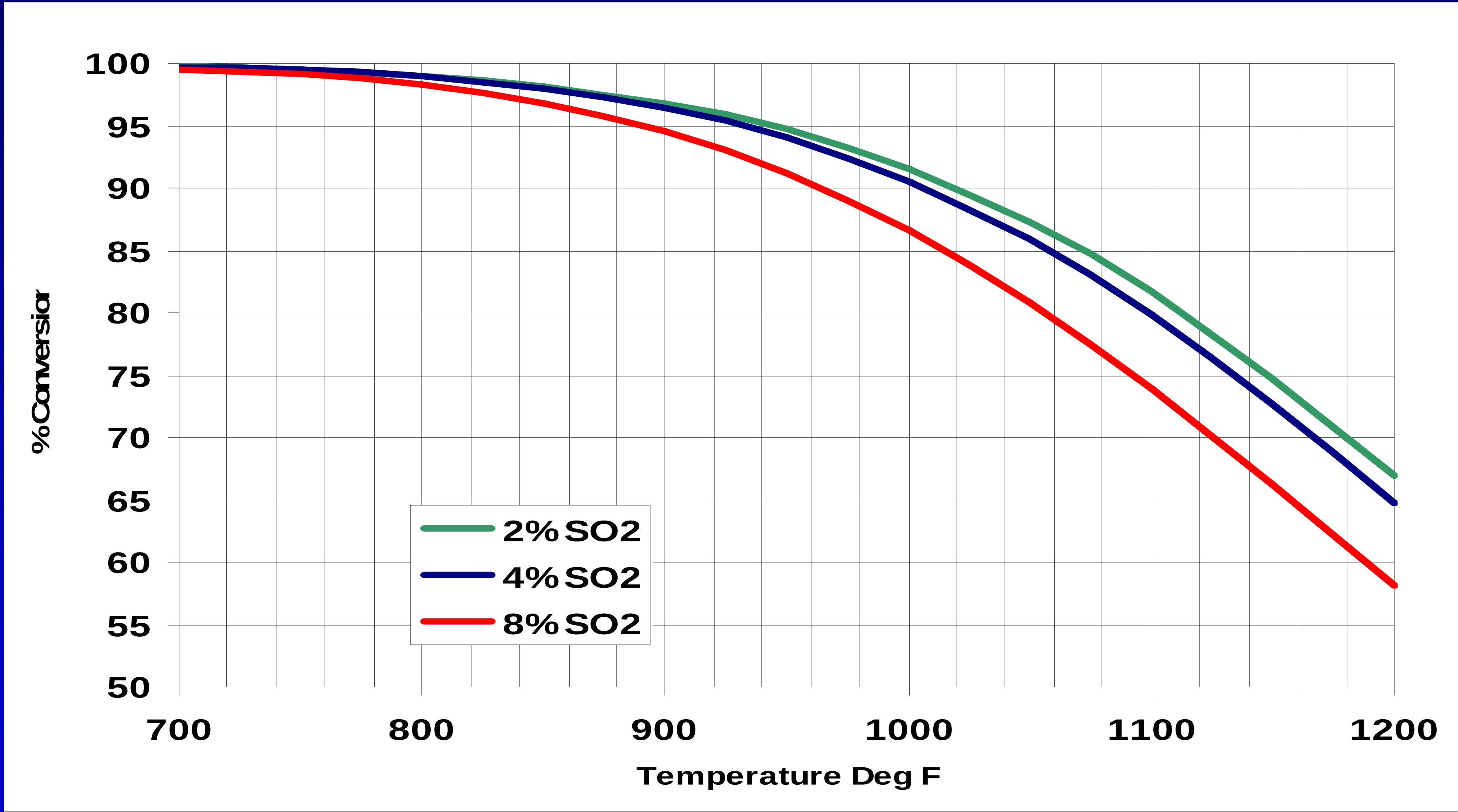
- Less nozzles
- Larger nozzles
- Improved Purging
- Nozzle at End of Injector
- Clean Out Path

New Design


COLD SIDE PROBE DETAIL
SEE DETAIL "A"
PLAN
INTERNAL PIPE REDUCTION
REMOVABLE THERMOWELL
ELEVATION
END MOUNTED INJECTION ORIFICE
DETAIL "A"

Design Improvements

Equilibrium Conversion for SO2 Oxidation



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High Efficiency Converter

- Low SO2 Gas Concentration
  - Improved Equilibrium Conversion
- Design Converter Gas Velocity Low < 3 fps
- High Activity First Catalyst Layer
  - Lower Light off temperature
  - Lower Outlet Temperature
  - Higher Conversion
- Second Layer Conventional Catalyst

SO3 System in Enclosure

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Air Heater Features

- Over sized air Heaters
- Rapid Startup
- Operating watt density less than design of 20 watts/ sq in
- Small easy to handle modules
- Vertical design assures good air distribution

Molten Sulfur Storage Tanks

- Typical 14 to 30 days storage at 20 ppm
- Tanks complete with platforms, and instrumentation
- Redundant steam coils – fast melt design
- Steam heated penetrations
- Single vent
- Single tank can feed multiple units

Advanced Ring Main Sulfur Pumping System

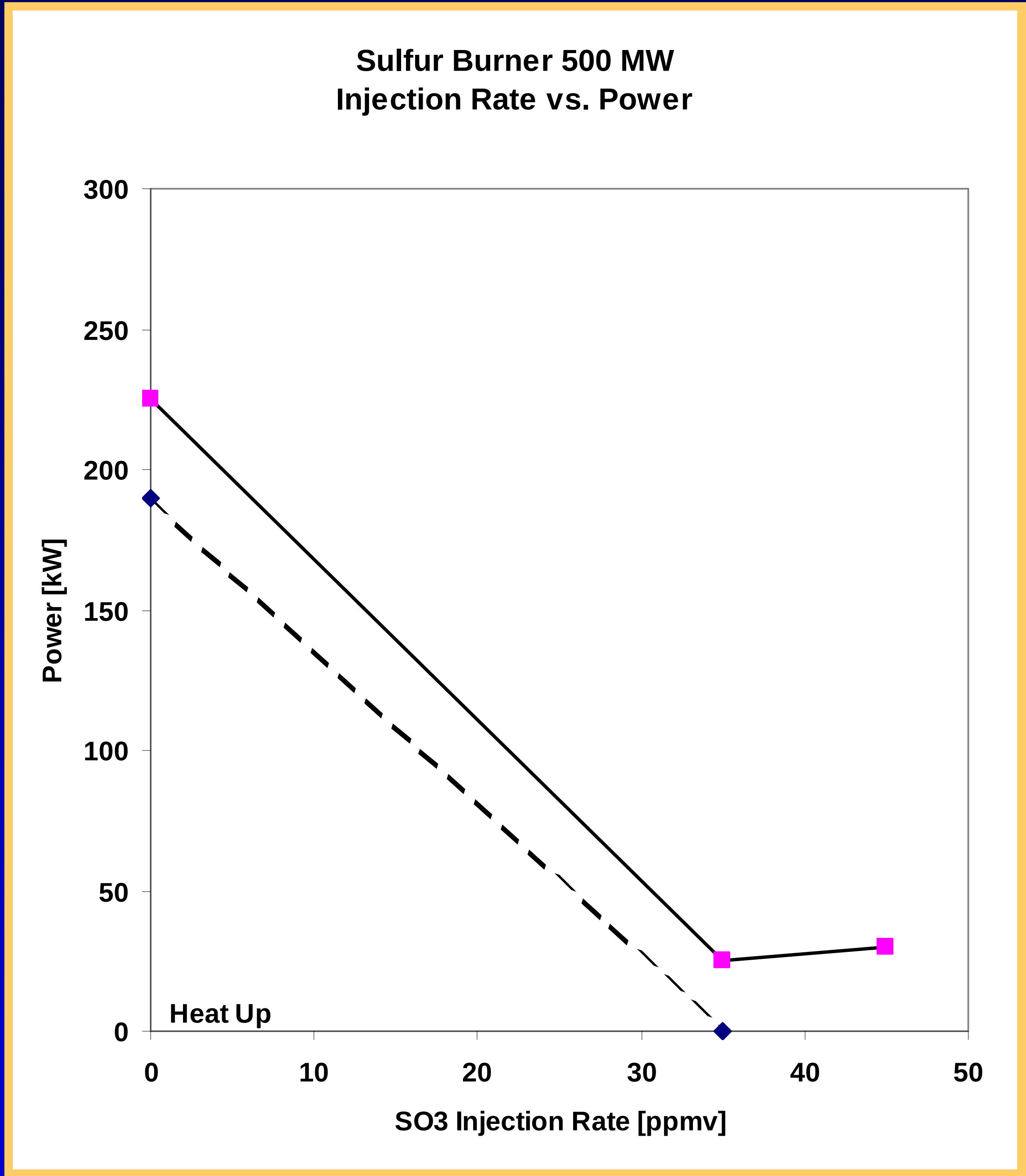
- Constant speed centrifugal pumps
- Robust low maintenance design, highly reliable, industry standard
- Redundant sulfur pumps
- Sulfur metered with Coriolis Flow Element
- Controlled at each sulfur burner with flow control valve

Hot Side Injection

- Increased SO_3 Residence time
- Minimal Injector Plugging
- Improved SO_3 Distribution
- SO_3 always above dewpoint – no injector corrosion
- Ideal for Tubular Air Heaters
- Enables control of SO_3 / Ammonia Ratio

Low Energy Consumption Design

- Significant Energy Savings
- Air Flow Varies with Sulfur Rate
- High Gas Volume for Rapid Startup
- Air Heater off at about 60% of Design
- No Blower Speed Control



Sulfur Burner 500 MW
Injection Rate vs. Power
Power [kW]
300
250
200
150
100
50
0
Heat Up
0
10
20
30
40
50
SO3 Injection Rate [ppmv]

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Advantages of Molten Sulfur Feed

- Molten Sulfur $^{1}/_{5}$ to ½ Cost
- Less Manpower Intensive
  - 20 tons unloaded in half hour
  - No Silo to Maintain
- Lower Energy Consumption
  - Sulfur is delivered molten
- More tolerant of Impurities
  - Large settling capacity of Tank

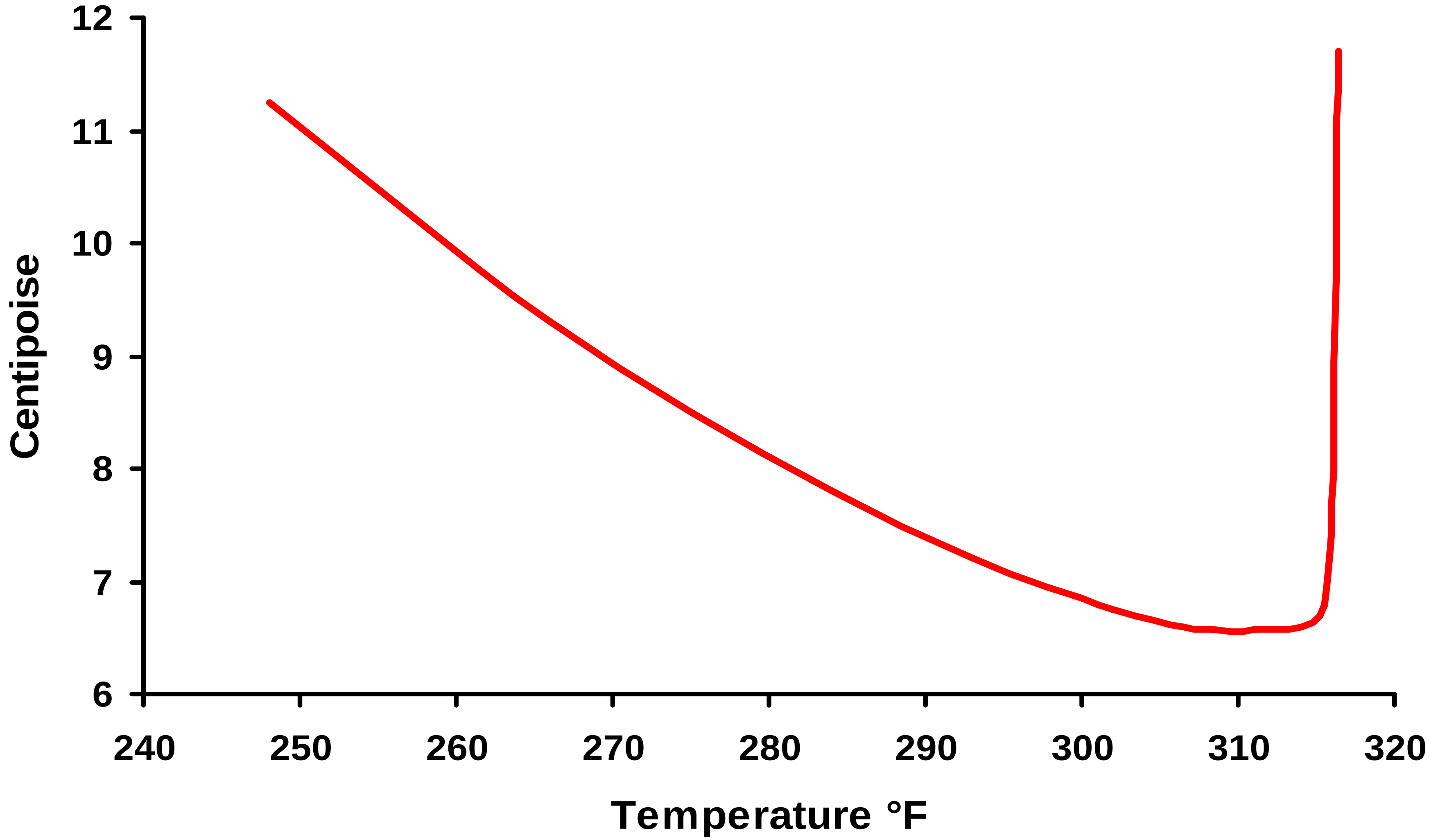
Advantages of Molten Sulfur Feed

- More tolerant of Impurities
  - Large settling capacity of Tank
- Safer
  - No sulfur dust hazards
- Molten Sulfur Readily Available
- Less Mechanical Equipment
- Hybrid Design has worst of both designs

Sulfur Properties

- Heat of Fusion ~ 17 Btu/lb
- Specific Heat 0.16 Btu/lb/deg F
- Molten Sulfur Viscosity of Wide Temperature Range
- 3952 Btu/ lb

Sulfur Viscosity



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Typical Molten Sulfur Specification

• Sulfur	99.9570%
• Ash	0.0007%
• Organic	0.0036%
• Moisture	0.0872%
• Selenium	< 1 ppm
• Tellurium	< 1 ppm

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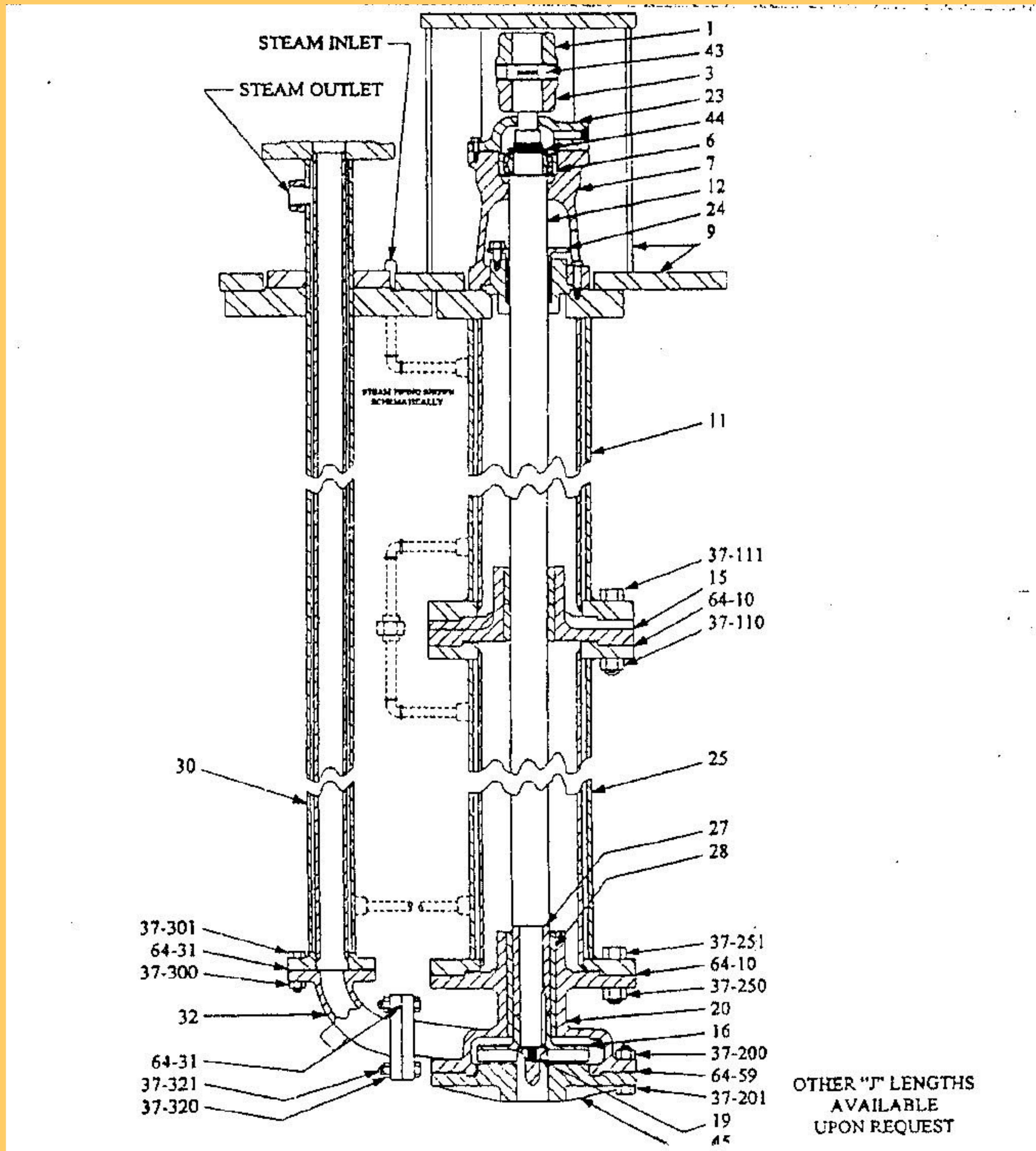
STEAM INLET
STEAM OUTLET
STEAM PIPING SHOWN SCHEMATICALLY
1
43
3
23
44
6
7
12
24
9
11
37-111
15
64-10
37-110
30
25
27
28
37-301
64-31
37-300
32
64-31
37-321
37-320
37-251
64-10
37-250
20
16
37-200
64-59
37-201
19
OTHER "J" LENGTHS
AVAILABLE
UPON REQUEST

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Summary

- Approximately 1500 FGC units installed worldwide
- Refined over 30 years
- Many units over 25 years still operating
- New systems use only 10% of the energy of older system
- Application of the technology is predictable
- Successful and competitive ash resistivity correction

Questions