Uniform Air Quality Training Program

Electrostatic Precipitators

Course #281

Presented by Joe Yager

California Environmental Protection Agency
AIR RESOURCES BOARD
Compliance Division

Course Overview

- Background/Applications
- Theory of Operation
- Major Types of ESPs
- Design Considerations
- ESP Components
- Performance Monitoring
- Inspecting ESPs

U.S. Mortality Figures

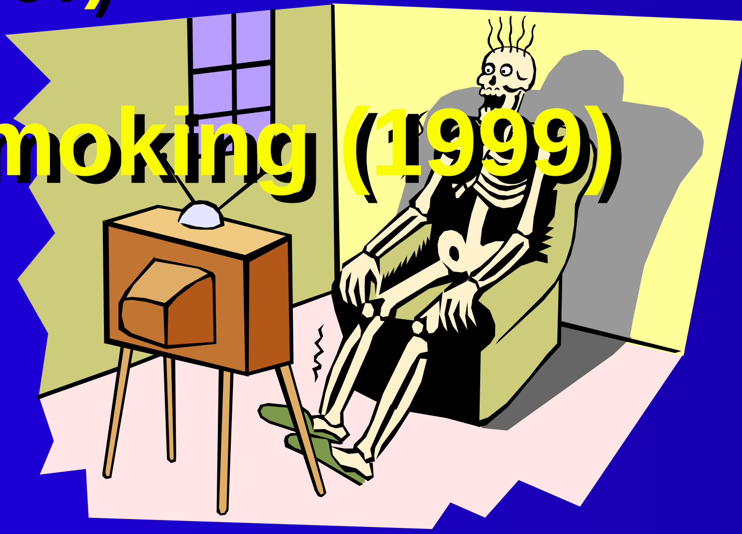
64,000 = Deaths from particulate air pollution (1996 report)

40,676 = Traffic accident fatalities (1994)

32,179 = AIDS deaths (1995)

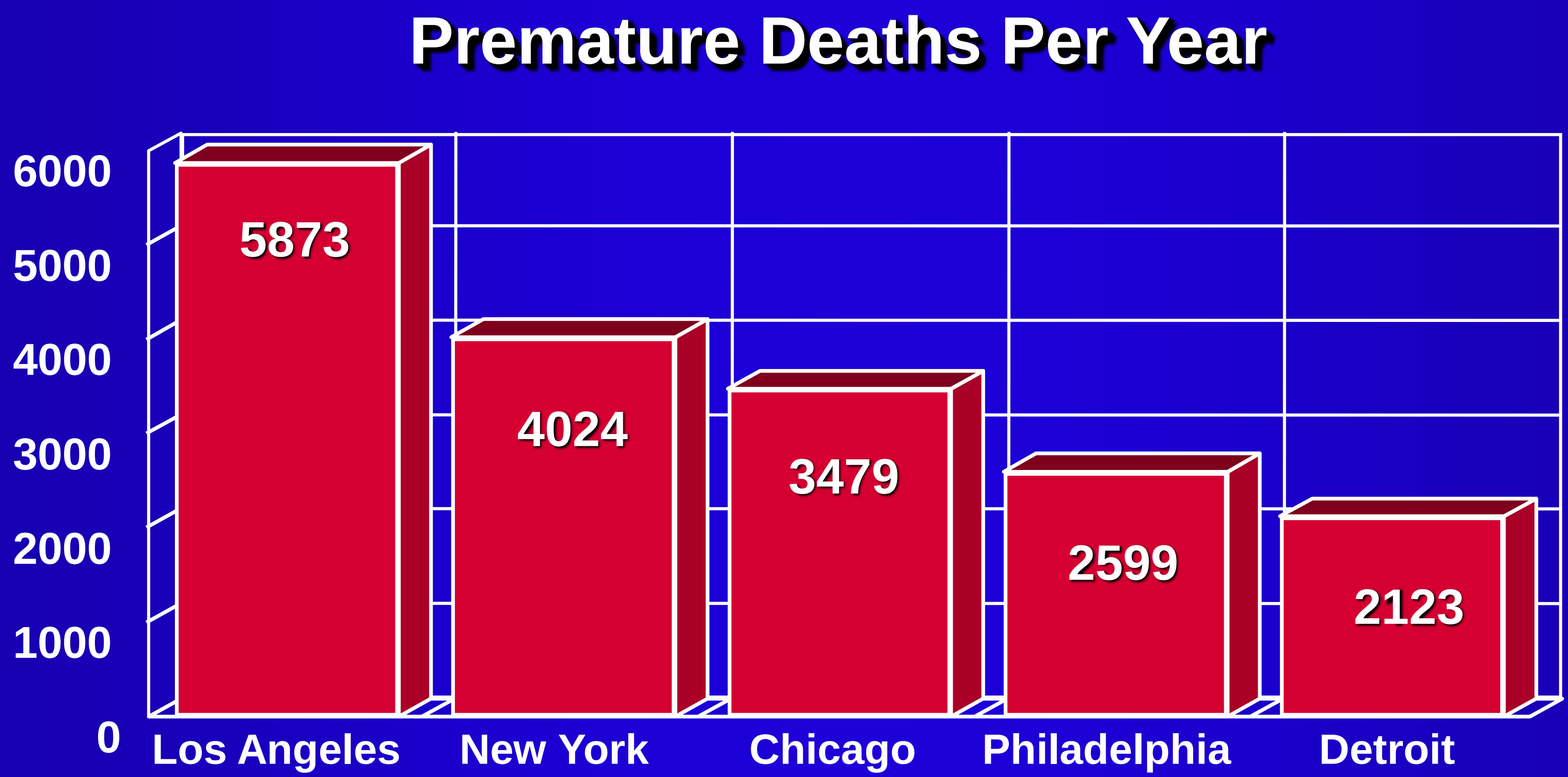
32,436 = Handgun fatalities (1997)

***430,700* = Deaths from smoking (1999)**

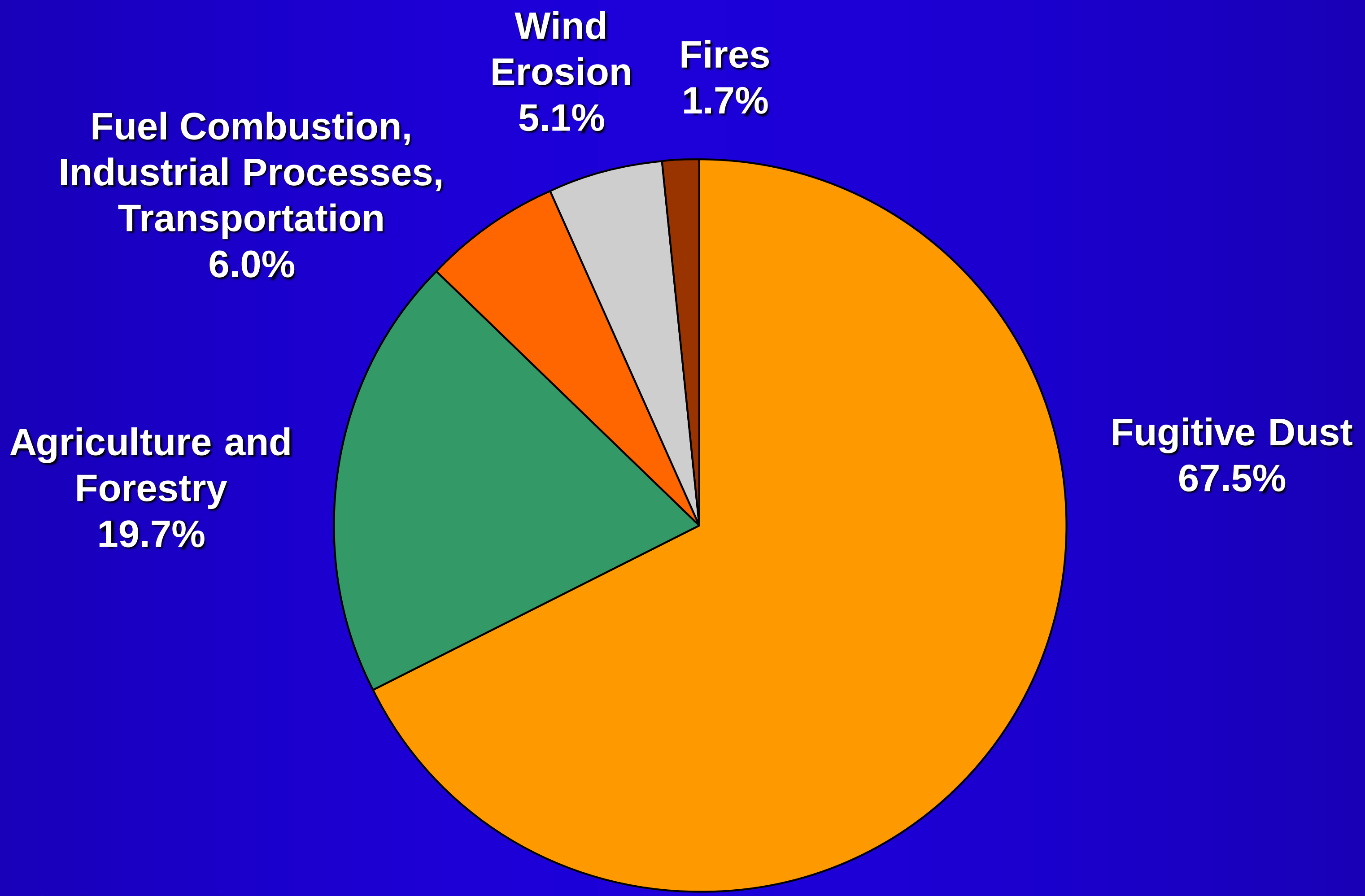


Particulate Air Pollution-Related Deaths

Based On 1996 Report

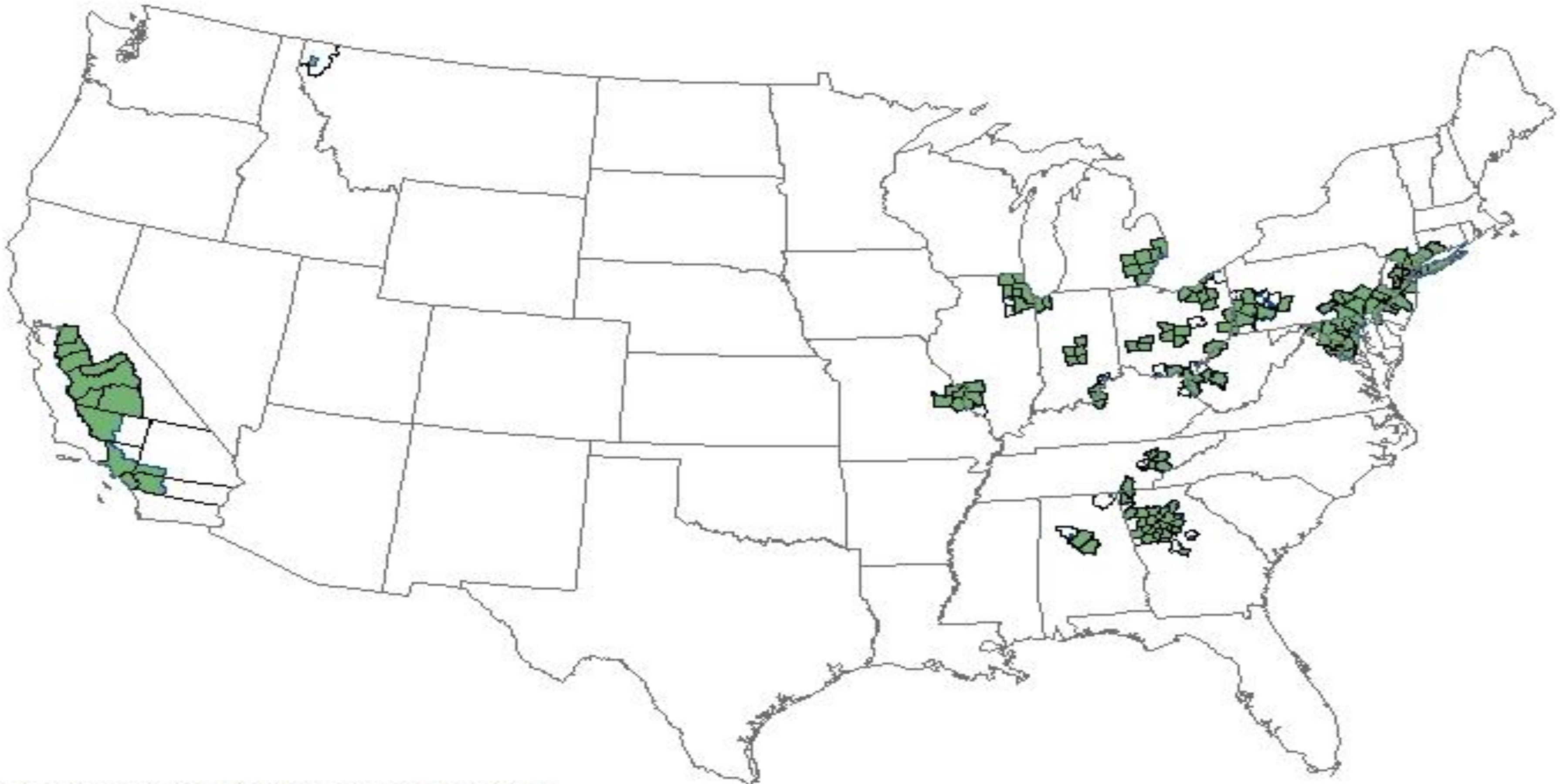


PM_{10} Emissions by Source Category (1995)



Source: EPA Trends Reports, Oct 1996

PM-2.5 Nonattainment Areas (1997 Standard)

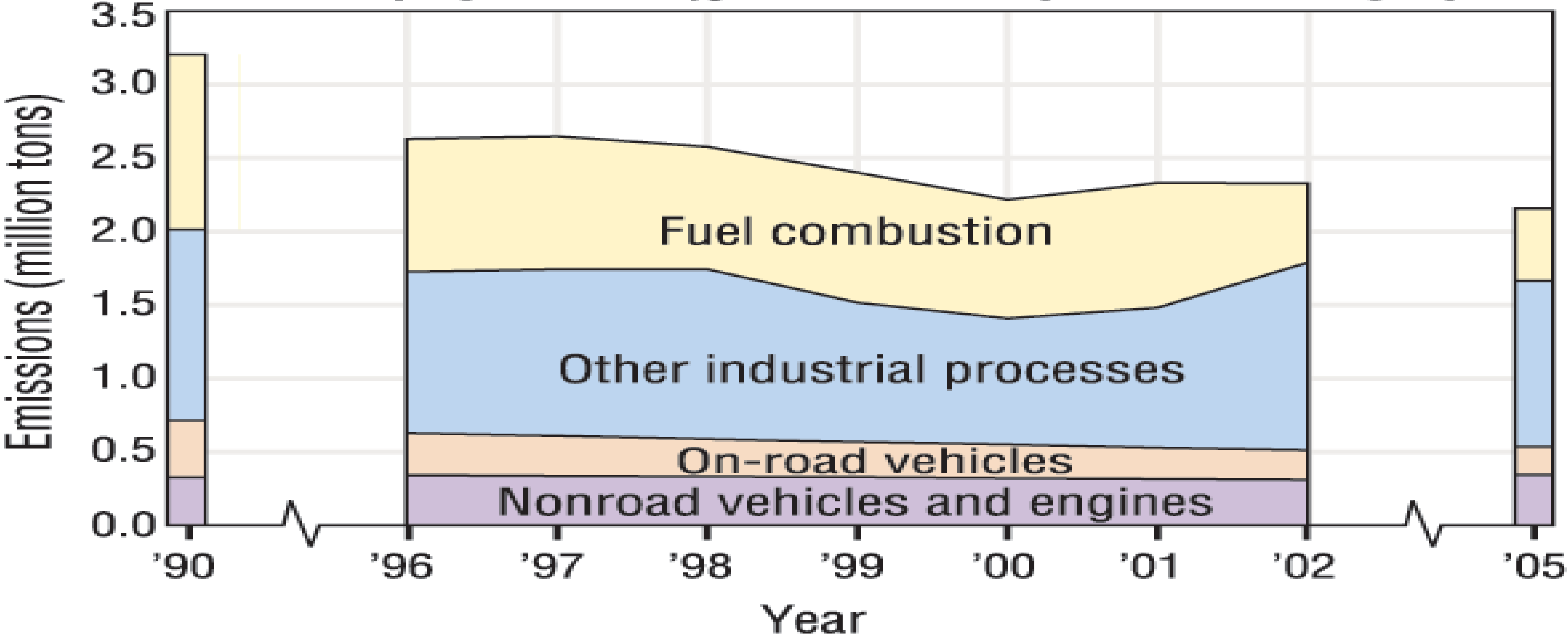


Nonattainment areas are indicated by color.
When only a portion of a county is shown in color,
it indicates that only that part of the county is within
a nonattainment area boundary.

3/2012

Exhibit 2-16. PM_{10} emissions in the U.S. by source category, 1990, 1996-2002, and 2005

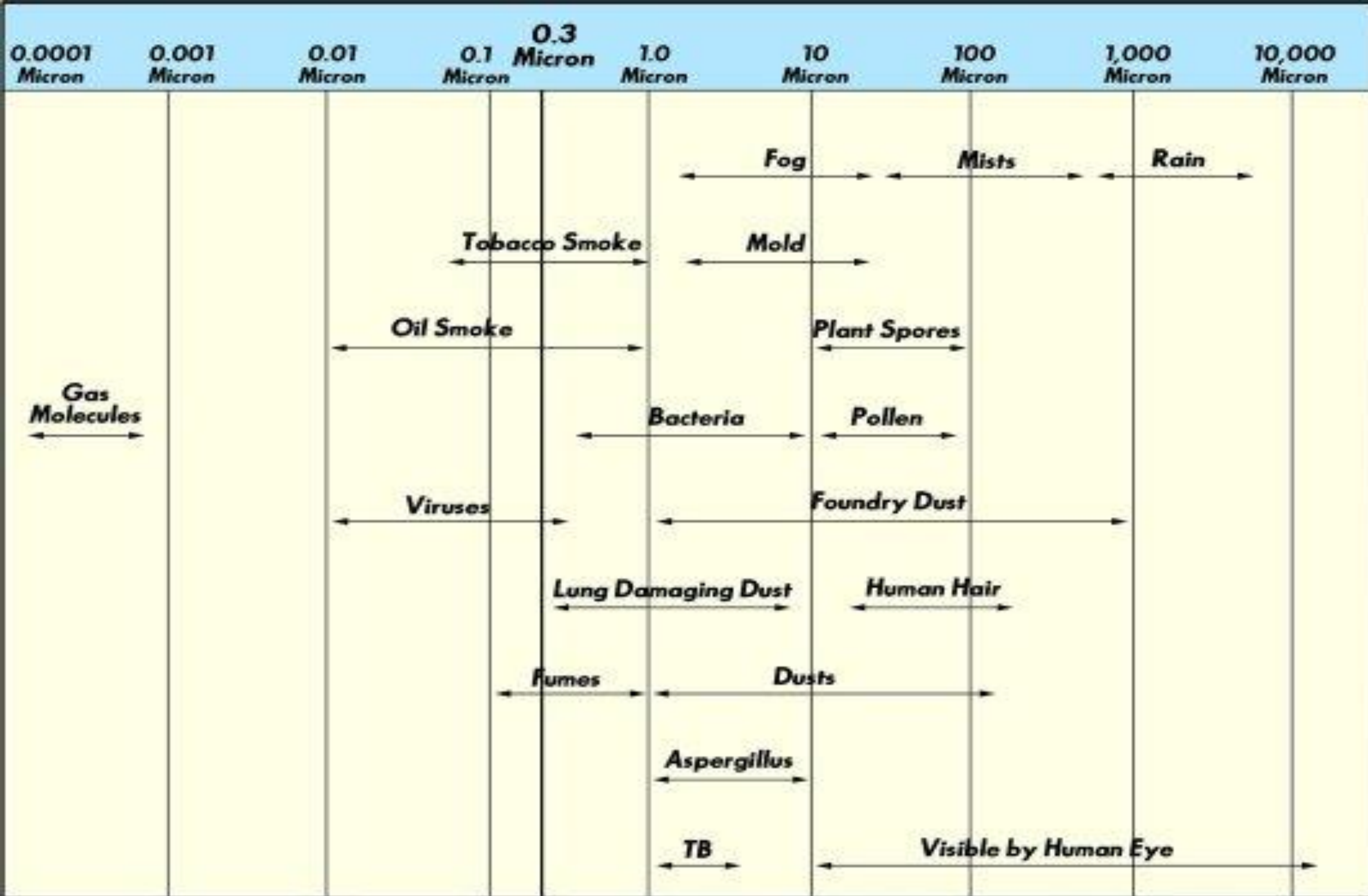
A. Anthropogenic PM_{10} emissions by source category[a,b]



[a]Data are presented for 1990, 1996-2002, and 2005, as datasets from these inventory years are all fully up-to-date. Data are

B. Relative amounts of PM_{10} emissions from anthropogenic and other sources, 2005[b]

Miscellaneous


0.0001 Micron
0.001 Micron
0.01 Micron
0.1 Micron
0.3 Micron
1.0 Micron
10 Micron
100 Micron
1,000 Micron
10,000 Micron
Fog
Mists
Rain
Tobacco Smoke
Mold
Oil Smoke
Plant Spores
Gas Molecules
Bacteria
Pollen
Viruses
Foundry Dust
Lung Damaging Dust
Human Hair
Fumes
Dusts
Aspergillus
TB
Visible by Human Eye

History

Single-Stage:

1913 Cottrell (US);

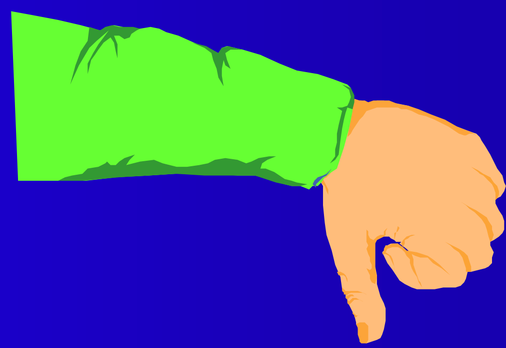
Lodge (UK)

Two-Stage:

1933 Penney

Background

- Advantages
- Disadvantages
- Applications



Two-Stage

Single -Stage

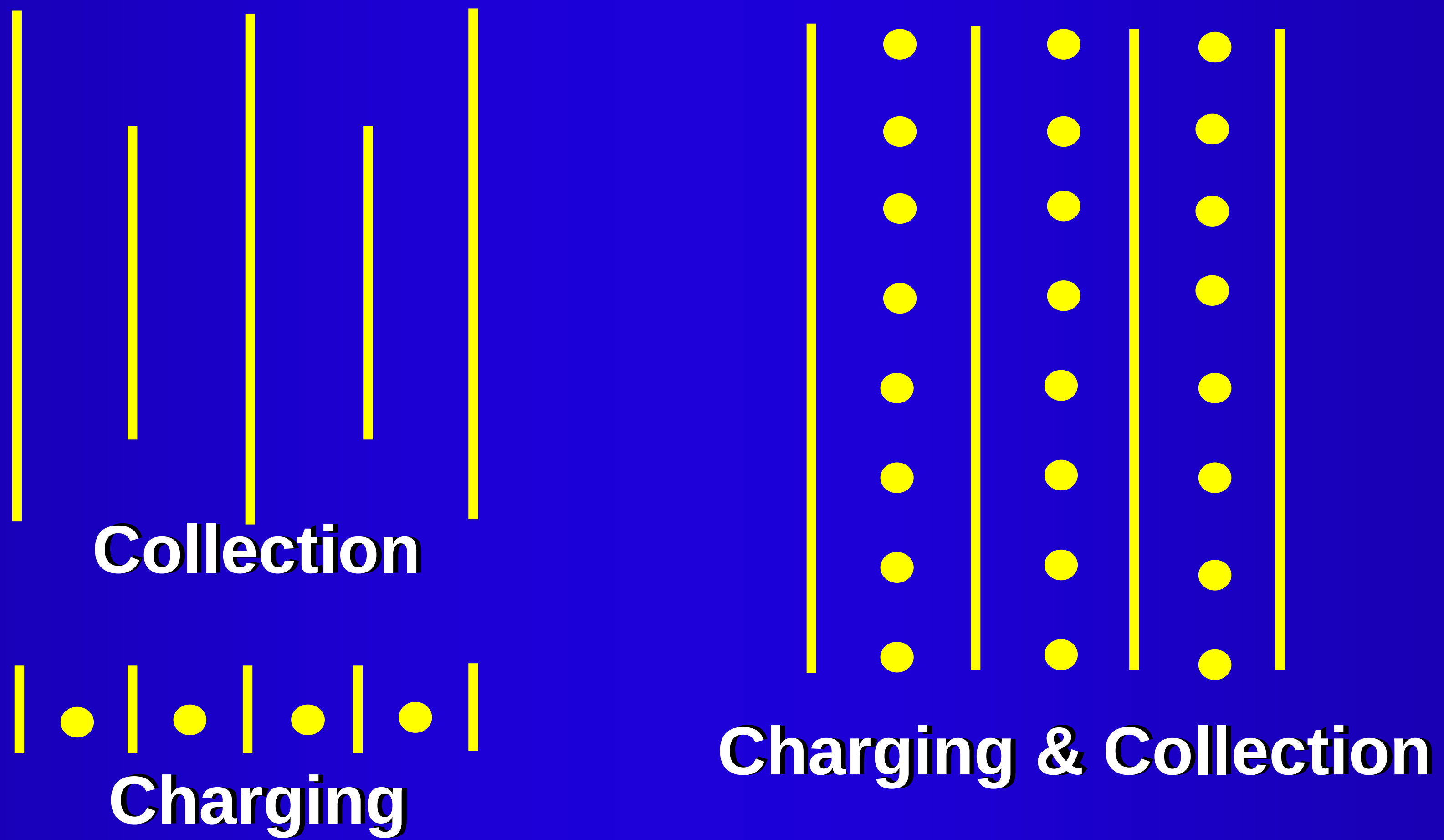
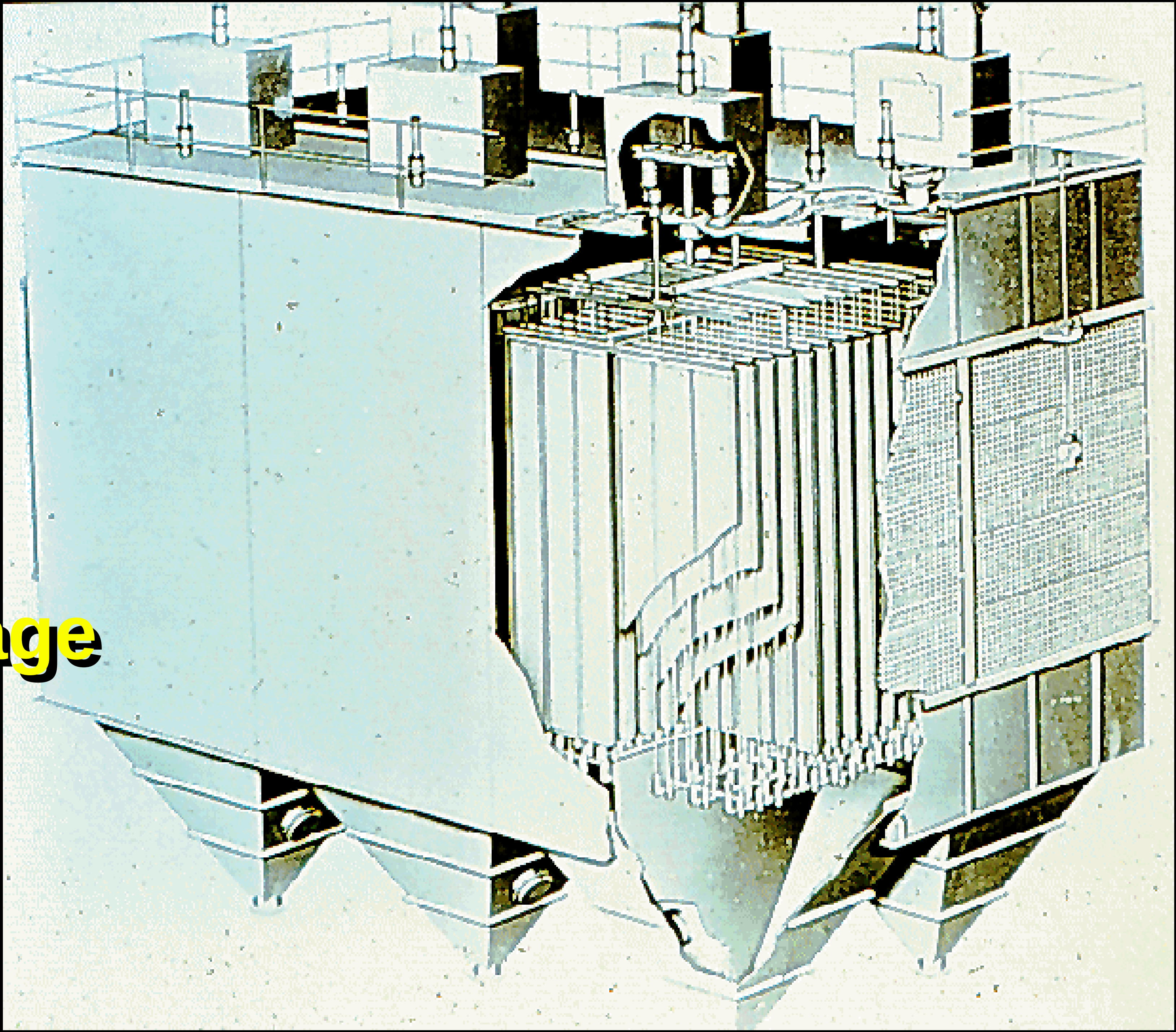


Figure 301.2

Single-Stage Industrial ESP



Concentric Plate Wet ESP

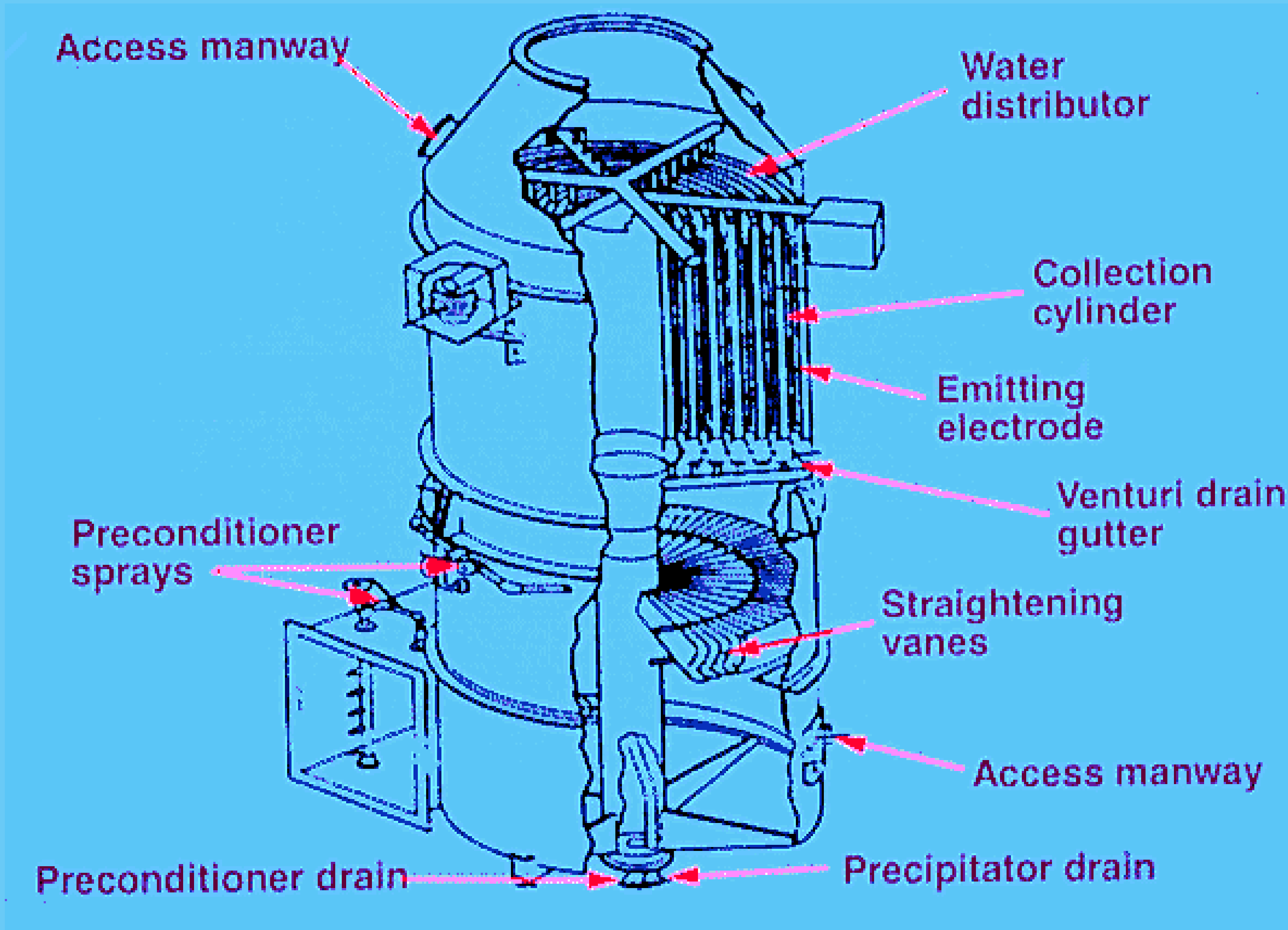
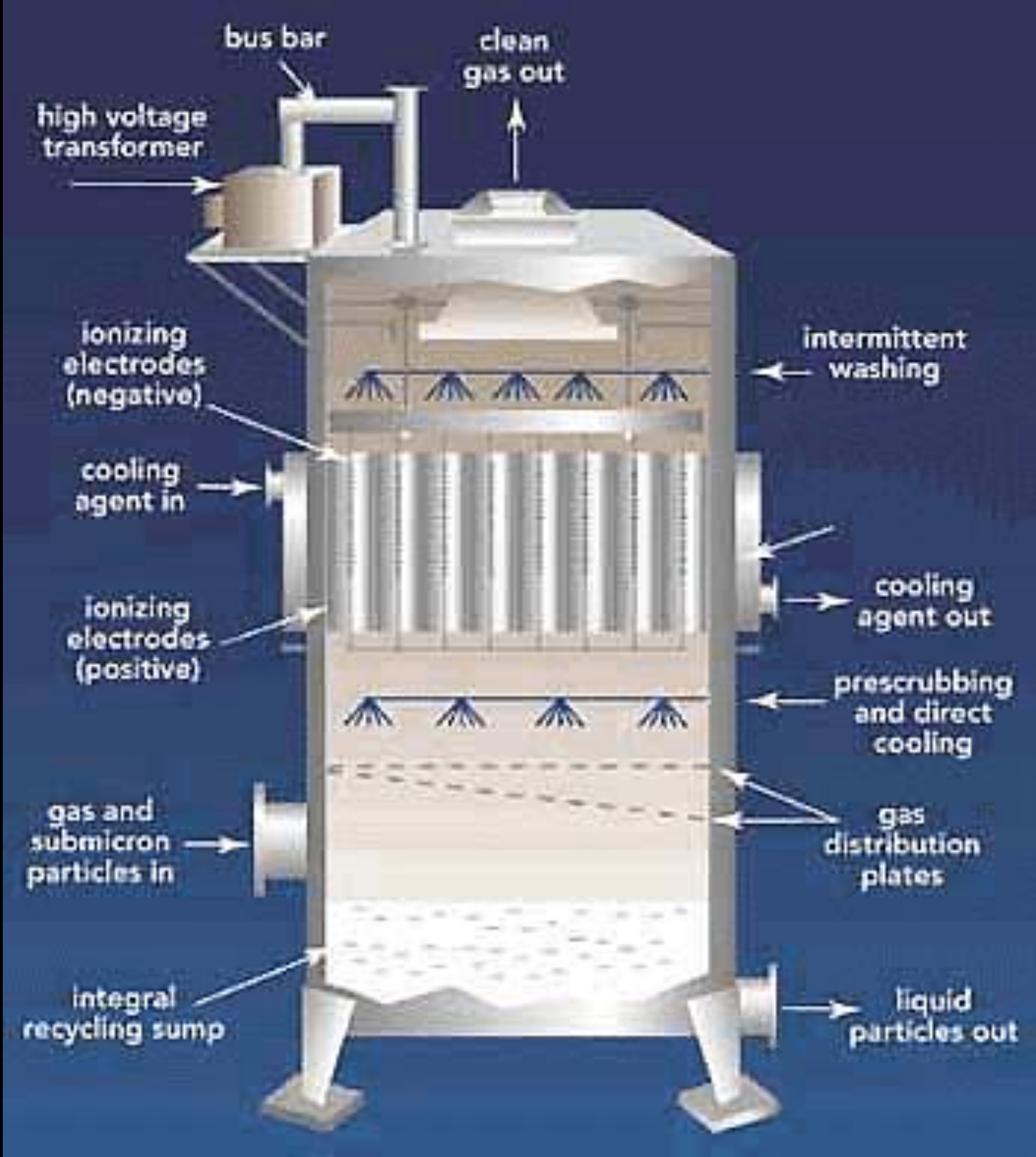


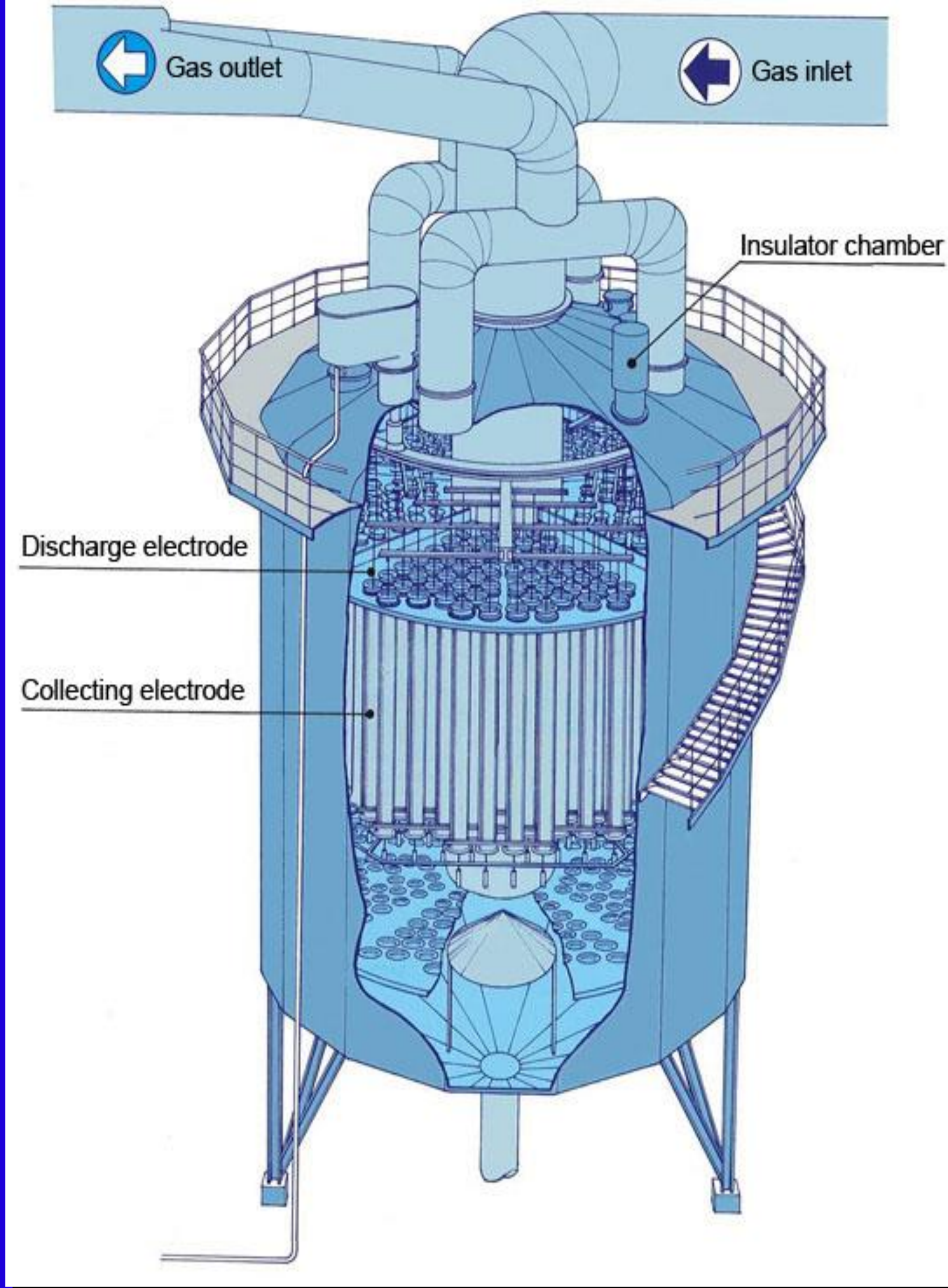
Figure 303.4

Tubular Condensing Wet ESP

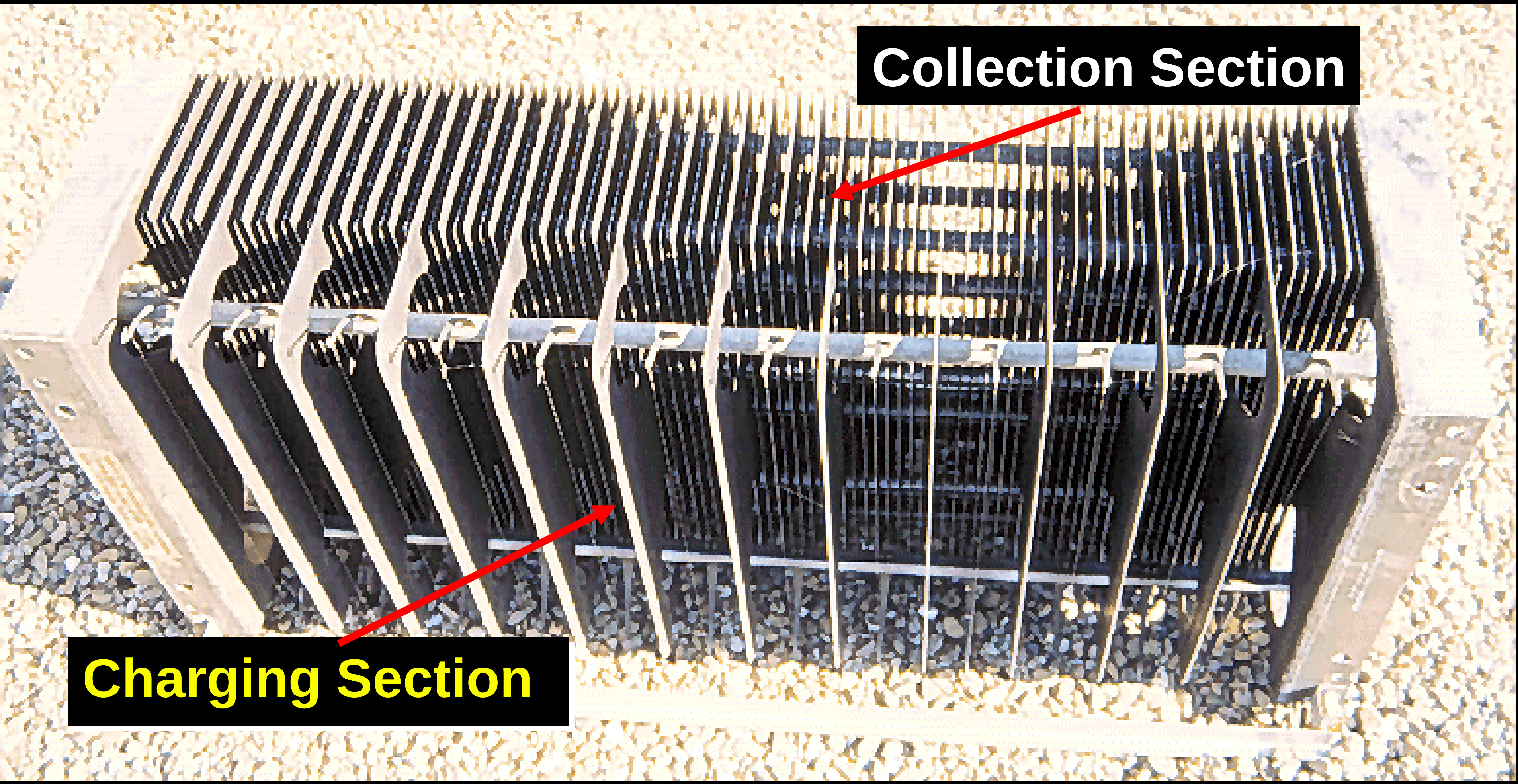


Courtesy Croll-Reynolds

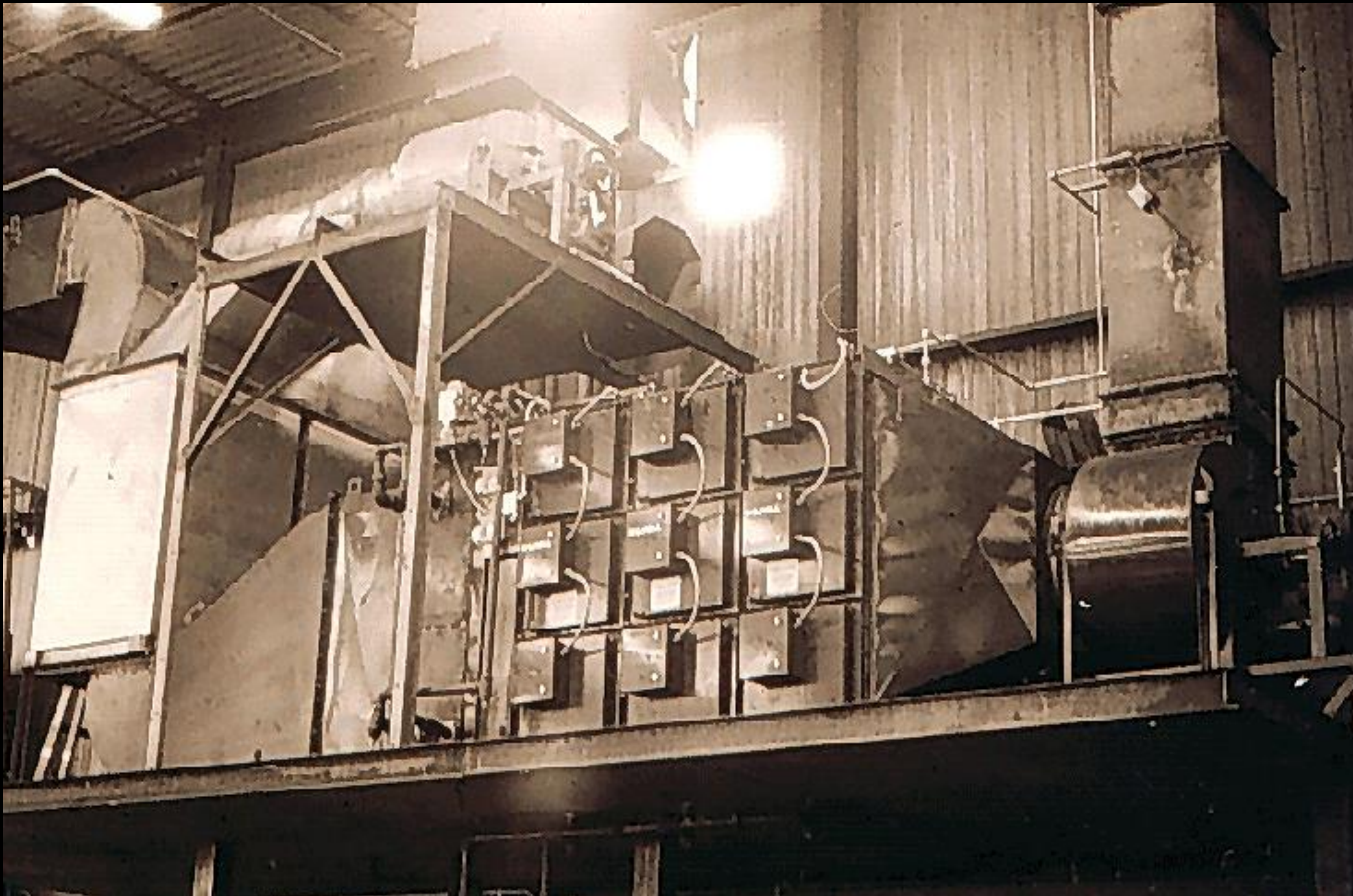
Hitachi Tubular Wet ESP



Two-Stage Module




AAF

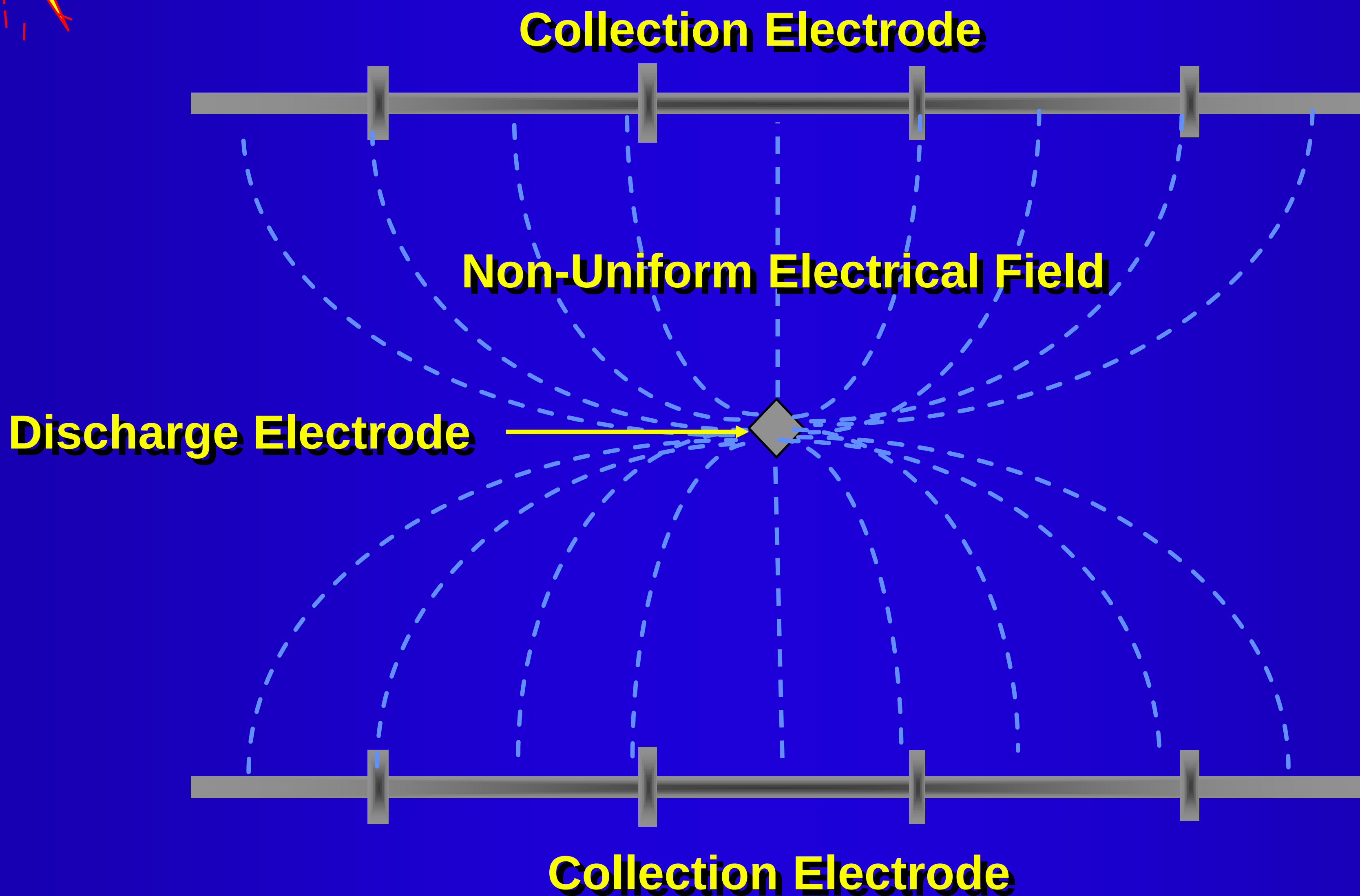



Plates
Wires
Ionization Section

ESP Processes

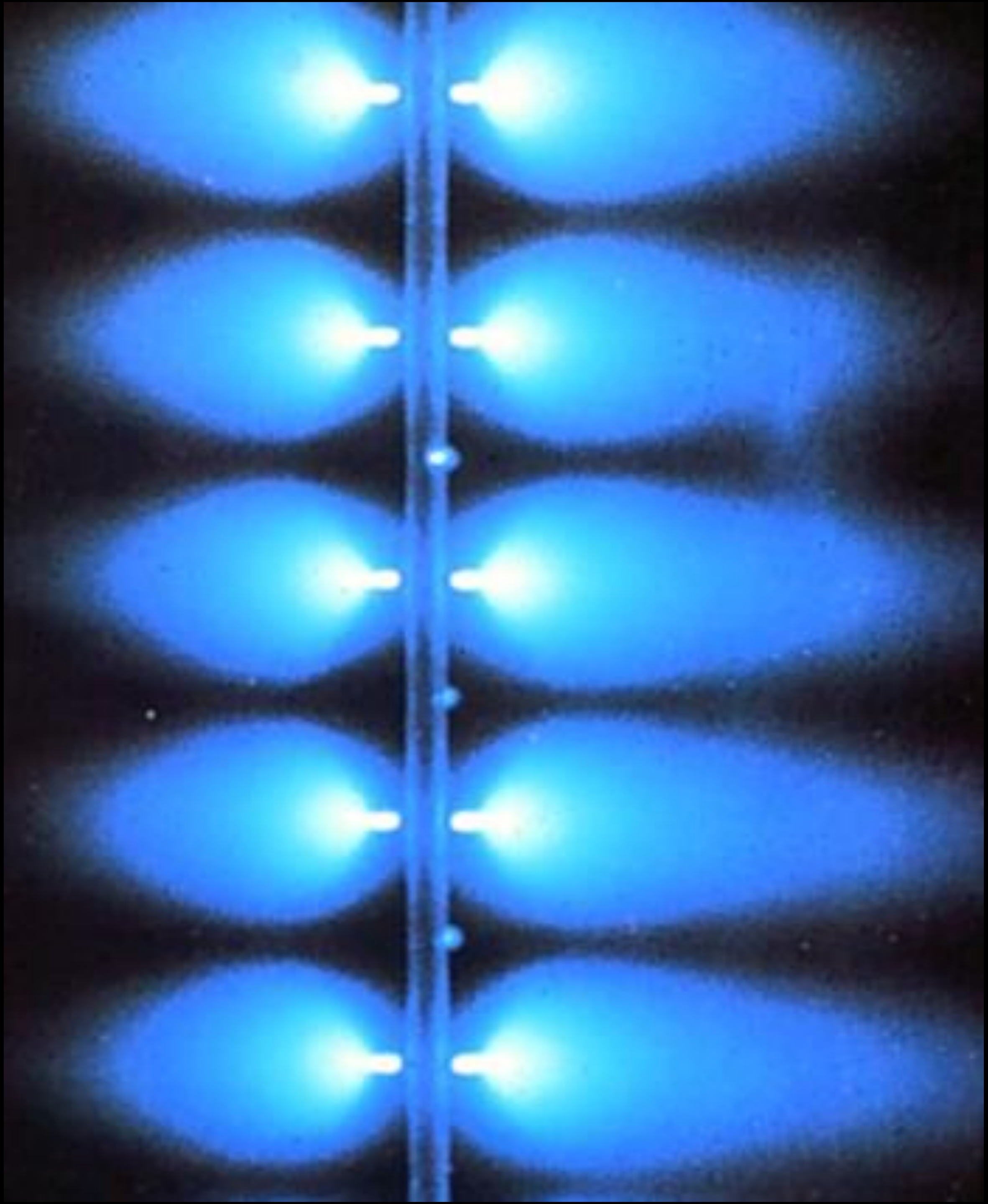
- Charging
- Collection
- Removal

Electric Field Generation



Corona

(voltage negative)



Avalanche Multiplication

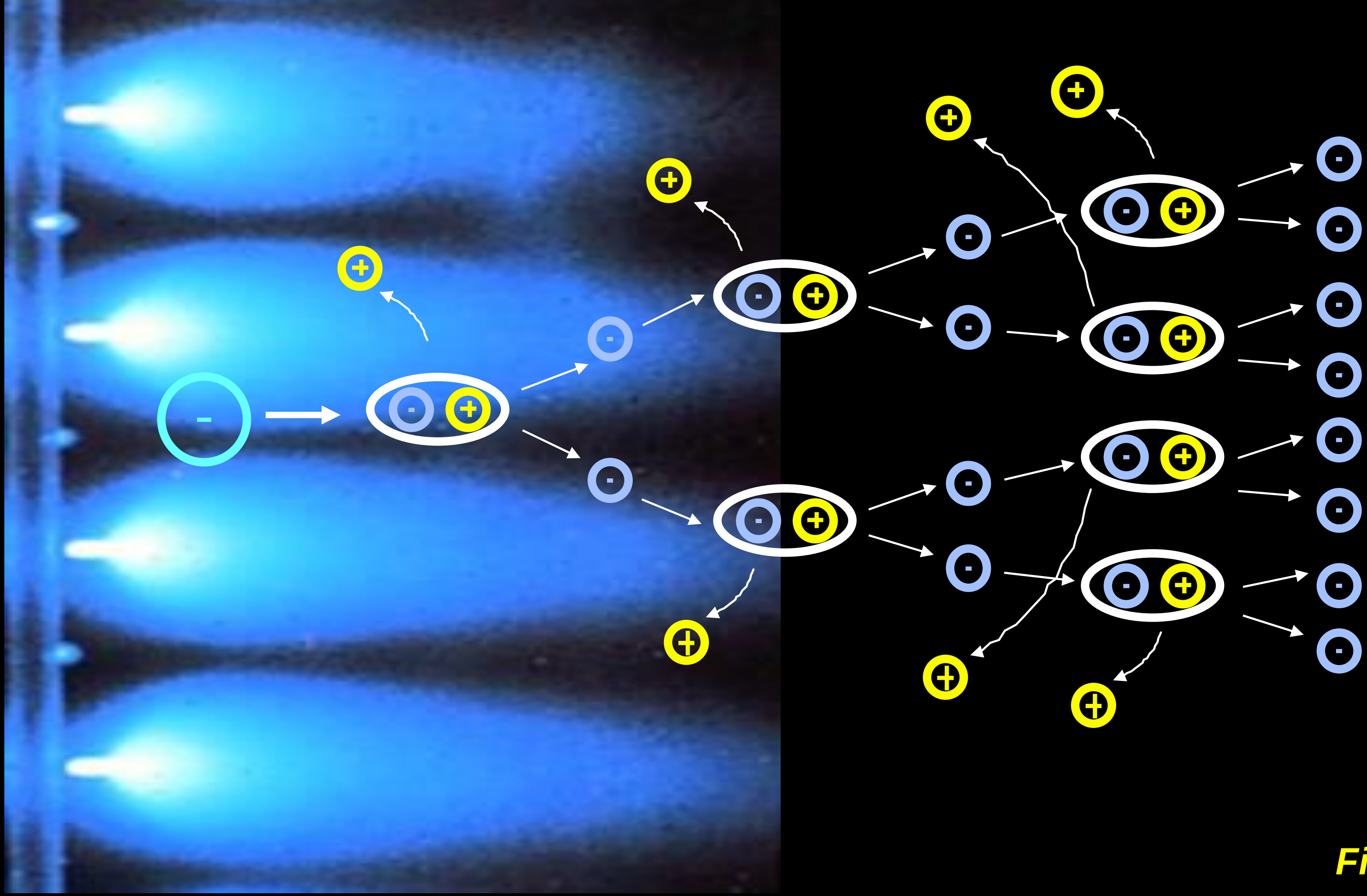


Figure 301.3

Charging and Collection

.....so far

1. "Corona" generated at discharge electrode = high-velocity electrons
2. Flue gas molecules ionized by high-velocity electrons = positive gas ions + free electrons
3. Free electrons migrate towards positive collection electrode
4. Free electrons captured by gas molecules = negative gas ions
5. Negative gas ions attach to particles which migrate to collection electrode

Charging & Collection

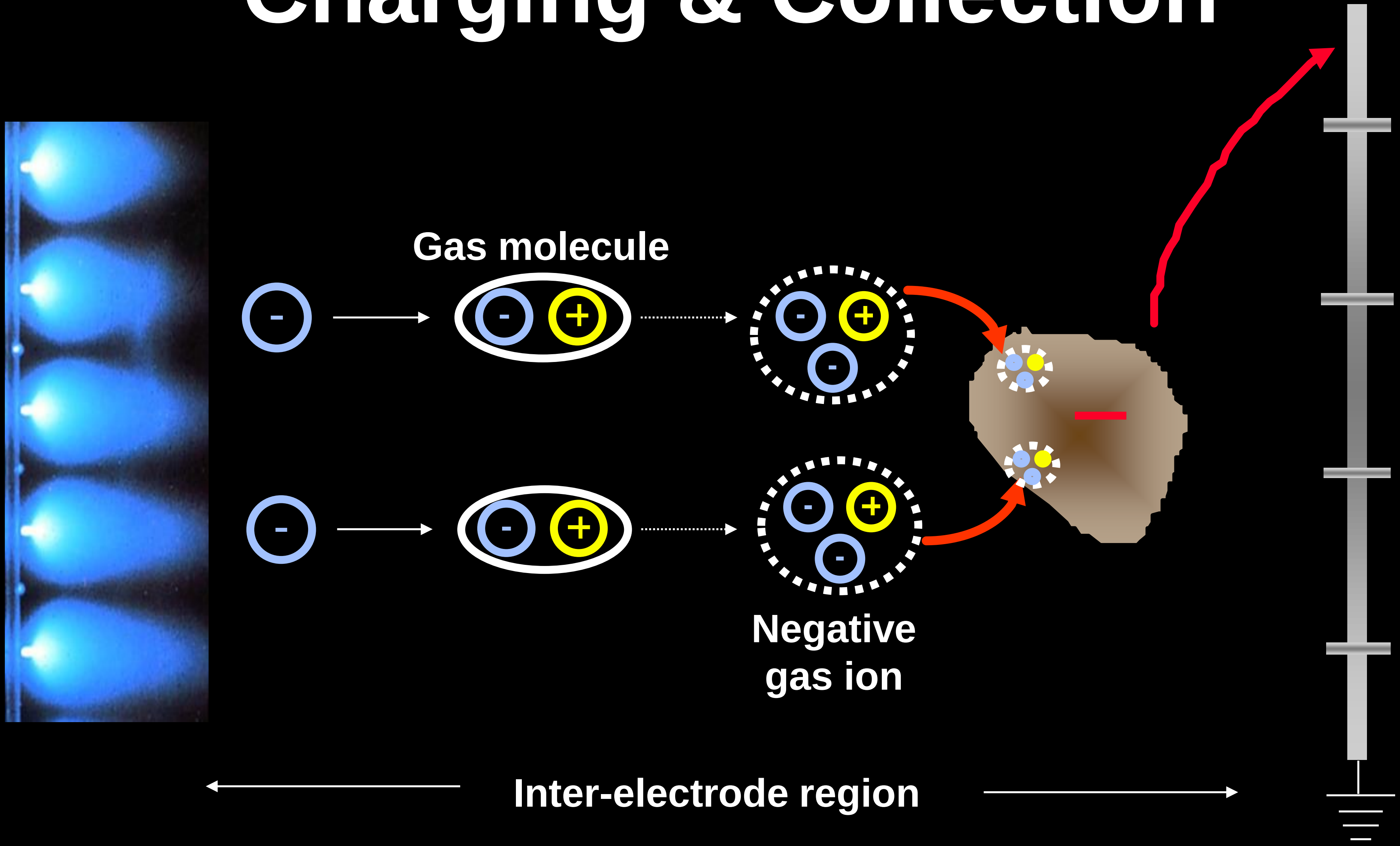
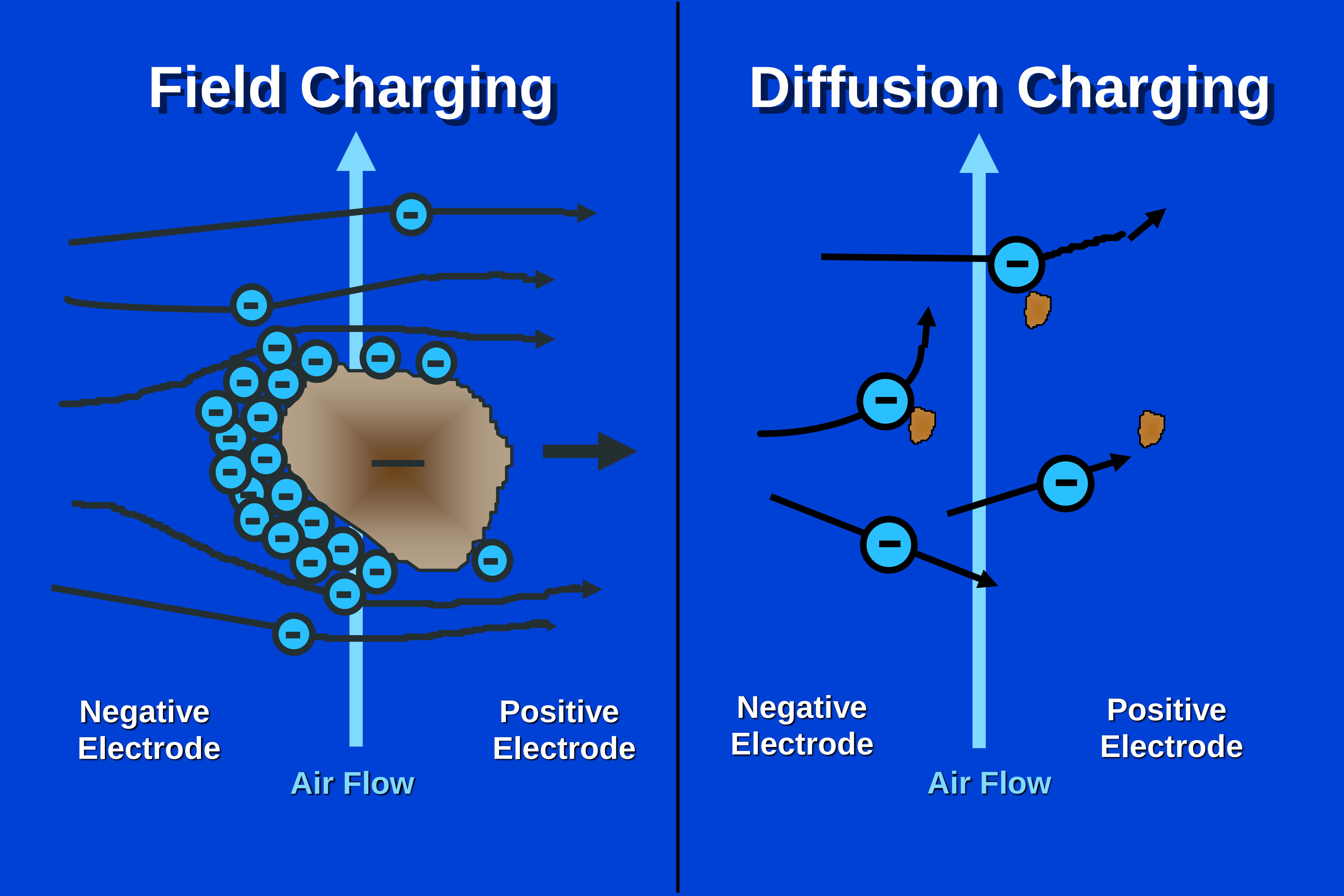


Figure 301.3


Field Charging
Negative Electrode
Positive Electrode
Air Flow
Diffusion Charging
Negative Electrode
Positive Electrode
Air Flow

Particle Size & Collection Efficiency

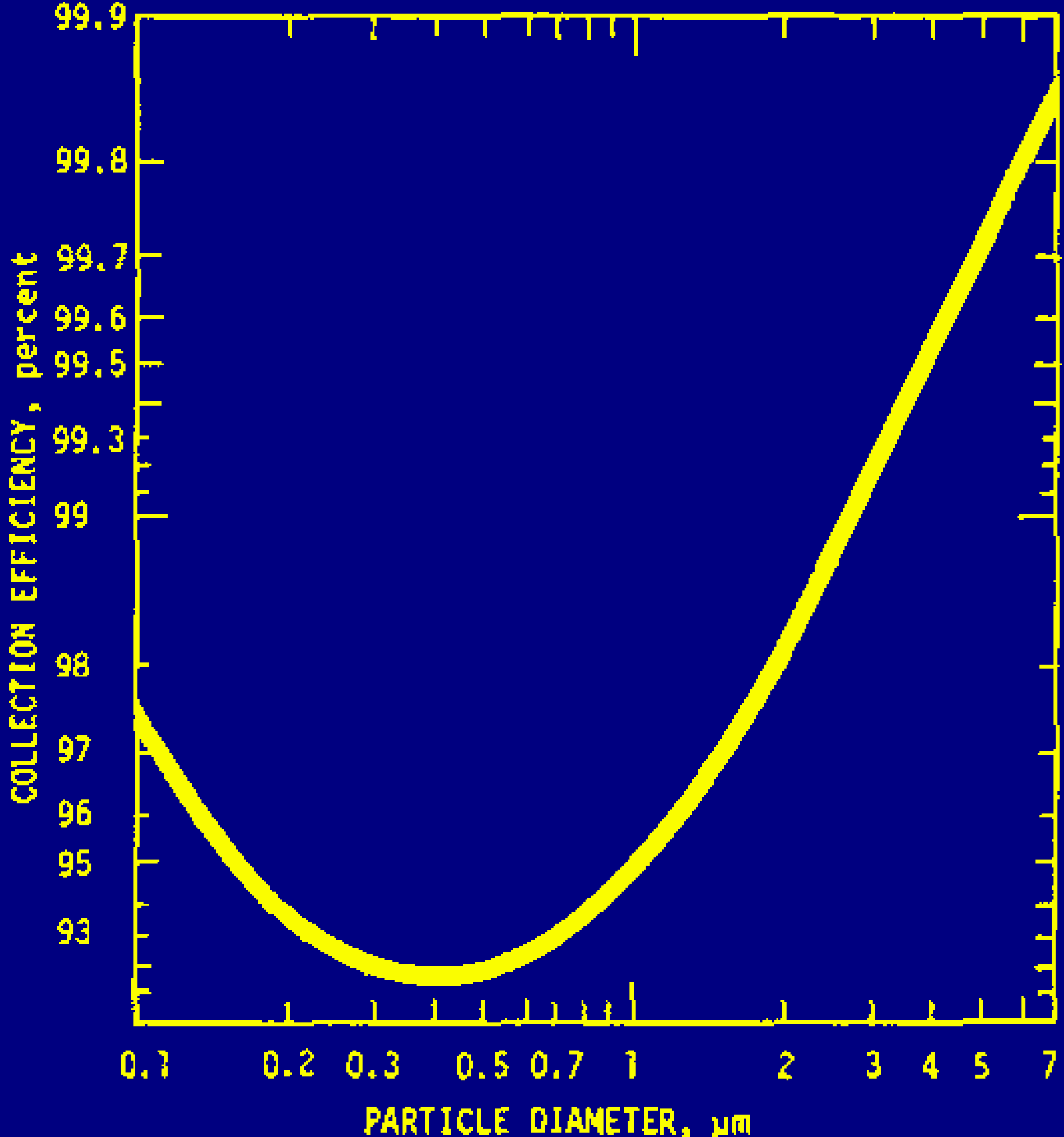
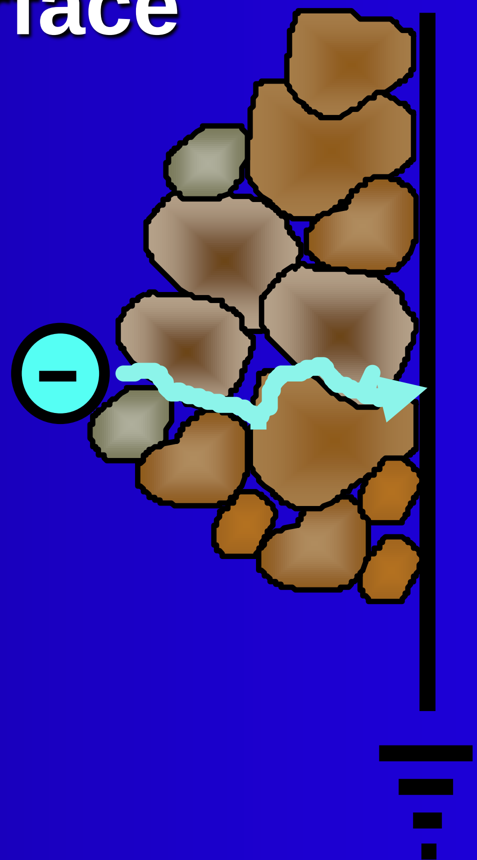


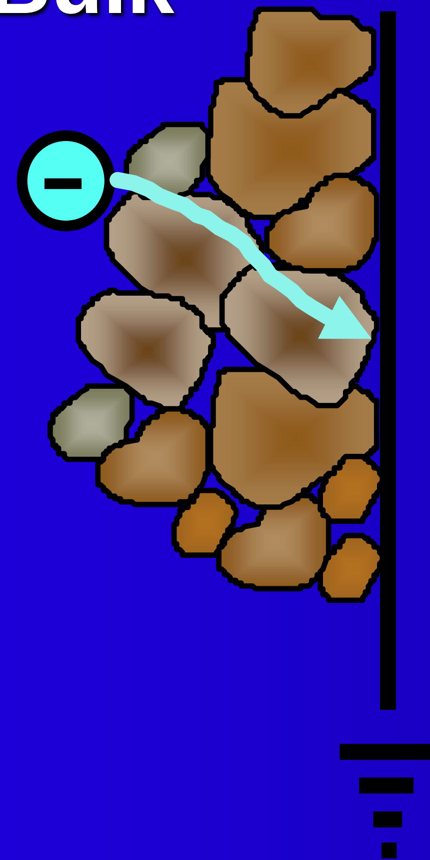
Figure 305.5

Conduction Mechanisms

Surface



Bulk



Two-stage precipitator

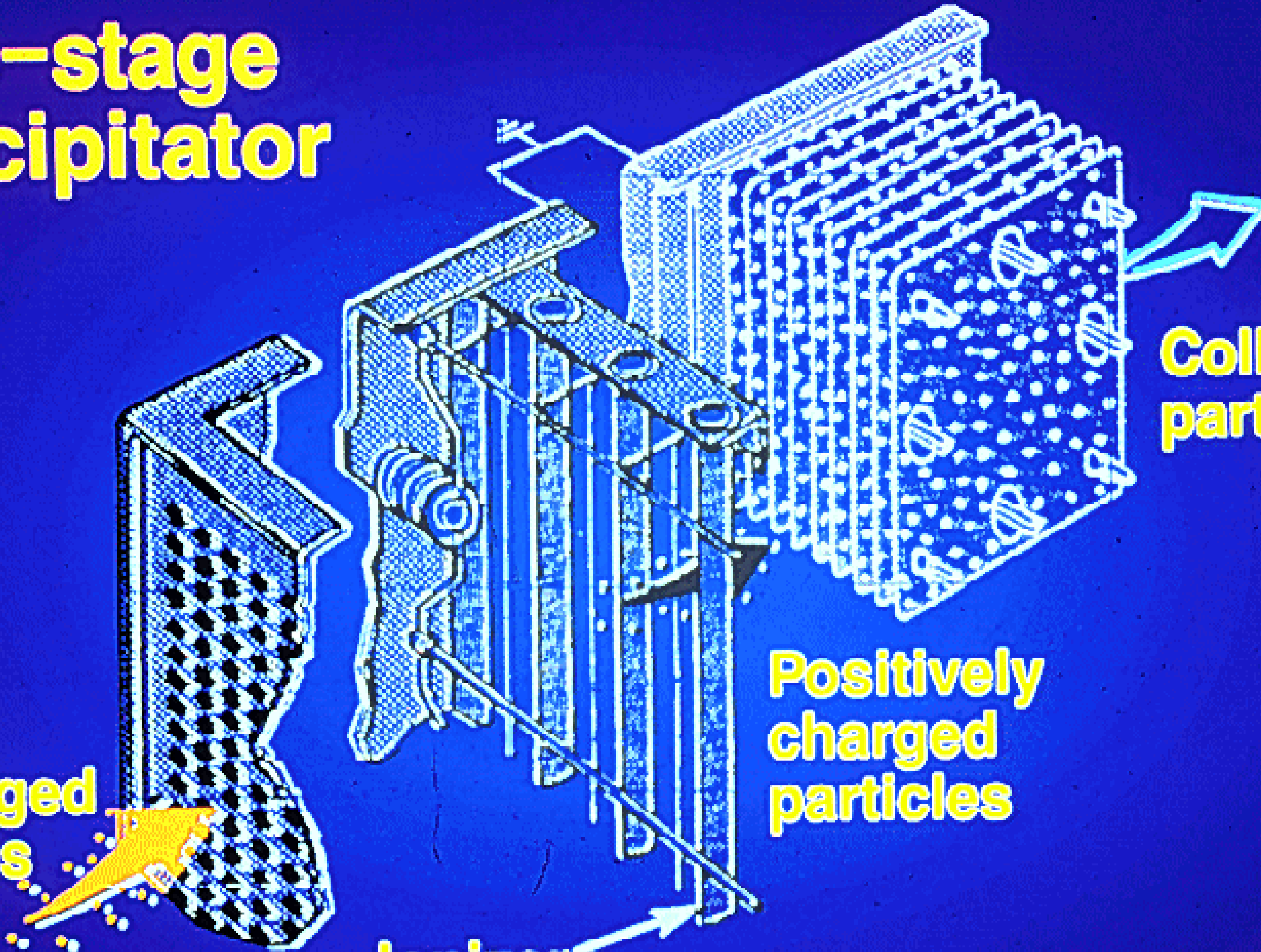


Figure 303.1

Design Considerations

(garbage in/cleaner air out)

- **Dust Properties**
- **Gas Flow Rate**
- **Gas Temperature**

Migration Velocity

- Characteristic of type and size of particles
- Experimentally determined or calculated
- Used with *collection area* and *gas flow rate* to calculate *efficiency*

Resistivity

- Tendency of a particles to retain a charge after collection
- Resistance of collected dust layer to flow of electrical current
- Affected By:
  - Chemical make-up of dust
  - Temperature
  - Moisture
  - Sulfur content of flue gas

Resistivity of Dusts at Various Temperatures

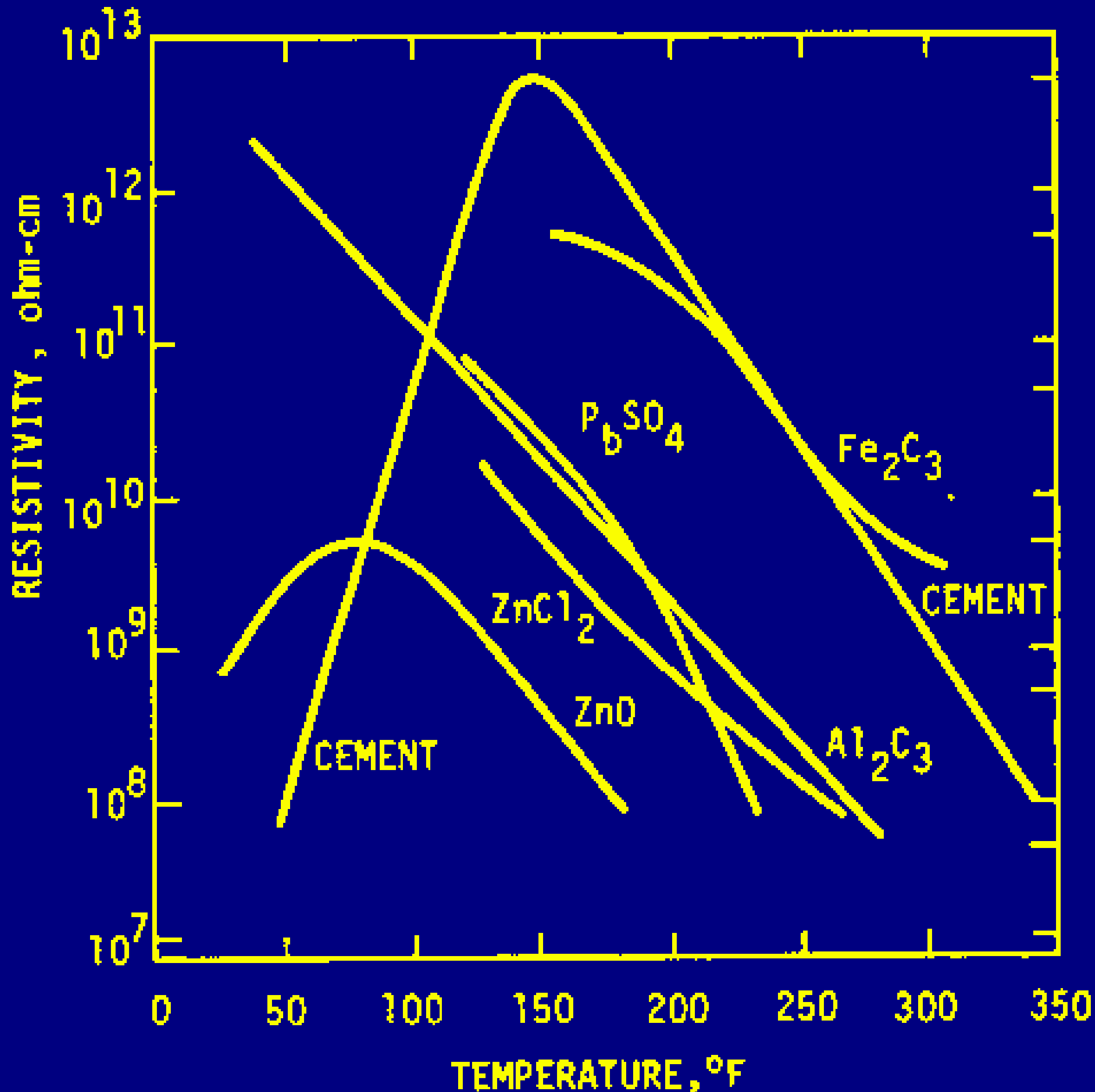
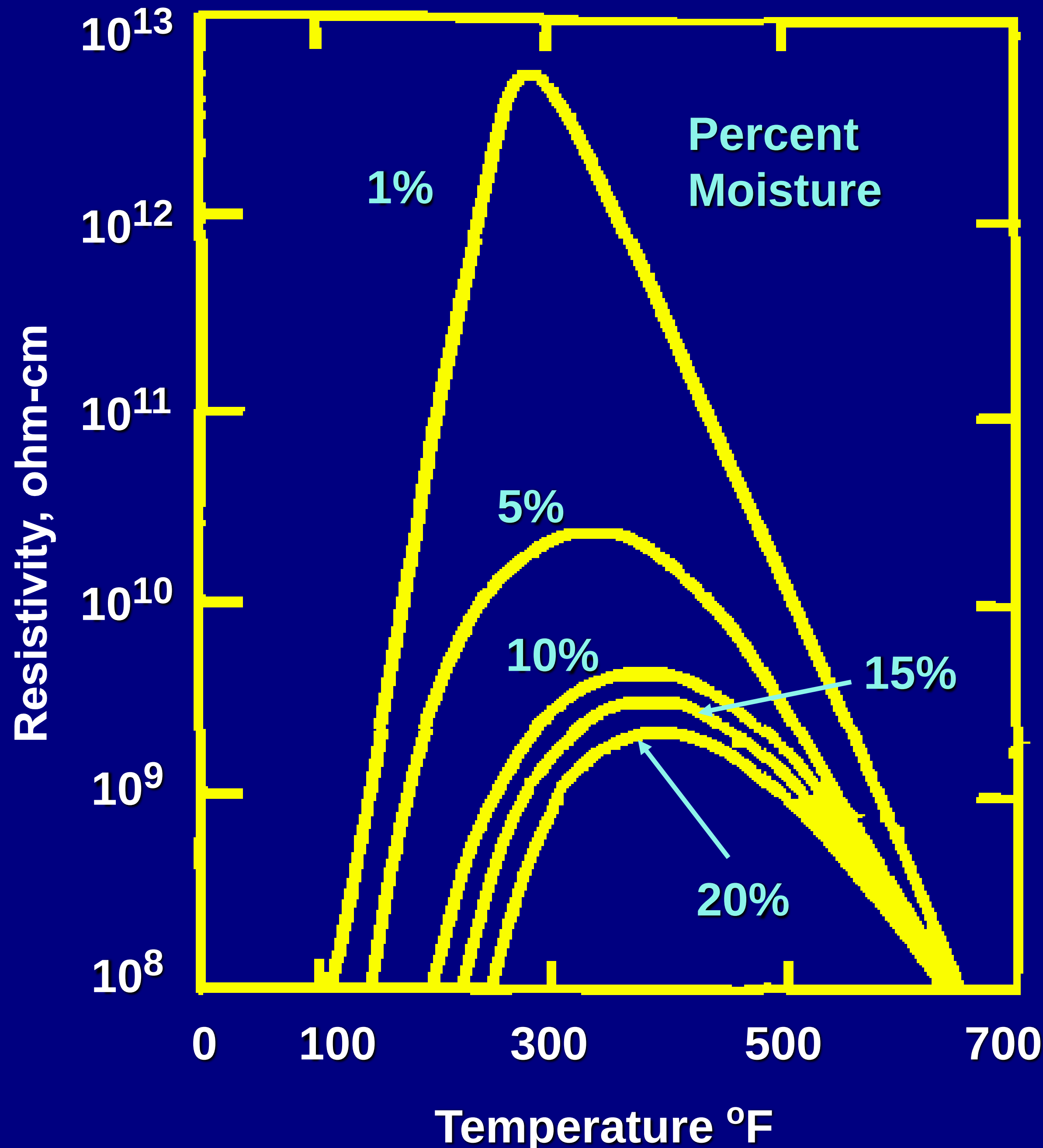
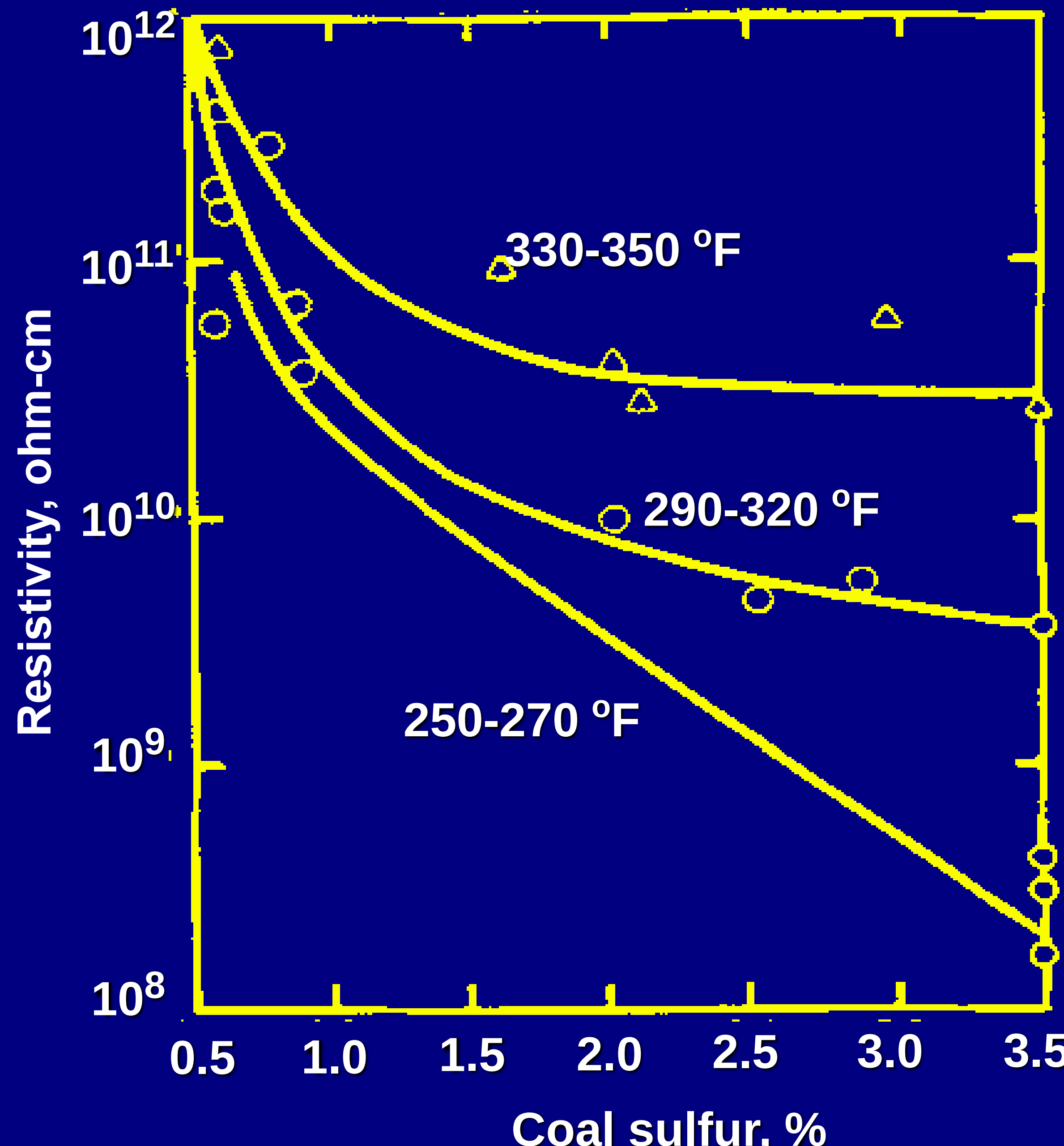


Figure 305.4

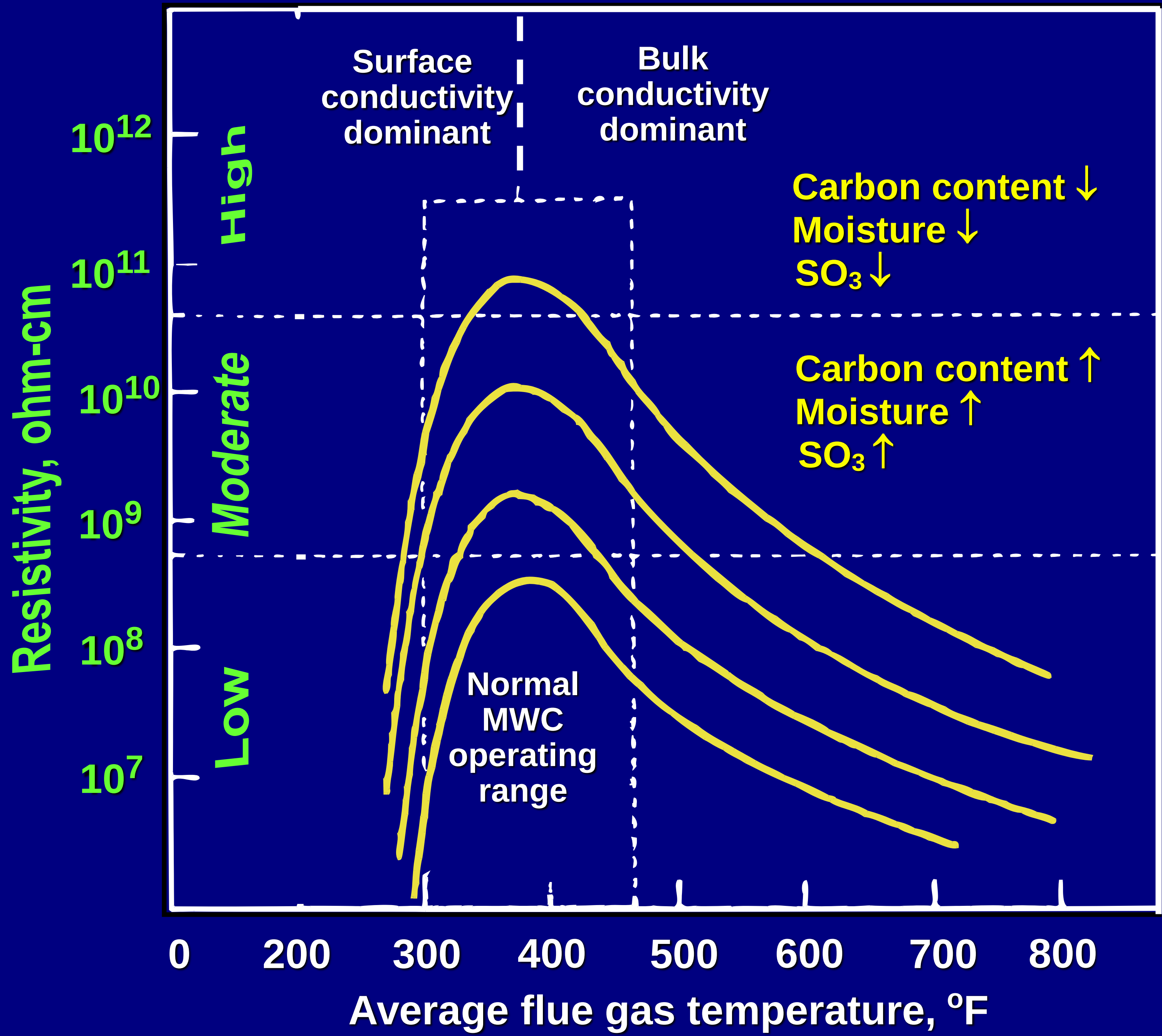
Effect of Temperature & Moisture on Resistivity of Cement Dust



Fly Ash Resistivity Versus Coal Sulfur Content



Generalized Effect of *Temperature* on *Resistivity* of Fly Ash

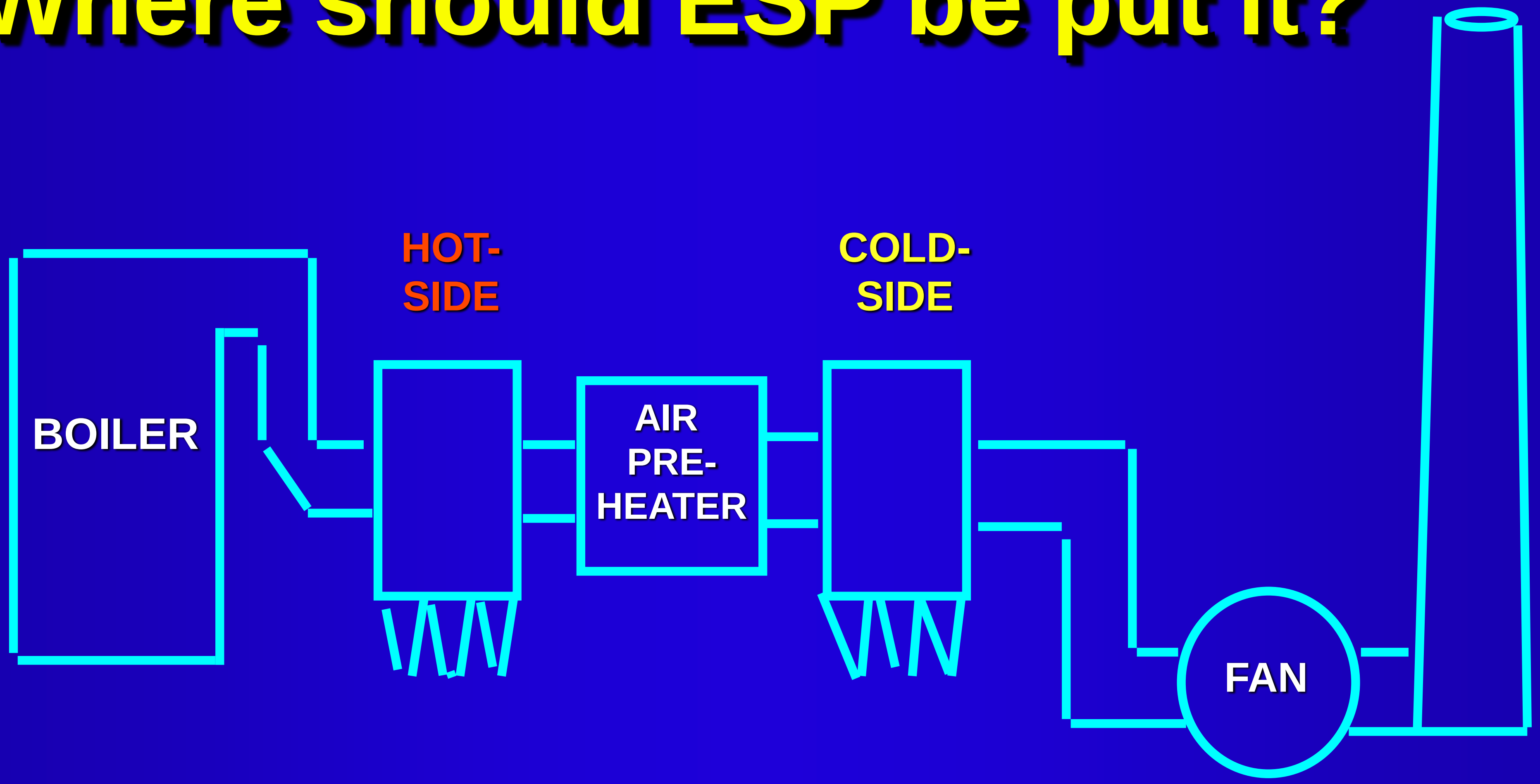


Problem Resistivity Conditions

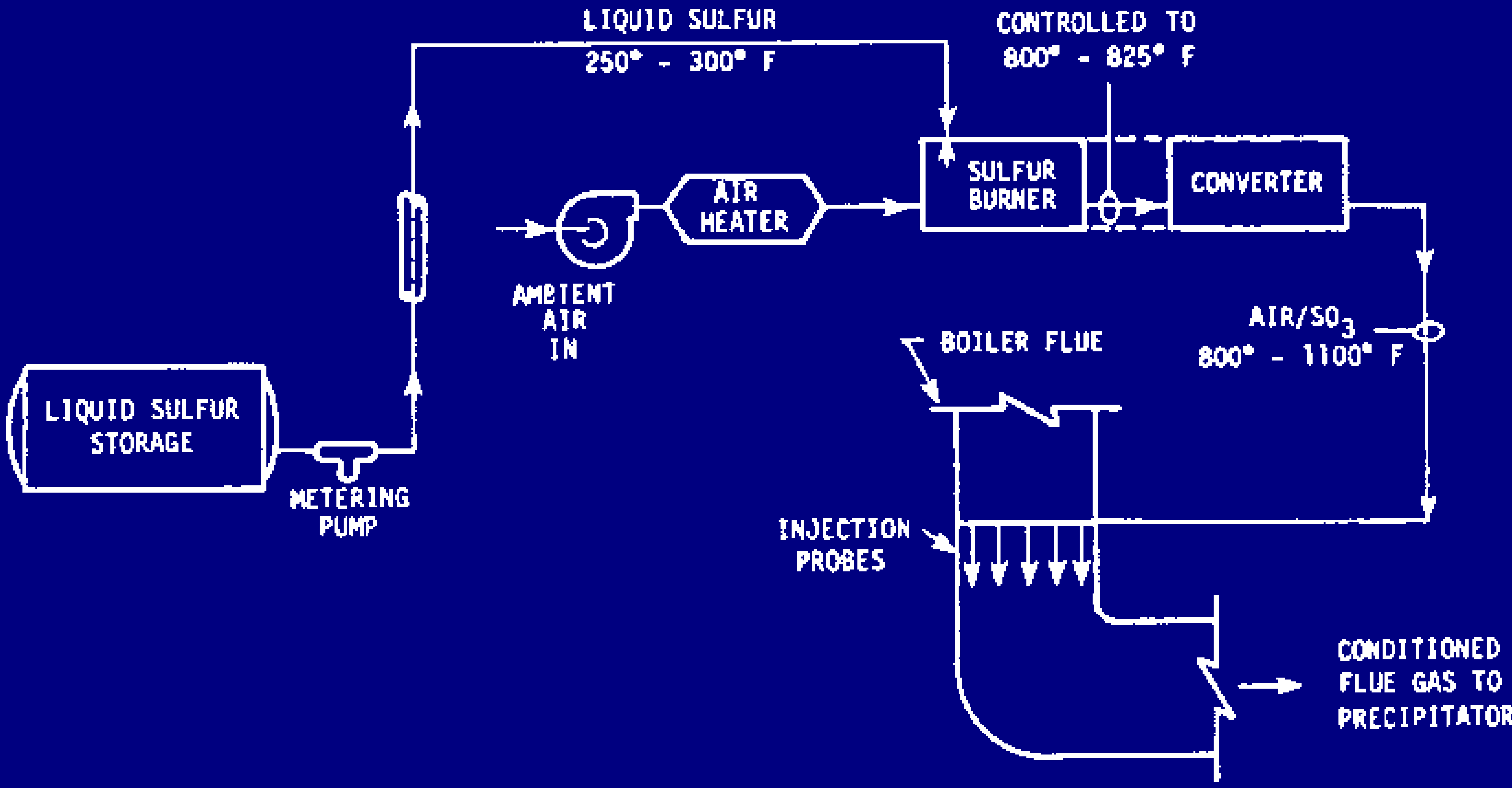
High
- Slower migration rate
- Excessive rapping forces
- "Back Corona"

Low
- Reentrainment

Where should ESP be put it?



Flue Gas Conditioning System



Design Factors Affecting Performance

(Making Your ESP Work)

- **Specific Collection Area**
- **Aspect Ratio**
- **Collection Plate Spacing**
- **Sectionalization**
- **Power Requirements/Spark Rate**

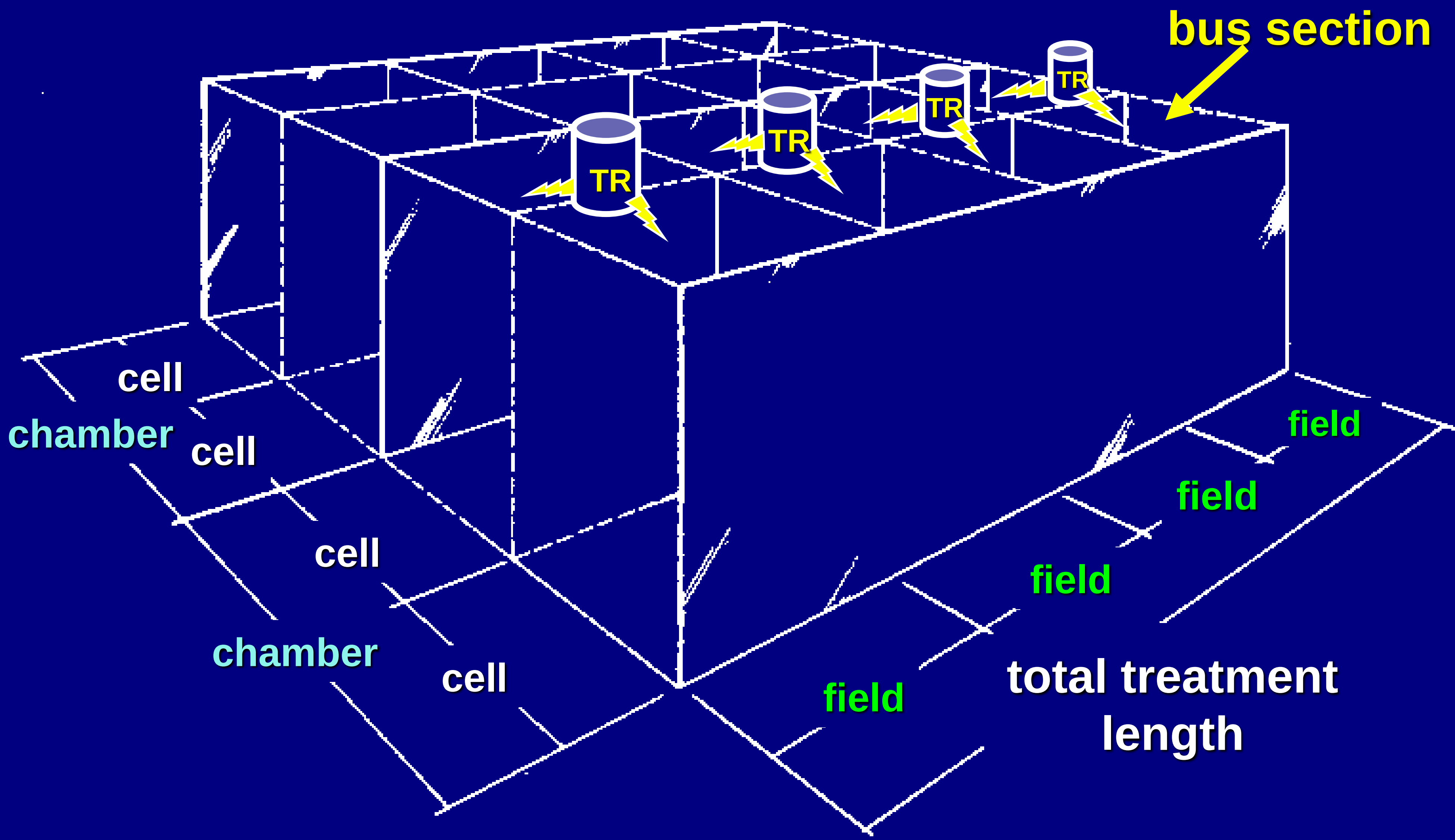
$$\text{Aspect Ratio} = \frac{\text{Effective Length}}{\text{Effective Height}}$$

- For efficiencies of 99% or higher, should be at least 1.0 to 1.5

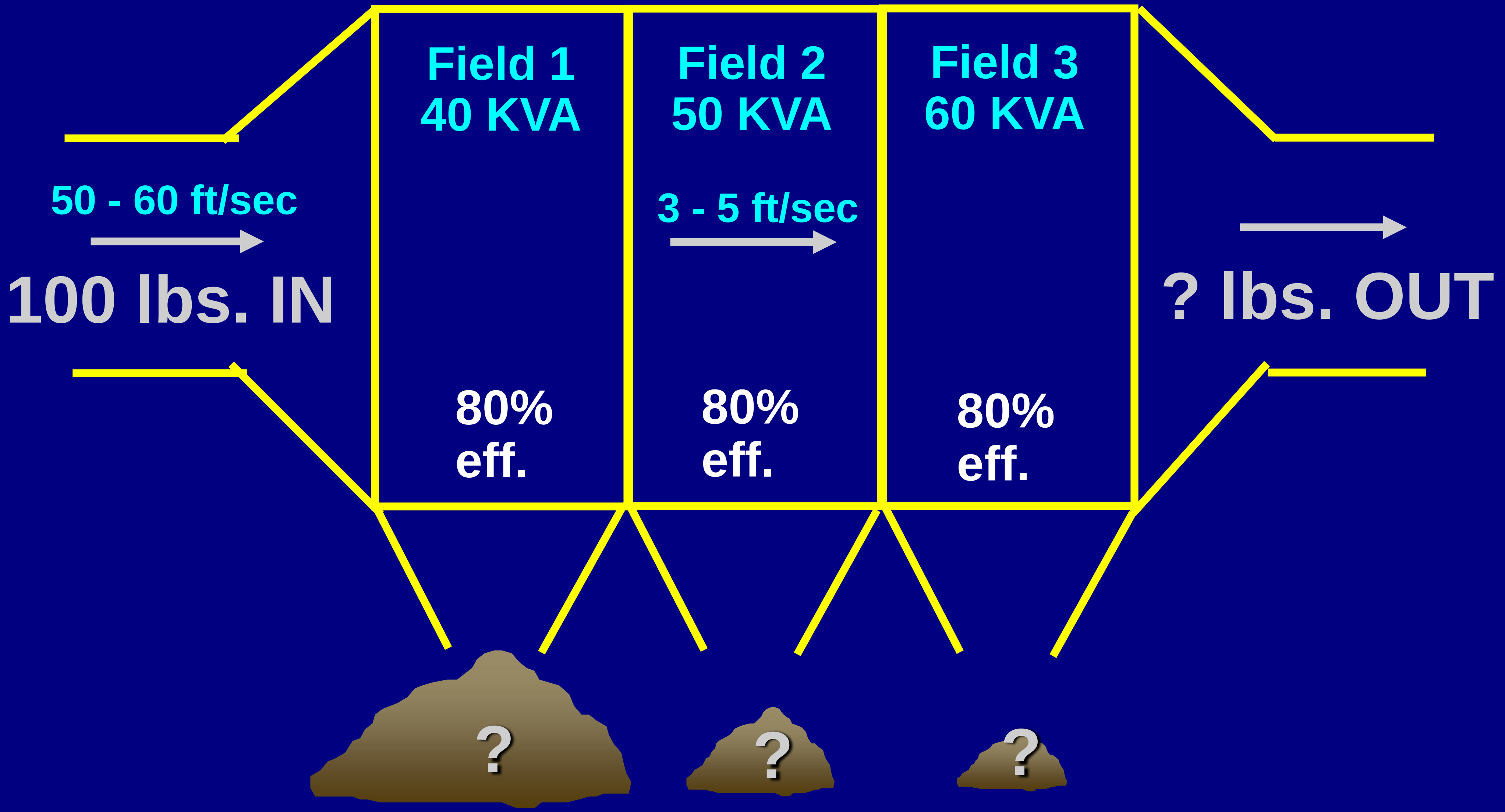
Collection Plate Spacing

- Critical Performance Factor
- Important Maintenance Point
- Single-Stage Spacing: 9 - 20 inches
- Wider Spacing = Higher Voltages

Sectionalization

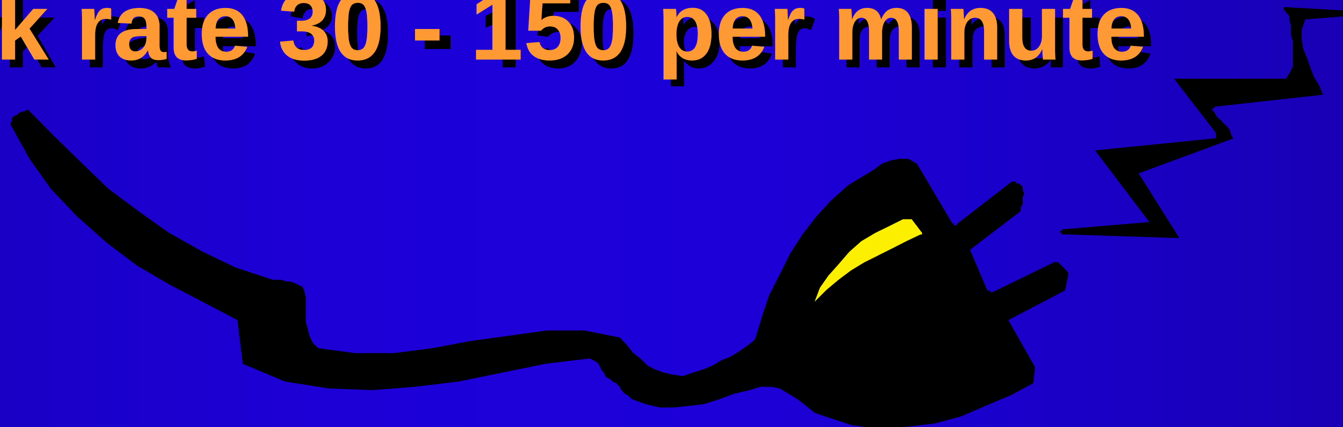


Fields and Yields



Power Requirements/ Sparking

- Corona Power = Voltage x Current
- Most ESPs designed to produce maximum corona power with spark rate 30 - 150 per minute

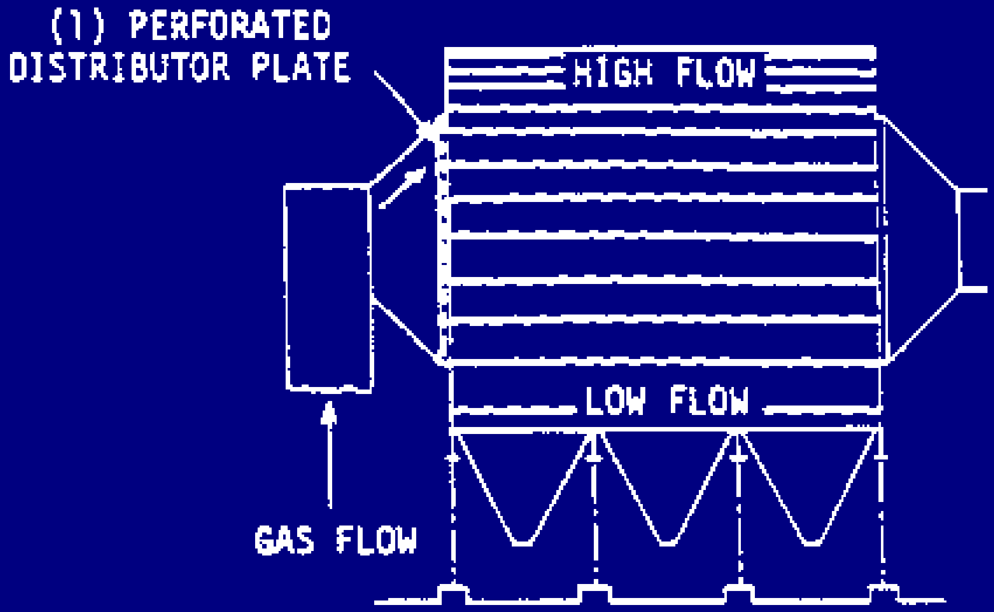


ESP COMPONENTS

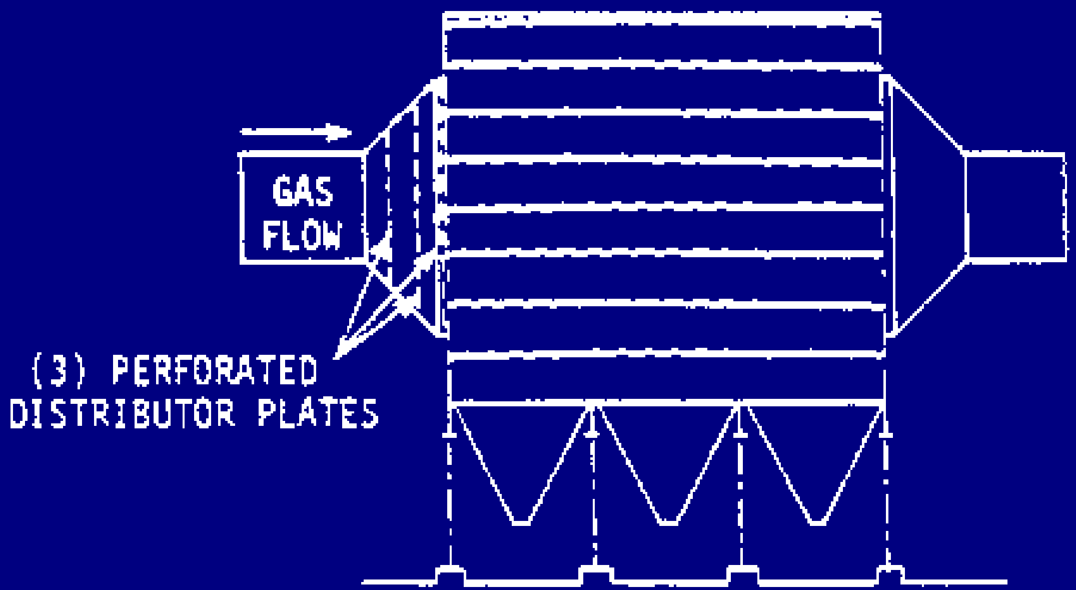
Section 306


Inlet Duct

Gas Flow Distribution

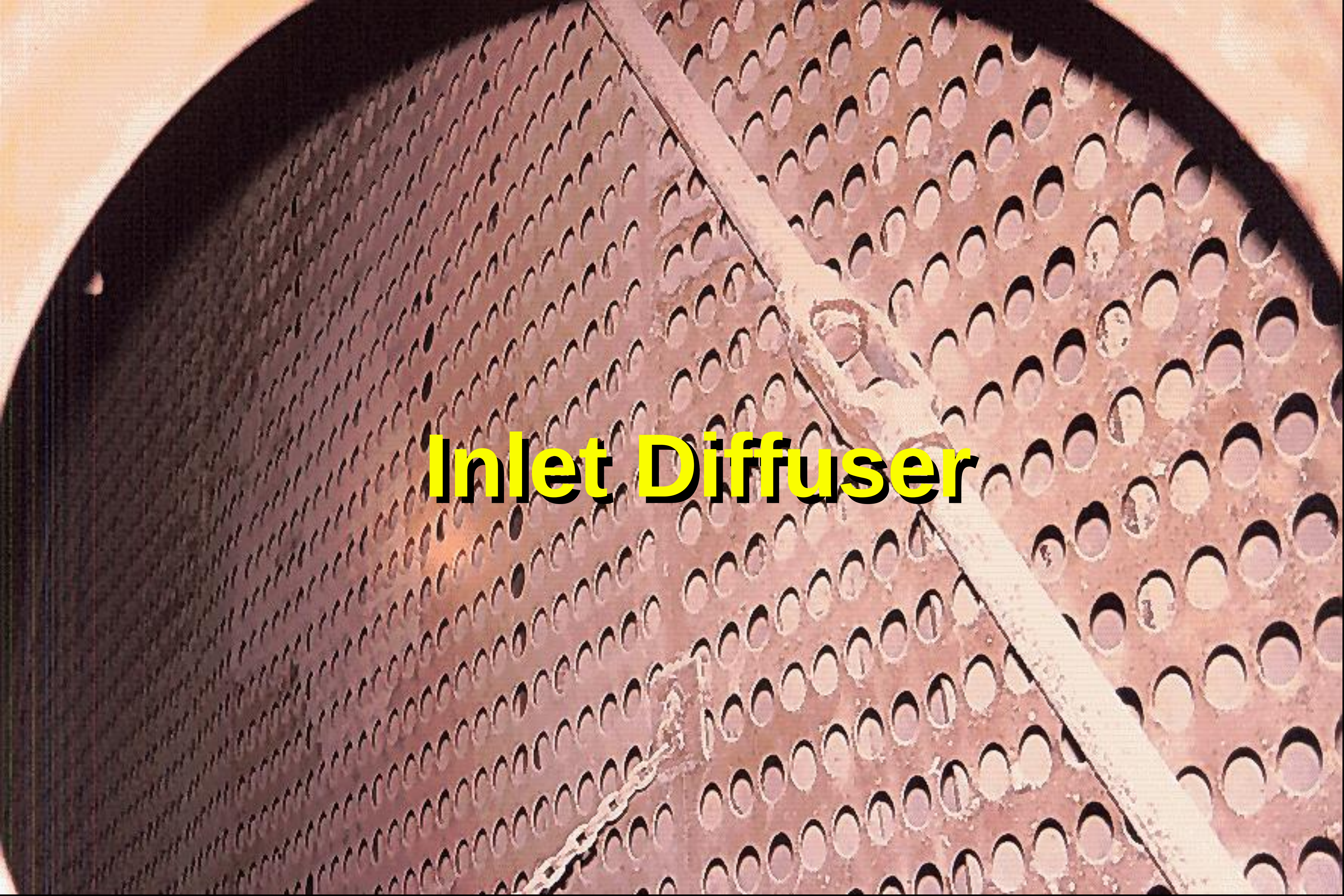


Not So Good

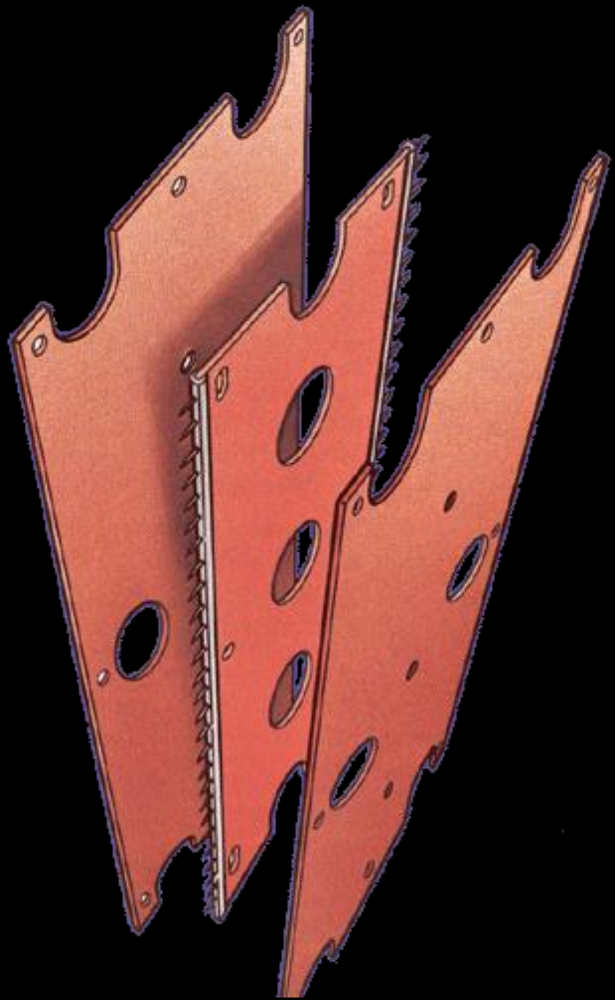


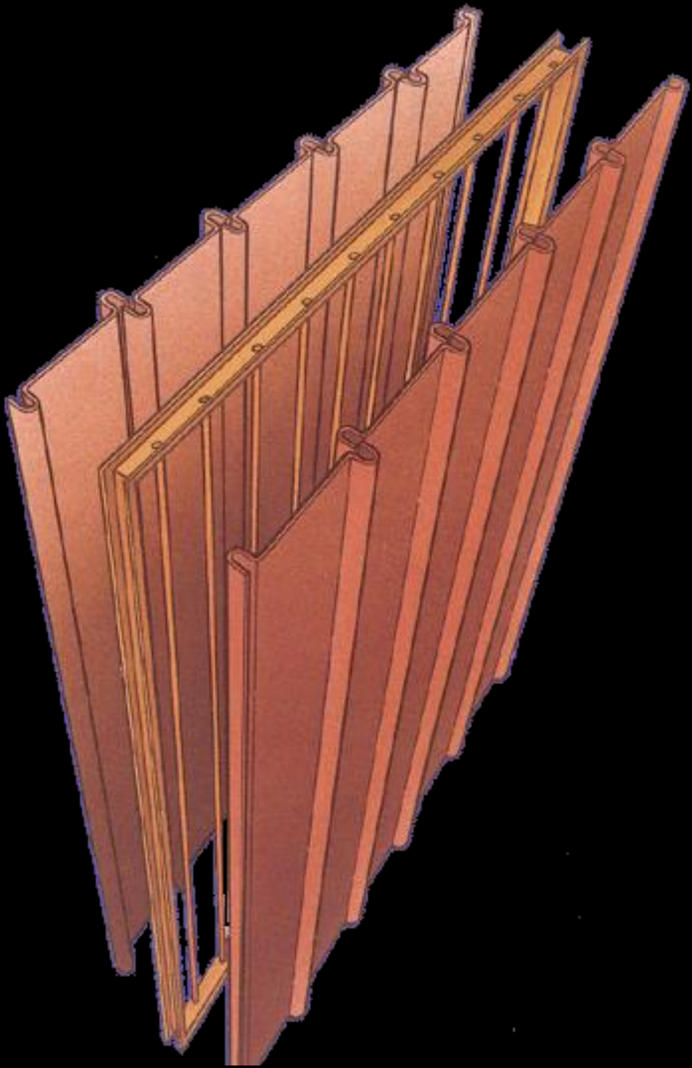
Better

Figure 306.9


Inlet Diffuser

Discharge Electrodes





Weighted-Wire Discharge Electrodes & Charging System

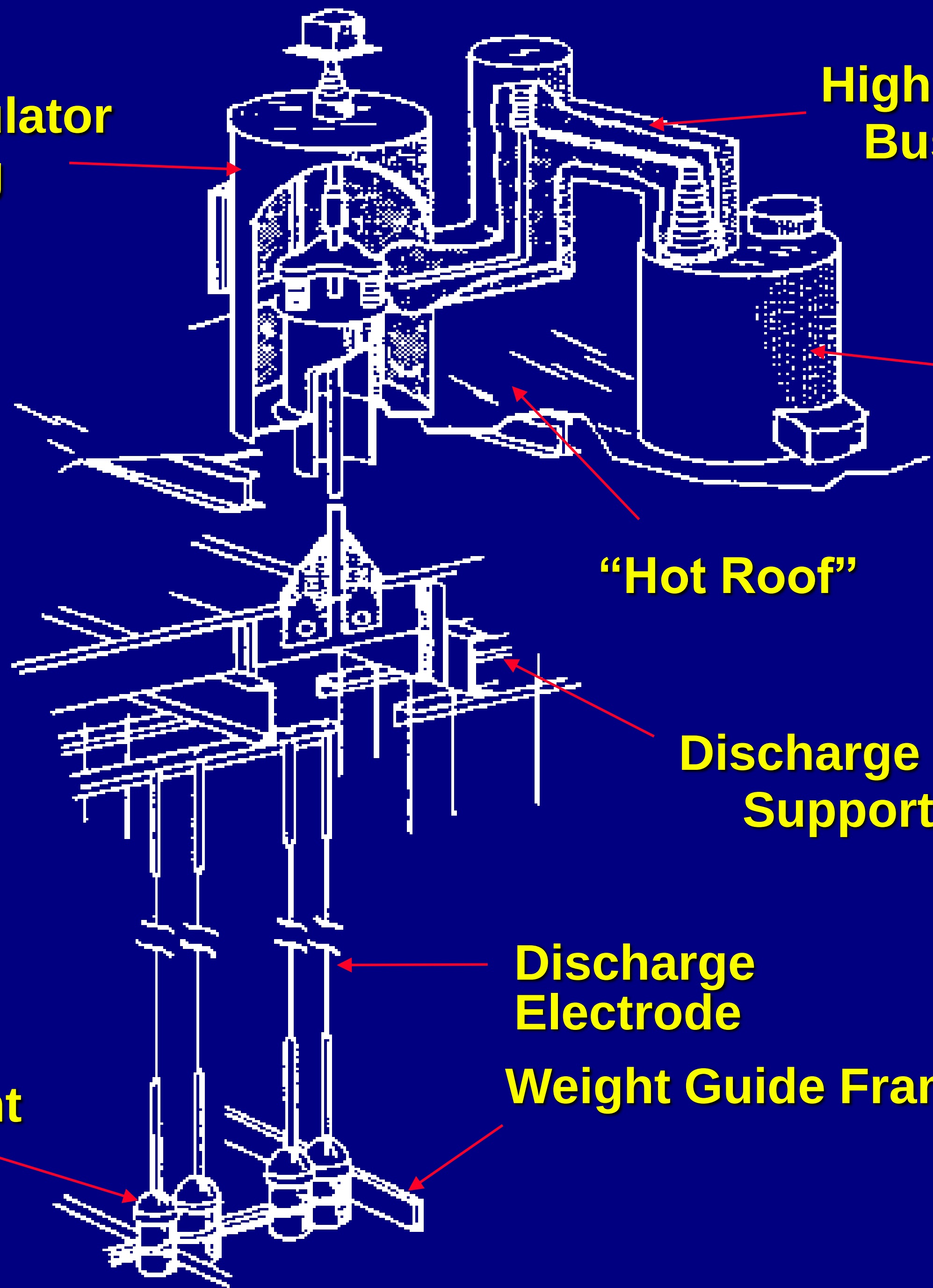
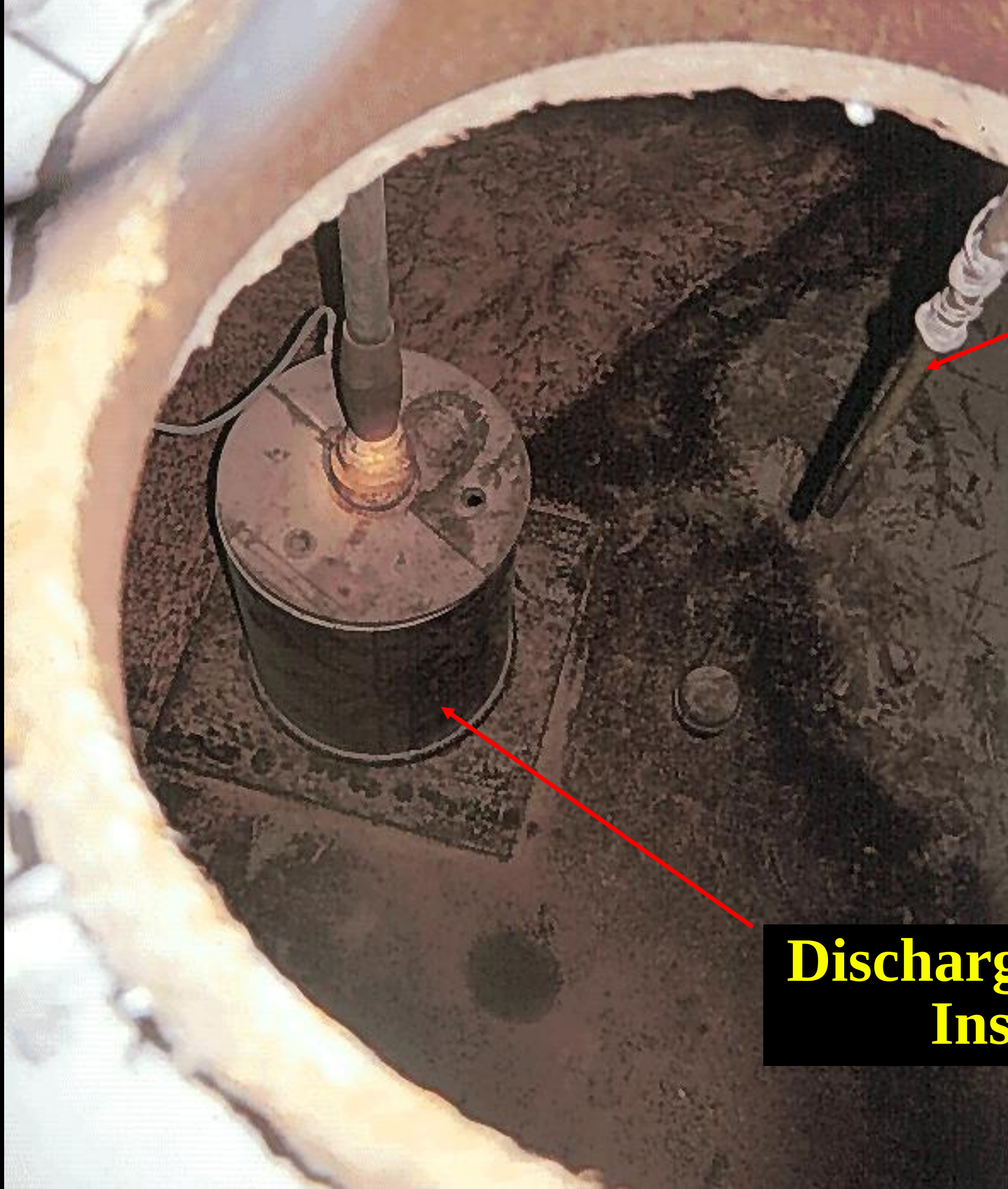
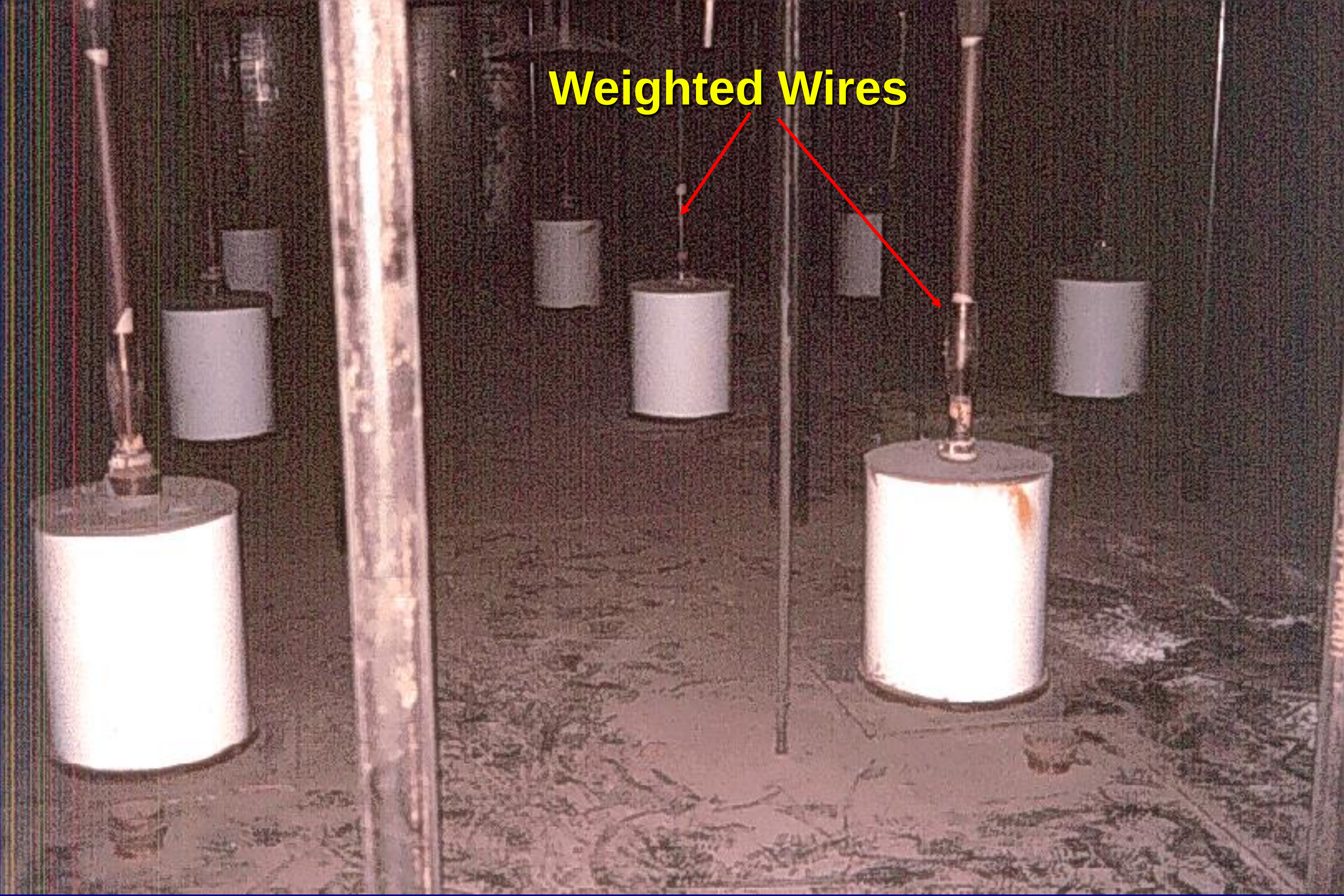


Figure 306.3

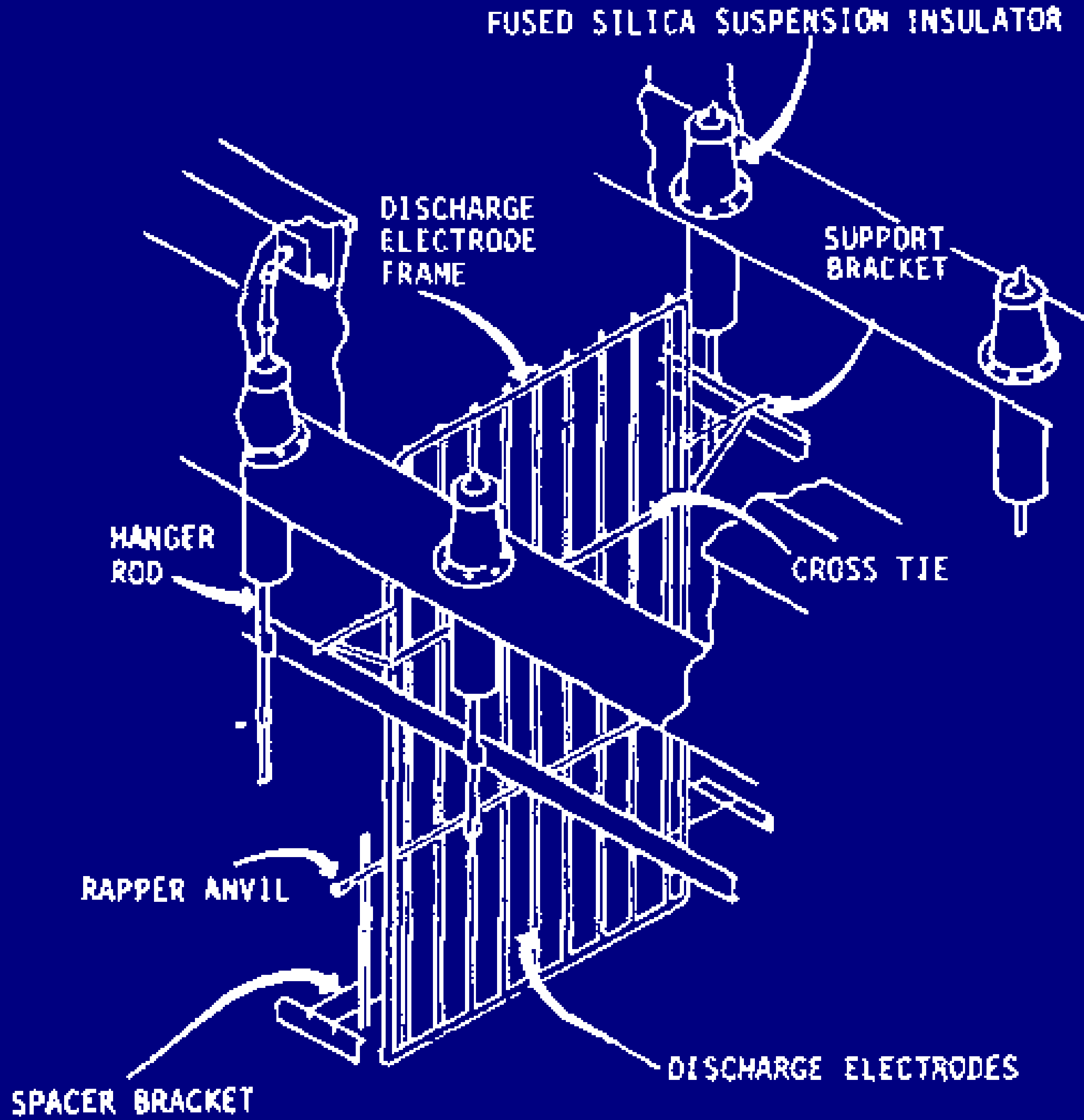
View into Penthouse



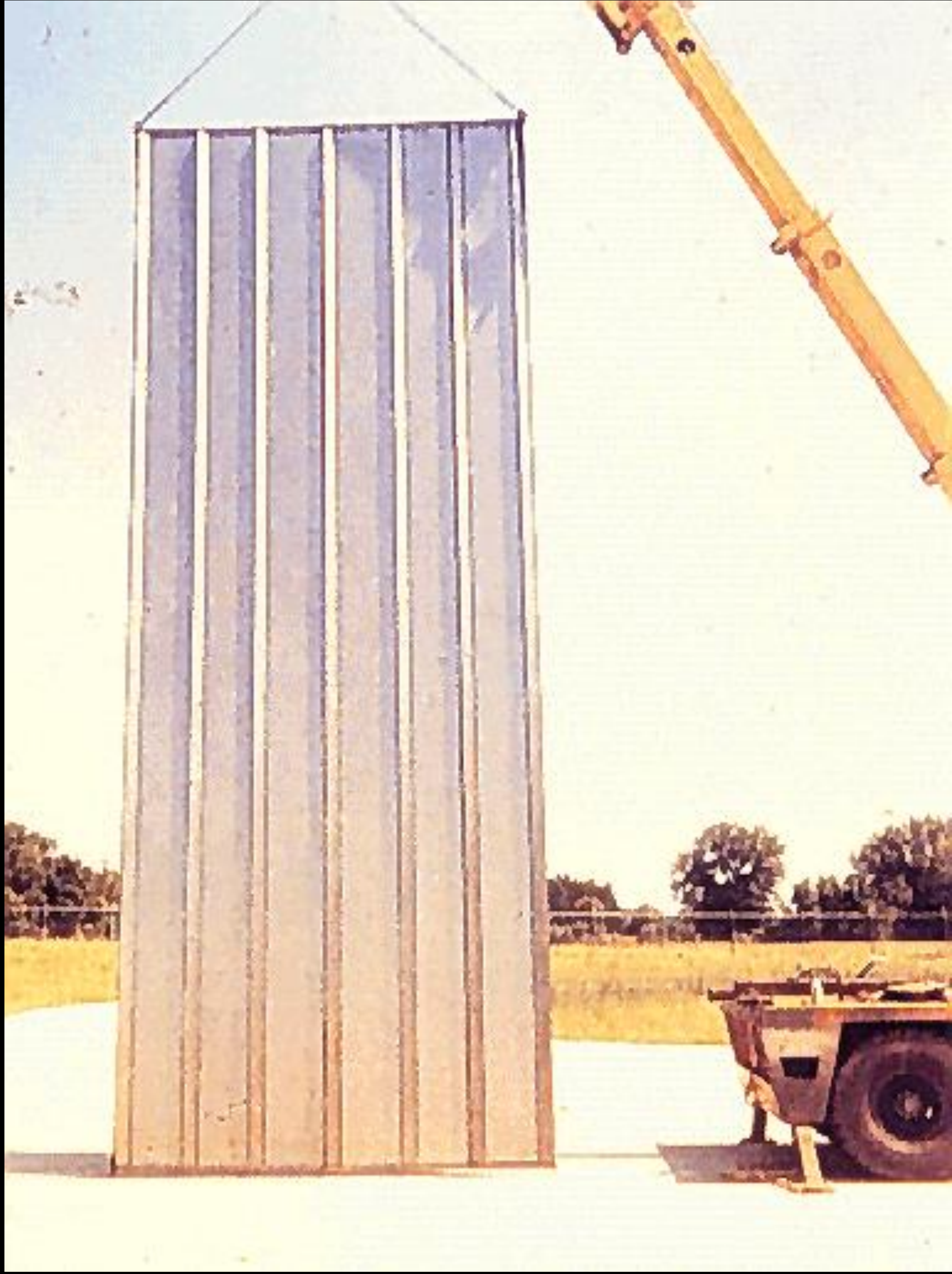

Water Tracks


Weighted Wires

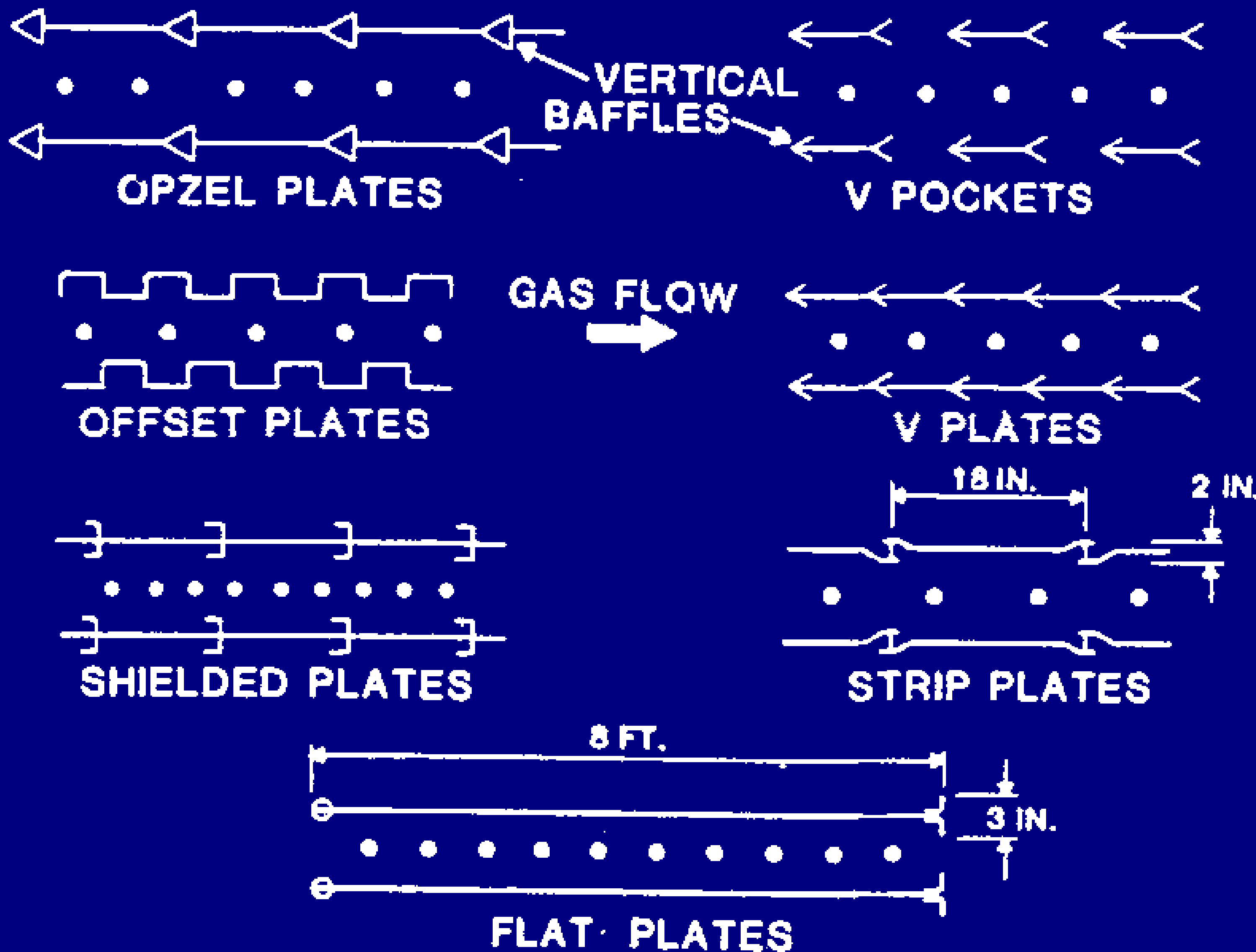
Frame-Type Discharge Electrodes

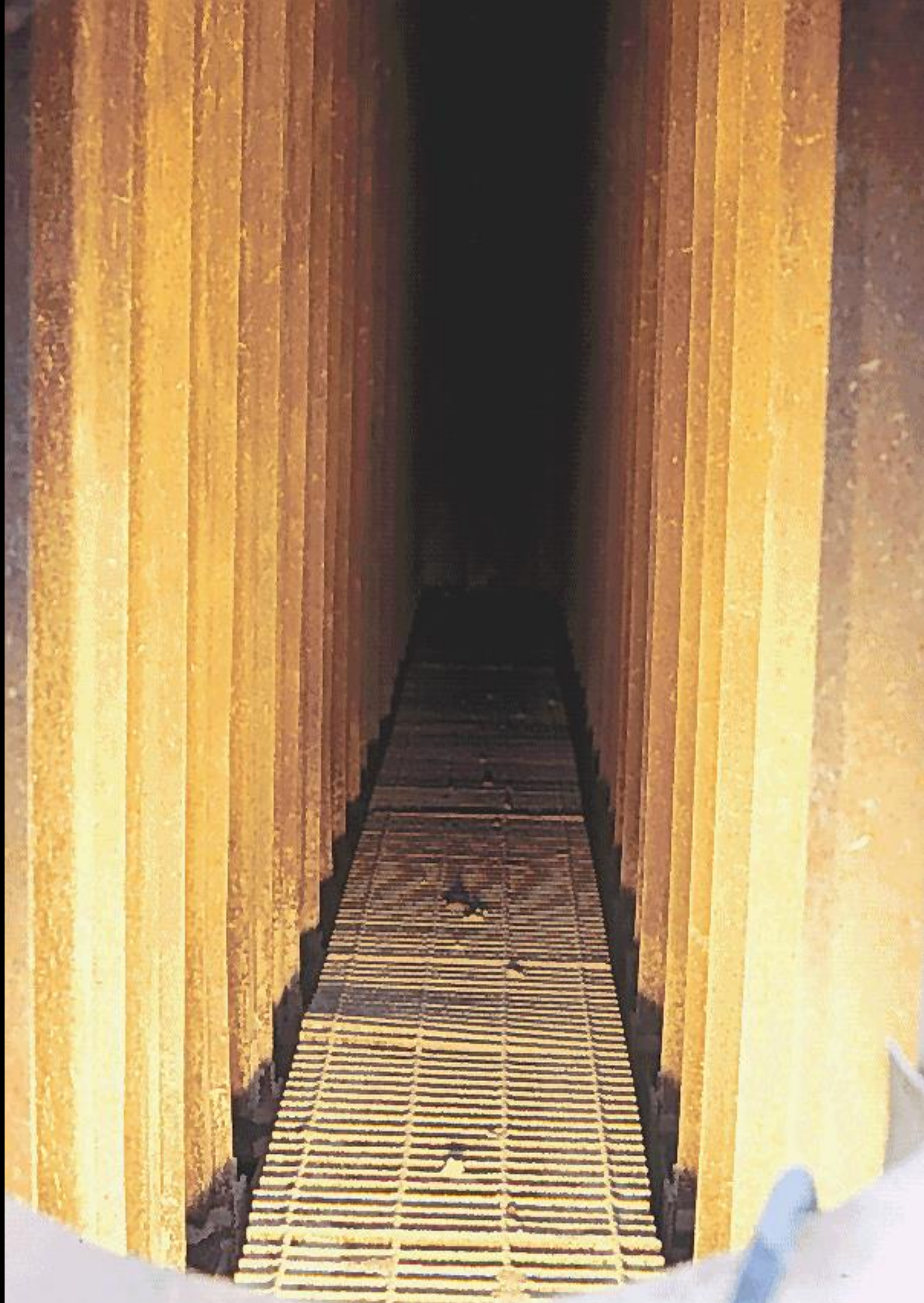


Collection Plate

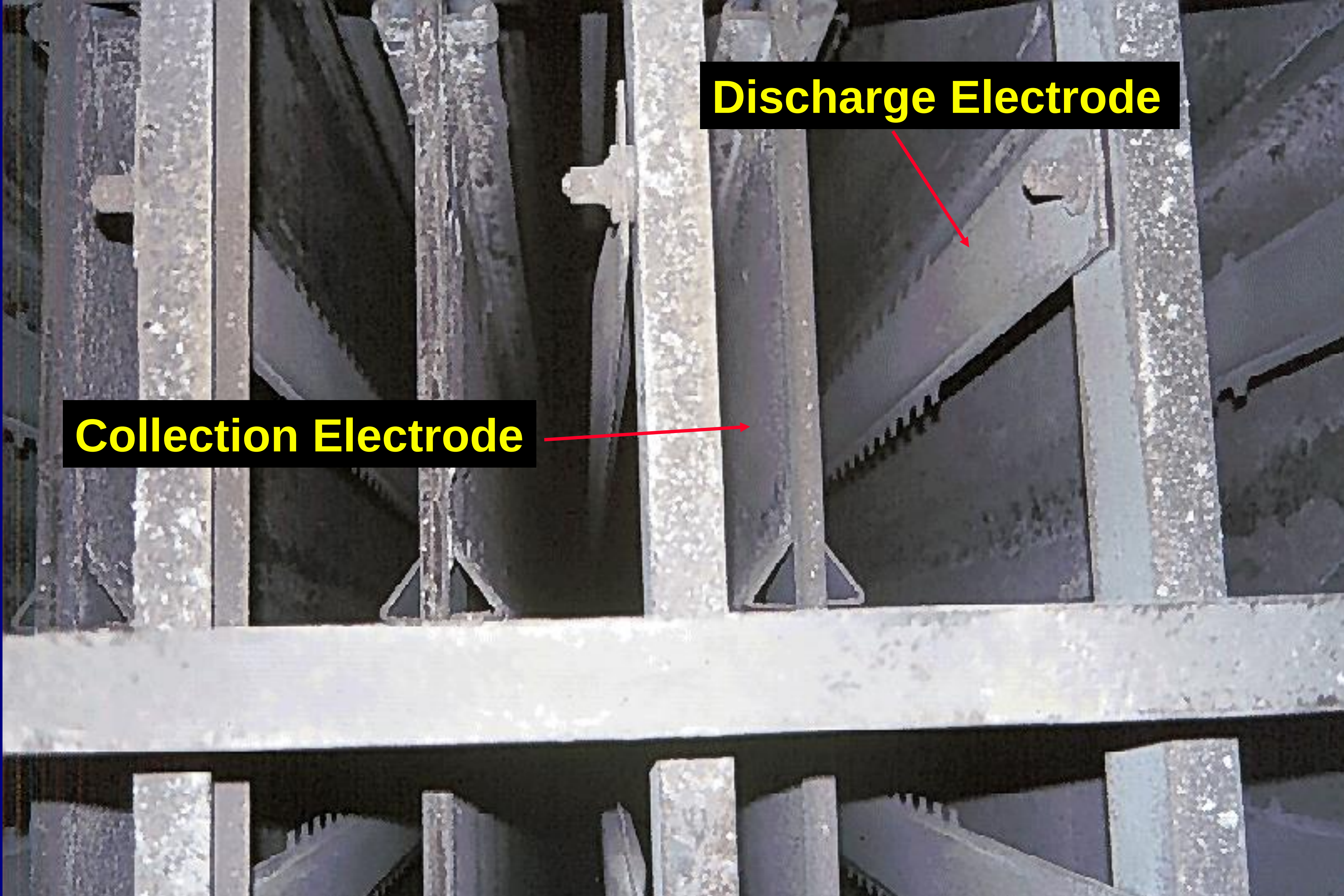


Collection Plate Designs

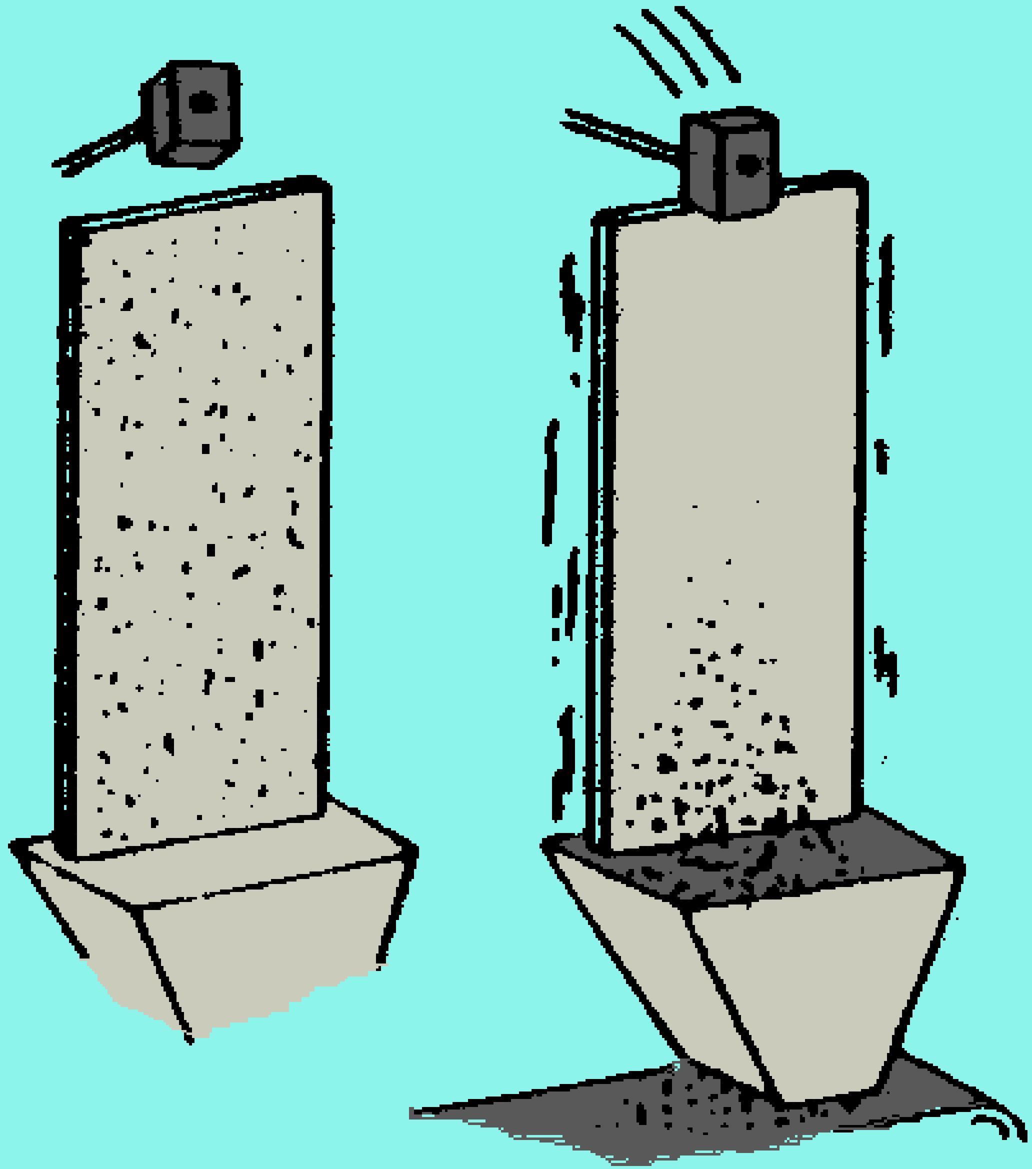




View into side port

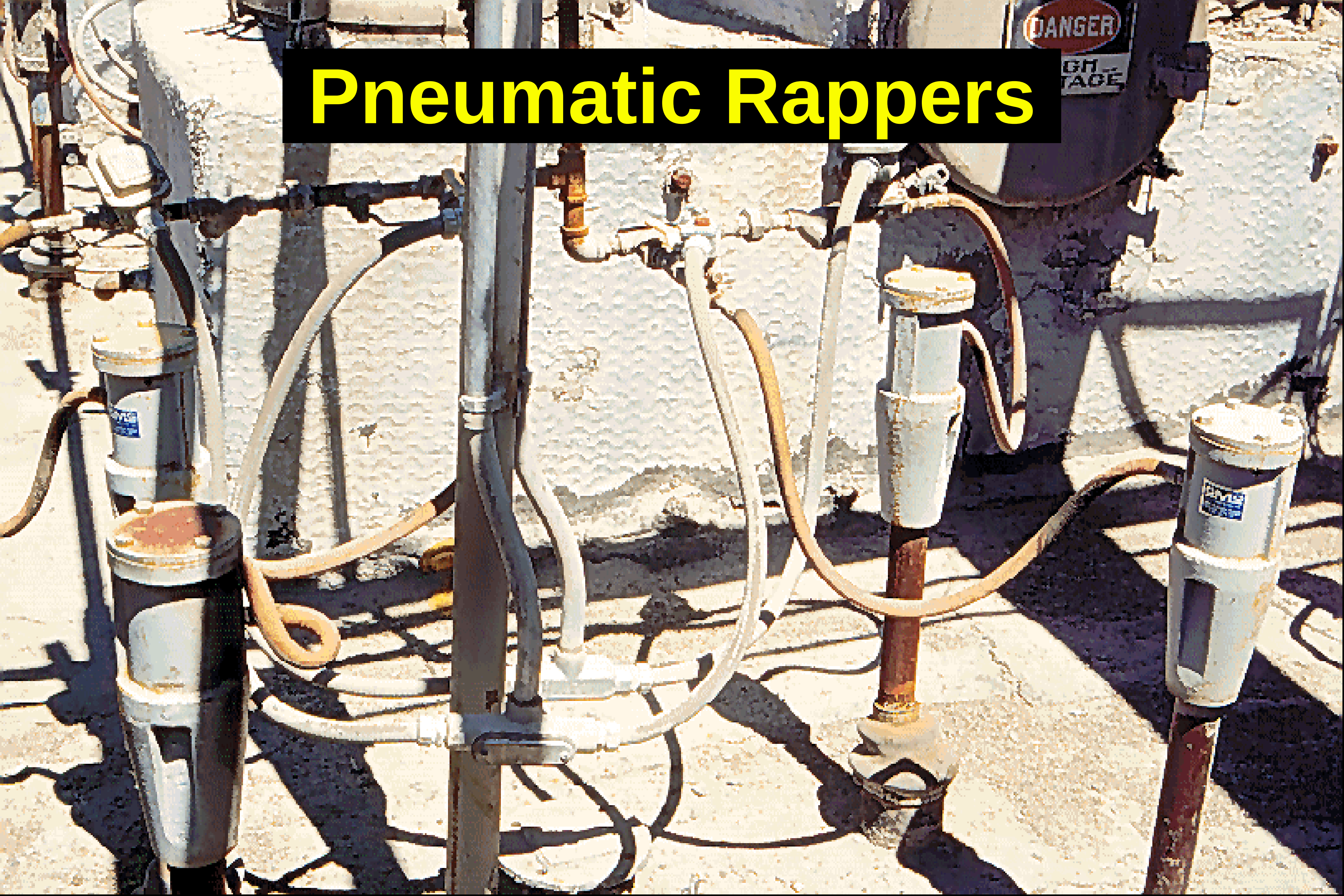

Discharge Electrode
Collection Electrode

Particulate Removal

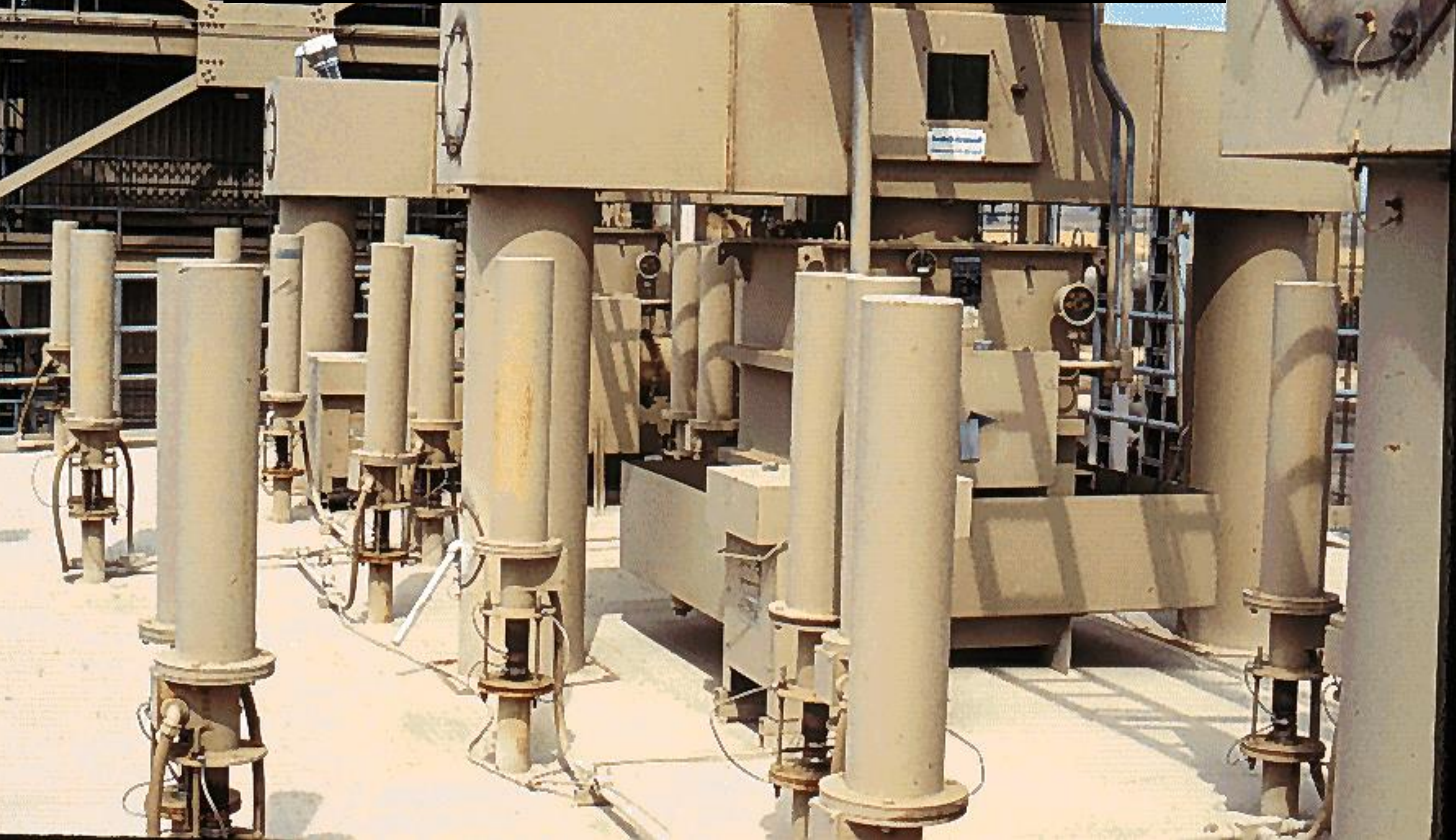


Rapper Types

- Pneumatic
- Magnetic-Impulse, Gravity-Impact (MIGI)
- Hammer and Anvil
- Vibratory

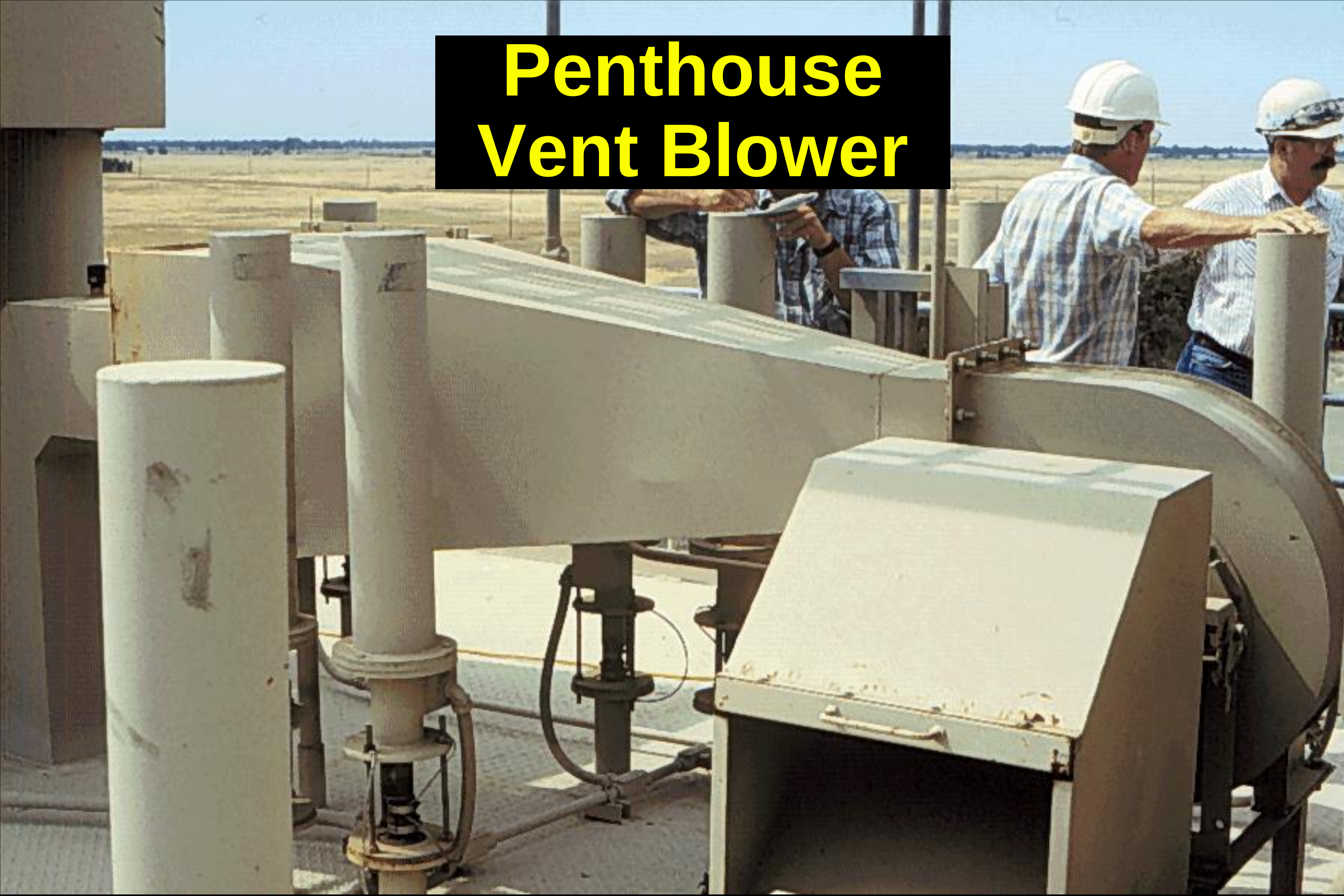

Pneumatic Rappers
DANGER

Magnetic Impulse Rappers

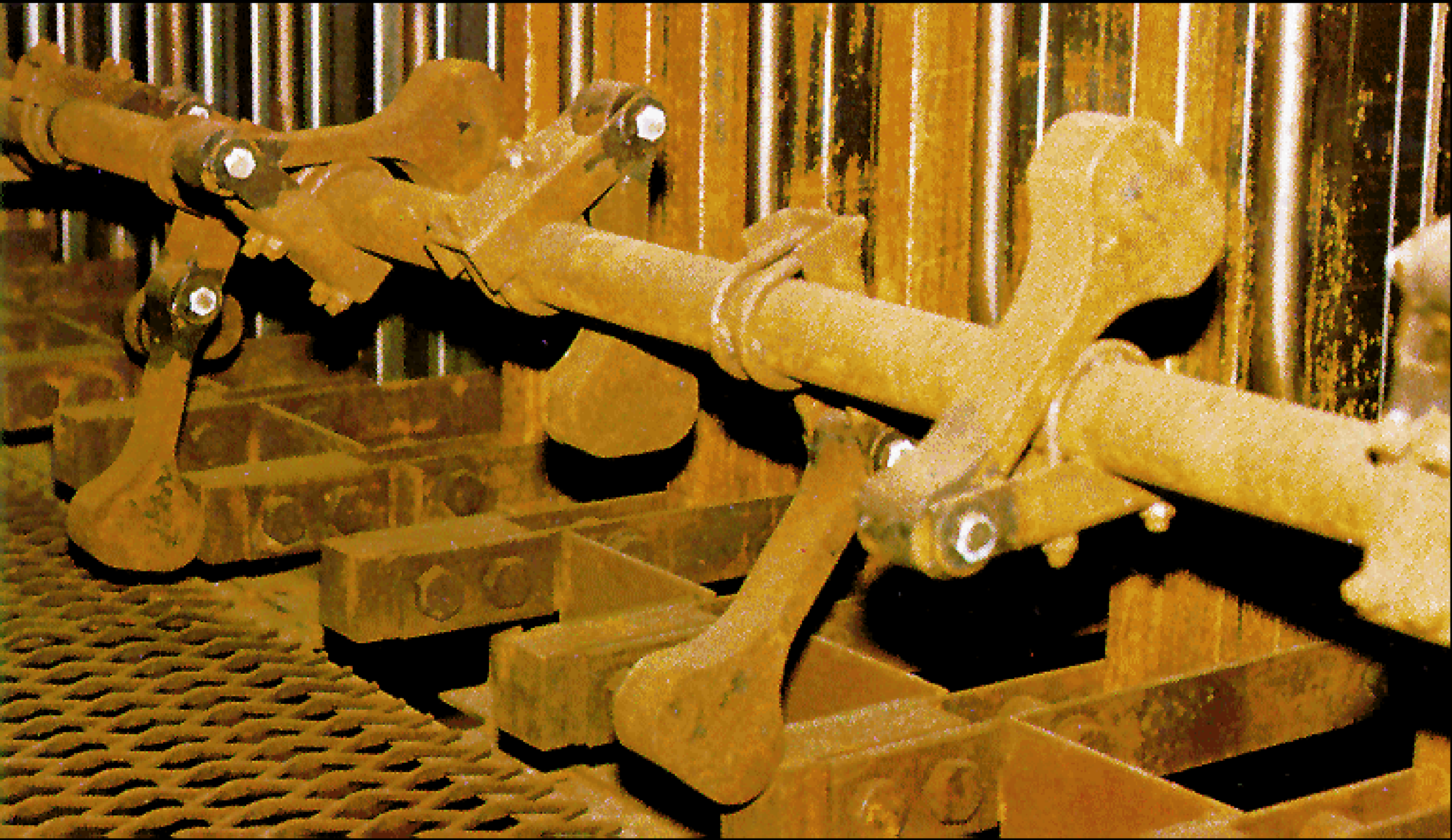


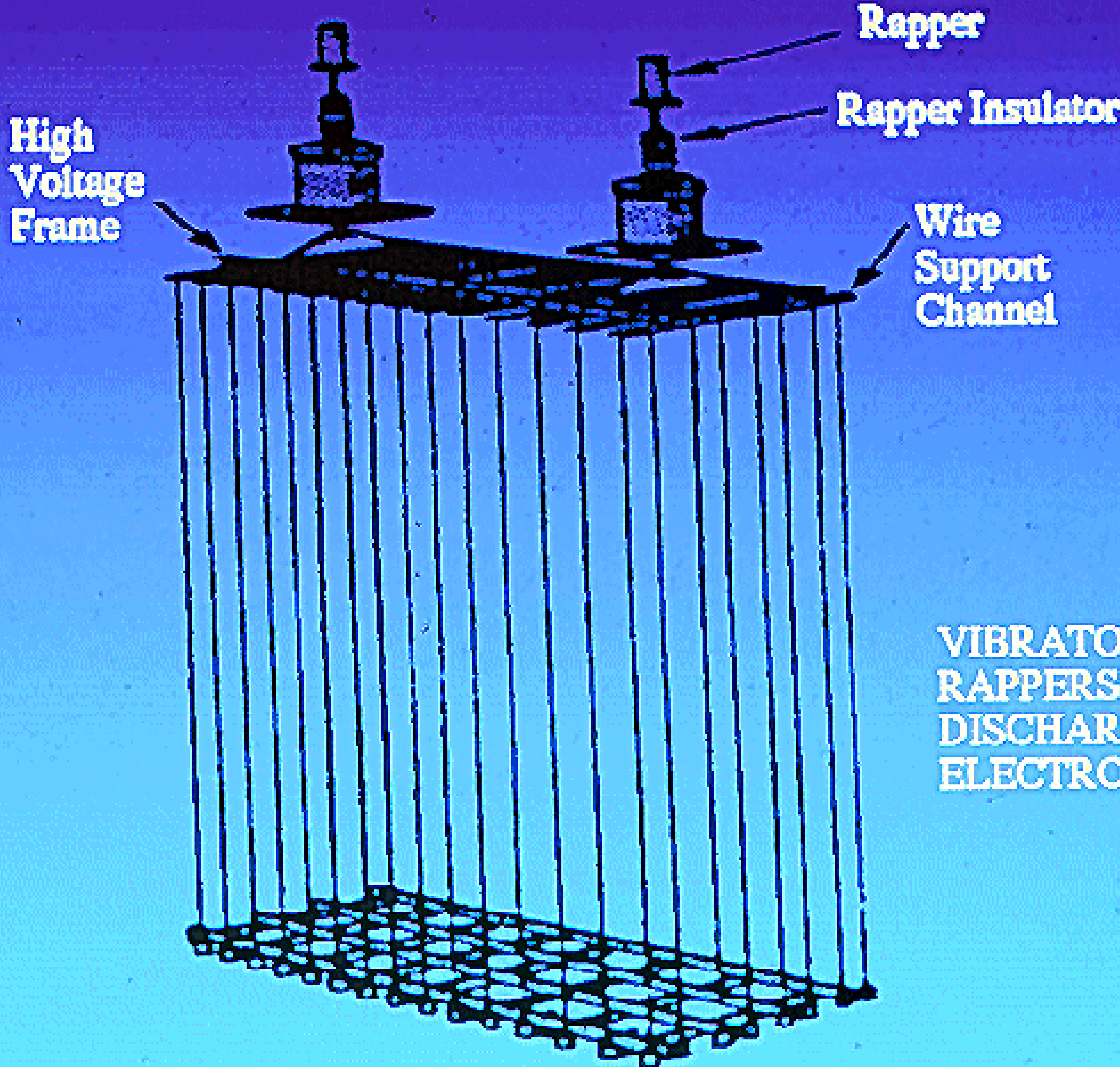
Magnetic-Impulse Gravity-Impact (MIGI) Rapper

Penthouse Vent Blower

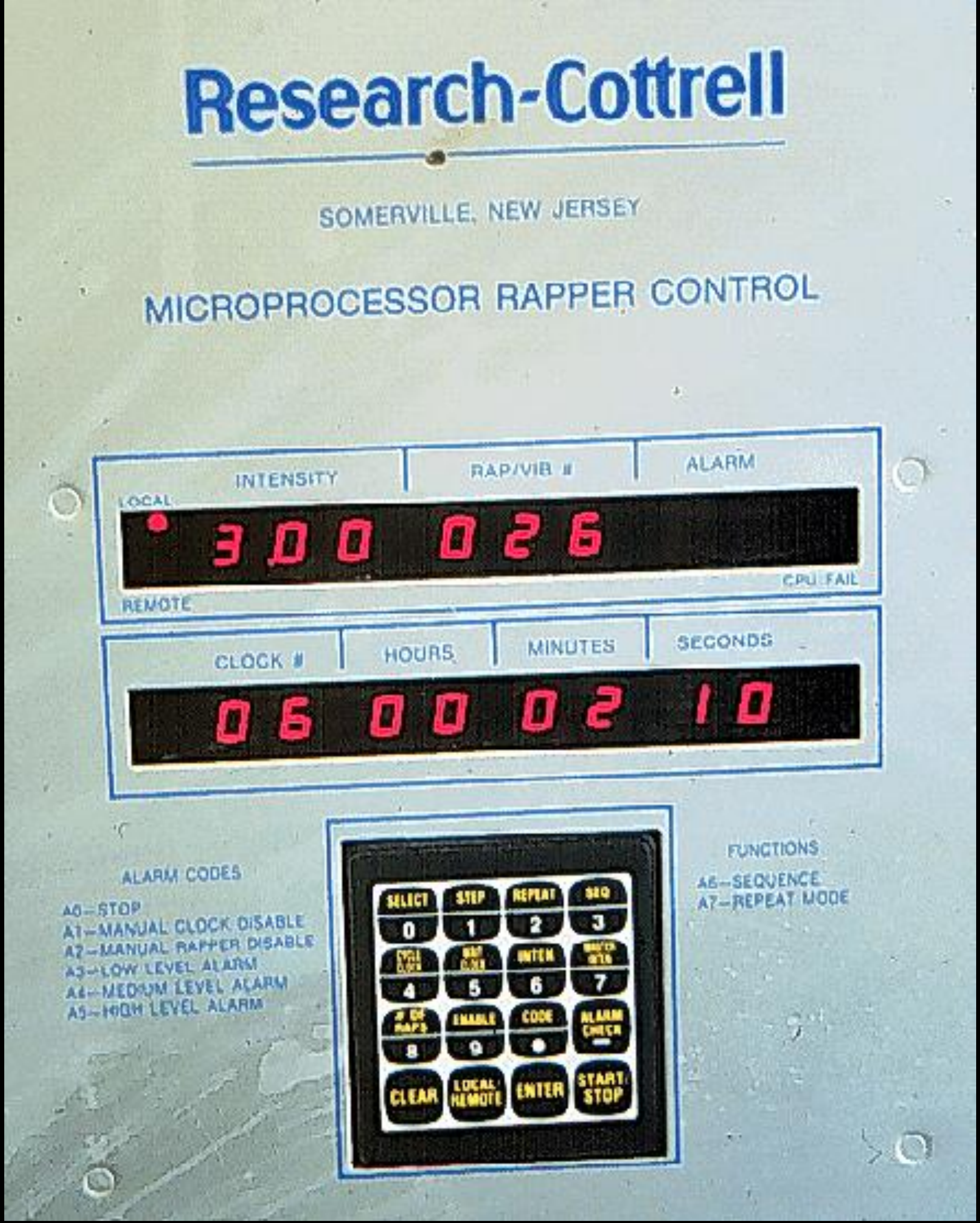


Hammer-Anvil Rappers





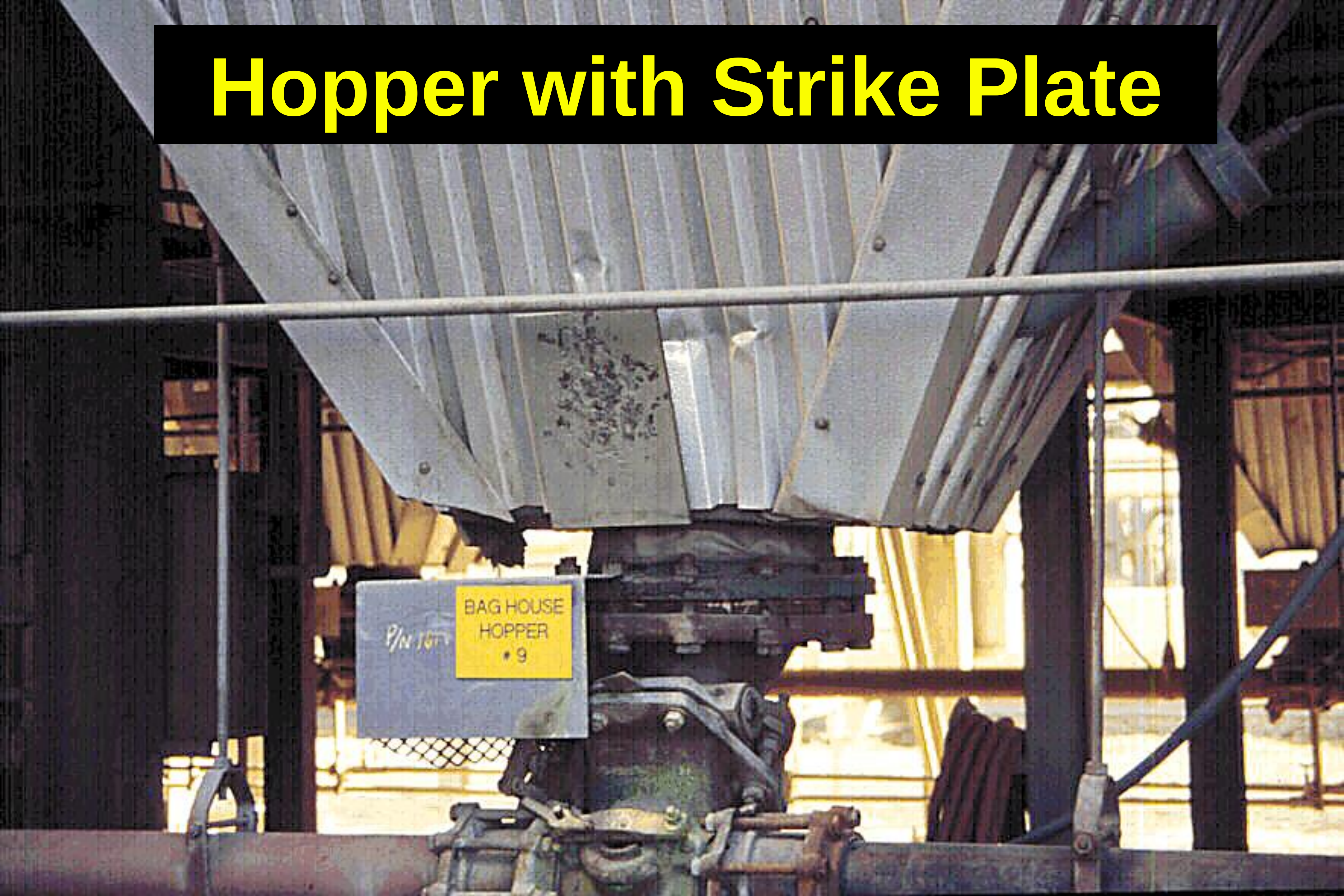
VIBRATOR RAPPERS FOR DISCHARGE ELECTRODES



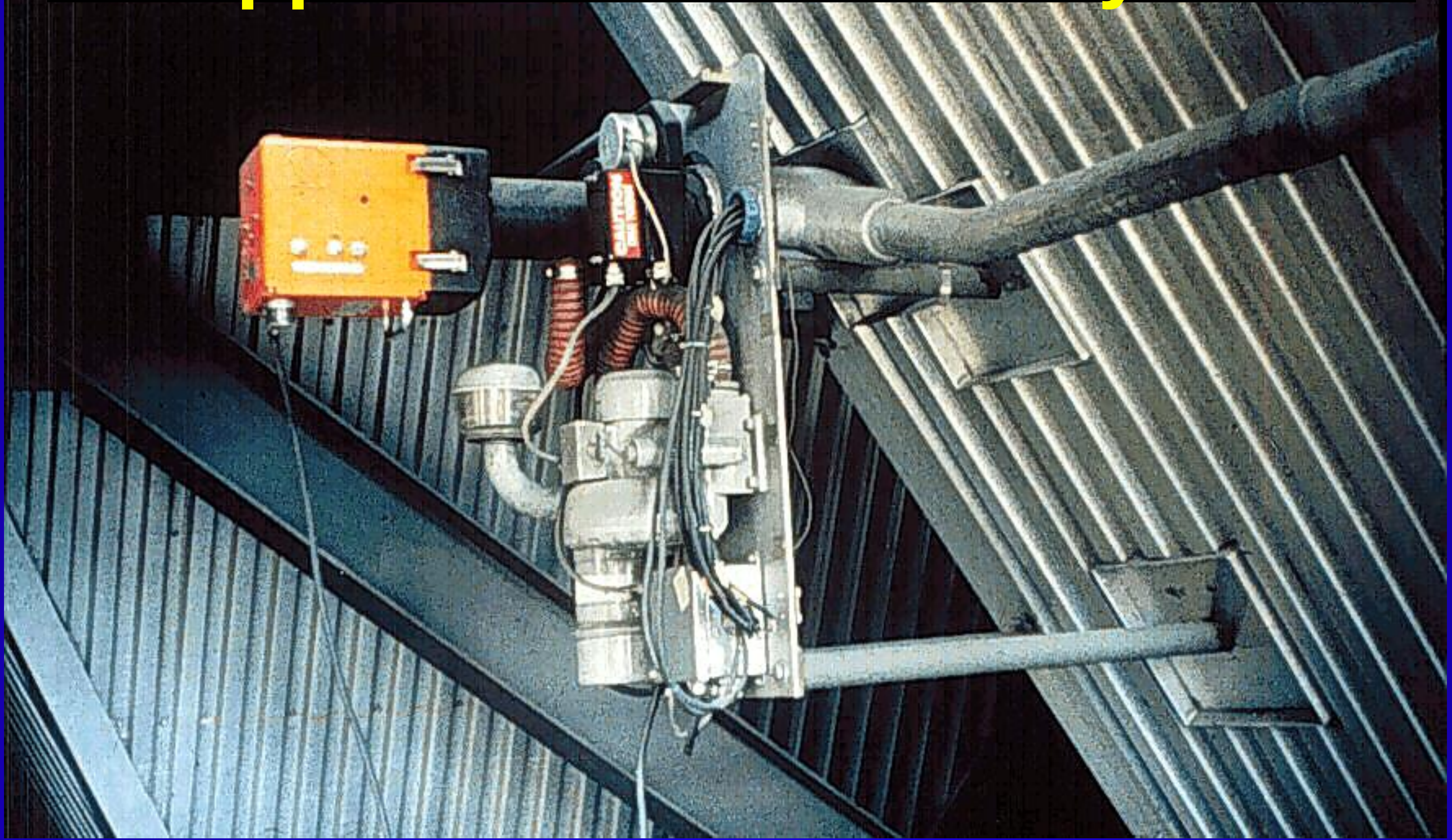
Rapper Control Panel

Collection Hopper

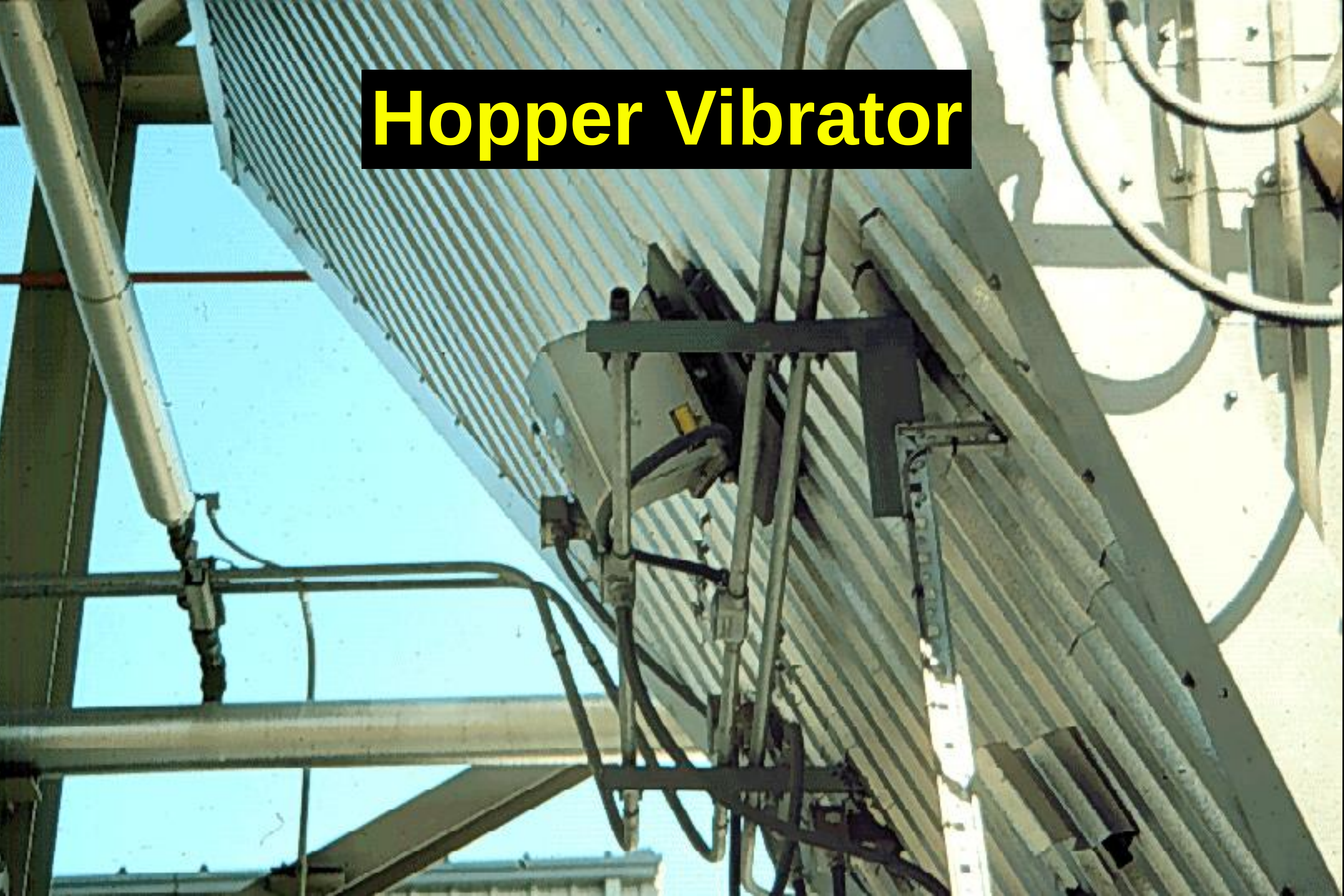
Hopper with Strike Plate



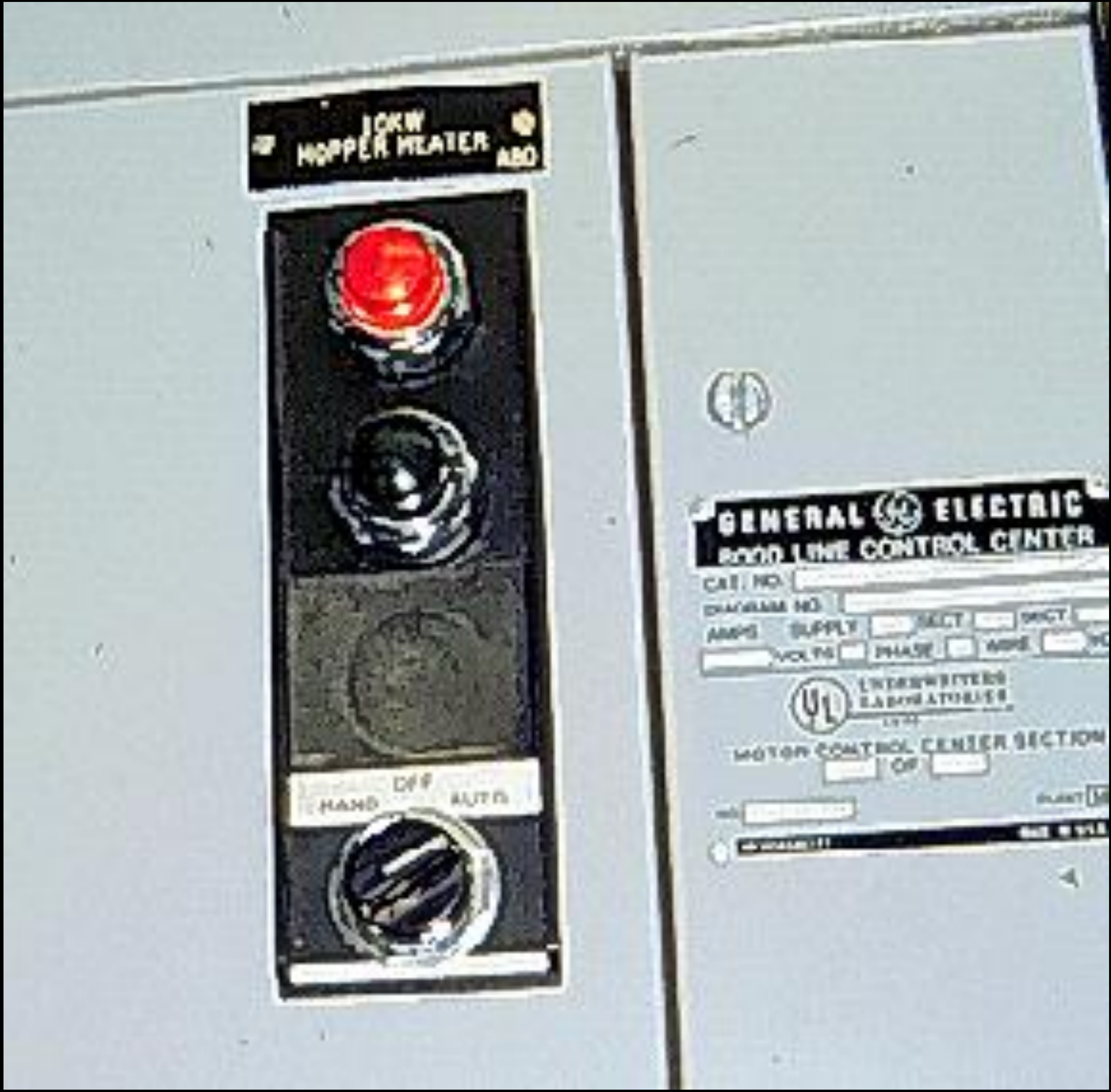
Hopper Level Indicator System



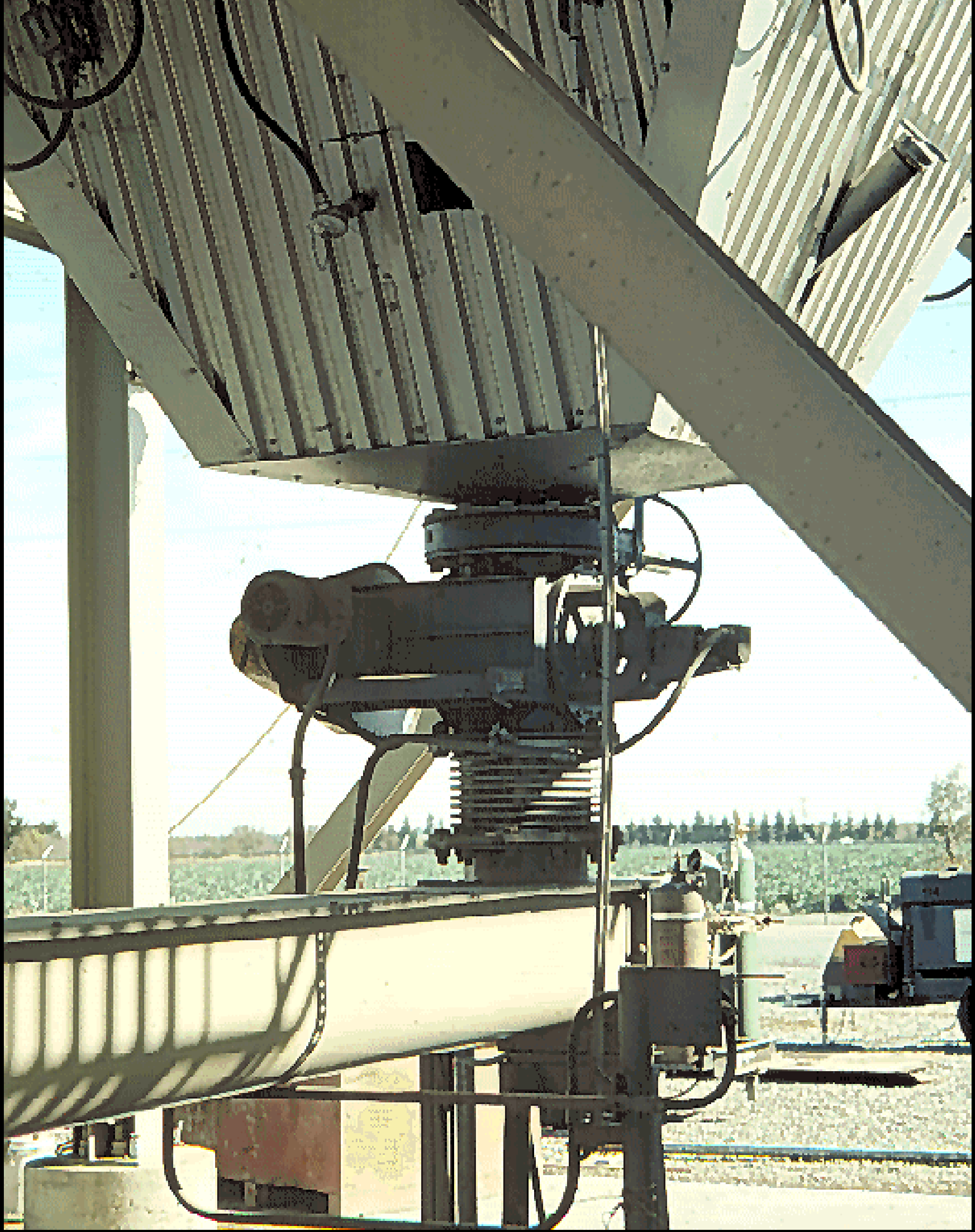
Hopper Vibrator



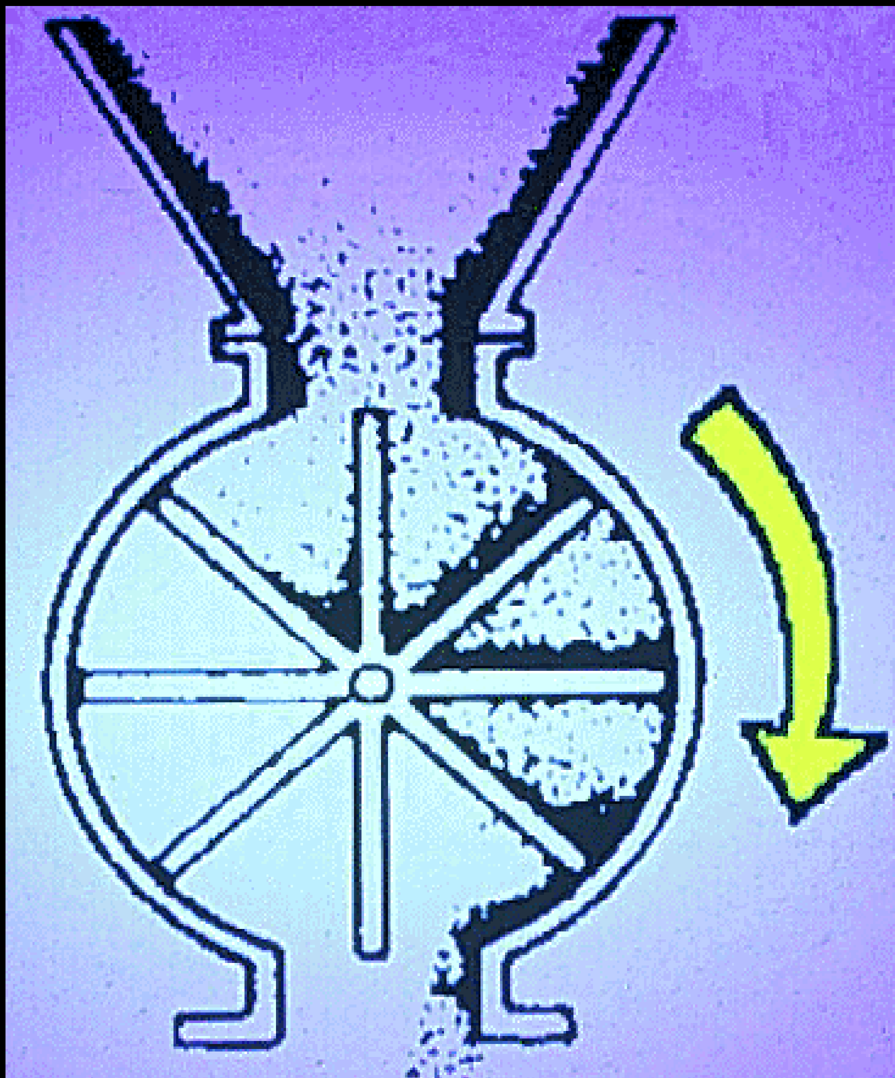
Hopper Heater Control

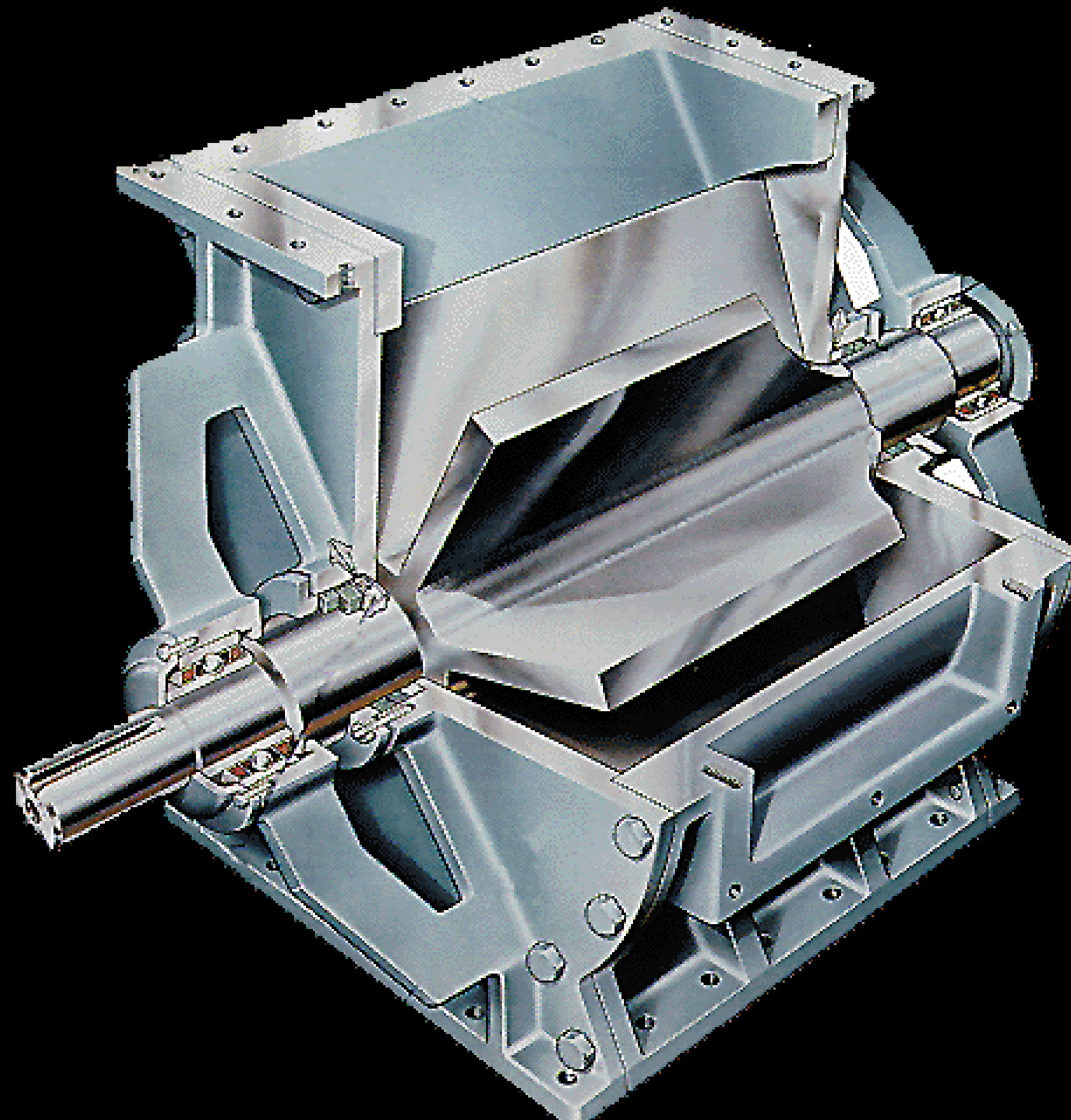


Airlock
&
Bin Screw



Rotary Airlock Valve





Pneumatic Dust Collection System

Dust Discharge Problems

- Inleakage
- Corrosion
- Dust Buildup
- Pluggage
- Fugitive Emissions

High Voltage Equipment

- Transformer
- Rectifier
- Sensors
- Control System

Transformer-Rectifier (T-R Set)

- ***Transformer*** **- Increases voltage at discharge electrodes**

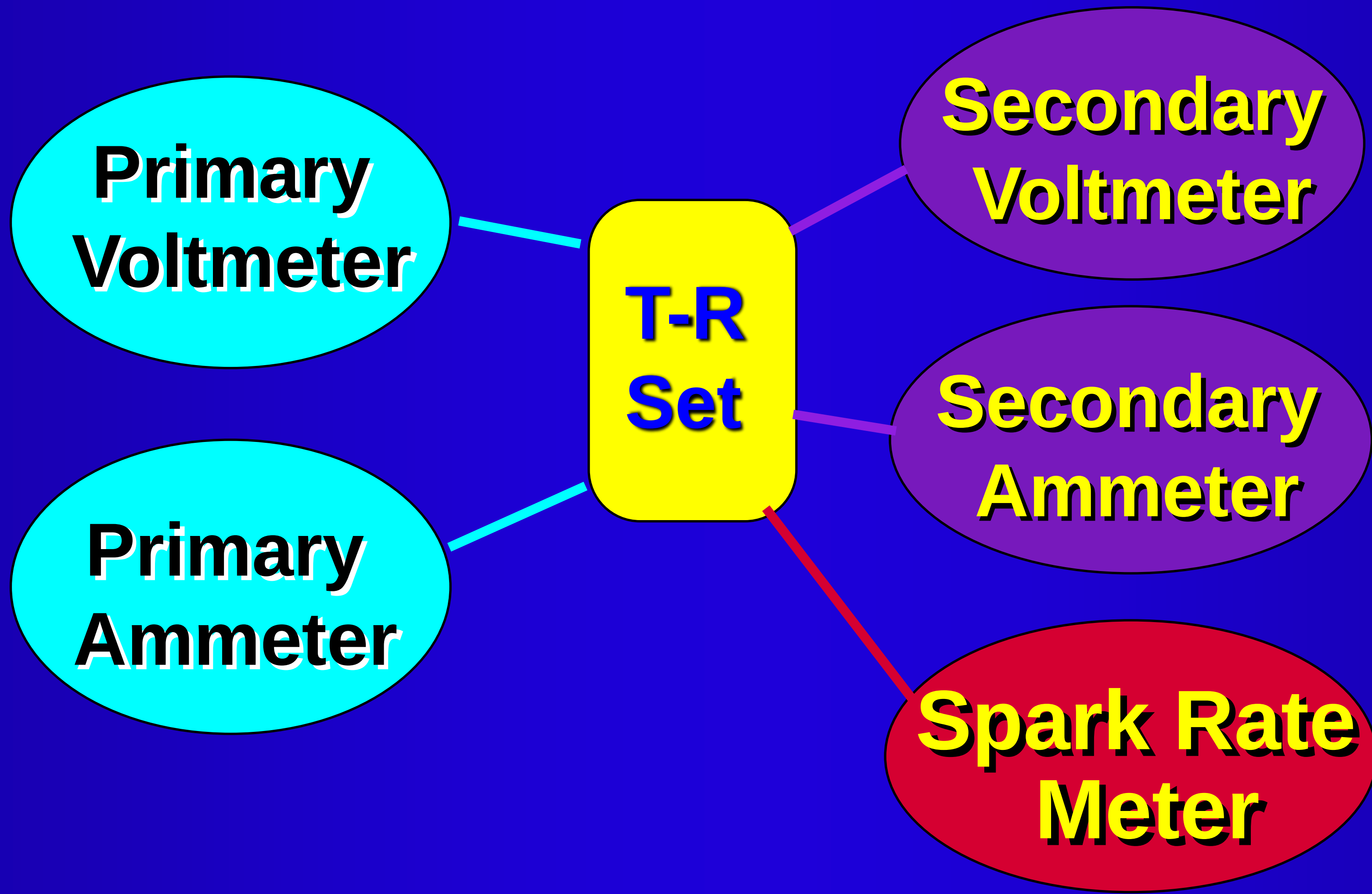
- ***Rectifier*** **- Converts alternating current (AC) to direct current (DC)**

Bus

Transformer-
Rectifier Set

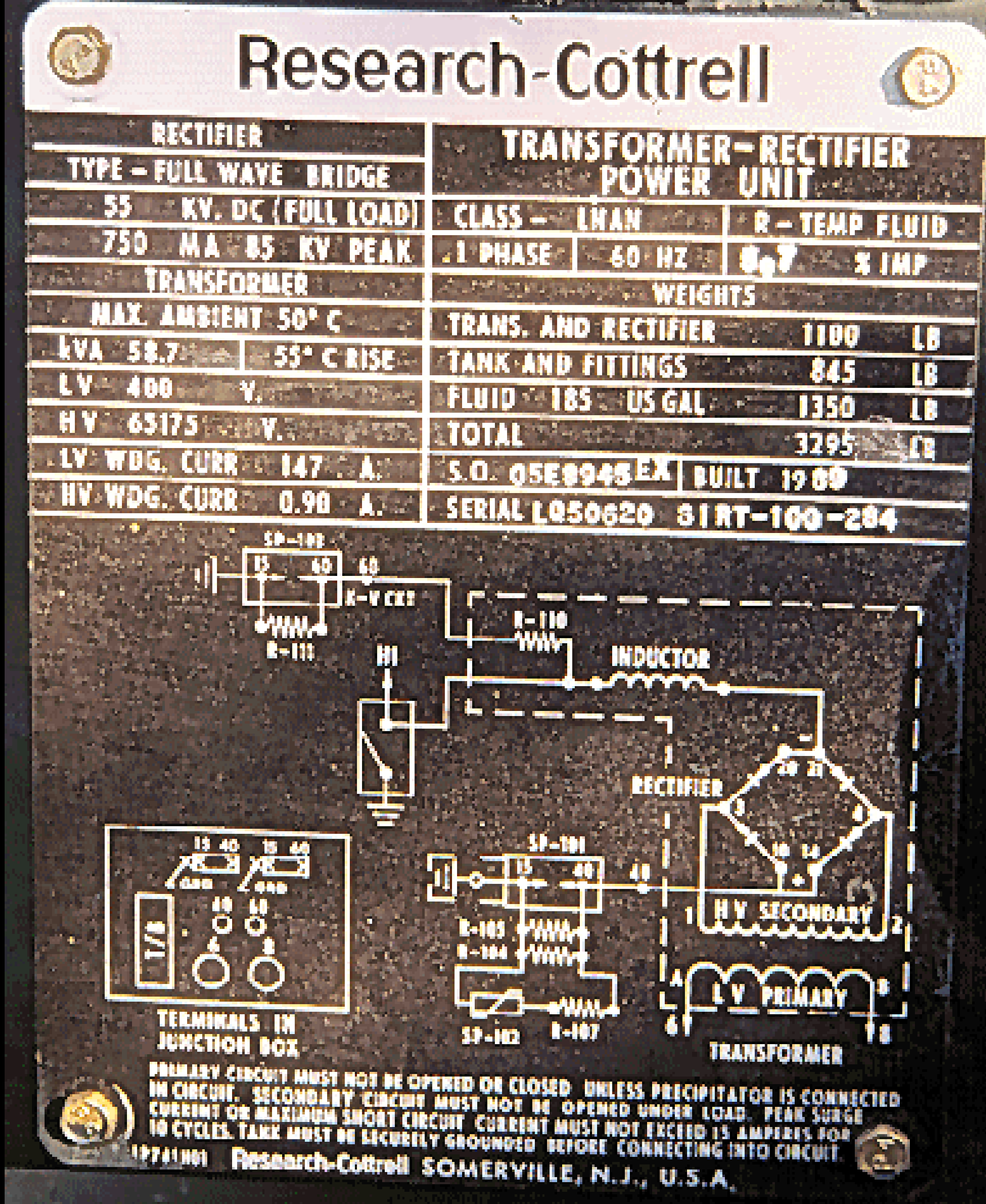

SMOG-HOG

Sensors/Gauges



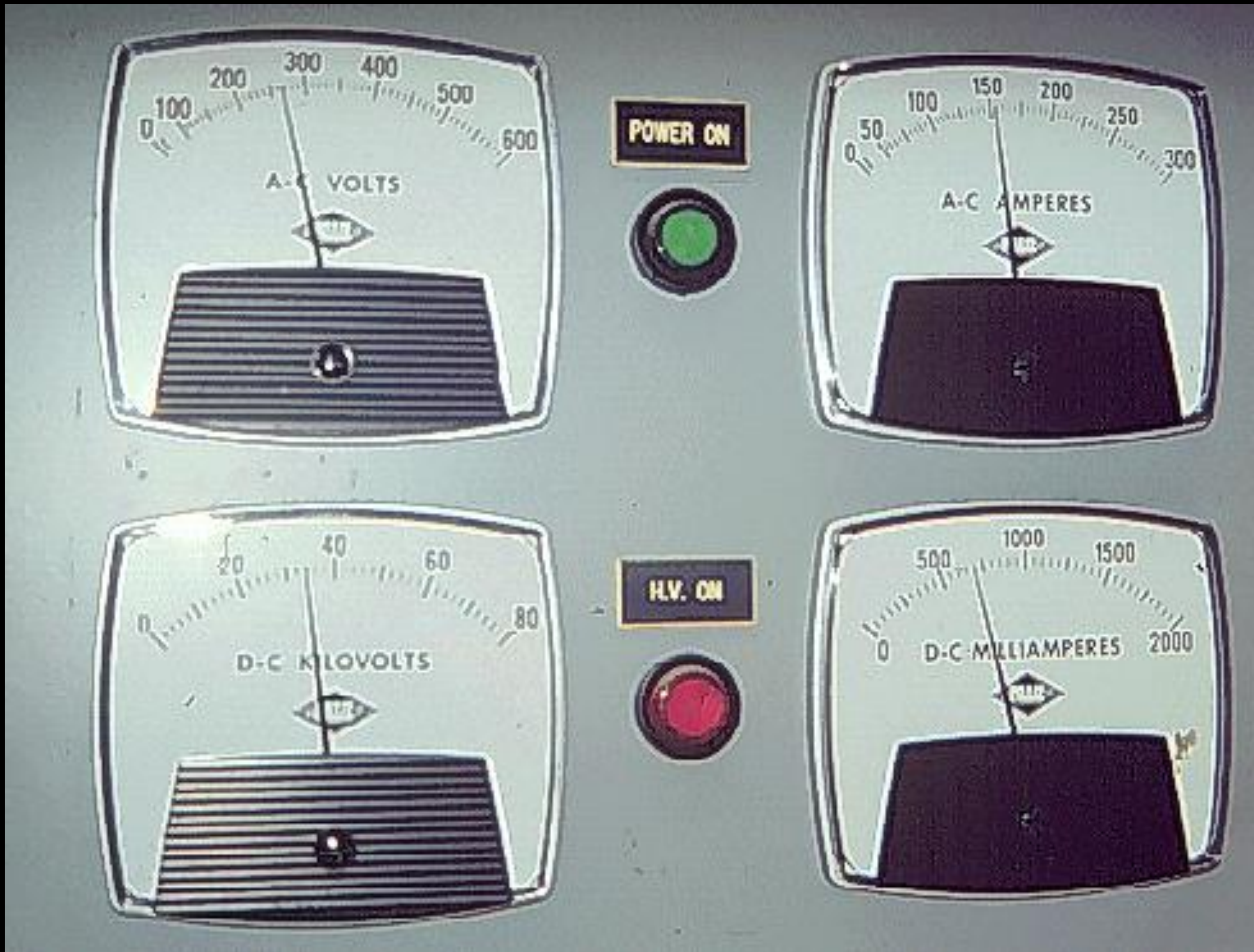
Control System

- Power Control Circuits
- Voltage-Limit Control
- Current-Limit Control
- Spark Control

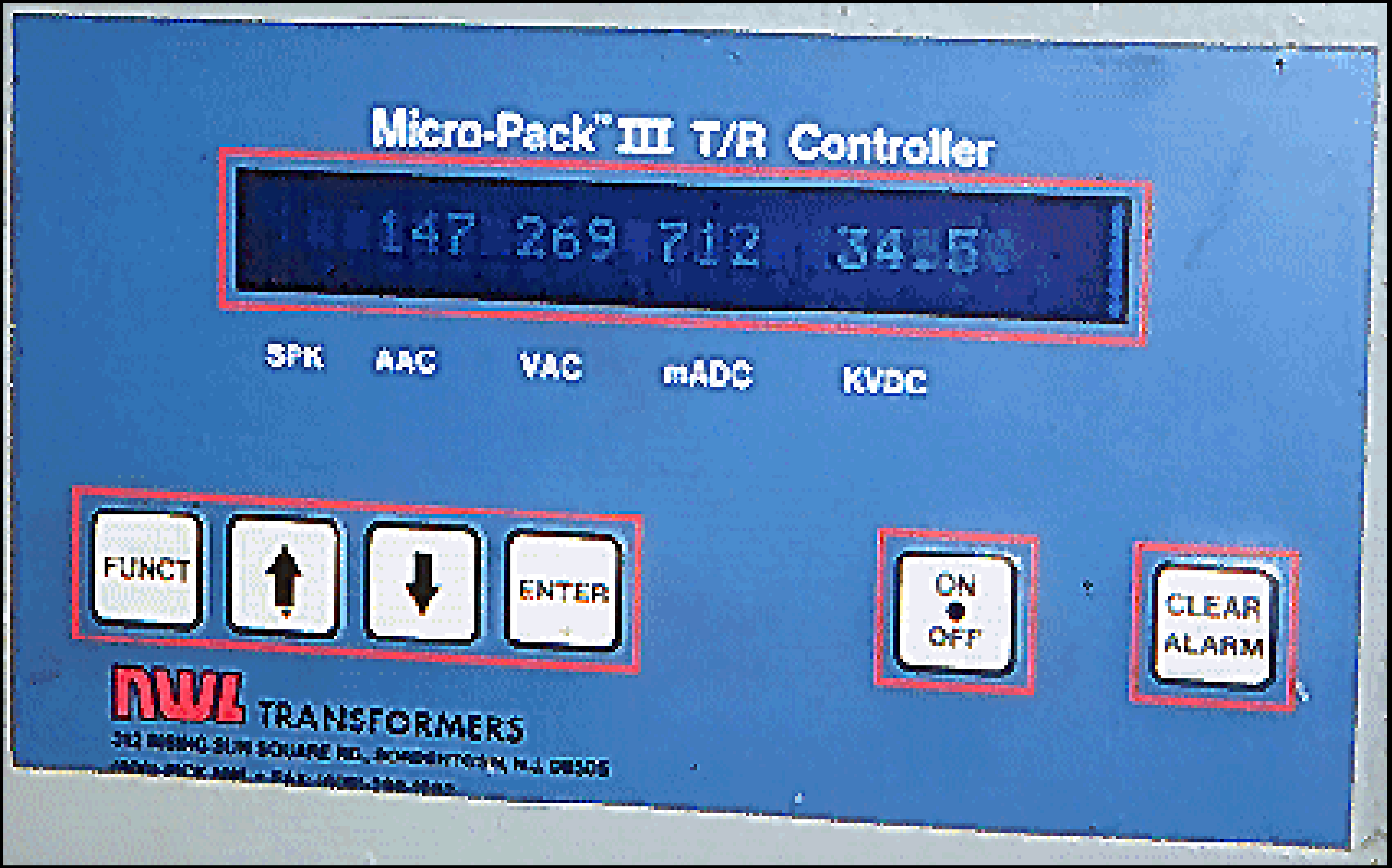


T-R Set Spec. Plate

Analog Gauges



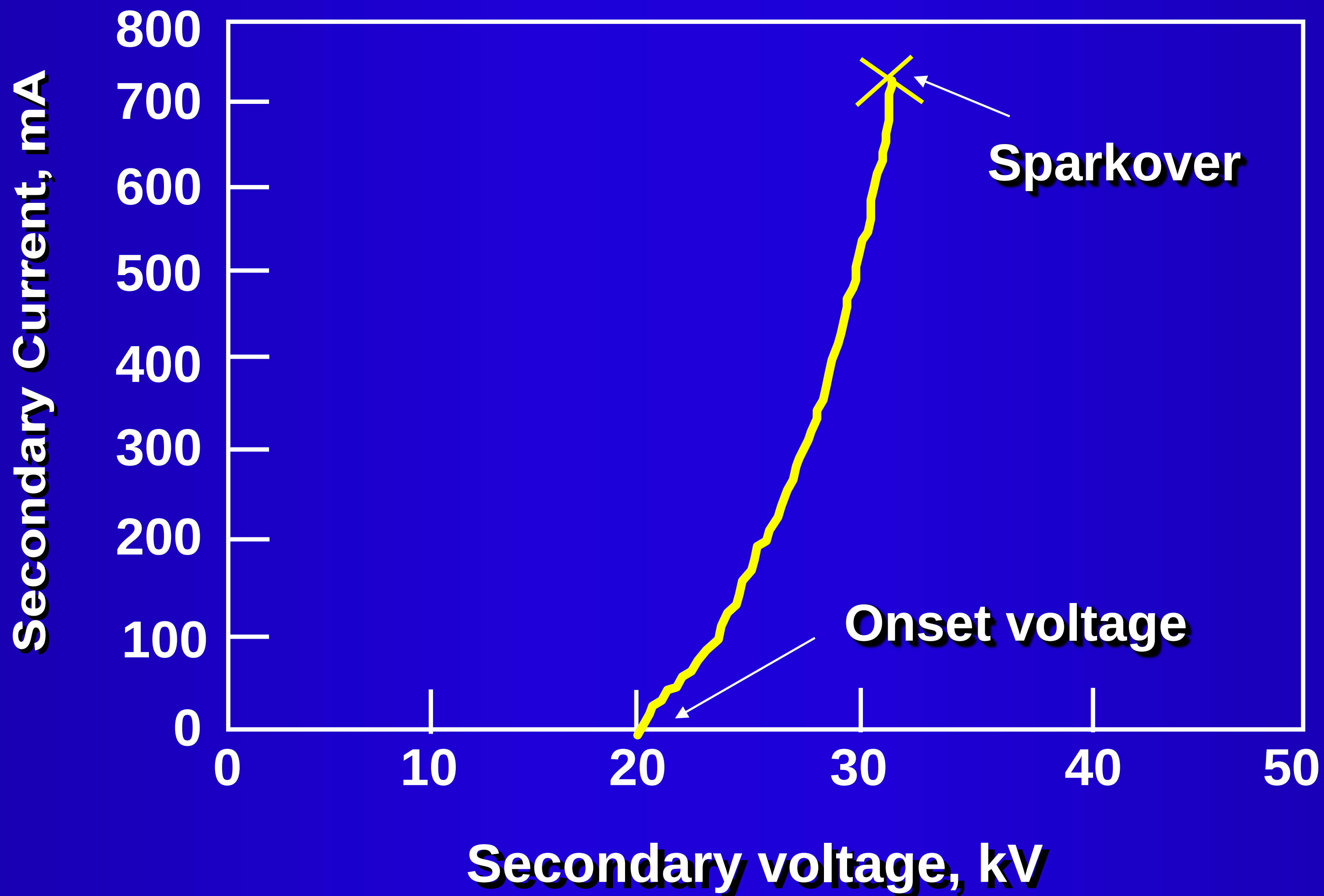
Digital Readouts



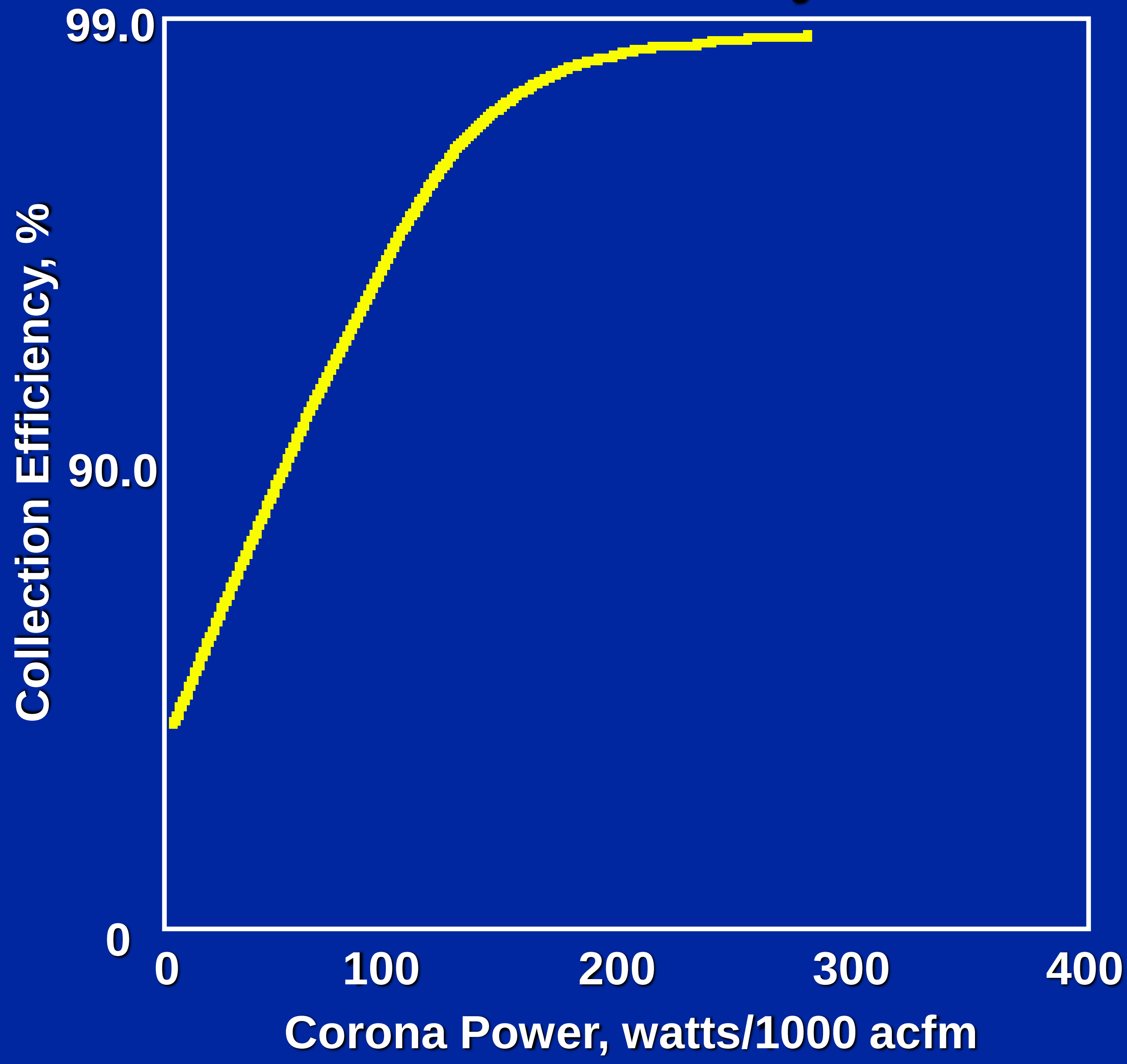
Performance Monitoring

- Air Load Testing
- Gas Load Testing
- Opacity
- Corona Power
- Spark Rate

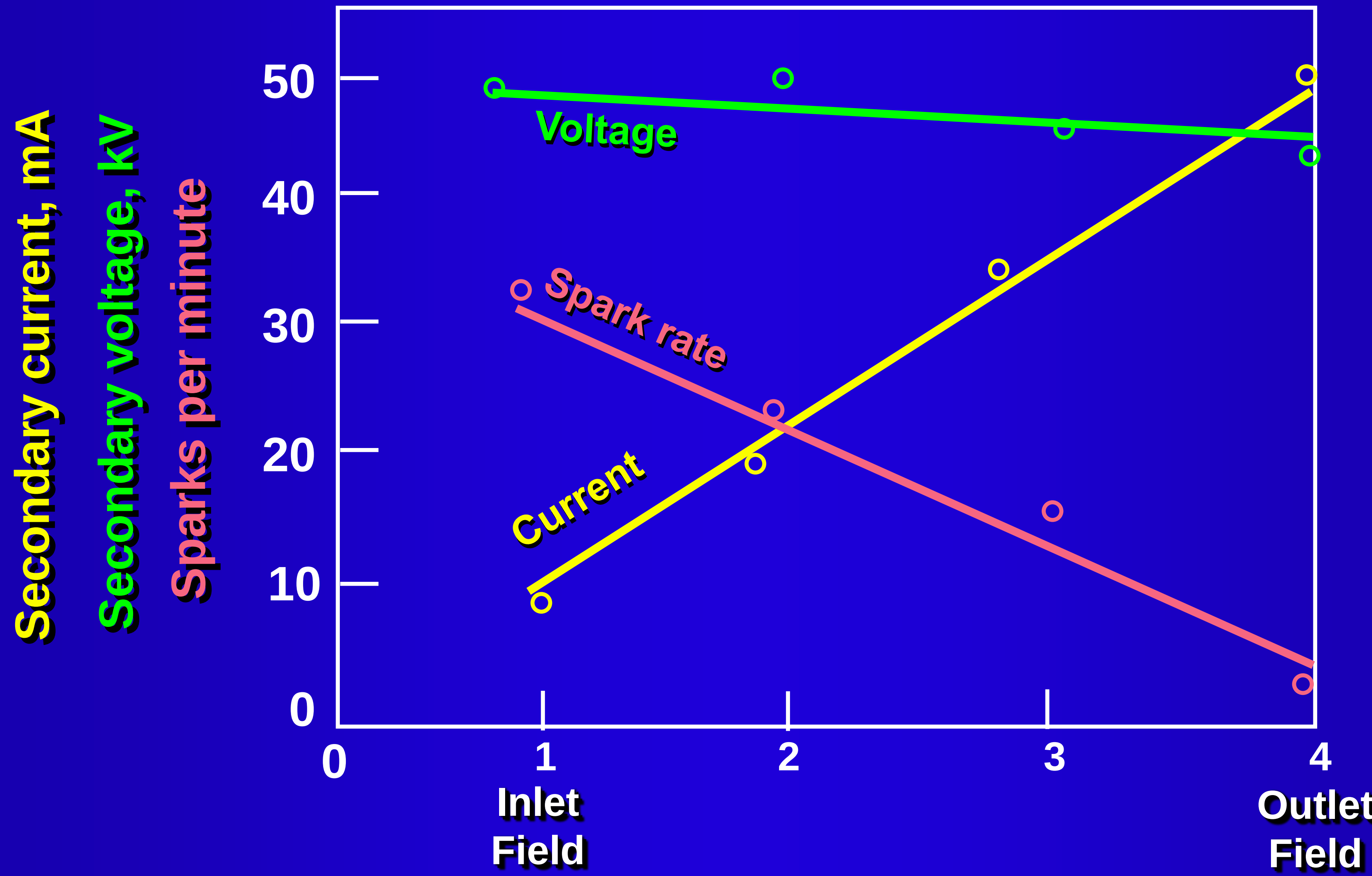
Voltage-Current (V-I) Curve



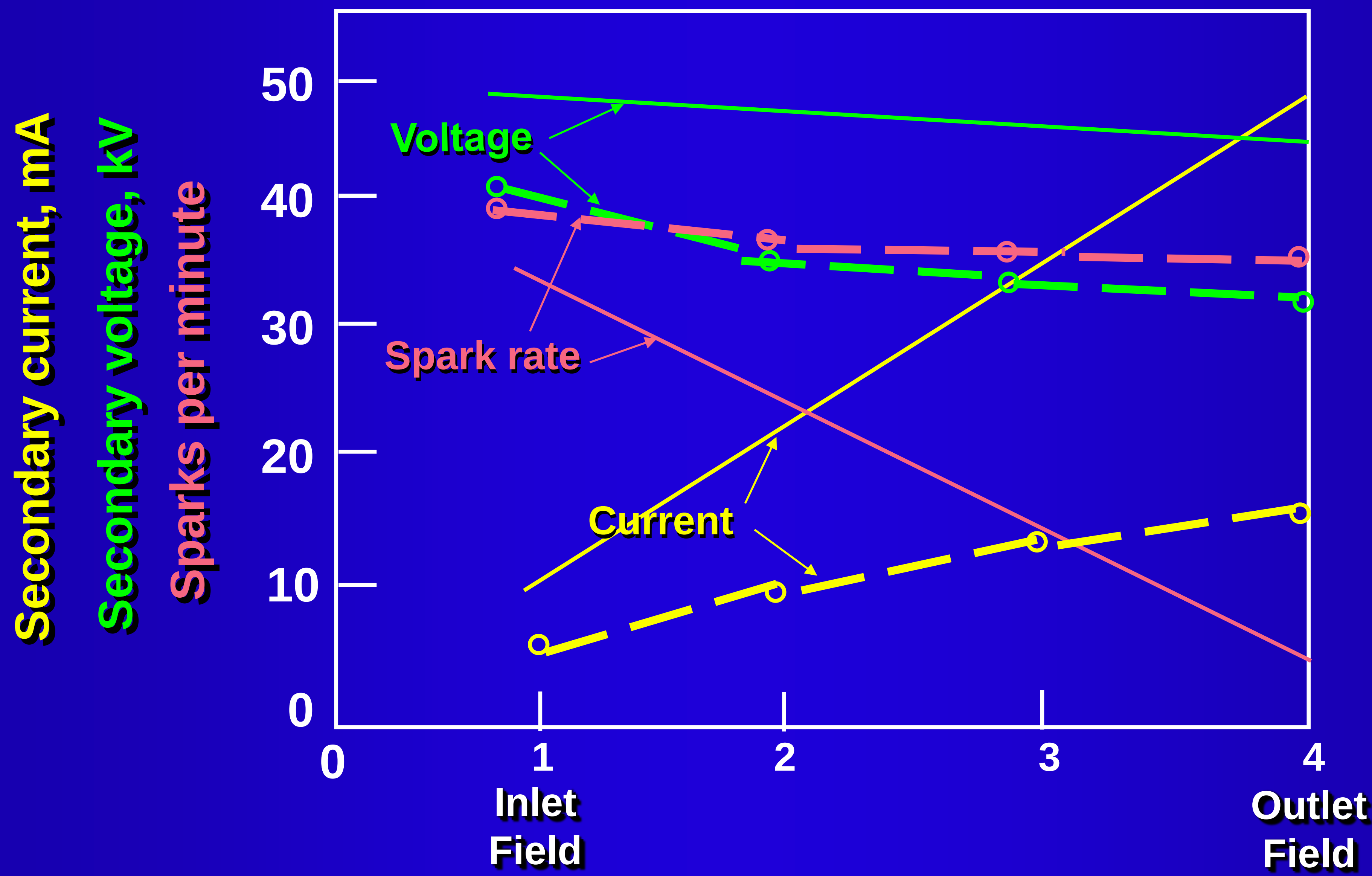
Corona Power versus Collection Efficiency for Coal-Fired Utility Boiler



Baseline Conditions



High Resistivity Shifts from Baseline



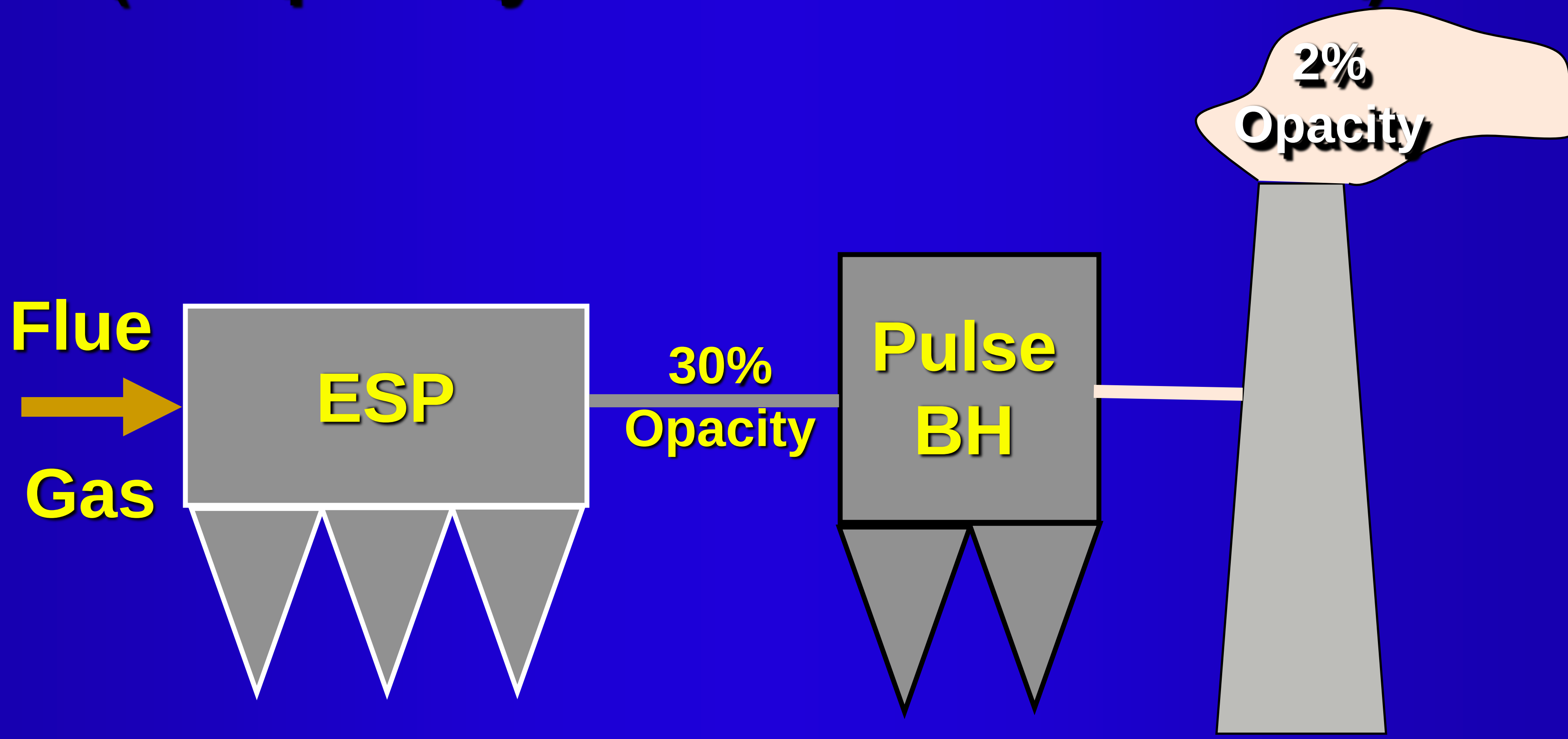
Common Problems

- Resistivity
- Hopper Pluggage or Overflow
- Misalignment or Warpage
- Insulator Failure
- Discharge Electrode Failure
- Air Inleakage
- Corrosion
- Rapping System Problems
- Control System Failures
- Particle Size and Concentration

Enhancing ESP Efficiency

- Wide plate spacing
- Pulse energization
- Automatic voltage controls
- Improved flow conditions
- Optimal rapper timing
- Flue gas conditioning
- COHPAC

COHPAC
(Compact Hybrid Particulate Collector)



INSPECTING ESPs

Typical Permit Conditions

- Opacity limits
- Grain loading limits
- Ranges of ESP inlet & outlet temperatures
- Minimum total corona power
- Maximum process rate
- Recordkeeping requirements
- CEM requirements
- Maximum allowable pressure drops
- Limit on the number of fields offline

Air Pollution Control System Points of Inspection

- System Entrance/Exit
- Transport
- Air Mover
- Control Device
- Instrumentation
- Subsystem
- Records

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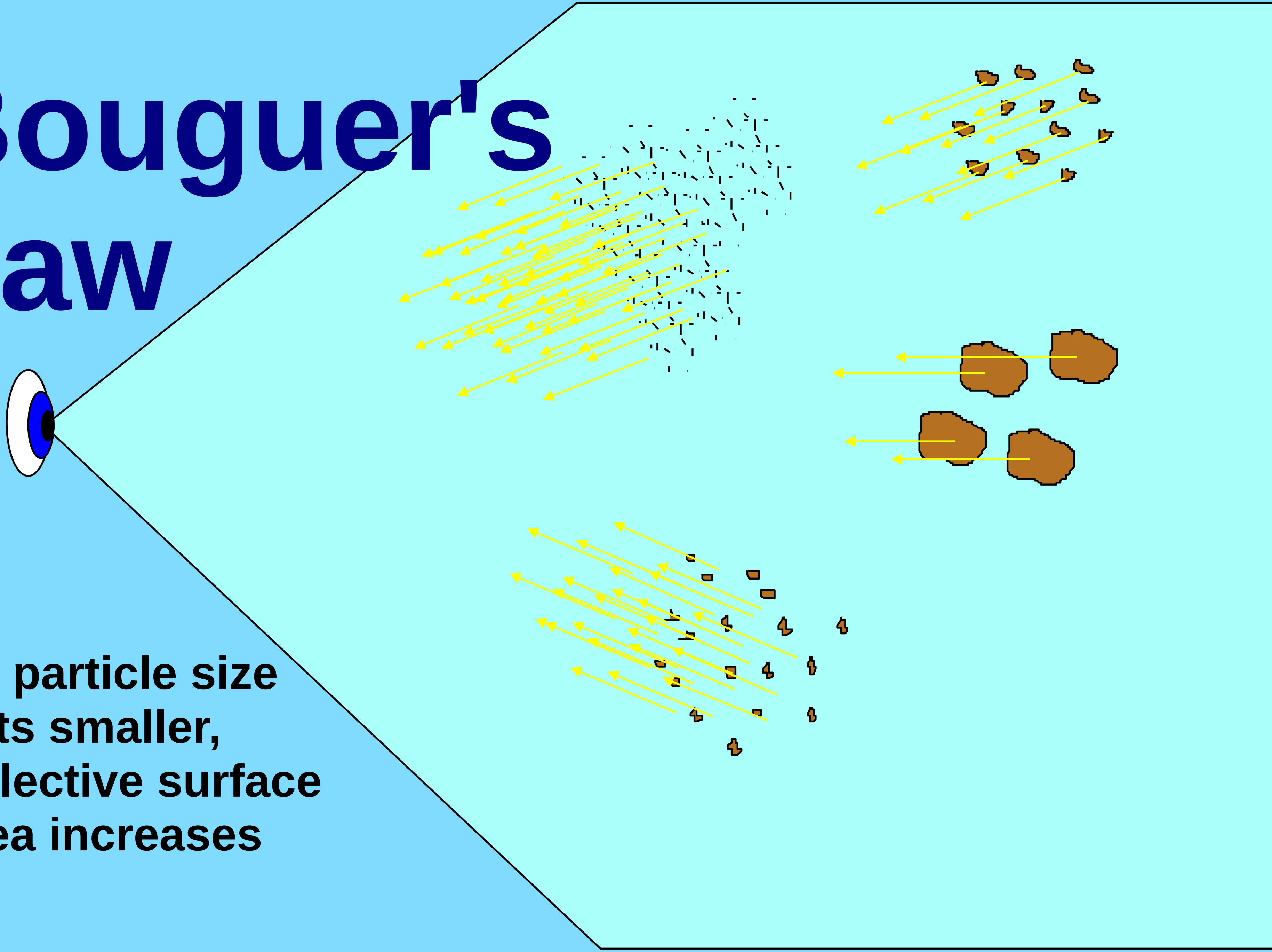
Observe Stack Effluent

- Opacity vs. Mass Emissions
- Plume Color
- Vapor Plume
- Puffing

Bouguer's Law



As particle size gets smaller, reflective surface area increases

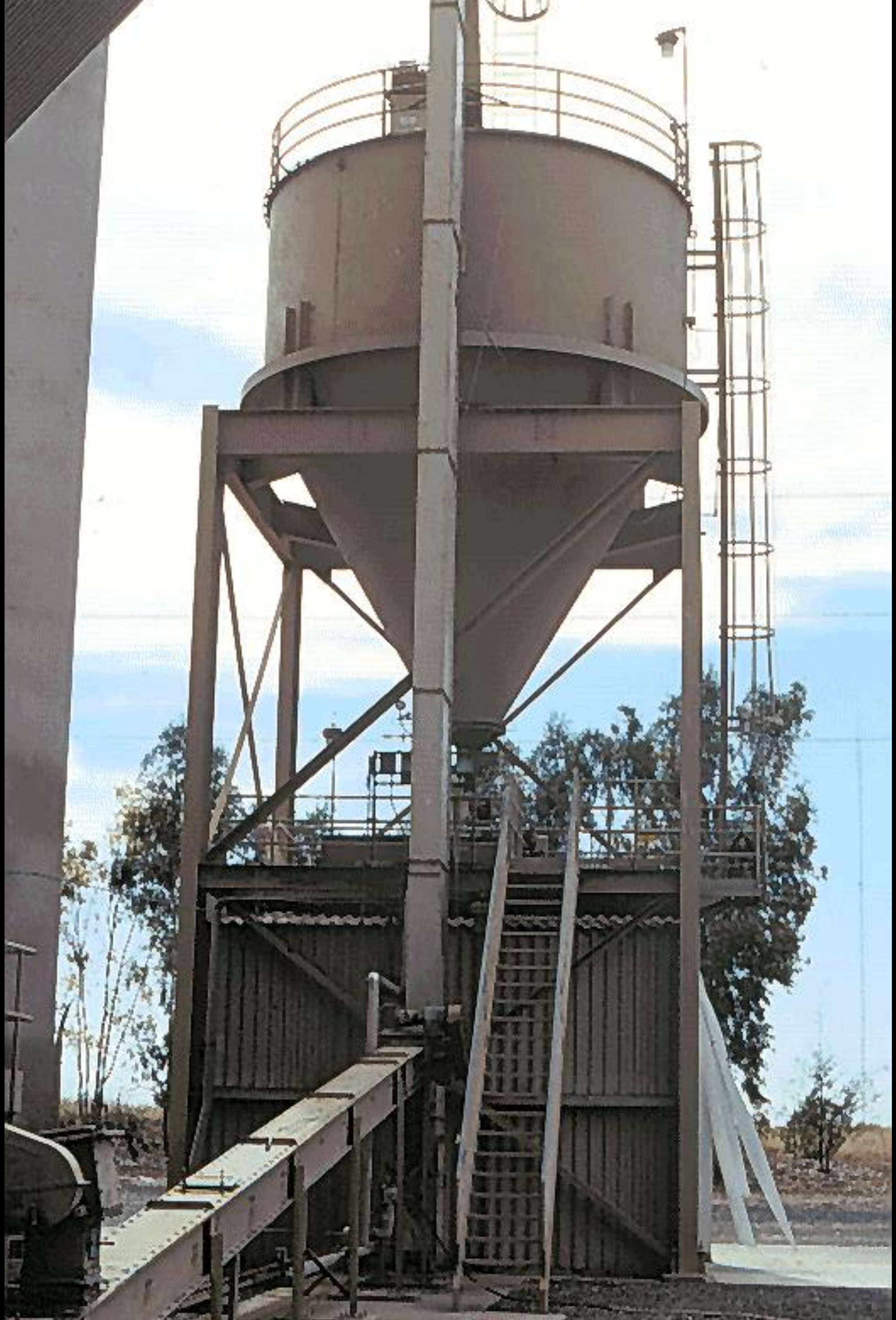
Perform External Inspection

- T-R Sets
- Rappers & Vibrators
- Insulators
- Shell
- Access Doors
- Ductwork


Note Exposed Insulation

Evaluate Ash Handling Procedures

- Evacuation rate
- Level alarms operating
- Hopper temperature
- Ash buildup



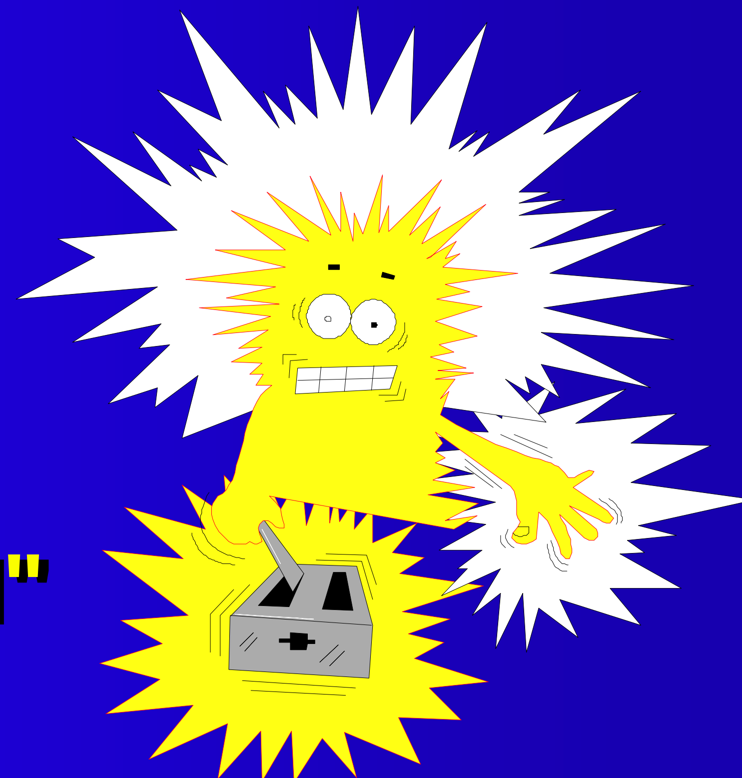
Ash Storage Silo

Instrumentation

- **Power Input:**
  - **1º/2º Voltage; 1º/2º Current; Spark Rate**
- **Gas Flow & Temperature**
- **Rapper Frequency/Intensity**
- **Hopper Dust Level Indicator/Alarm**
- **Opacity Monitor**
- **Oxygen Monitor**

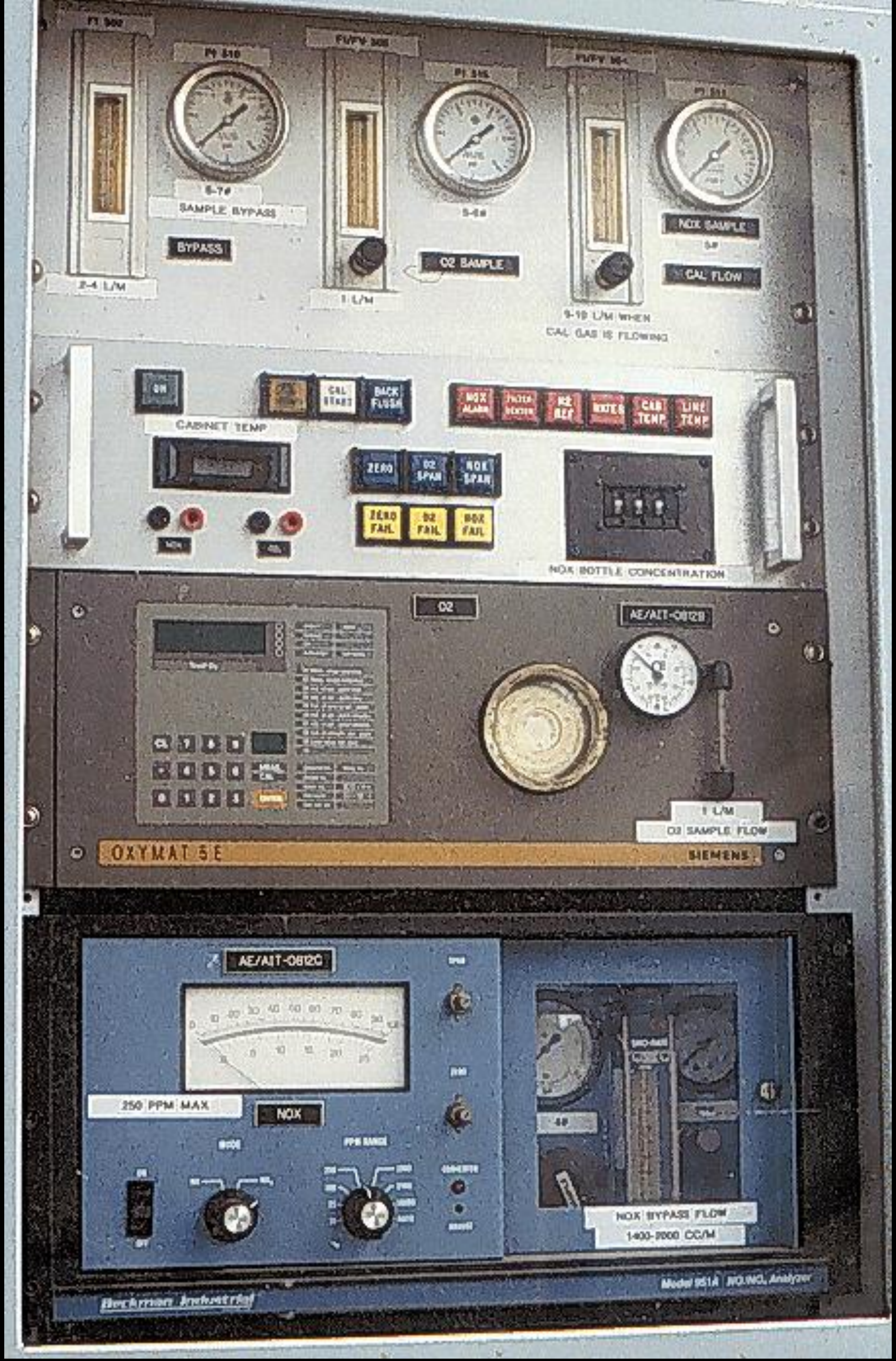
Check High Voltage System Operation

- Observe control panels
- Check log for drift in electrical data
- Note inoperative meters
- Note T-R sets on "manual" and "auto"



Analog Gauges

CEM System Readouts & Controls



Review Recordkeeping

- Design Specifications
- Operating Data & Records
- Inspection & Maintenance Records
- Component Failure Records

Safety


KEEP OUT
DANGER
HIGH VOLTAGE
WARNING
HOPPERS ARE EMPTY
BEFORE DOOR IS OPENED


CAUTION
BEFORE YOU START
LOCKOUT
FOR
SAFETY

THE END