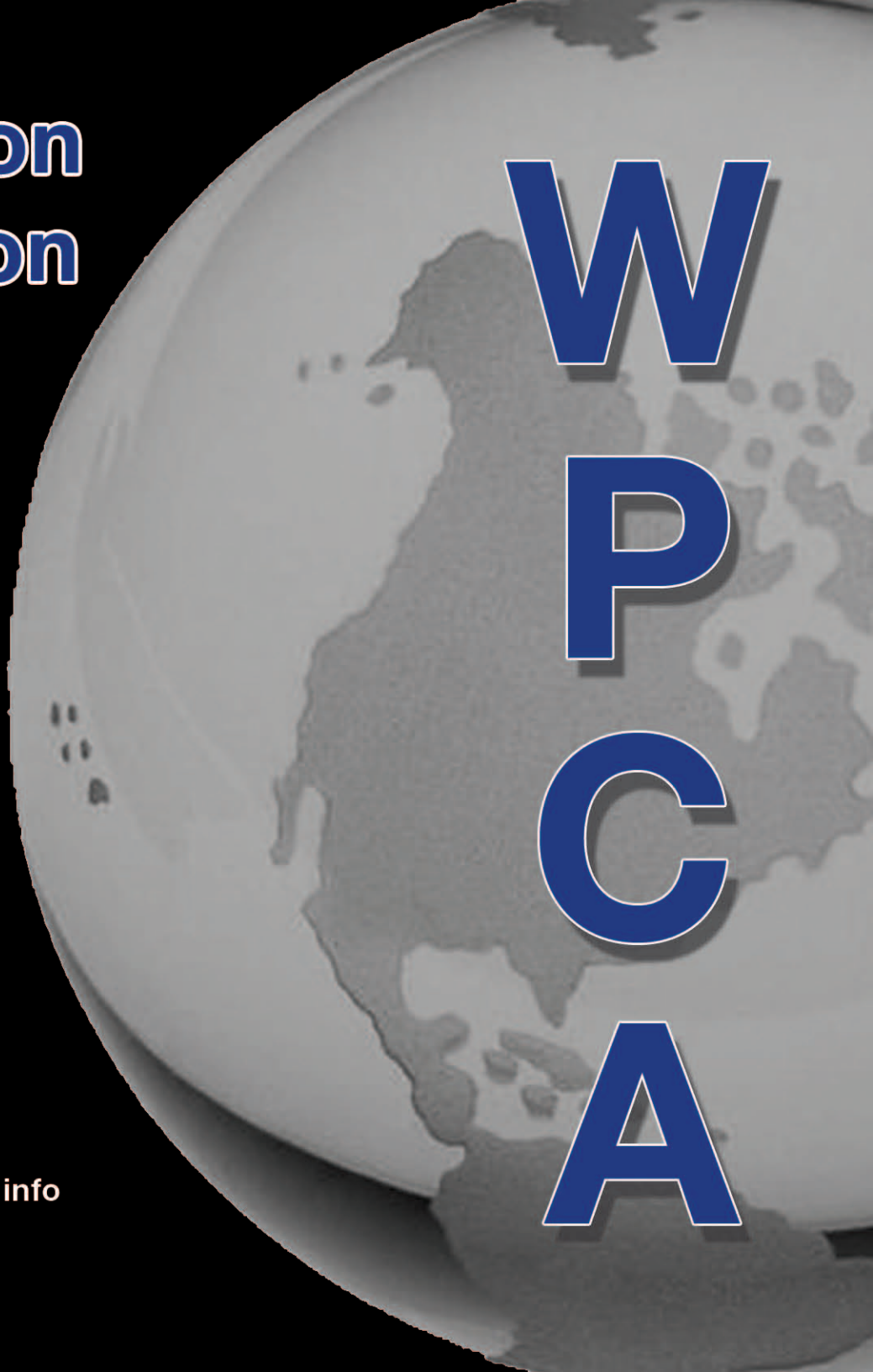
Worldwide Pollution Control Association



Particulate Control O&M Training

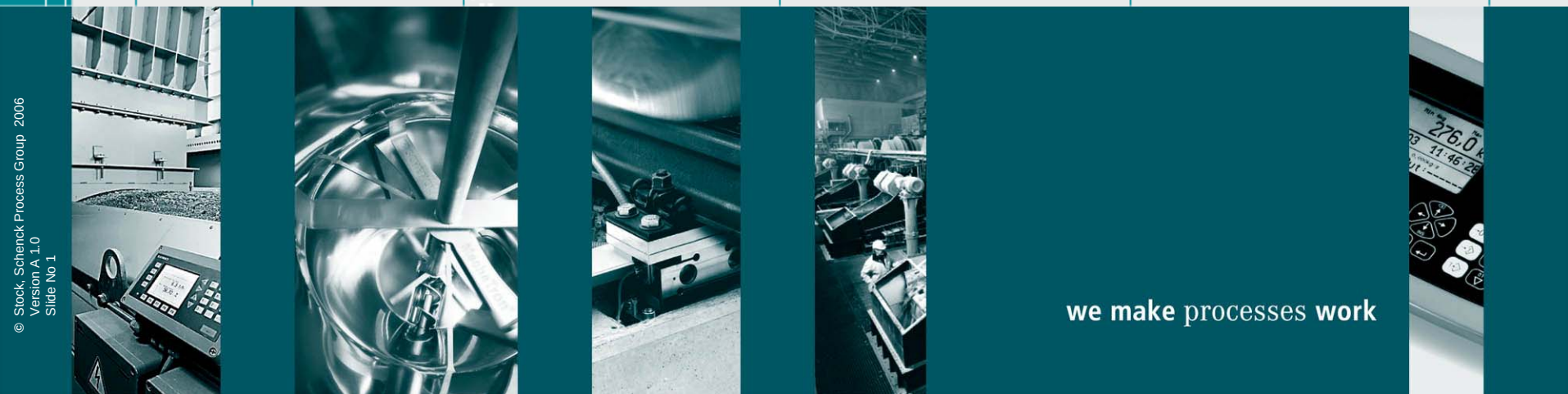
APC/PCUG Conference
July 12-16, 2009
The Woodlands, TX

WPCA

Visit our website at www.wpca.info

WPCA Particulate Training Seminar – July 11, 2009

ESP Power Supply Choices



Precipitator Power Supplies

- Conventional (60 Hz) Power Supply
  - AVC cabinet + Transformer / Rectifier
- Mid Frequency (400 Hz) Power Supply
  - Converter/Control + Transformer / Rectifier
- High Frequency (>= 25 kHz) Power Supply
  - Converter + High Voltage Unit (T/R but smaller in size)

Conventional T/R – Main Components

- Tank
- Core and Frame
- Winding
  - Primary
  - Secondary
- Rectifier
- Choke
- Switch
- Bushings (LV and HV)
- Gauges and Options
- Insulating / cooling fluids

Conventional T/R Windings

- **Primary**
  - **PV= 350 to 600 V AC Single Phase**
    - **(typically 40 – 80 V less than Line supply voltage)**
  - **PI = 40A to 600A**
  - **Single or multiple rectangular conductors used in winding**
- **Secondary**
  - **SV = 30 kV to 80 kV Average**
  - **SI = 250 mA to 3000 mA Average**
  - **Form factors: ratio of average value to RMS value of similar sinusoidal waveform**
    - **describes shape of waveforms**
    - **Typical values: CFF = 1.2 VFF = 1.19**
  - **Single round conductor used in winding**
- **Copper vs. Aluminum**
  - **Copper has higher current density.. Less cross sectional area needed**
  - **Aluminum is cheaper and lighter, but approximately 66% larger cross sectional area required resulting in larger tank / footprint**
  - **Oxidized aluminum in exposed connection points becomes and insulator joints are not properly connected / maintained.**
- **Insulation**
  - **Thermally Upgraded Kraft Paper (TUK) or fish paper**
  - **Breakdown of insulation over time is primary limitation in operating life (25 yr. expectation)**
  - **Pressboard in various thicknesses**

Tanks

Round

- **Higher Pressure Rating**
- **1 seam on wall**
- **Typically no seam in lid gasket**
- **CLR always outside tank**
- **No Internal Ground Switch**

Square / Rectangular

- Often need belly band stiffeners
- 2 seams on walls
- Option for side output
- Option for internal CLR
- Option for internal Ground Switch

- Typically Carbon steel
- +5 PSI relief valve is common
- Liquid Level Gauge zeroed at 25°C
- Painted inside and out
- Penetrations:
  - Drain Valve
  - LV bushing
  - Temperature gauge
  - Relief valve
  - Hand Hole
  - HV bushing
  - Pressure gauge

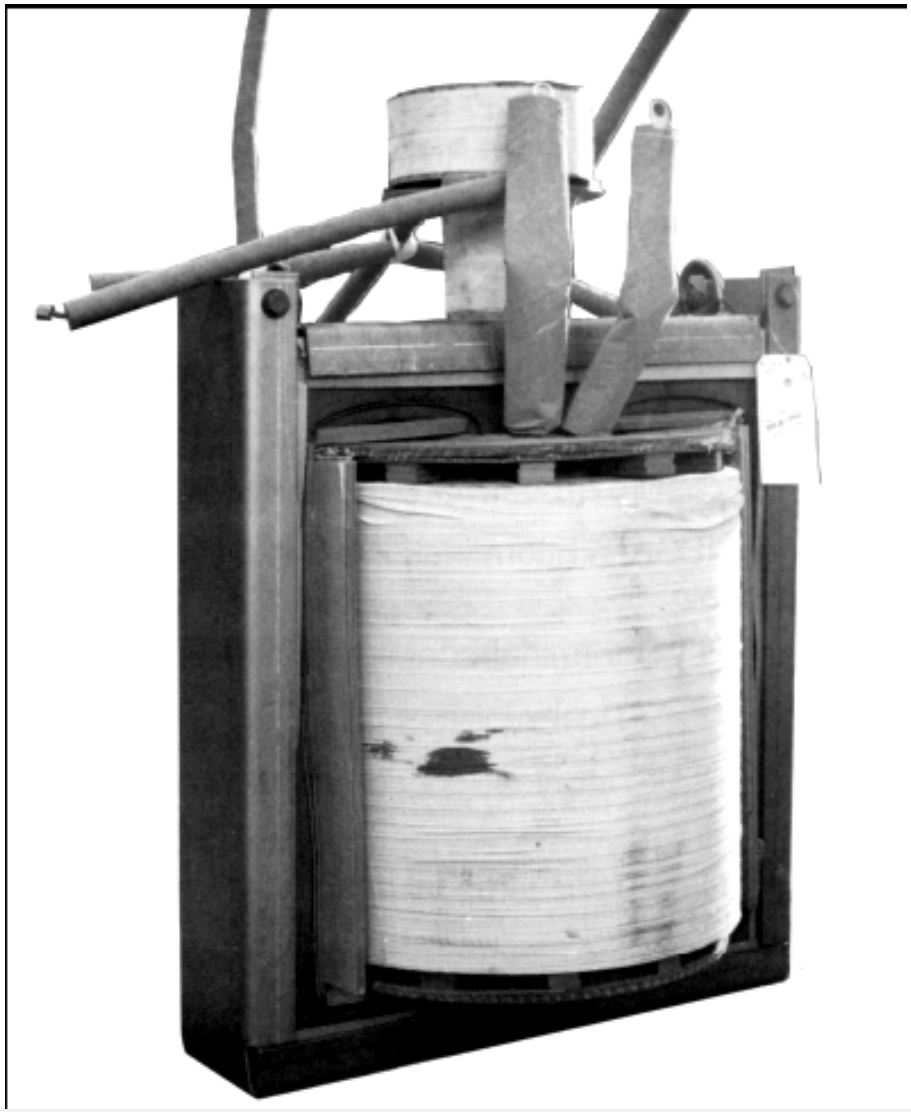
Tank Configurations

TR Core & Frame

- Grain oriented electrical steel
  - **Iron alloy with 0 to 6.5% silicon**
  - **Processed to align crystalline structure of steel**
  - **Increased magnetic flux by 30%**
  - **Decrease magnetic saturation by 5%**
  - **Used for higher efficiency (lower losses)**
  - **C, S, O2, and N2 need to be kept low**
  - **Produced thin rolls that are slit to correct width**
  - **Laminations are cut and stacked from rolls**
  - **Shell or Wound Construction**

- Core Frame
  - **Used to provide structural stability for the core / winding**
  - **Commonly sits in channel on inside of tank and bolted to tank base**
  - **Frame is grounded to tank. Core is grounded to frame.**
  - **Welded vs. Bolted**

Typical Wire-Wound Core



Bushing Choices

- **Low Voltage:**
- **Primary connections (typically 2.. More if there are multiple taps)**
- **SI feedback – connection to the grounded (+) side of the secondary winding.**
  - **Surge arrestors and protection resistors advised to prevent high potential**
- **SV feedback (optional) – HV side of secondary attached to resistor (kV divider) inside or outside of the tank. Resistor commonly 80 M ohm to 400 M ohm.**
  - **Surge arrestors and protection resistors advised to prevent high potential**
- **Epoxy or ceramic: epoxy commonly used if connection is on side of tank and under fluid level (less chance of leaks)**
- **Connections are usually bolted w/ ring lug terminations… Older bushing use compression connections on bare conductor.**

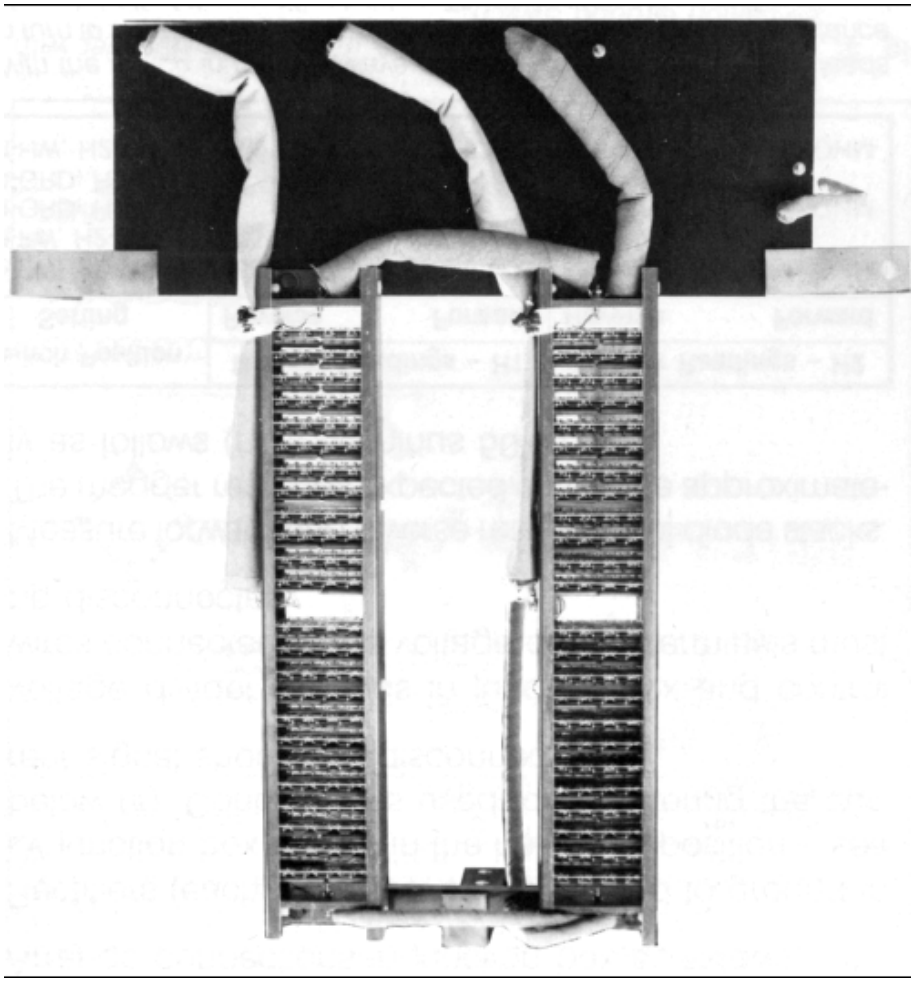
- **High Voltage:**
- **Output of the T/R set**
- **1 bushing if full wave output. 2 bushings for dual half wave.**
- **Epoxy or ceramic / alumina: ceramic and alumina are usually the preferred media… easier to clean, and inspect… won't melt…**
- **Connections can be compression with bare conductor, bolted with ring lug, or screw in solid pipe conductor.**
- **Allowance for hot / cold steel thermal growth differences required to reduce physical stress on bushing**

Rectifiers

- Full wave vs. dual half wave

- RC compensation vs. Avalanche diodes

Diode “Stacks” on TR Secondary



TR Set Pro's & Cons

Pro's	Con's
• Extremely Durable	• HEAVY
• Very Fault Tolerant	• Difficult to Repair in-place
• Long Operating History	• Very High DC Ripple

Mid-Frequency TR Sets

- Utilize Existing (or New) Conventional Single-Phase TR sets
- Replace Conventional AVC with 3-Phase IGBT Switching Technology on Line Side to Reduce DC Ripple and Gain Higher Average Power to ESP

Replacement Cabinet & Retro-fit Mid-Frequency Options

Replacement

Retro-Fit

Mid-Frequency TR Set Pro's & Cons

Pro's

- Keep Existing TR's
- Good Ripple Reduction
- Might Fit in Existing Cabinets

Con's

- Will 20+ Year Old TR's Sustain Stresses?
- 3-Phase Infrastructure Still Required Although can Possibly Reside at Grade
- Little Economy Achieved if Adding Power Supplies

High Frequency, Switched Mode Power Supplies

- Fully Integrated, i.e. Switching, Transformer & Control Systems On-Board Utilizing 3-Phase AC
- Designed to Deliver Nearly “Pure”, Ripple-Free DC to an ESP

Typical (& Atypical) HF Power Supplies

HF TR Set Pro's & Cons

stock
schenckprocess group

Pro's

- Light Weight (500-700 lbs.) Requires Little Structural Modification
- ESP Performance Improvement Characteristics Undeniable
- Maintenance & Repairs can be Performed in-Place on Some Designs
- More Efficient

Con's

- Require a Higher Level of Maintenance Attention
- Can be More Expensive Depending on Application
- Some Suppliers Heavily Dependent on Proprietary Components
- Failure Rate High on Early Generations of the Technology

Important Design & Selection Criteria for HF TR sets

- What is the Application?
- What is the Operating Environment?
- Be Redundant in the Redundancy Department!
- Maintenance Requirements Different from TR Set?
- This Thing is Different - Train Your Staff!

Thank You!

Questions??