REINHOLD ENVIRONMENTAL ®

2025 Reinhold/PCUG Round Table Presentation

Hosted by AEP and Buckeye Power

in The Hilton Columbus Polaris Hotel, Columbus, OH

on June 23-24, 2025

PRECIPITATOR 101

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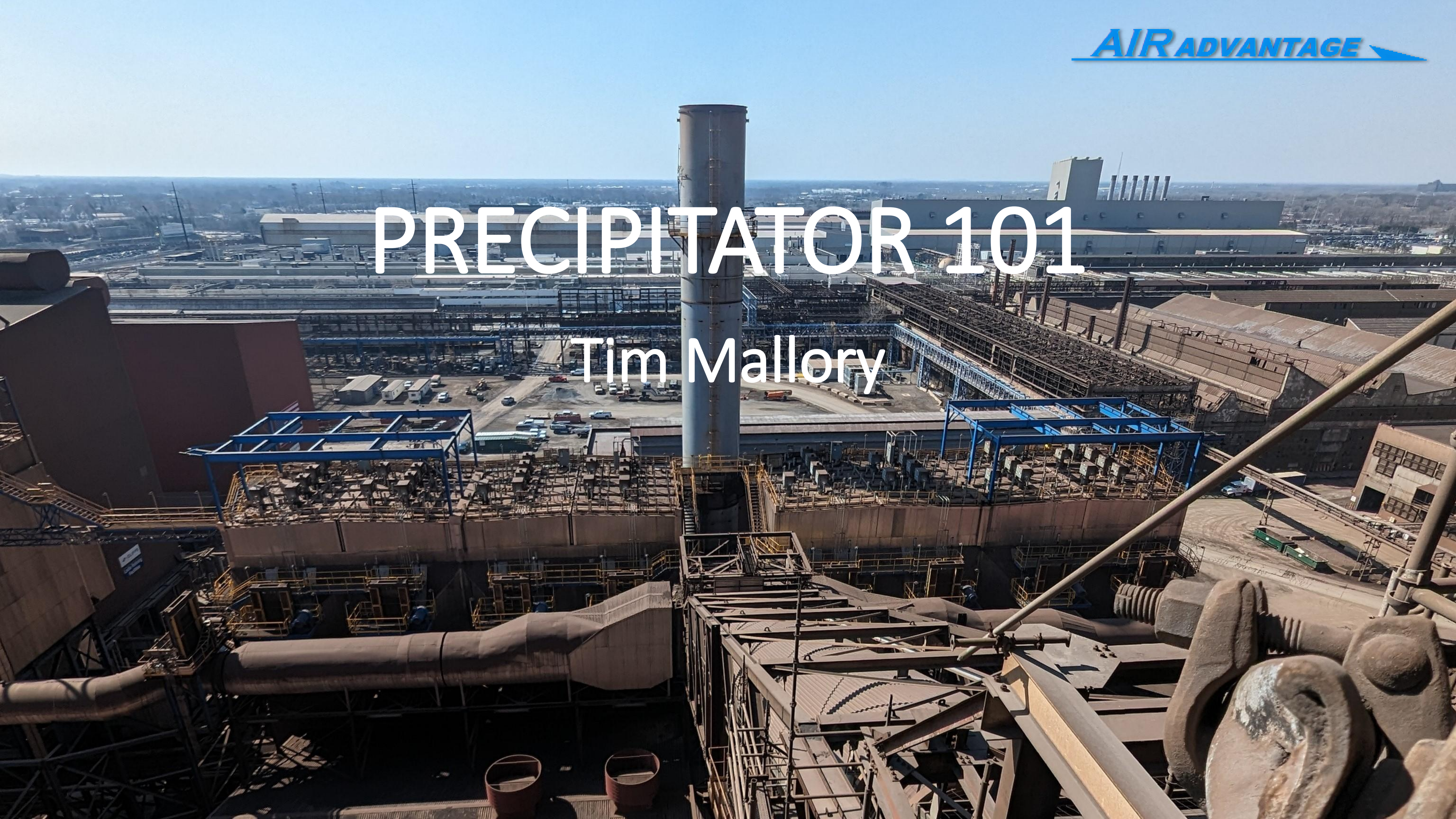
AIR ADVANTAGE



FREDERICK G. COTTRELL
1877-1948

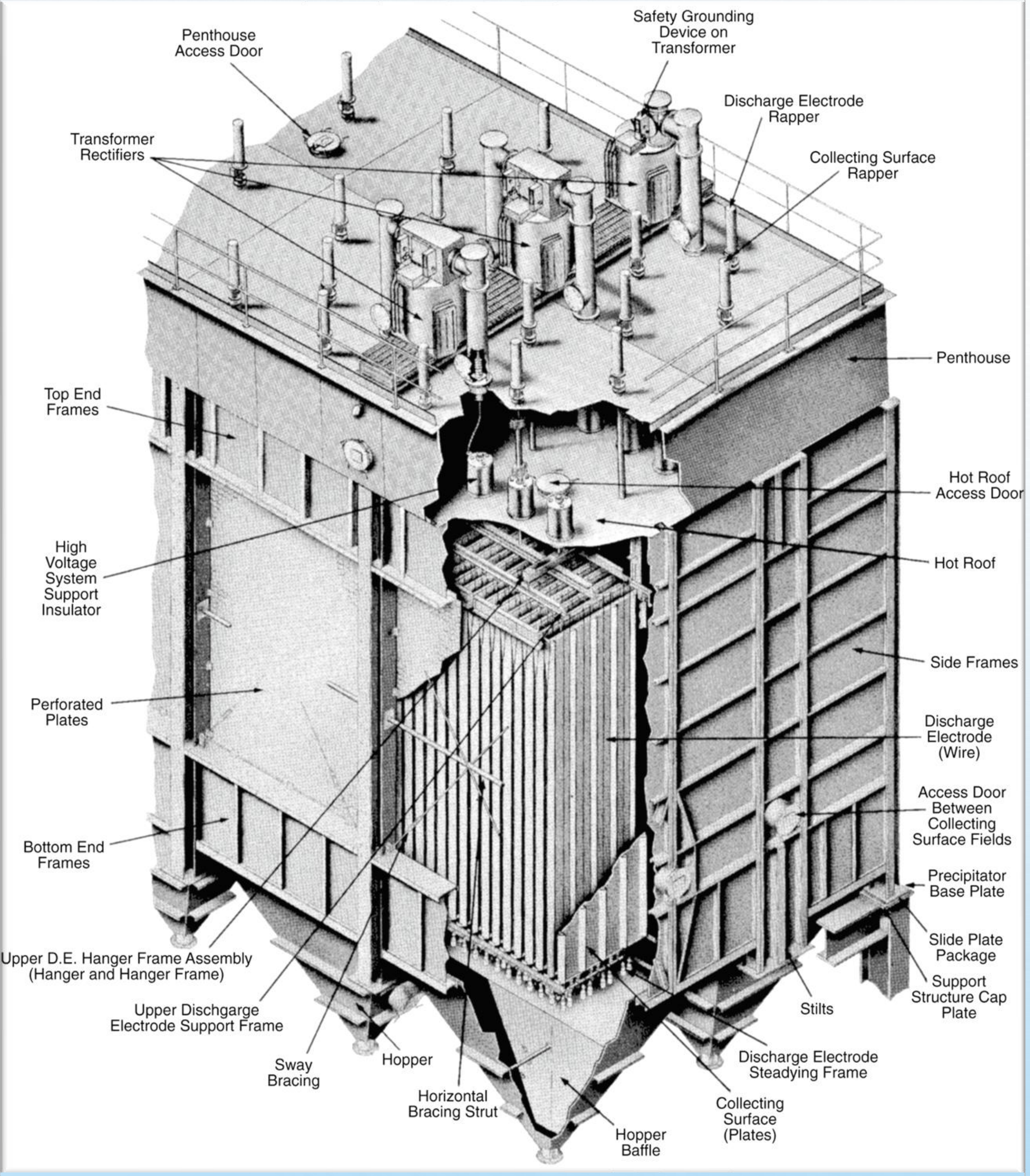
Before we get too far into the workings of electrostatic precipitators, lets take a moment to pay homage to the inventor of the technology.

Frederick Cottrell not only invented the precipitator, but he donated the money and the patents to form the Research Corporation, a non-profit that still funds scientific research and provides scholarships.

Originally invented to remove acid mists and lead fumes, the first precipitators were wet ESPs.

I invite everyone to look this guy up on Wikipedia or at: https://rescorp.org/rcsa/our-history/

The Precipitator



- Precipitators have been the primary particulate control device for many years because they have the right mix of important features.
- Low pressure requirement, high availability, high survivability, and high efficiency.
- To the left is a typical penthouse style electrostatic precipitator.
- This picture shows a weighted wire electrode system which indicates the age of the graphic.
- There are details here such as door configuration, collecting plate type, high voltage rapping insulators, and transformers that indicate this is a Research-Cottrell unit, and is most likely from the mid 1980s.

- This is a typical precipitator during construction. This view is useful to show the construction of the precipitator casing.
- In casing design, it is important to minimize cold spots caused by metal that sticks through the insulation.
- The supports for the accessway, and the doors on the hoppers will protrude.
- In addition, the walkways must grow with the casing. Since the stairs will not expand, they will tilt and must not bind. So, single point supports are used that can pivot.
- If these supports are connected directly to the skin of the casing, monitoring for corrosion takes on a more important role.
- It’s harder to see the slide bearings that allow the casing to move in this photo, but they still require maintenance or at least monitoring.

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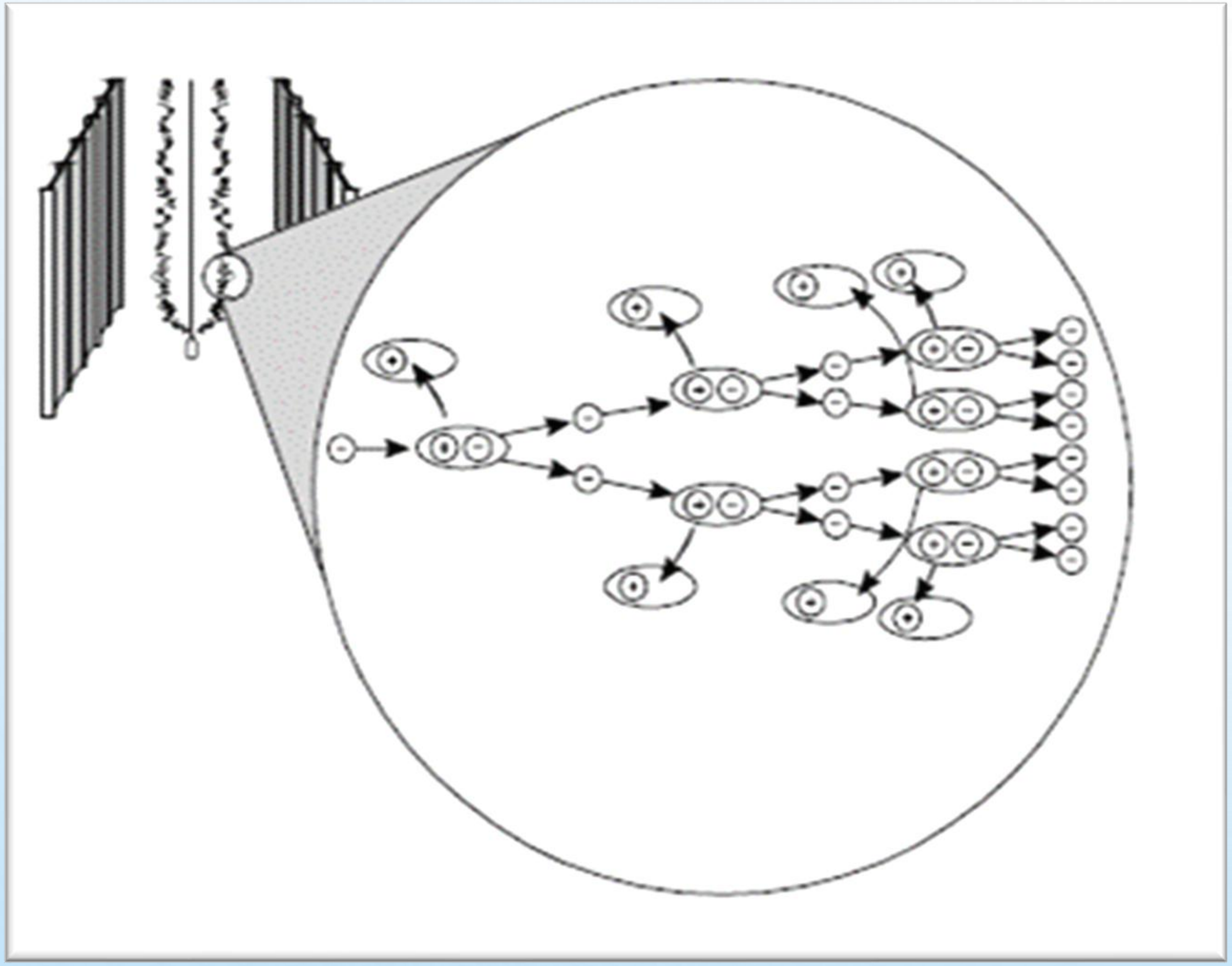
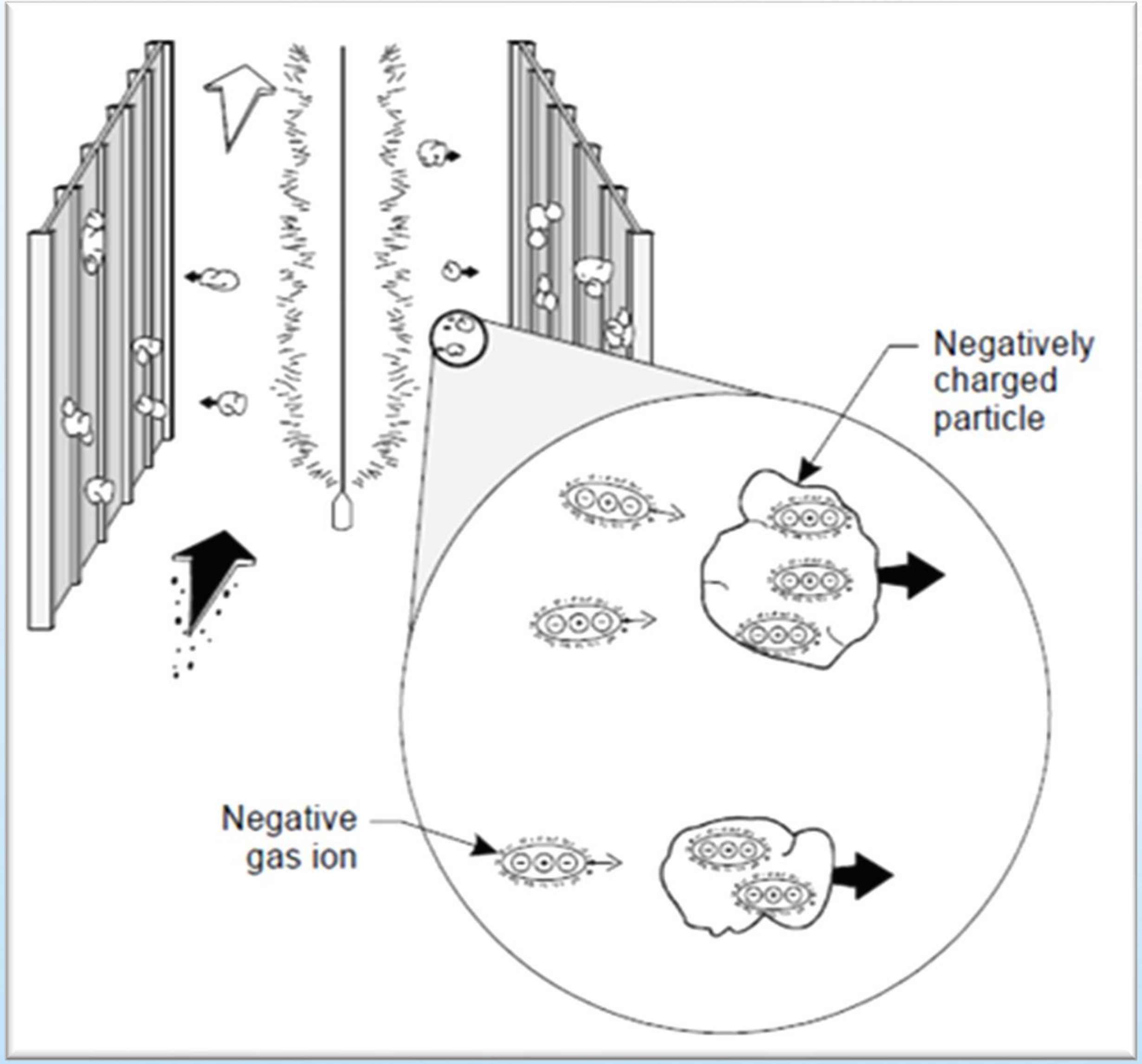
Avalanche Charging

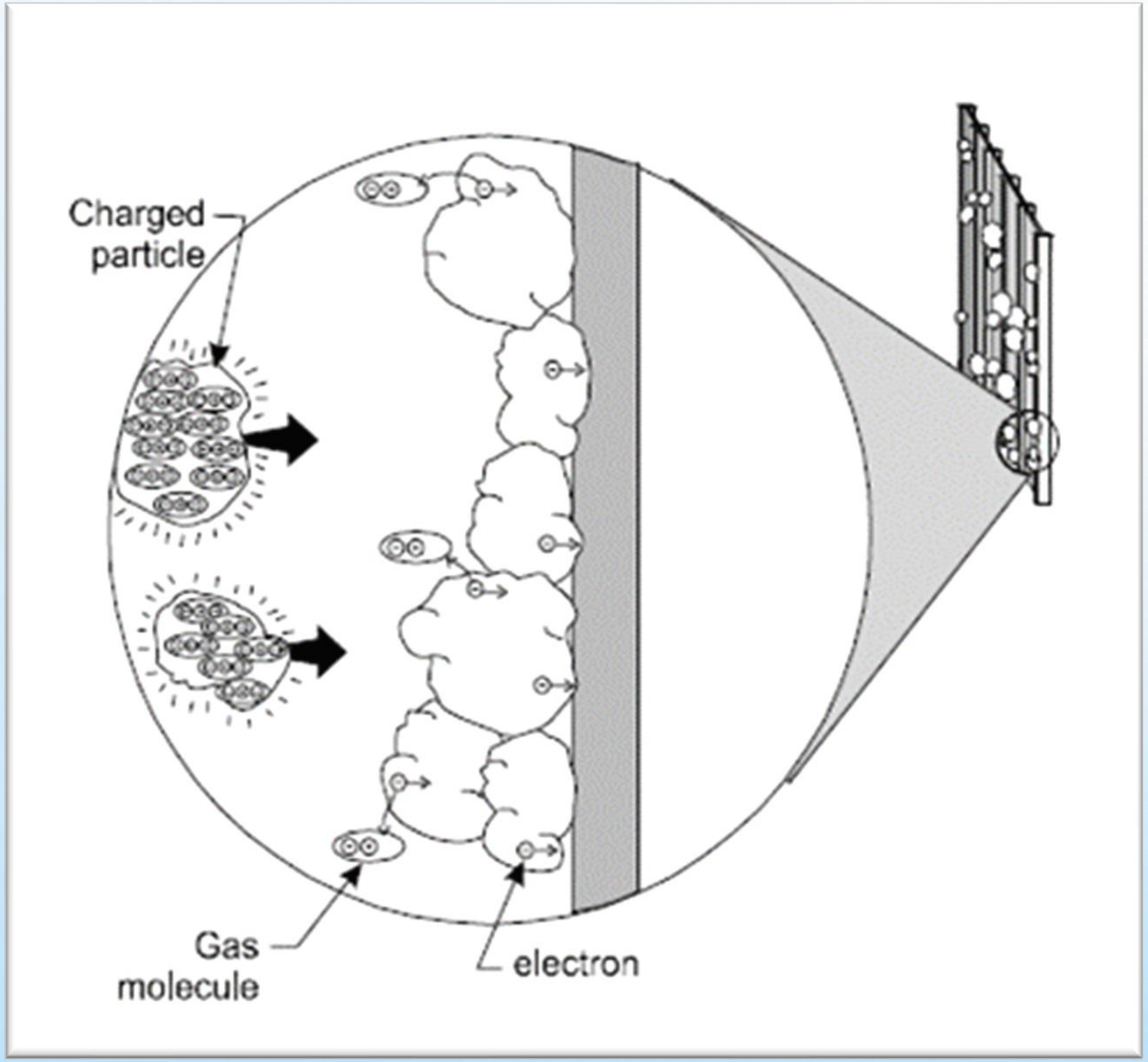


- Depicted here in graphic form is the process of avalanche charging.
- This is the process by which highly energetic electrons give off their energy by slamming into other gas molecules at high speed.
- This process creates many negatively charged ions in a cascading fashion.
- Creates a field of highly ionized gas around the discharge electrodes in the precipitator.
- The color of the ionized gas will depend on the make up of the gas. In air it is a light blue glow that becomes brighter as the intensity increases.

Particle Charging



- Eventually the gas ions begin to charge the solid particles.
- The smallest solid particles are huge compared to the gas ions.
- The O2 and N2 molecules common on air are approximately 300 picometers in diameter.
- The average particle size for a flyash particle is about 18 micron, or 60,000 times larger.
- 1 micron = 1 million picometers
- So, the particles do not just get one or two charges, they become saturated with charges all over them.
- Then they become attracted to the grounded surface as the charges attempt to complete the electrical circuit.

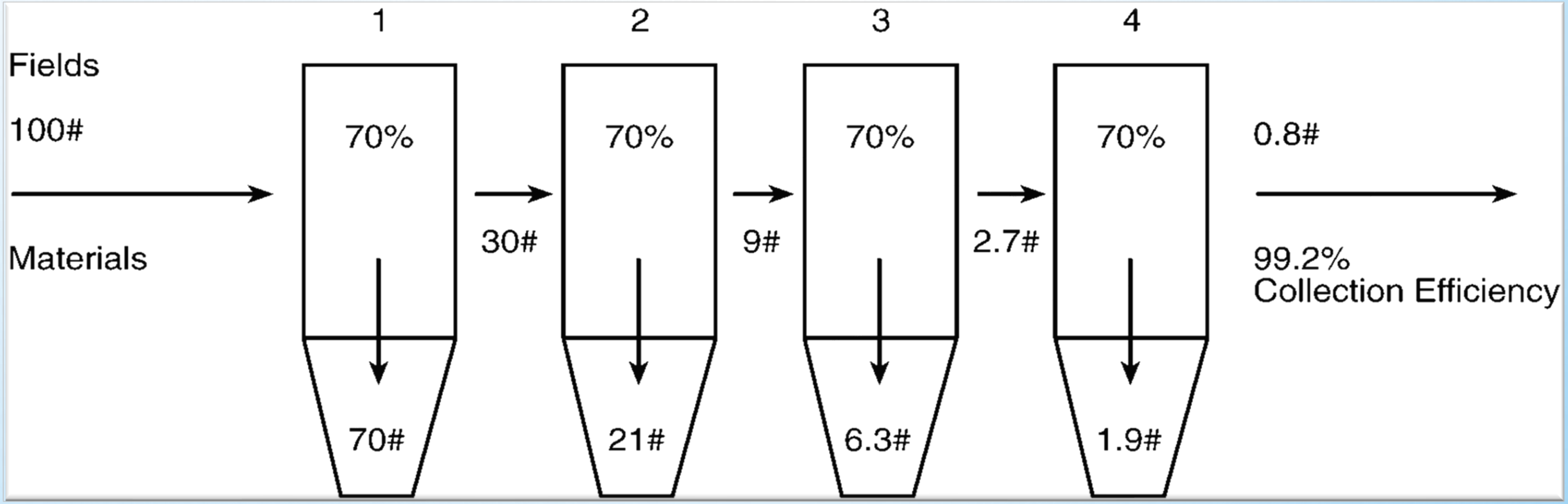


Particle Collection

- As particles attach to the grounded collecting surface the charges leave and the particles are no longer charged.
- They would fall off, but other particles land behind them, and these new charges must migrate across two layers of particles to exit.
- Then three layers. Then four layers. Etc.
- Each successive layer adds its electrically attractive force as the charges migrate to the ground. This creates the “clamping force” that retains the dust onto the collecting plates.
- As the clamping forces multiply the dust layer is compressed into a dust cake that can be dislodged by the rappers and collected in the hoppers.

Fields in Series - Equal is not Equal

AIR ADVANTAGE



Each field of this precipitator is the same size and produces the same performance.

The dust handling system; however, needs to be designed to handle the individual rows of collected material.

Equal performance does not mean the same in each field.

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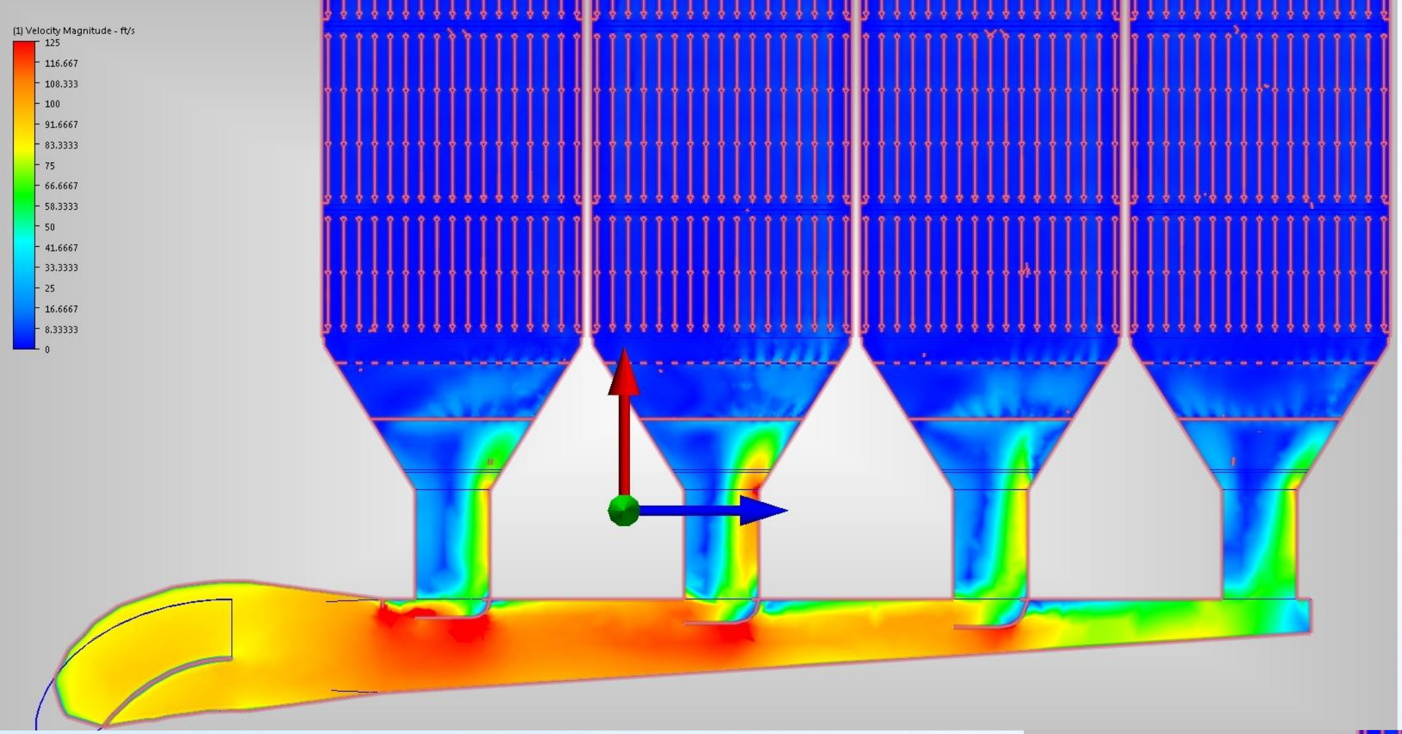
Safety Moment

- We have discussed The theory of electrostatic precipitators and how they work.
- Before we go inside the unit for our virtual inspection, we need to complete our virtual confined space training.
- No one wants to be as sad as this guy looks.
- An electrostatic precipitator is a single large electrical device.
- Climbing inside it is like climbing into a giant electric motor.
- The collecting plates and electrodes are components of a huge capacitor that can store energy for quite awhile.
- Thus, we always ground it and then ground it some more. Not only to ensure it's grounded and stay that way, but to be sure someone doesn't use us as their welding ground while we are in there.

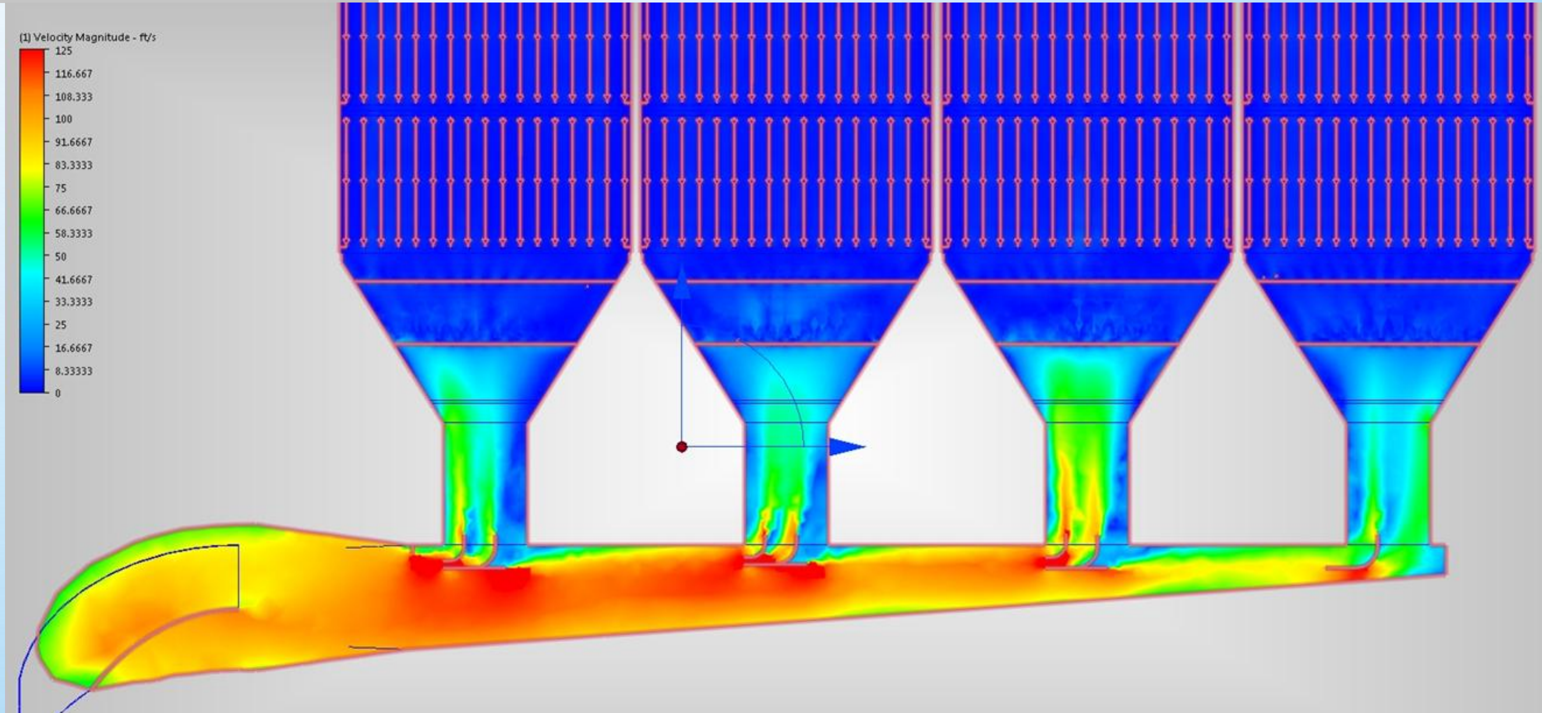
Precipitator Gas Flow

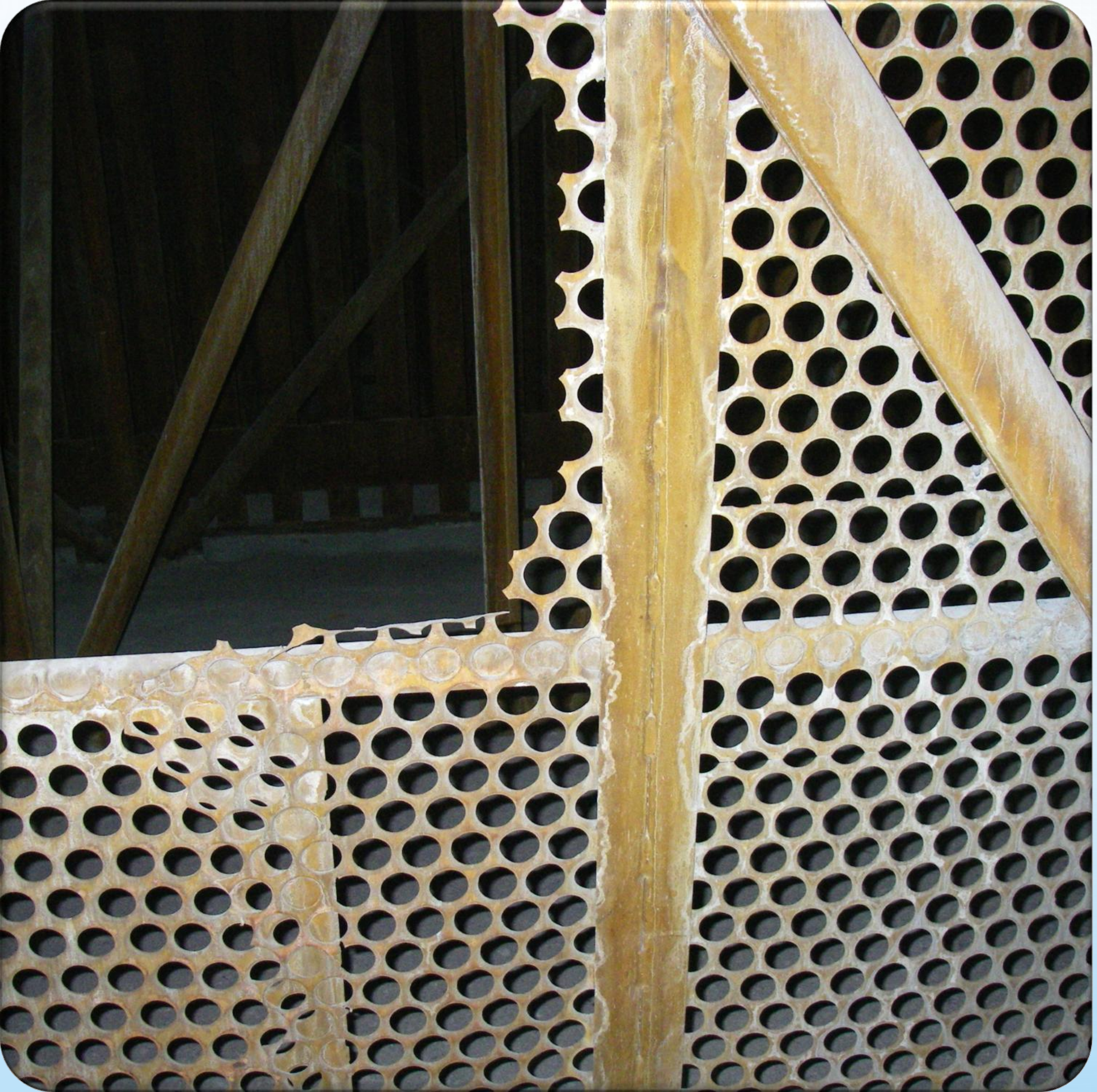


- This unit continuously wore through the perforated plates at the right wall.
- The CFD model simply confirmed what everyone knew.

Corrected

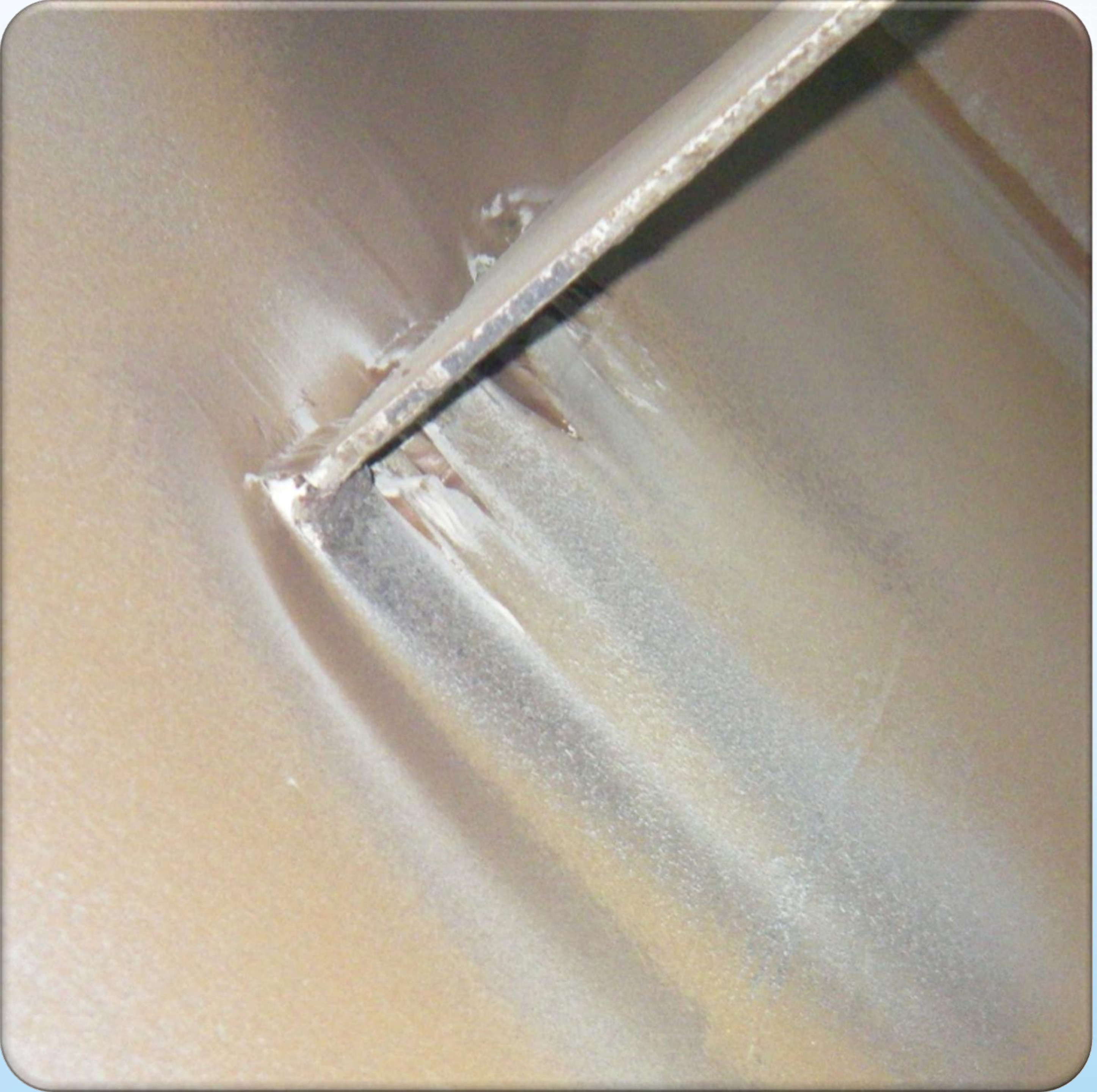
- New turning vanes were designed to make the flow more uniform and to equalize the flow between chambers.





Perforated Plates

- At the inlet of the precipitator the velocity is much higher, and fly ash is very abrasive.
- Watch for wear on the perforated plates.
- Once a large opening is made through the perforated plate, it redirects additional gas to this area. This causes even more localized abrasion and compounds the issue. Eventually this will begin wearing away the collecting plates and electrodes.
- This type of wear can also change the gas distribution severely enough to force a derating or an outage.
- The unit in this picture was forced into a rebuild in 6 years due to this type of erosion.
- USE BIG HOLES. Perforated plates with large holes do not plug as easily.



Stitch Welding of Turning Vanes

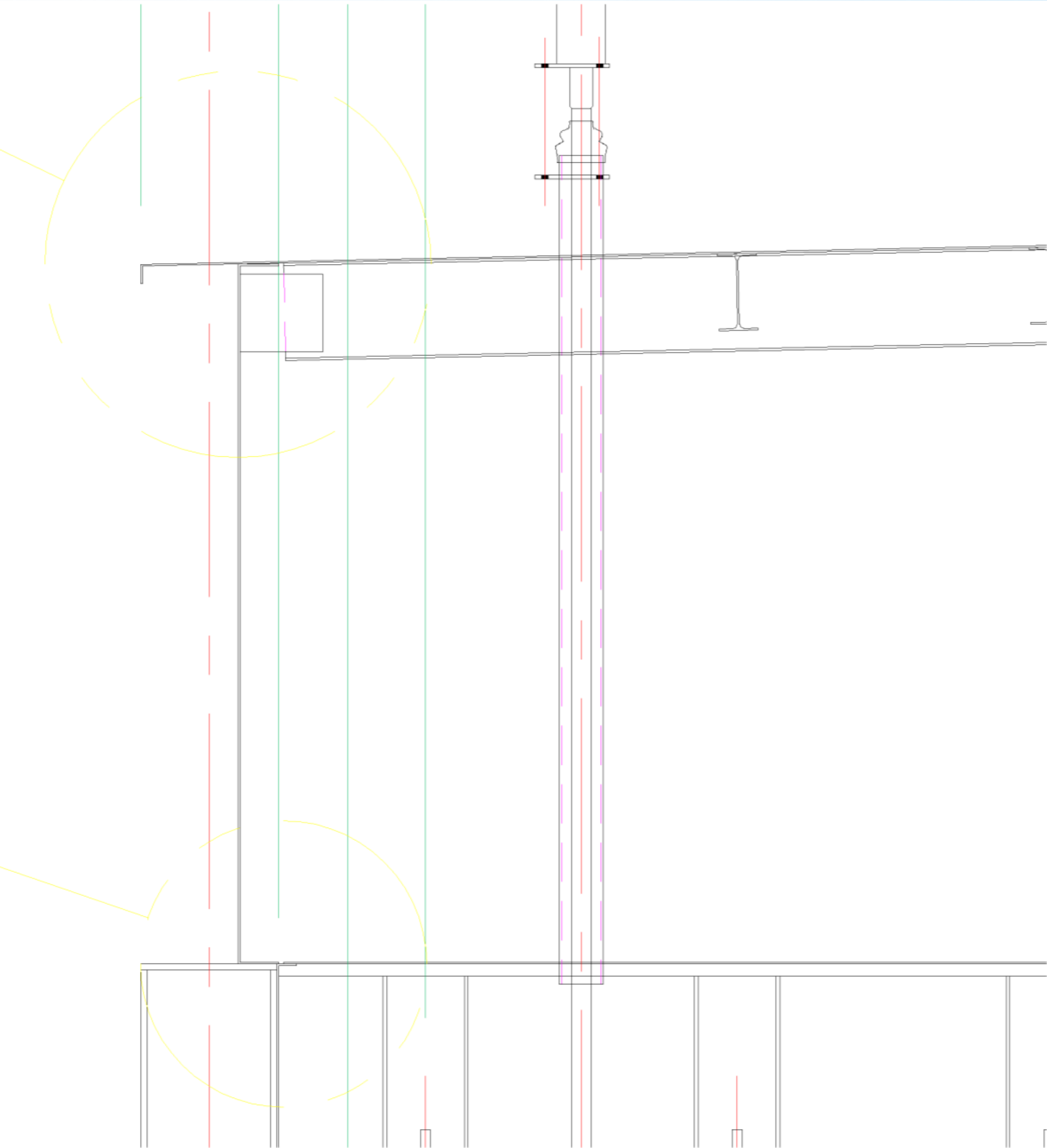
- Almost all turning vanes are stitch welded.
- Any good structural engineer knows that a continuous weld is not needed. There isn't much load on the vanes.
- But look behind these vanes. The gas sneaking through the gaps in the stitch welds wore holes right through the duct wall.
- Maybe a continuous weld is not needed from a structural standpoint, but a backing angle or a continuous weld would have prevented the high velocity gas flow and would have prevented this failure.

Rigid Electrode Erosion

- Just like gas flow devices, rigid electrodes can be subject to erosion.
- This rigid electrode has been eaten away by the sandblasting effect of poor gas distribution.

Thermal Expansion

- This is the corner of a precipitator penthouse.
- At the bottom is the hot roof. (350°F)
- At the top is the cold roof. (90°F)
- Assuming the roof is 50 feet wide the hot roof will grow 1” more than the cold roof.
- If both roofs are welded to the penthouse walls, then some allowance must be designed in to allow for this differential growth.
- Along the sides it will lean in, but the corners cannot lean.



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Penthouse Corners

- Without a place to grow at the corners, the cold roof will hold back the walls and as the hot roof pushes outward the stress will increase and concentrate.
- Eventually the corners will attempt to rise and either the penthouse will tear loose from the hot roof, or the hot roof will peel away from the casing walls.
- These corners get welded during outages on a huge number of precipitators every year.

Penthouse Roof

- Even above the roof, outside the precipitator, thermal expansion can be an issue.
- This photo shows the column of a weather enclosure on top of a precipitator roof.
- The wind bracing has broken loose from the column.
- Obviously, the column base is not sliding correctly.

Hopper Corners

- The corners of the hoppers can also experience high stress concentrations from the push and pull of the slide bearings during startup and shutdown.
- Sometimes the slide bearing will not move correctly.
- Most precipitators will eventually have cracking as shown here.
- This can be welded but will come back faster than before due to fatigue of the metal.
- Permanent fixes require engineering and are always very expensive.

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Insulation & Lagging

- The insulation is an integral part of the equipment, and this photo is a great example.
- The lagging was left off after the expansion joint was changed. Now the insulation has been wet, it is ruined, and the life expectancy of the new expansion joint frame is significantly impaired.
- Even had the lagging be re-installed, it was installed wrong. Imagine the water running down the ribs like little gutters. To where? The expansion joint. Maybe that’s why it failed to begin with?
- Look around your plant at the top surface of duct work and see how many places the ribbing takes rainwater right to a duct joint like this.

Corrosion

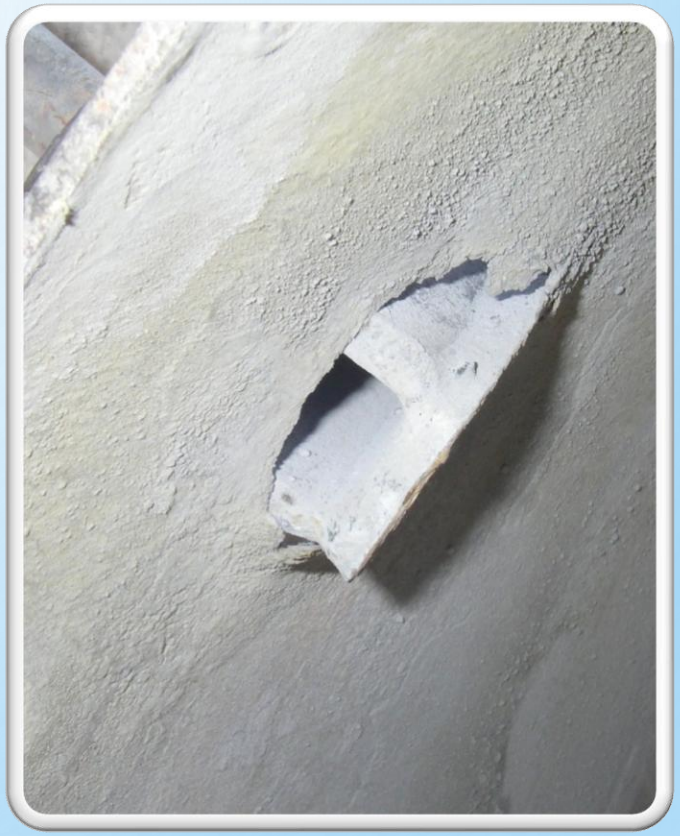
- Sometimes just looking at the outside of the box can tell you where the corrosion is.
- This is a picture of the joint between the outlet plenum of a precipitator and the vertical section above the hopper.
- Once a hole corroded through the casing wall, the gases escaped and attacked the aluminum siding.

Corrosion

- In this case there were multiple precipitator casings side by side.
- In the areas between them cold air was drawn in at the bottom and hot air went out the top due to stack effect from heating by the walls.
- This cools the side walls and condensation forms on the inside of the walls.
- Eventually the walls corrode through in large areas.
- In this photo the insulation and lagging have been removed so the crew can enter the space between the casings for repair.

Check The Small Stuff

- In these two photos we see the combing around a side access door from first the outside and then the inside.
- Door combings corrode because they pull heat out of the wall and cause condensation. The corrosion will be worse as you move further from the wall.



Rapping Systems

- Dirty Inspection !! Why you do them
- This photo shows the result of a failed rapper.
- These are roof mounted rappers, so the energy comes down the vertical shafts.
- All of them are clean except this very first one.
- If this rapper were functional, there is no way this build up could remain on the shaft.

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Electromagnetic Rappers

- A popular rapping method is the electromagnetic solenoid rapper.
- Note how this shaft mounted rapper leans.
- This makes the steel slug slide up and down inside the unit against the inside of the tube.
- The friction makes the rapper hit with less force than a straight up and down unit.
- It also shortens the life of the rapper as it will eventually wear through the inner tube and break the coil.
- Never just trust the rapper control to tell you that rappers have failed. Every now and then someone needs to feel the rapper function. They can fail by binding and the control will not know.

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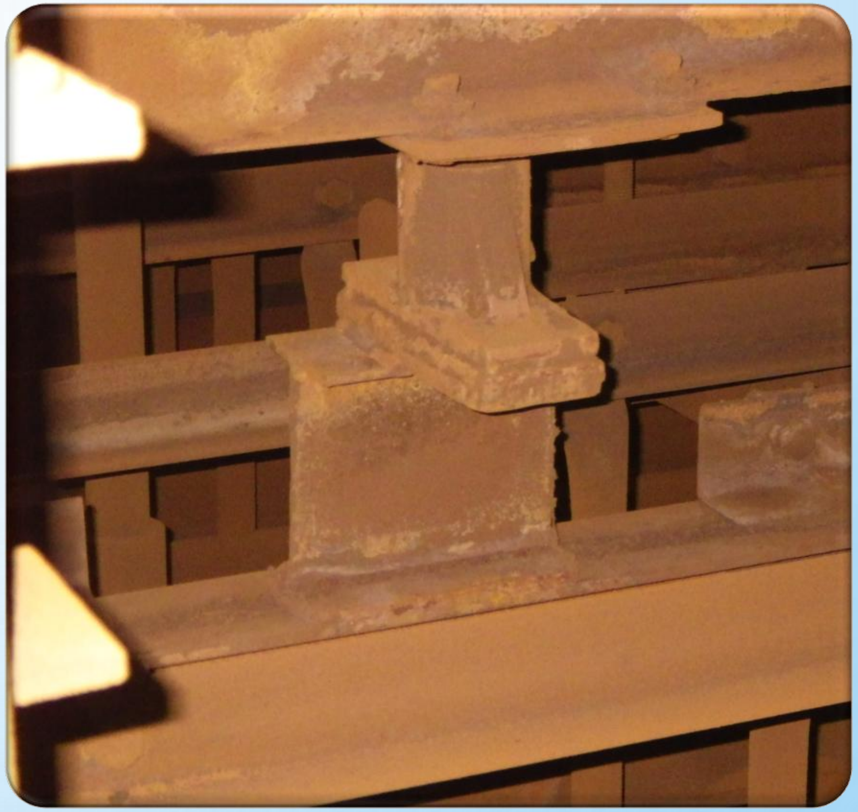
Wall Penetrations for Rapping

- Probably the best argument against using roof mounted electromagnetic rappers is that they require many roof penetrations and can be a leakage point.
- This is a rapper shaft that normally would have a vertical pipe sleeve. The sleeve had completely corroded away.
- This was an expensive fix as the roof had asbestos insulation that had to be removed first.
- But this roof had been in service for 48 years prior to this.

Rapper Installation

- This rapper was supplied with a shaft that was too short for the installation, so the contractor added the shown piece of 8” beam to make up the difference.
- It was too short because the high voltage frame had been installed upside down.



- These photos show two different kinds of weld failures in rapping systems
- The left is a shaft mounted directly to the channel that holds up the collecting plates.
- The crack is right at the top edge of the original weld.
- This is a common issue as the 2” thick shaft is very difficult to heat and get a good weld.
- The right side is poor penetration on the lower base metal when welding heavy cast steel to mild steel.

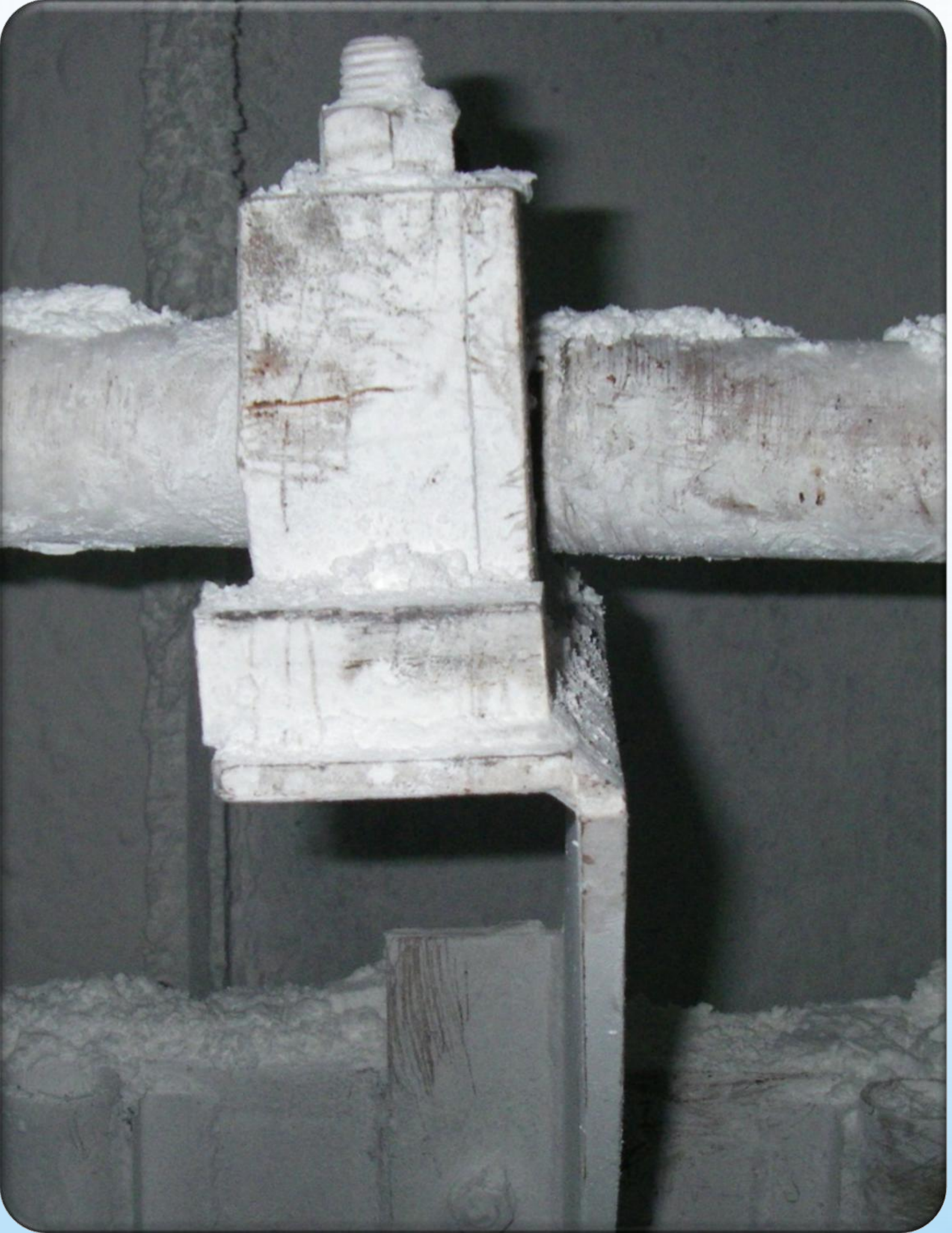
Rapper Welds

Tumbling Hammers

- All tumbling hammer type systems utilize some method of attachment to connect the hammers to the turning shaft.
- In this case, brackets are welded to the shaft and then pinned to the individual hammers.
- We can see the result of fatigue of the steel from the repeated pounding.
- Usually, the hammers fall off and are found in the ash system.
- These are easy to locate and then during the outage you go inside the unit and look for missing hammers.
- Failures like this are harder to find and are just waiting to fail right after going back online.

Hammer Shaft Bearings

- Most every tumbling hammer system uses cast iron or steel bearings.
- Other softer materials just wear out too fast.
- Fly ash eats graphite for lunch.
- Even in the condition above, this bearing is working.
- But it has just about had it. I generally like to see less than 3/8” gap in these types of bearings.
- Also, be careful that as the bearings wear, the alignment does not move too far. If the hammers hit too low on the anvil, they will introduce an upward force and can damage the collecting curtains.



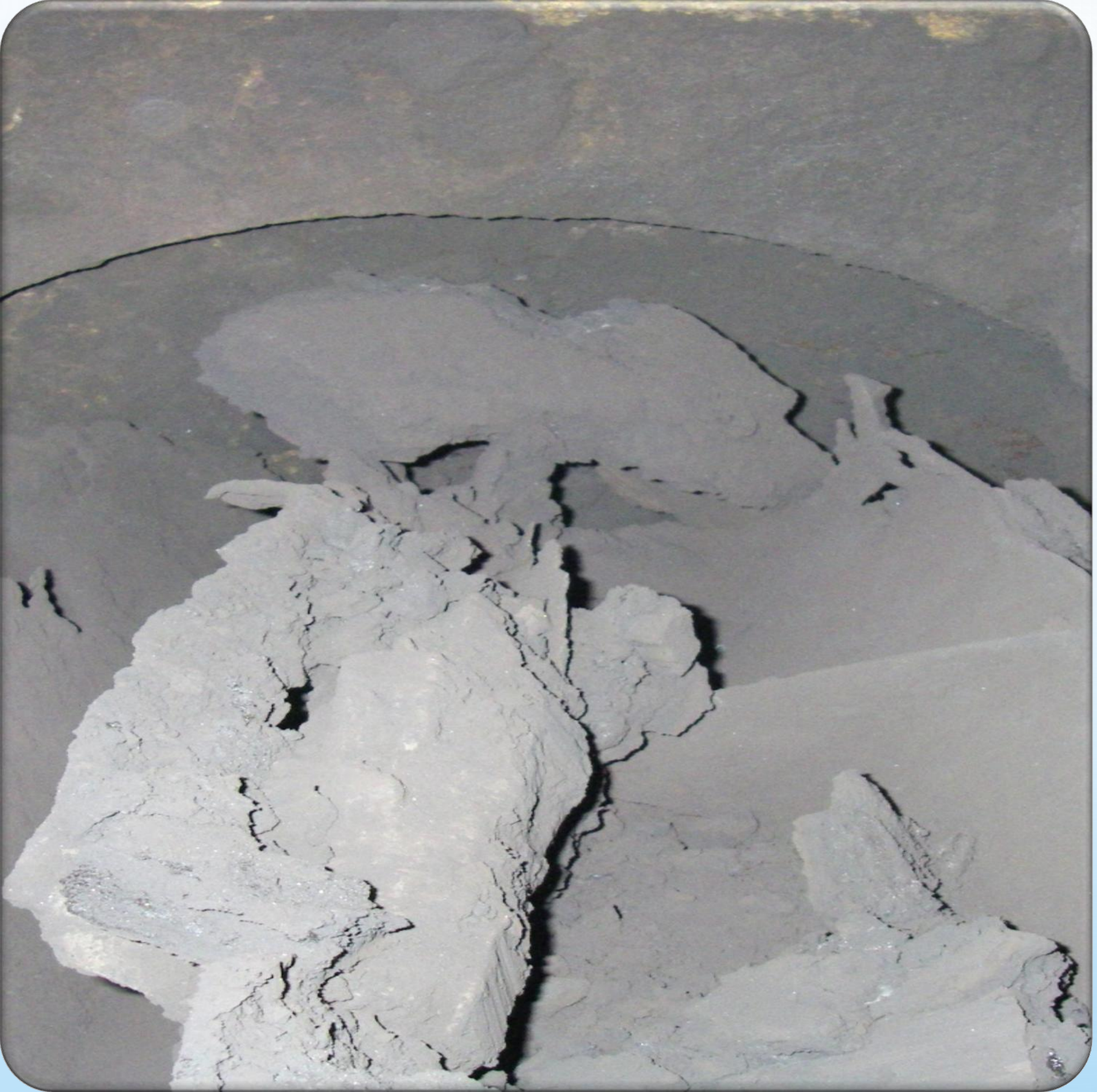
Hammer Shaft Bearings

- Always look at the bearing supports also.
- This support was a fabricated piece that basically held up the bearing off center of a piece of plate.
- Over time the plate sagged and caused the bearing to try to bind.
- This created a lot of wear on the bearings, shafts, motors and gearboxes.
- In this case we straightened the bracket and modified the design to stiffen it.

Collecting Plate Mounting

- The rapping forces are intended to go to the collecting plates. These forces are the highest at the rapper hammer, but travel through the entire support system.
- This photo shows the clip that holds up the upper tadpole of a collecting plate. This clip is welded to the web of the anvil beam channel.
- The clip material has broken right at the edge of the weld.
- Typical for a fatigue type fracture.

- This is a similar fatigue failure in a different collecting plate design.
- There are two bolts at the top of the pad that connect the collecting plate.
- In this case the lower part of the collecting plate has begun to crack loose from the end plate clip.
- Straps were used to reconnect these as a field repair.



Rotary Valves

- Ash handling systems are a topic for another day, but if the blades in a rotary valve look like this, it's a problem.
- Air was being continuously pulled back through the valve sucking all the dust back into the precipitator.
- When the unit failed a performance test, a particle size test revealed that the average particle size was over 100 um.
- Particles that large cannot get through a precipitator so this had to be a precipitator bypass issue.
- Check the valves in the ash system. Make sure they seal.

Discharge Electrodes

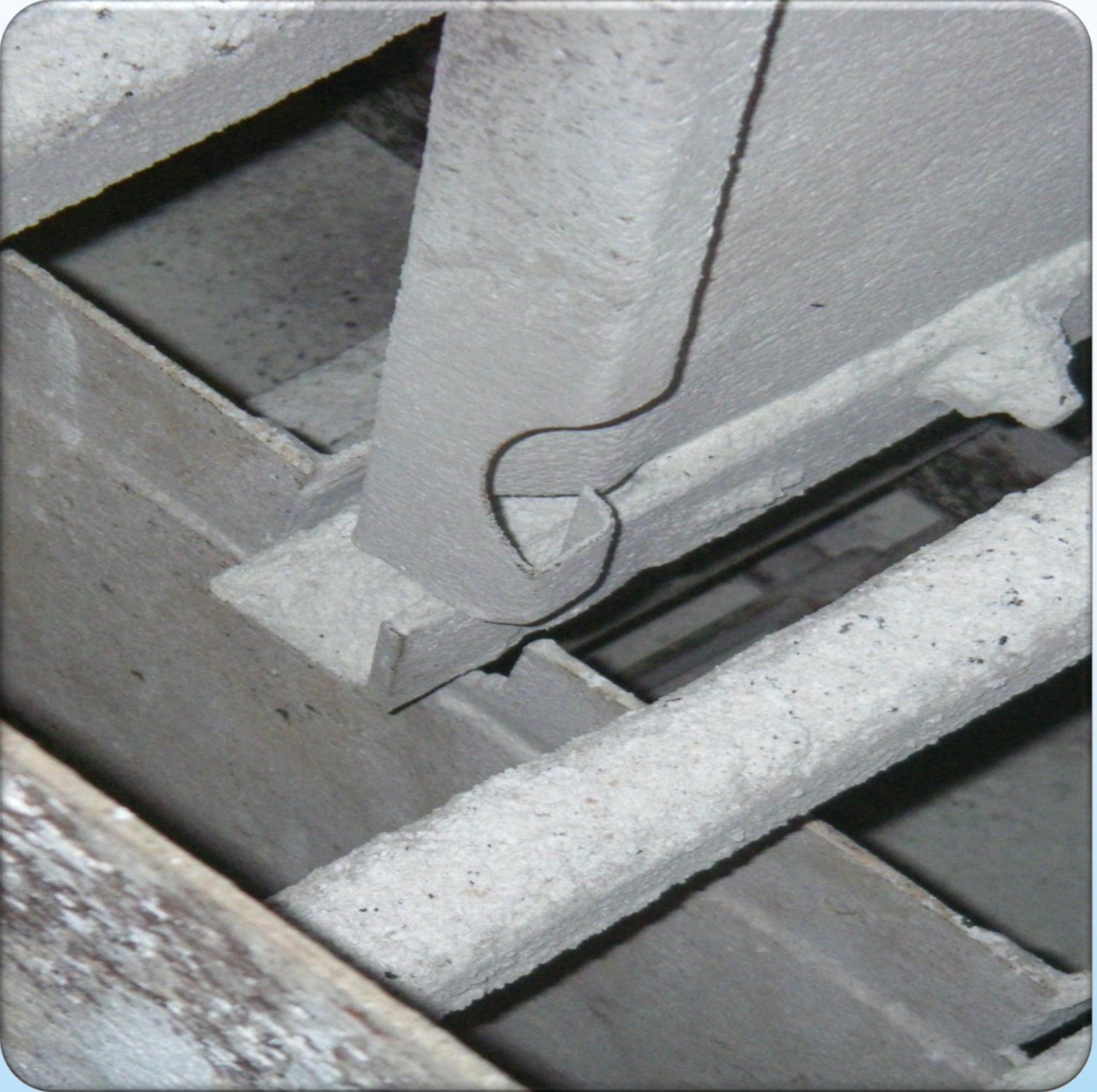
- This photo is a typical broken wire. All wires break.
- In this case, the wire did not short anything out and the operators had no idea it was loose until an internal inspection was conducted on an outage.
- Not all broken wires are this easy to see.

Rigid Electrodes

- Many people have characterized rigid electrodes as unbreakable wires for precipitators.
- Not so. They are less breakable.
- Everything breaks given enough time and stress.
- In this case the original connection was bolted and failed.
- Angles were added to stiffen the joint.
- This caused a different failure, but the result was the large horseshoe crack shown here.

Alignment

- This title bigger because it's just that important.
- This is the effect of misalignment on a collecting curtain.
- Once a hole is developed there is an edge on the grounded side. After there is an edge, even fixing the alignment will not recover the power levels correctly.
- Precipitators use negative charging because a sharp edge on the positive side will arc at about a 20% lower value.



- This is another example of the same type of damage, because alignment is that important.

Rigid Electrode Bows & Misalignment

- In new equipment it is common to measure every gas passage and make sure everything is in alignment within ¼”.
- Once upon a time this was common for maintenance inspections.
- Today, it is more common to be looking for places more like this, where a ruler is not required. This photo is the distance from the discharge electrode to the collecting plate.

Misalignment + High Frequency Power Supplies = Broken Wires

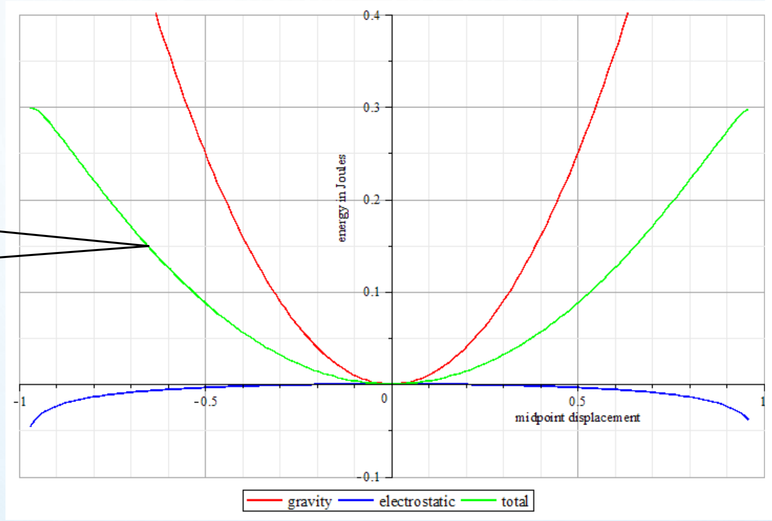
- This is a precipitator sparking.
- New high frequency power supplies enhanced the electrostatic forces inside the ESP, which is the main reason to use newer power supplies.
- In weighted wire unit, the wires need to resist these higher forces.
- This means more weight unless the alignment is perfect.

Misalignment Effect on Sparkover

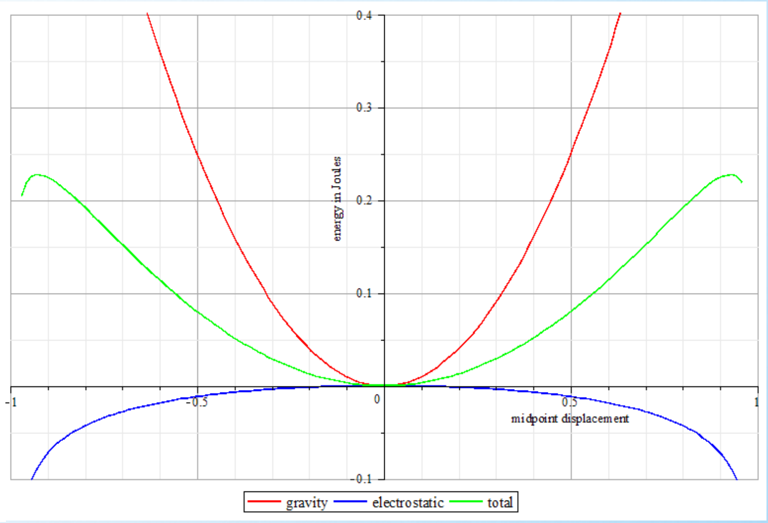
Energy required to pull wire to the collecting plate

- The weights on weighted wire precipitators were designed mostly empirically.
- Here the offset of 0.9” lowers the overall energy to cause oscillation on a wire by about ½.
- The additional forces from adding higher electrostatic energy lowers this by nearly ½ again.
- In many cases the initial energy could be from a spark or from vertical vibration of the ESP.

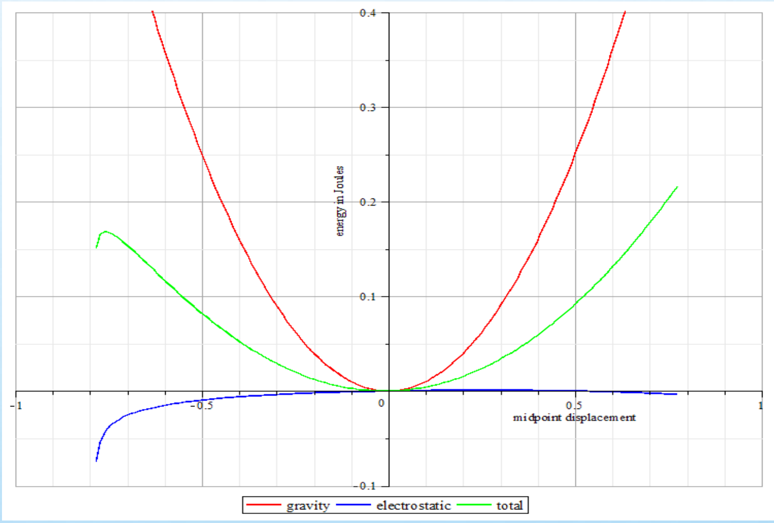
0 Misalignment @ 60 Hz



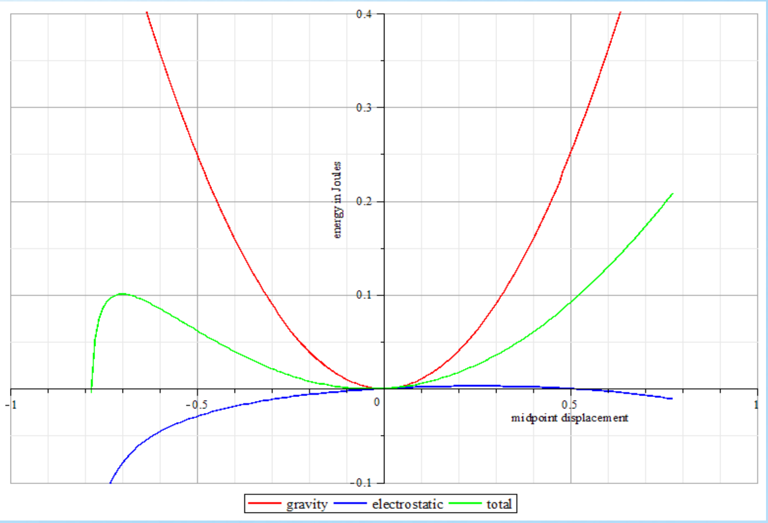
0 Misalignment @ 35 kHz



0.9” Misalignment @ 60 Hz



0.9” Misalignment @ 35 kHz



Oil Level Gauge

- Just like a car, oil level is important.
- The spark over distance through a typical oil at 70 kV is about 2 inches, whereas the spark over distance at 70 kV in air is about 6”.
- Clearances of 2-3 inches are not all that uncommon inside transformers. Therefore, if the oil level drops, these close clearances will produce arcs inside the transformer.
- Sparks on the surface of the oil can crack the mineral oil into acetylene and then ignite.
- Please don’t just add more oil when it gets low. Find the leak and fix it.

Electrostatic Precipitator 101

Timothy Mallory

Question and Answer