REINHOLD ENVIRONMENTAL Ltd.

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Operation and Maintenance Electrostatic Precipitator "Mechanical"

Tim Mallory

AIR ADVANTAG

Precipitator Components

Power Supplies

Rapping Systems

Insulators

Collecting Surfaces

Discharge Electrodes

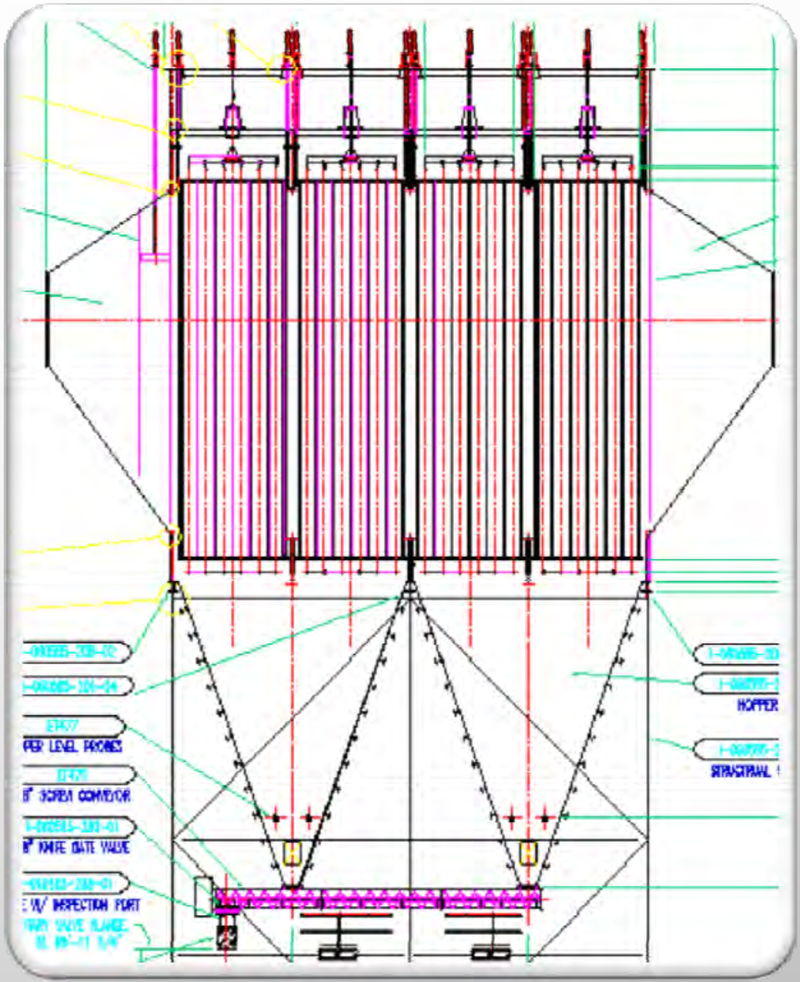
Gas Distribution

Doors

Casing Walls

Key Interlocks

Ash Handling



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Shift Operations

- Check operation of all of the voltage controls on each shift noting any significant changes in power levels
  - This is done to keep a record of any changes in the precipitator and also to detect mechanical or electrical failures as soon as they occur. Modern data systems such as PI do a great job of keeping records as long as the data points are set up right. A well made graphic showing precipitator power levels over time can be made and referenced.
- Check the overall function of the rapping system and ensure that the rappers are running.
  - On electromagnetic systems check the screens for rapper failures and make sure the rapper control is actually rapping.
  - On hammer type systems check the motor feedback for operation.
- Check the ash handling system and look for signs of hopper plugging
  - This is a big deal. Full hoppers do more damage to precipitators than age or wear. Many units have been so damaged by a full hopper that the precipitator had to be rebuilt costing millions of dollars.

Weekly Operations

- Walk down the rapping systems.
  - Most rapper controls can be set up to rap in a straight line sequence so that electromagnetic rapper operation can be observed. Not all rappers that function are working.
  - Motorized hammer rappers can be turned on with a hand switch to check operation.
  - Look at the shaft as it enters the wall. The gearbox or coupling could be loose and the motor still operate.
- Check the purge air fan and filter.
  - Loss of purge air will create much more cleaning during the next outage and could mean changing many insulators.
- Check casing penetrations for leaks.
  - Even a small leak will create accelerated corrosion.
  - On high sulfur coal this becomes critical as every leak makes acid condensation.

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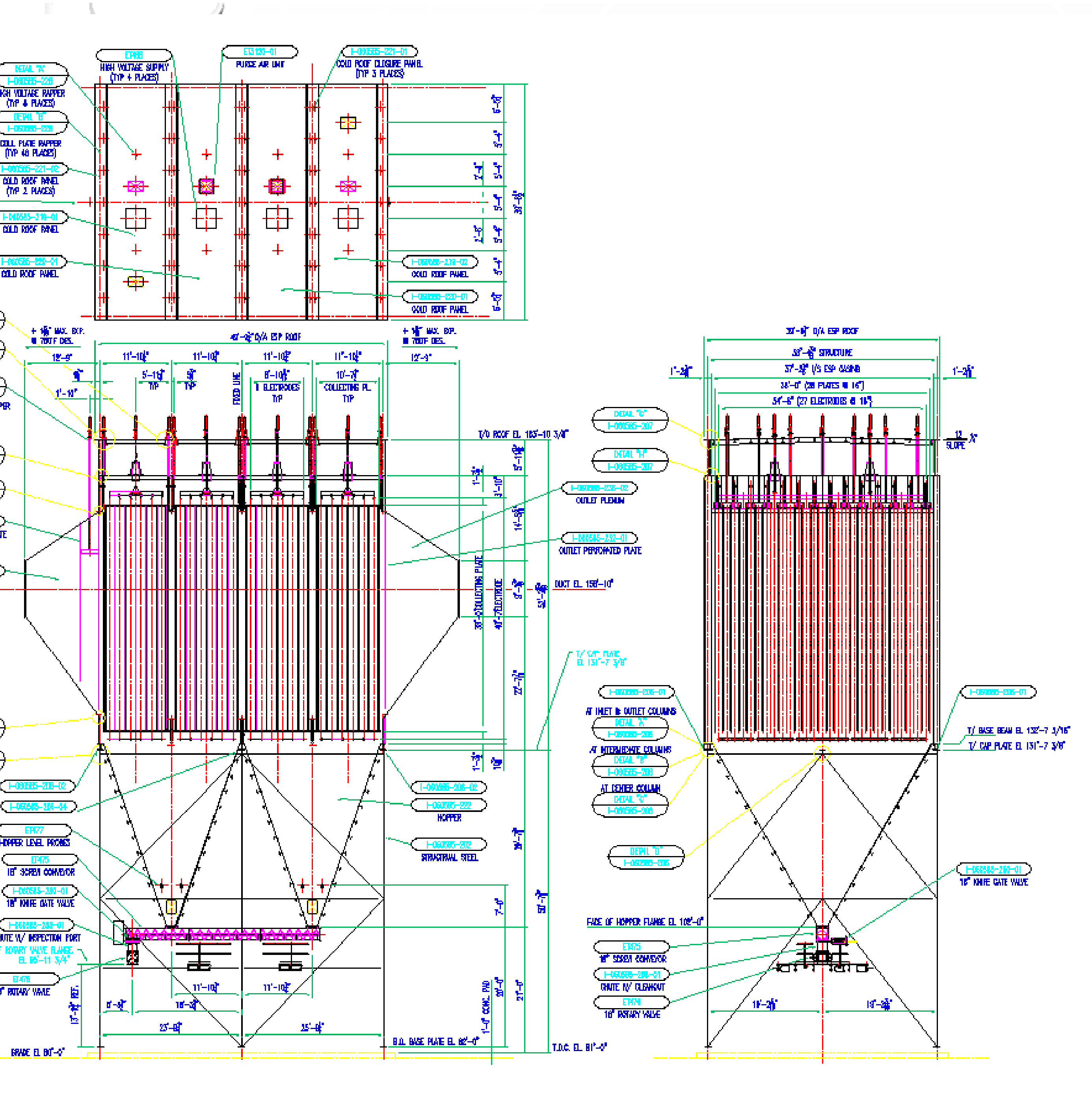
During Shut Downs

- Clean the insulators in the precipitator.
- Inspect all of the gas distribution devises and their rappers.
- Check the hopper ash systems.
- Inspect interior of the unit.
    - Internal alignment
    - Cracks, Holes, Rips, Tears in the casing
    - Cracked welds and worn moving parts in the rapping systems

Remember

IN ALL Things

Safety first



This is a typical small precipita utilizing the north American st design.

This design features electromagnetic rappers on th roof and a full upper penthous but has no side access doors.

All inspection is done from the top or the top and bottom of t field.

This is the same precipitator during construction, and is useful to discuss the maintenance of the precipitator casing.

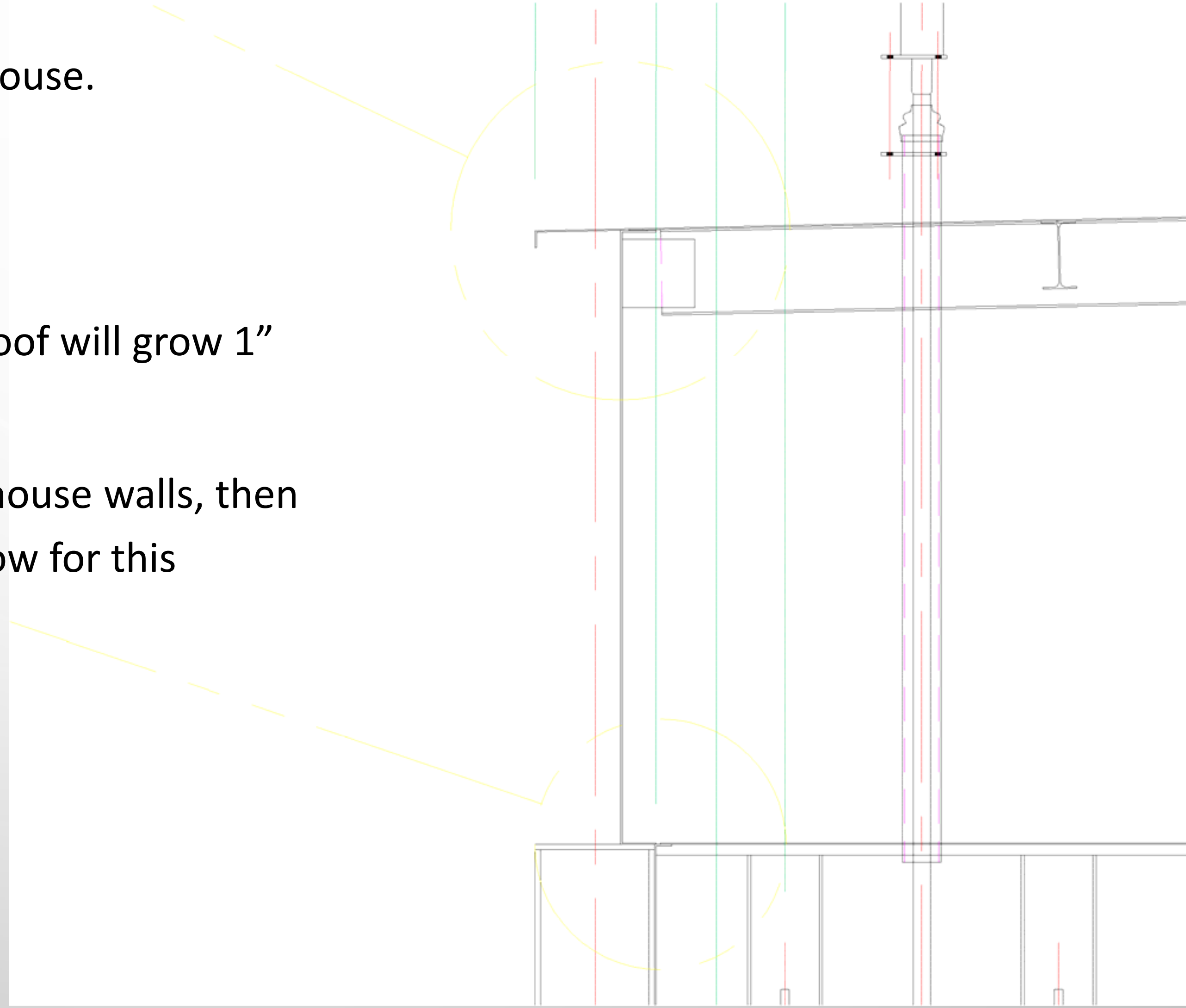
Every casing design has cold spots caused by metal that sticks out through the insulation.

Here we clearly see the supports for the access way. Also, the doors on the hoppers will protrude.

In addition the walkway 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.

Harder to see are the slide bearings that allow the casing to move. These actually do require maintenance or at least some monitoring.

- This is a blow up of the corner of the penthouse.
- At the bottom is the hot roof. (350°F)
- At the top is the cold roof. (100°F)
- Assuming the roof is 50 feet wide the hot roof will grow 1” more than the cold roof.
- If both of the roofs are welded to the penthouse walls, then some allowance must be designed in to allow for this differential growth.



Without a place to grow, the cold roof will hold back on the walls and as the walls grow out the stress will increase and concentrate at the corners.

Eventually the corners will rise up tearing loose from the hot roof or peeling the hot roof off of the casing walls.

These corners get welded during outages on a huge number of precipitators every year.

Hopper Corners

The corners of the hoppers can also experience high stress concentrations from the push and pull of the slide bearings during start up and shut down.

Sometimes the slide bearing will not even 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.

Penthouse Weather Enclosure

Even above the roof outside the precipitator thermal expansion can be an issue.

This photo shows the column of the weather enclosure on top of the precipitator roof.

The wind bracing has broken loose from the column.

Obviously the slide bearing is not doing its job.

Clues to 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.

In this case there were multiple precipitator casing side by side.

In the areas between them cold air was drawn in at the bottom a hot air went out the top due to heating from the walls.

This cooled the side walls and condensation tended to form on the inside of the walls.

Eventually the walls corroded 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 Even Small Stuff

In this photo we see the combing around a side access door.

One of the door latches can be seen.

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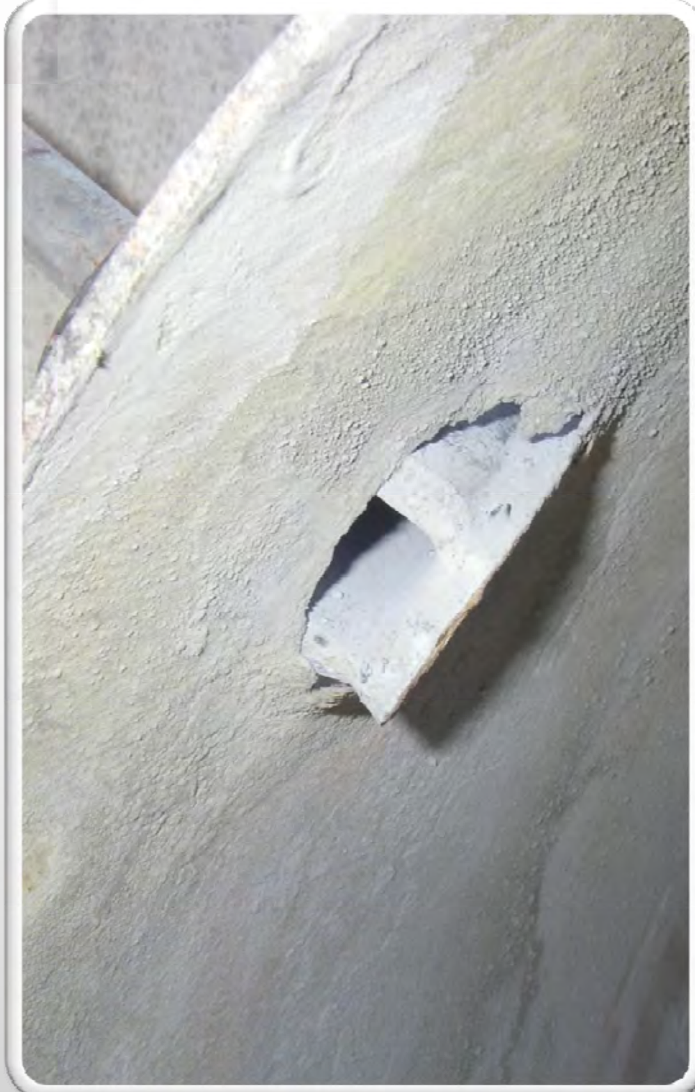
This is the same door latch as viewed from the inside of the door.

The door combing did not appear to be thin because the edge of the combing had been repaired before with a ¼” x 3” wide ring the previous year.

Just replacing the very outer ring was easy since the hardware didn’t have to move.

Door combings corrode because they pull heat out of the wall and cause condensation. The corrosion will be worse as you move toward the wall.



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The problem with door latches like this is that once they crack loose then they don't hold the door closed correctly.

Then air leaks in and the corrosion accelerates.

Depending on the door design, you get this.

In this case the door has a tube type combing that brings the door through the insulation.

This type of door is hard to get in and out because of the need to lay down and slide through the tube.

Many people put handles above these so you can swing feet first through the tube.

These also corrode very fast because the side of the tube is exposed to both the flue gas and the cold winter air.

This pile of ash is hardened due to condensation. If this had been high sulfur coal ash, the door would last no time at all.

Here we have a rectangular similar design.

In this case the door itself has a bit of insulation.

As you can see, the corrosion happened anyway.

Dissimilar Metals

Here is an example of stainless steel welded to carbon steel.

This was done just the right way with 309L rods and pre-heat and everything.

But stainless steel grows more than carbon steel, and in this case it grew more that the weld would stretch.

This particular weld was also attacked by the chlorides in the flue gas which made it more brittle.

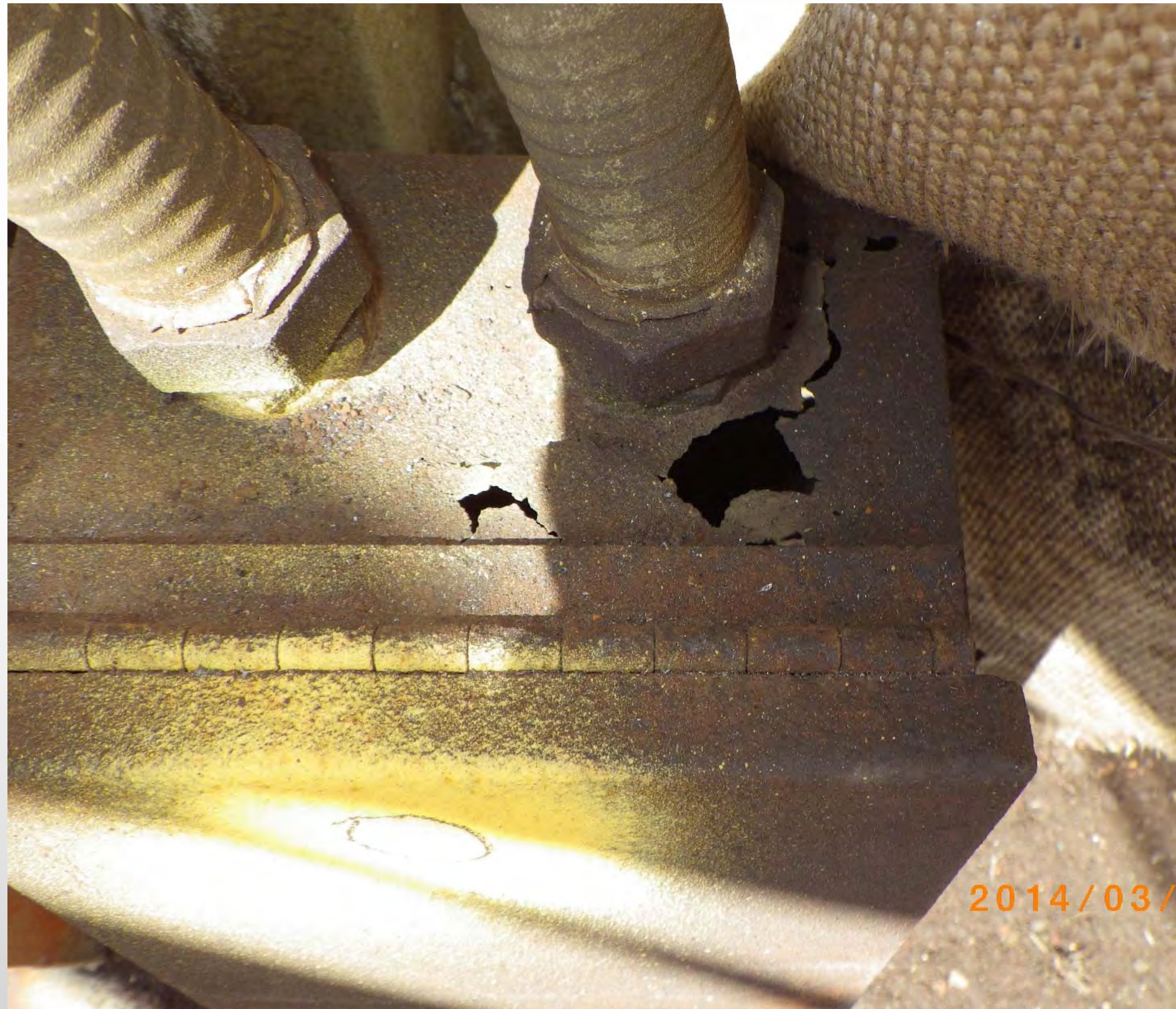
Even the Really Small Stuff Matters

This is a small electrical box on the precipitator roof used to connect the high temperature wire from the insulator heaters to the normal feed cables.

The bottom of this box is a 1" conduit into the precipitator penthouse.

Gases came up into the box and condensed, then corroded the box.

Then it rained in the precipitator penthouse and corroded the hot roof.



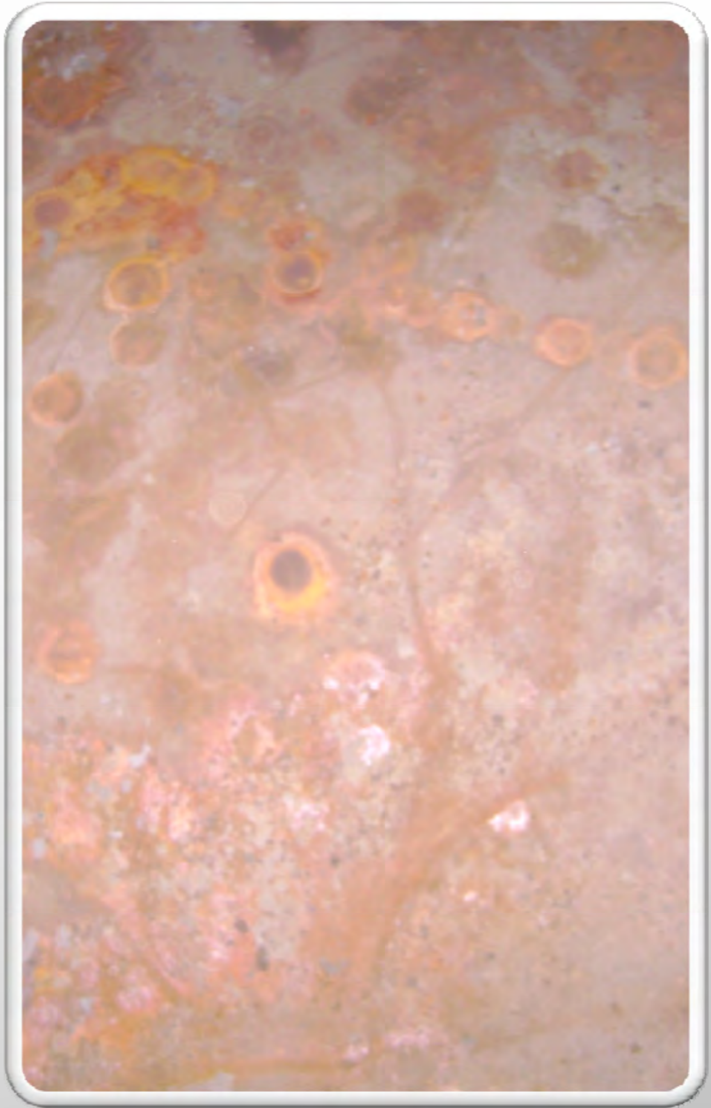
Which takes us to the floor below.

This is really why we noticed the conduit box.

It’s hard to see the actual cracks in the floor, but this floor is so thin it was cracking apart.

When you put your foot on it, it would give way.

The spots are where the water ran around on the underside of the roof above and then dripped.



Insulation & Lagging

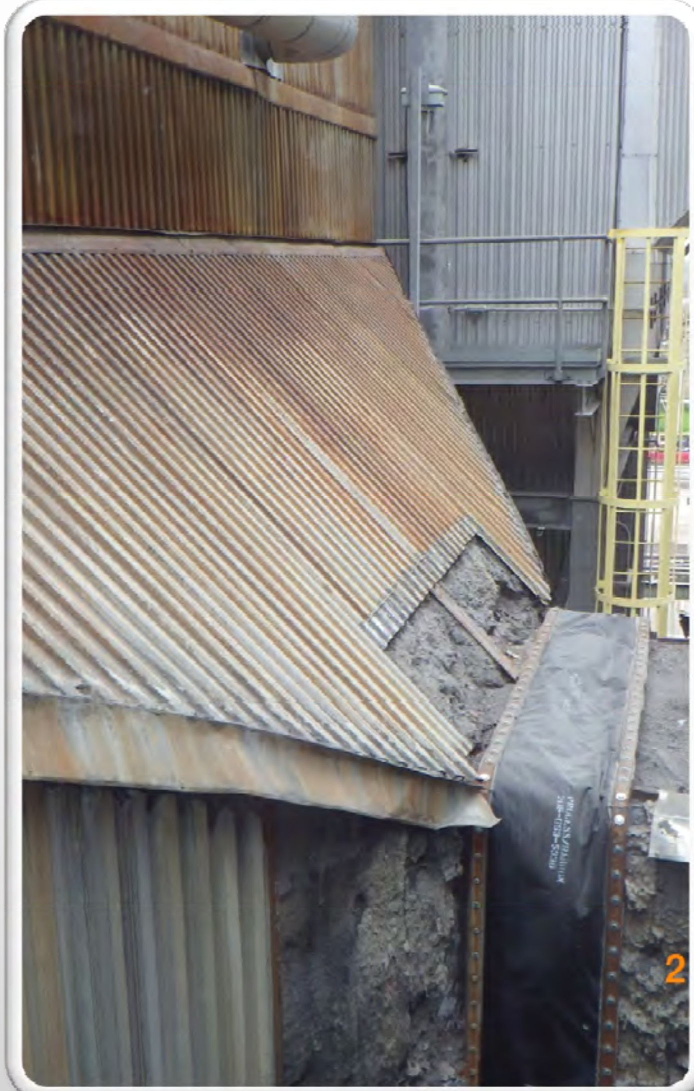
The insulation is an integral part of the equipment.

This photo is a great example.

First the lagging was just left off after the expansion joint was changed. Now the insulation has been wet and is ruined and the life expectancy of the frame of the new expansion joint is probably now a couple of years.

Second. Even with the lagging in place. The lagging was installed wrong all along. Imagine the water running down the ribs like little gutters. To where? The expansion joint. Maybe that's why it failed to start 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.



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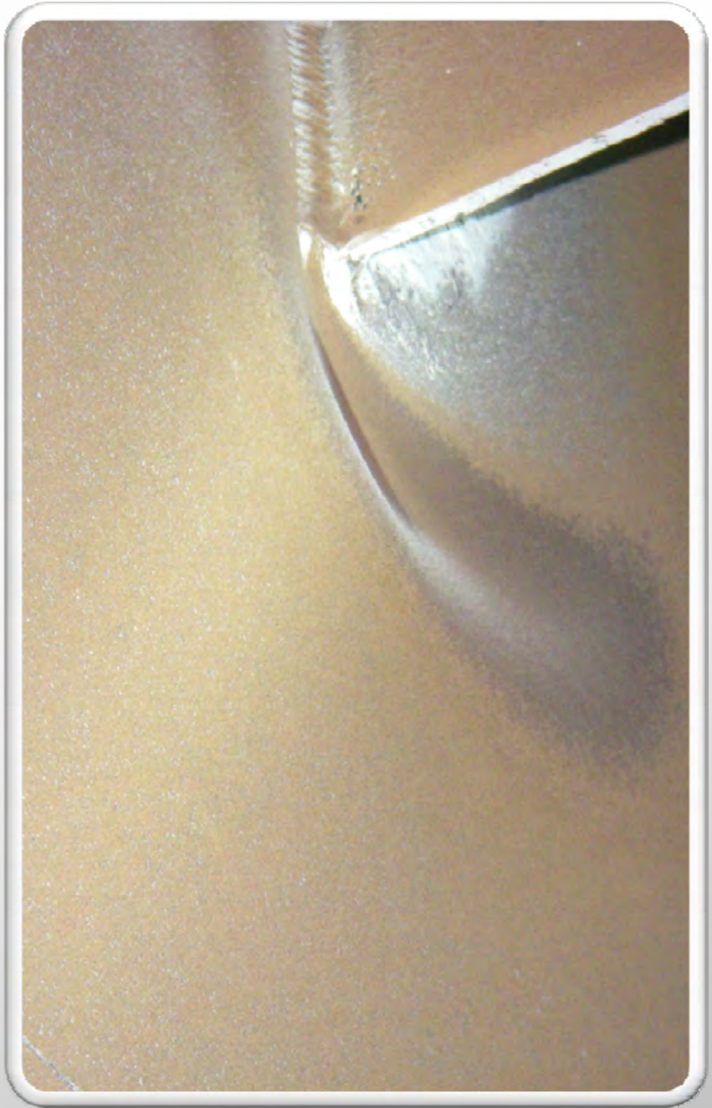
Erosion & Abrasion

This is a picture of the edge of a turning vane.

Note that the high velocity gas flows around the edges of the vane.

This will wear through the side wall of the duct.

This can be reinforced in advance much easier.



Stitch Welding

Almost all turning vanes are stich welded.

Any good engineer will tell you that you don't need a continuous weld. There isn't much load on the vanes.

But look behind these vanes. The gas sneaking through the gaps in the stich welds wore holes right through the duct wall.

You don't need continuous welds, but a backing angle would have made this much stronger and prevented most of this flow.

Perforate Plates

The closer to the inlet duct you go, the higher the velocity.

Fly ash is abrasive.

Watch the wear on the perforated plates.

Once a large hole is made through the plate, even more gas goes to this area. This causes even more localized abrasion and makes the hole bigger.

Eventually is will begin wearing away the collecting plates and electrodes.

This assumes, the change in gas distribution doesn't de-rate the unit to offline.

I have seen a brand new precipitator forced into a rebuild in 6 years due to erosion from just this issue.

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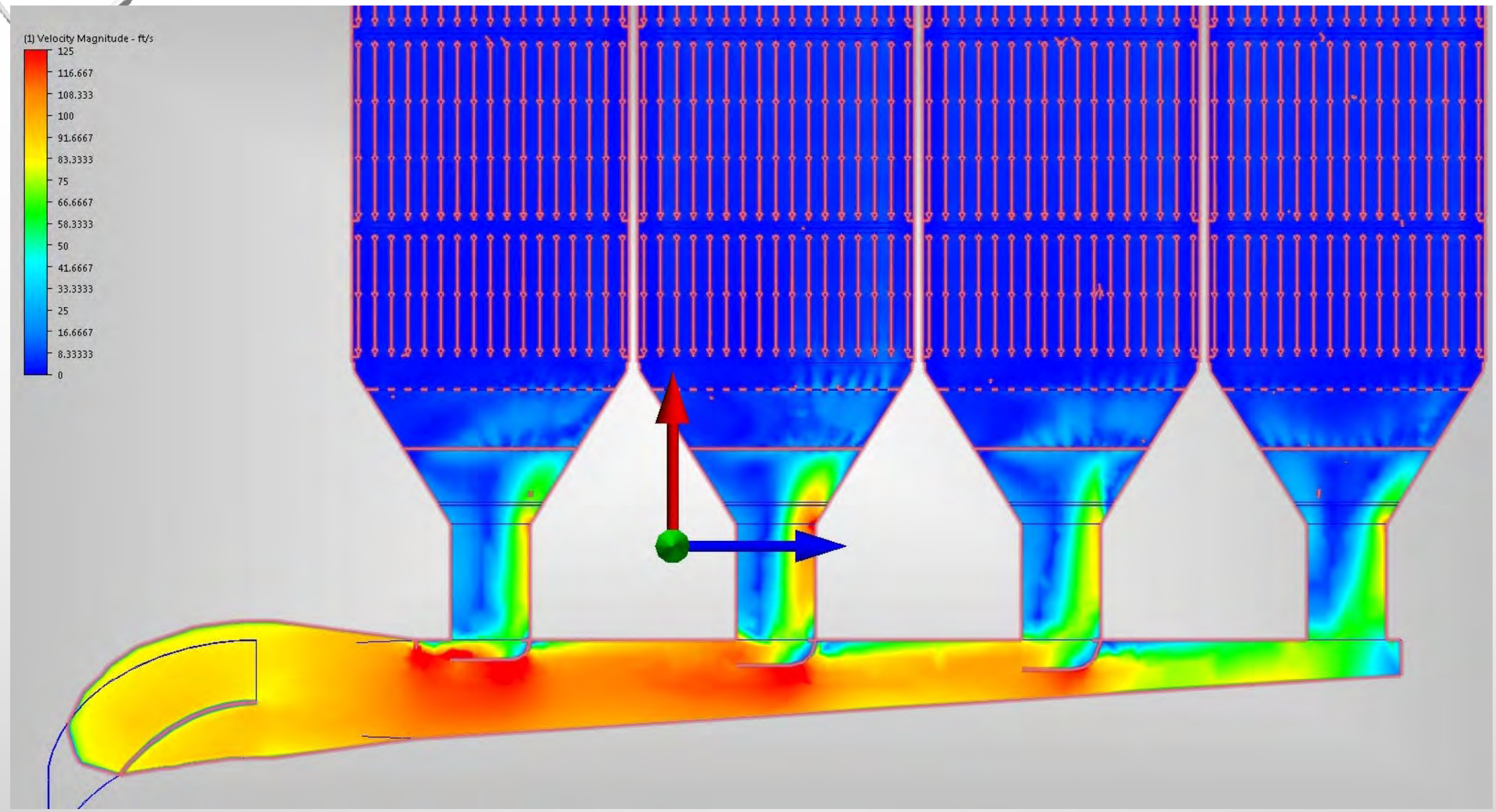
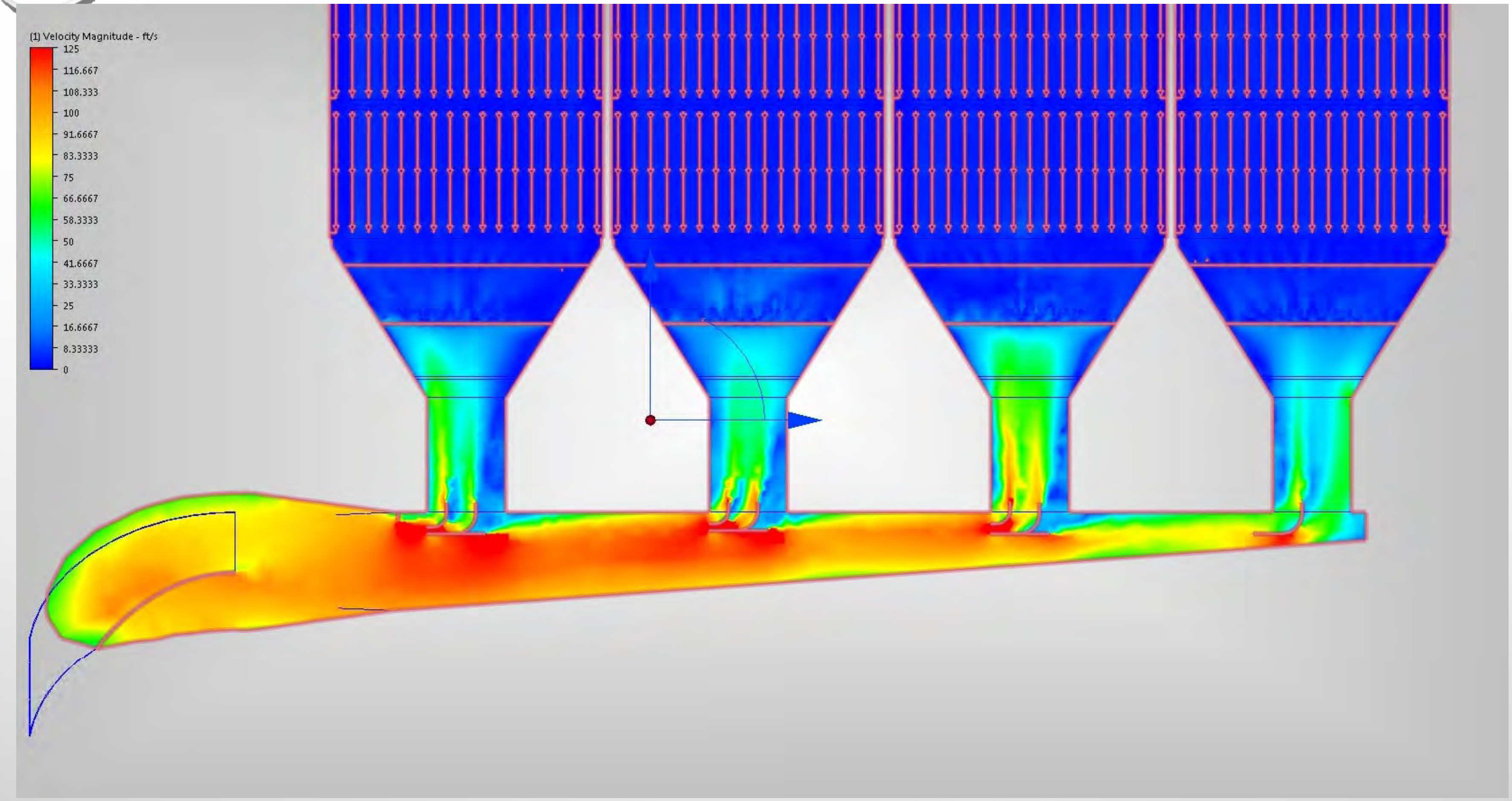


Just an example of what bad gas flow actually looks like. This unit continuously wore through the perforated plates at the right side wall. Everyone knew there was an issue, but finding it and correcting it are never easy.



In this case a flow study was used to redesign the turning vanes. The performance of the unit was improved and hopefully the wear problems have been resolved.

Now on to Some Power Supply Discussion

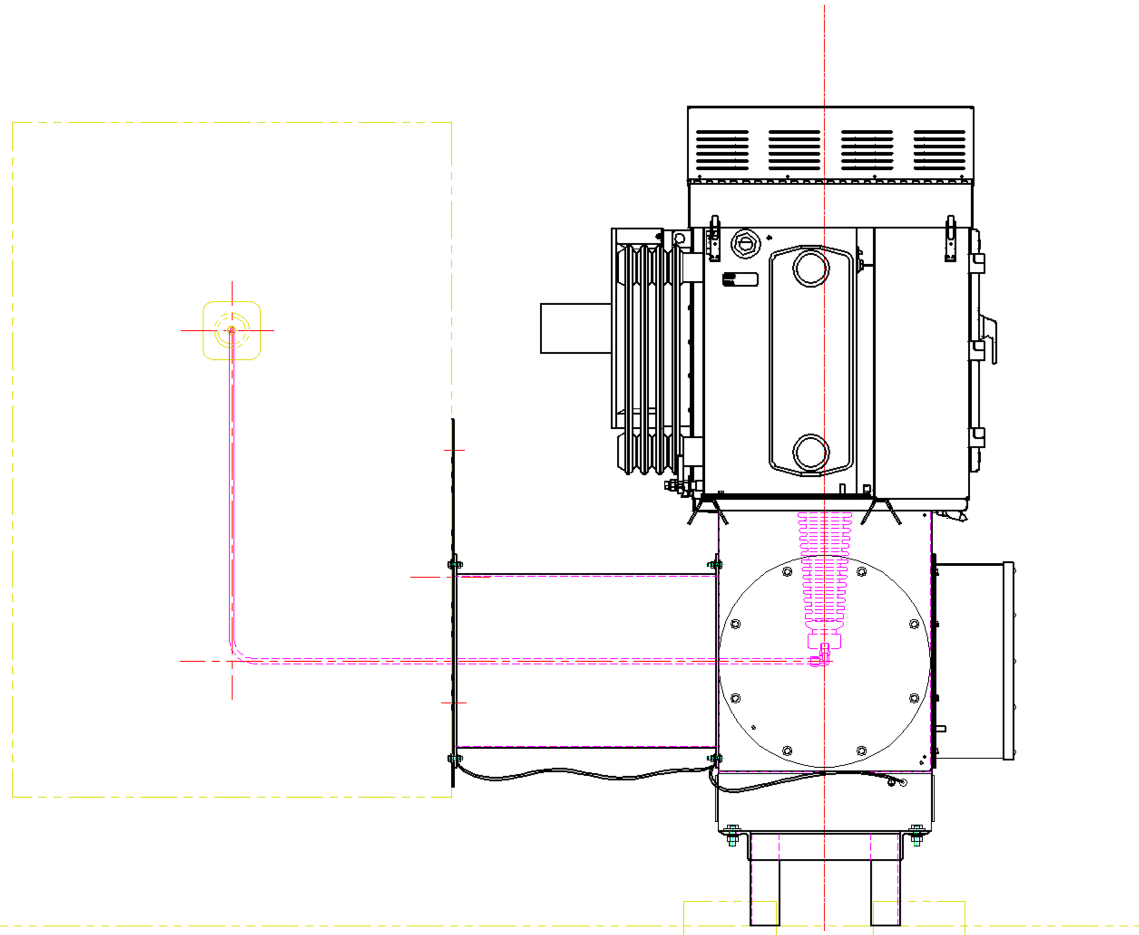
We used to call these TR sets and many people still do.

The fact is that TR set refers to Transformer / Rectifier.

Most new equipment today is coming with high frequency power supplies such as shown here.

General speaking, since I was asked to stay with the mechanical side of things, we just want to make sure the insulator is cleaned and the bus bar is in good repair.

Yes, the bus bars break.



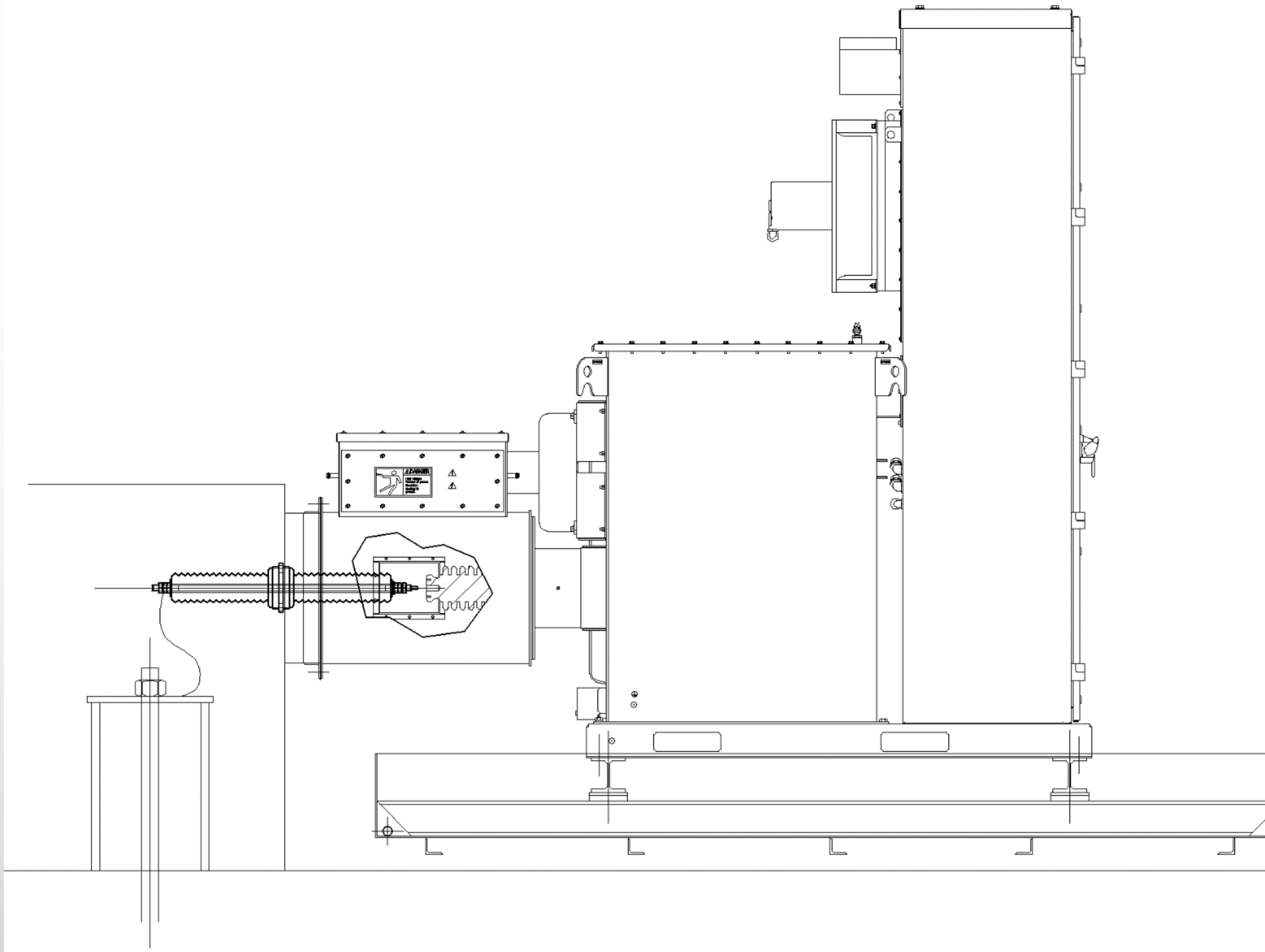
This is just a view of a larger unit. This particular one is the largest I have personally been involved with.

It is 2860 mA at 70 kV

Note that in both of these cases, there is a through bushing that is the power supply output bushing, and another through bushing at the precipitator.

This air gap is there because these new power supplies must be well protected from the heat of the precipitator.

In the early days of these we tried to make them connect directly and we cooked a lot of parts due to localized overheating of the oil.



Oil Temperature Gauge

This is the normal oil temperature gauge.

It shows current temperature with the white needle.

It also shows the max it has seen in the red needle.

You can reset this red one during an outage and then keep track of how hot the unit gets during a campaign.

Oil Level Gauge

Also important is the oil level.

Just like a car. No oil can be very bad.

The spark over distance through a typical oil at 70 kV is about 2 inches.

So clearances of 2-3 inches are not all that uncommon inside this equipment.

The spark over distance at 70 kV in air is about 6”.

A spark on the surface of the oil can crack the mineral oil into acetylene and then explode.

Please don’t just add more oil when it gets low. Find the leak and fix it.

Oil Level

Yes, oil level is critical.

Here we see some clean up cloths placed to retain the leaking oil from an older TR set.

The operator in this case just refilled the tank and it looked like this a year later.

I know of one plant that nearly burned down a precipitator because TR set oil ran into through into the penthouse and caught the hot roof on fire. In that case they didn't know it was leaking because it leaked through the output bushing into the closed bus duct.

But most power supplies today have gauges. Check them from time to time.

Bus Duct Insulators

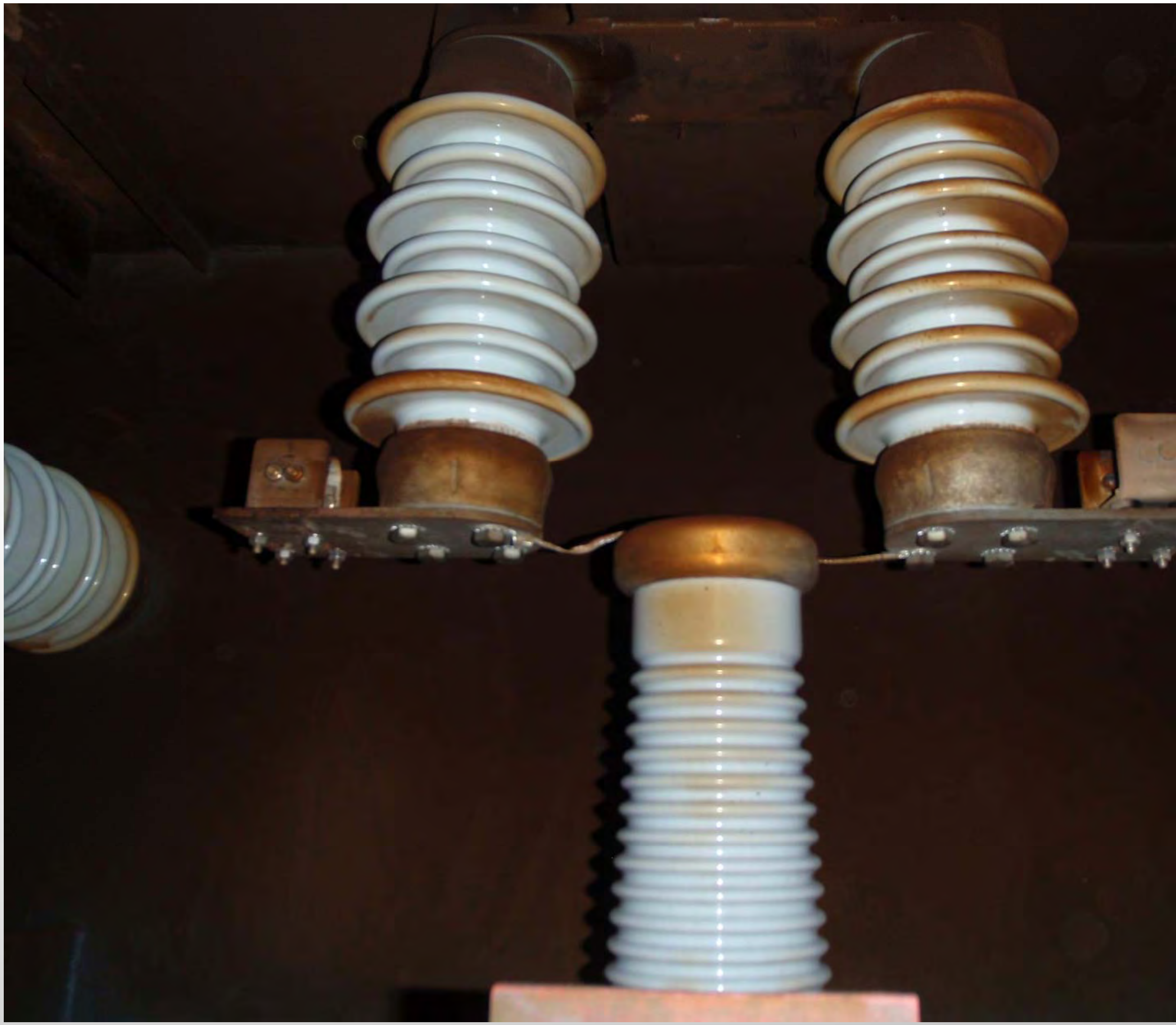
The insulator at the bottom is a power supply output bushing.

This unit is switch connected to two (2) electrical sections of the precipitator.

See how the dirt is just on the one side of the one insulator.

This is because the purge air from the penthouse is creating more pressure on the one side and blowing dirt out of one penthouse into the other.

These insulators should be cleaned every year or two as required.



Through Bushing Insulators

This is one of those through bushings used to connect the power supply to the field.

These are hollow to allow the bus bar to pass through.

This type of crack was likely caused by either stress from the bus bar being too tight or flue gas got inside an corroded the bar and made it swell.

This type of bushing normally has a spring loaded end on one end.

This one also really needed cleaning.

Support Bushing Insulators

This is the actual support bushing that holds up the high voltage electrical field.

These should be cleaned both inside and outside every outage.

Many precipitators can run for years with no cleaning.

Most cannot.

It is really hard to know how long a particular unit will run until you don't clean them and a huge pile of them break.

Support Bushing Insulators

This is a good example of a typical broken insulator.

This vertical crack on the outside looks nice.

On the inside, it likely sparked over causing rapid heating and non uniform thermal expansion. This is what actually breaks most insulators.

There have been cases where the rappers on units were simply hitting so hard that the insulators shattered, but thermal shock from sparking is the most common issue.

Rapper Insulators

Bringing us right to rapper insulators.

This photo actually shows an insulator that failed due to heavy impact.

In this case, it was not because the rapper hit too hard. It was because the clamping mechanism that held the shaft came loose.

Then the end of the insulator laid right against the end of the casting.

This created a lot of shock force as the hammer hit the end of the shaft.

This is another thing to look for. Rapping systems love to come loose and them break themselves.

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This is another example of a rapper insulator.

This one is not broken

See how the ends are clamped. These clamps also have spring washers and defined torque values.

It is also best to tack the nut on rapping systems. The constant pounding and thermal growth together loosen things.

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Anti-Sway Insulators

Anti-sway insulators are used by many manufacturers to stabilize the lower end of the high voltage frames.

They need to be cleaned. Just like the others or they will track over and fail.

Not all manufacturers use these.

Some precipitator that do not use them, should.

Swaying in the lower frames shows up in rhythmic multi-sparking followed by a wait period.

Think of a pendulum swinging and 2-3 sparks coming off every time it gets close to one side.

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Motor Driven Rappers

One of the most popular designs for rapping is the use of a motorized gearbox to turn a shaft with tumbling hammers.

In many cases the motor is installed in the vertical position with the shaft pointing down.

For some reason just below the doors is a favorite location, making the motors into steps from entering the precipitators.

Change these motors to TENV and eliminate many issues with crushed fans and housings.

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Tumbling Hammers

All tumbling hammer type systems have to 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.

In this case we see the result of fatigue of the steel from all of that repeated pounding.

In most cases 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.

Failure like this are harder to find and are just waiting to fail right after going back online.

Before everyone says “ wow, bad weld. It broke right through the center of the weld.”

Why was there a weld here?

Because this is where it broke before.

Instead of replacing the failed hammer they welded it back. (never works)

It’s best to just replace the hammer.

Most of the designers of these systems will actually tell you it is best to simply replace them all on a schedule.

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.

So. 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.

Always take a look at the bearing supports also.

In this case the support was a fabricated piece that basically held up the bearing off center off 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.

Electromagnetic Rappers

Another popular rapping method is the use of an electromagnetic coil to raise a steel plunger and then drop it.

In this picture we have one of these electromagnetic rappers mounted on a shaft on the precipitator roof.

Note how it 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.

Mounting Arrangements

This is actually that same rapper from the previous slide.

Note how the sleeve of the rapper itself is significantly larger than the shaft it is mounted on.

This is what is allowing it to lean.

So the issue was built in during installation and now the plant has to deal with the maintenance.

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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.

Here we see that the vertical rapper pipe sleeve that normally has the seal on it is completely gone and the roof around it is corroded out.

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.

Rapper System Welds

This is a picture of the joint between an electromagnetic rapper shaft and the anvil 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.

Many times cold rolled high carbon steel shafting is also used to make these shafts and they tend to harden when they are welded.

These cracks can be hard to see, so you have to look at each shaft.

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Steel Rapper Sockets

Many designs use a steel rapper socket so that the shaft is just inserted in the socket.

This provides a large area for welding.

In this case the contractor welded everything so cold the weld is actually smooth on the flat surface.

I have actually found that socket such as these can be installed using compression fasteners such a Huck™ bolts to great effect.

Another design for connecting electromagnetic rapper shafts to the collecting curtains.

This one works by actually just guiding the shaft and not trying to hold it tight.

This worked well until the bolt holes shown here began to wear allowing the whole object to lean.

Once it started leaning the shaft acted like a jackhammer and broke its way through everything else.

Another use of this design spanned across two collecting plates and had far better results and even loose or worn bolts holes remained flat.

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Collecting Plate Mounting

Of course all of that rapping force is intended to go to the collecting plates.

The 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 simply a different collecting plate design.

There are two bolts at the top of the pad that bolts up 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.

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 end result was the large horseshoe crack shown here.

Rigid Electrode Erosion

Earlier we covered erosion of walls and components.

Here is an actual photo of a rigid electrode that has been eaten away by the sandblasting effect of poor gas distribution.

Rotary Valves.

We are not going to get into ash handling systems here today because we just won't have the time.

But, I just want to say that if the blades in the rotary valve look like this, it's a problem.

In this case, air was being pulled up through the valve sucking all the ash back into the precipitator.

When the unit failed a performance test we checked the particle sizes and our average particle size was over 100 um.

This tipped us off to a precipitator bypass issue.

So, check the valves in the ash system. Make sure they seal.

Discharge Electrodes

Now that we talked about everything except the working parts of the precipitator, we will look inside the units.

In this photo we see a typical broken wire. This is a particular design, but all wires break.

In this case, the wire did not short anything out and the operators had no idea it was loose until we went inside and looked.

Not all broken wires are anywhere near this easy to see.

Not the same wire, but I do believe it is a wire in the same precipitator.

In this case the wire actually laid out through the field and shorted out the electrical section.

Alignment

I made this title bigger because it’s just that important.

Here we see the effect of misalignment on a collecting curtain.

Once a hole is developed there is an edge on the grounded side.

Precipitators use negative charging because a sharp edge on the positive side will arc at a 20% lower value.

So after there is an edge, even fixing the alignment will not recover the power levels correctly.

This is just another example of the same type of damage.

This is how this looks when the hole first occurs.

Ok, in this case the wavy looking bar is actually the alignment bar for the collecting plates.

High hopper levels shoved some things around and the bar was pretty bent up.

If you look you can see one collecting curtain not being held at all.

And others that are held to the bar via tie wire.

This will not last very long and may not even last until the next outage.

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 so much required.

This photo is the distance from the discharge electrode to the collecting plate.

This photo is the other side of the same electrode.

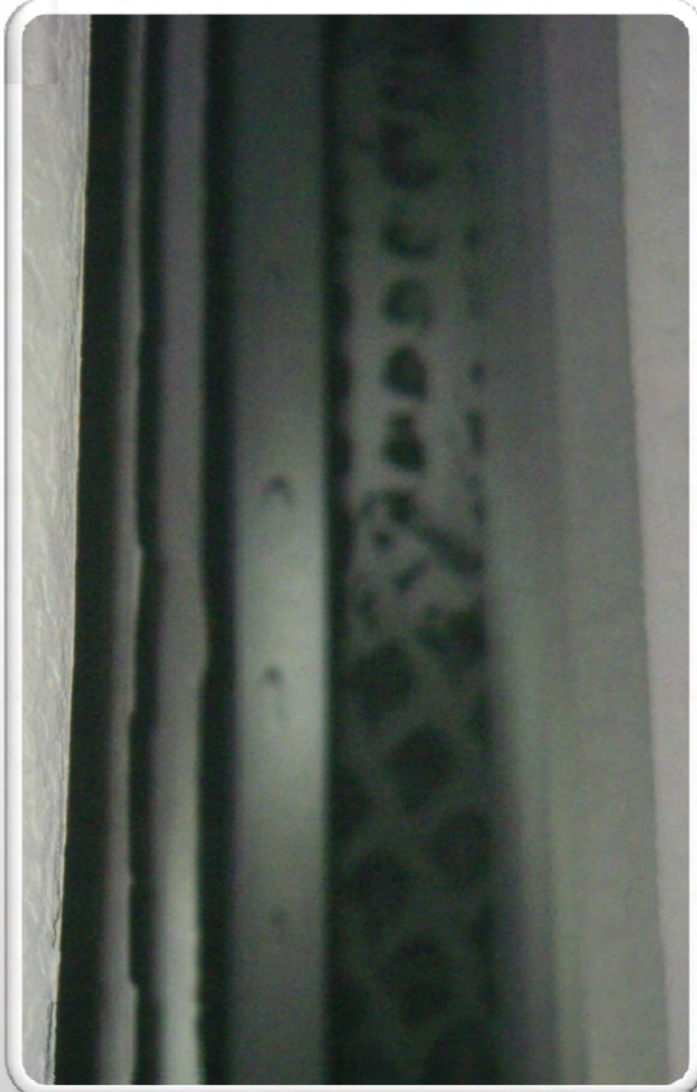
Another photo of misalignment.

This one looking down from the side walkway at the lower framing.

And yet another photo of an alignment issue.

In this case we can see the rigid electrode nearly touching the collecting curtain.

Also…note the fallen piece of perforated plate on the other side of the field.

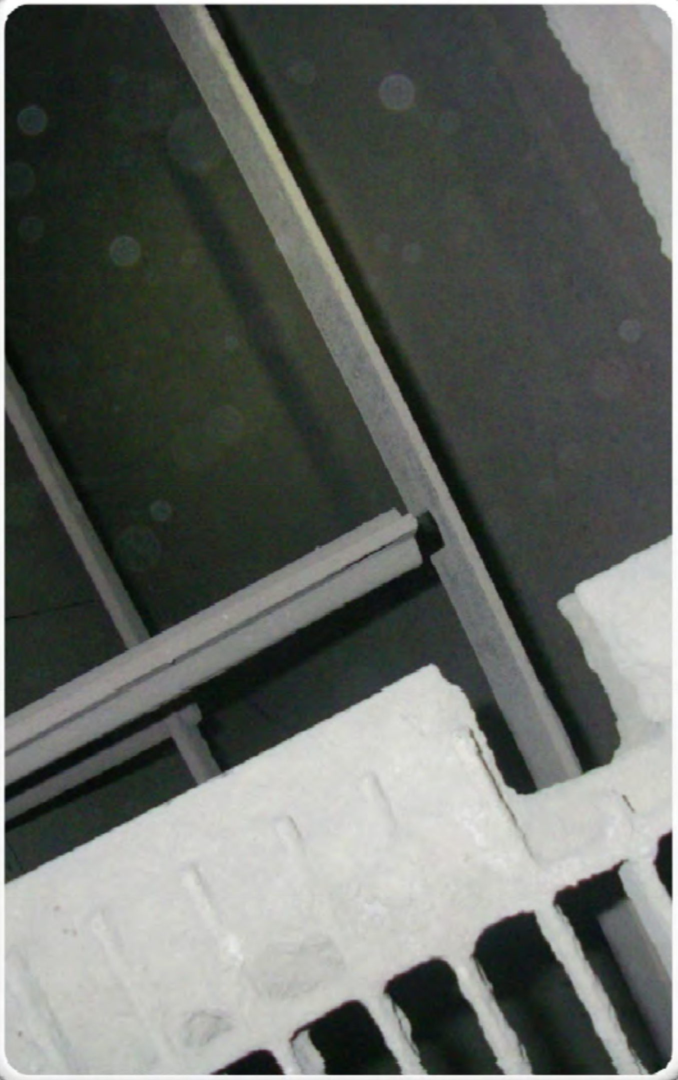


Construction Errors

Just because the unit has operated for a year since the construction, doesn't mean everything is all right.

In this case, the connector that holds the collecting plate to the lower alignment bar was never installed.

This field had never operated at full power and no one knew why.



This is another case where the collecting plate has come loose from the lower alignment bar.

In this case, the pipe once had a sleeve that connected here that has fallen out.

Once this connection comes loose the collecting plate can swing causing odd intermittent clearance issues.

Corrosion

This picture is actually looking up at the bottom of a collecting plate.

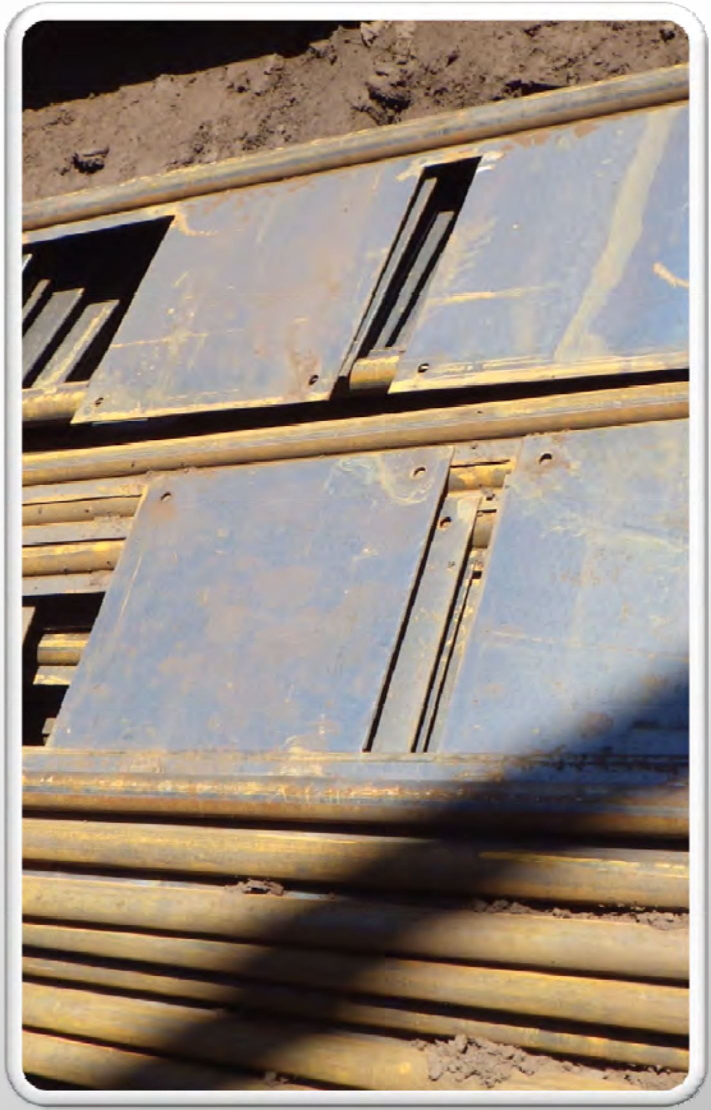
As you can see it is paper thin and falling apart from corrosion.

Patch Plates

In this case sandwich style patch plates were used to completely replace the bottoms of the collecting plates.

This type of repair, while effective, only lasts 5 or so years depending on the corrosion of the upper sections of the collecting plates.

It is also very labor intensive.



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Please Remove Falling Objects

In this picture is a electrode weight just sitting alone on the lower frame.

It might sit there forever, or it could flip over and fall off.

If it plugs up the ash system it could cause an outage.

It could also prevent people from entering the hopper.

Operation and Maintenance Electrostatic Precipitator "Mechanical"

Tim Mallory

Question and Answer

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