MATS Solutions for Oil-Fired Power Plants
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ABSTRACT
The utility power industry is approximately halfway into the Mercury and Air Toxic Standards (MATS) compliance window with less than 18 months until the compliance deadline (pending further extensions). The MATS rule, which became effective April 2012, further limits the amount of mercury, acid gases and other toxic pollution emitted from utility boilers. For oil-fired utility boilers, the specific pollutants addressed in the MATS rule are filterable particulate, hydrogen chloride and hydrogen fluoride.

The prelude to the MATS rule was released in April 2011, at the time known as the Utility MACT rule. As a result of comments received, the final MATS rule ended up being much different than the proposed Utility MACT rule.

As Siemens was actively involved on an oil-fired utility project at the same time that the MATS rule was being finalized, much investigation was done in order to arrive at a solution which would meet MATS. In addition to the specifics of the MATS rule, this paper walks through the investigation that was done for the project, some of the project challenges that were faced, and details one possible solution for older units needing to achieve MATS compliance.

THE RULE
The specific MATS emissions limits in the final rule for existing oil-fired boilers are defined in Table 1 below:

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Emissions Limit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Filterable PM</td>
<td>0.030 lb/mmBtu or 0.30 lb/MWh</td>
</tr>
<tr>
<td>Hydrogen Chloride</td>
<td>0.0020 lb/mmBtu or 0.010 lb/MWh</td>
</tr>
<tr>
<td>Hydrogen Fluoride</td>
<td>0.00040 lb/mmBtu or 0.0040 lb/MWh</td>
</tr>
</tbody>
</table>

Table 1: Final MATS Emissions Limits for Existing Oil-Fired Boilers

A couple of caveats to Table 1 are necessary; (1) the above table is based on using continental fuel and (2) surrogates are allowed for both HAP metals and fuel moisture testing (which will be discussed later in this paper).
EMISSIONS INVESTIGATION
Prior to the MATS proposed rule being issued in April 2011, Siemens was actively involved on an oil-fired utility boiler project. The specification developed for this project required Electrostatic Precipitators (ESPs) for filterable particulate collection and opacity reduction. As a result of the evolving MATS rule at the time, Siemens had to investigate multiple scenarios and provide different options to the customer before proceeding with the project.

Particulate Matter Control
As is the case with many utility oil-fired boilers, the existing particulate control was not capable of reliably meeting MATS particulate emissions levels. This particular project had a tubular-style mechanical collector previously installed for particulate collection. The mechanical collector was performing as well as can be expected; with emissions in the 0.03 – 0.04 lb/mmBtu range at a pressure drop of 5-6” w.c and an opacity of 15-20%. As is the case for most tubular mechanical collectors, most likely the mechanical collector was performing well with PM$_{10}$ however total PM removal was inhibited by PM$_{2.5}$ collection (particulate matter of 2.5 microns and less). PM$_{2.5}$ emission is a major contributor to high opacity levels. As the induced draft fan was already limited, it was not possible to increase the pressure loss across the mechanical collector to attain higher total PM removal.

Many oil-fired utilities are finding themselves in similar situations with aging particulate removal equipment based on previous EPA / state regulations. Utilities that have ESPs installed may find it possible to upgrade their equipment depending upon when the ESP was installed (limited by footprint). However with mechanical collectors, this may not be the case. As pressure drop across a mechanical collector increases, the PM removal also increases. However there becomes a point where either the upper limits of the PM removal are reached or the ID fan limit is reached.

When the proposed rule was issued in 2011, emissions limits were placed on Hazardous Air Pollutant (HAP) metals. The requirement was to meet either a total HAP metals emissions concentration or individual HAP metals emission concentrations. As such, Siemens investigated the defined HAP metals and provided guarantees for total HAP metals emission. In order to meet these guarantees, some limitations on the concentration of volatile metals in the fuel were necessary. These limitations were defined to address metals that remain in the gaseous form through a precipitator; metals such as selenium and mercury.

As a result of comments received to the proposed rule, the EPA reissued the final MATS rule with filterable particulate matter emissions limits and eliminated the HAP metals emissions limits. The EPA explains this substitution in the comments section of the rule, stating that they found that control of PM was indicative of the control of HAP metals and that control of
filterable PM provided the best indicator of performance for control of some HAP metals emissions. A comparison of the proposed/final MATS rule is provided in Table 2 below.

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Emissions Limit</th>
<th>Removal Req’d for MATS</th>
</tr>
</thead>
<tbody>
<tr>
<td>HAP Metals (Proposed Rule)</td>
<td>0.000030 lb/mmBtu</td>
<td>98%</td>
</tr>
<tr>
<td>Filterable PM (Final Rule)</td>
<td>0.030 lb/mmBtu</td>
<td>85%</td>
</tr>
</tbody>
</table>

**Table 2: Particulate Removal: Comparison of Proposed & Final MATS Rule**

The final MATS rule allows for surrogates of total/individual HAP metals in place of filterable PM however it is unlikely that utilities will pursue this avenue due to the additional testing complexity of HAP metals. Methods 5, 5B or 17 are typically used for filterable PM emissions testing and Method 29 is typically used for metals emissions testing. While both sampling methods are similar in the field, the laboratory analysis for Method 29 is much more involved and will result in higher lab costs when compared to the filterable PM emissions testing methods.

**Hydrogen Chloride / Fluoride Control**

When the proposed rule was issued in 2011, it was necessary to provide HCl and HF removal at a high removal rate. Depending on the inlet concentration, removal rates in excess of 93% were required in order to comply. Siemens investigated many different options and decided on dry sorbent injection systems. The DSI systems would inject sorbent upstream of the proposed ESPs to achieve the HCl and HF emission limits.

When the final rule was released, the emissions limits were increased as shown in Table 3 below. The HCl limit was increased by a factor of 6 while the HF limit was increased by a factor of 2. DSI would still be required however at a lower sorbent consumption rate than as previously investigated.

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Emissions Limit</th>
<th>Removal Req’d for MATS</th>
</tr>
</thead>
<tbody>
<tr>
<td>HCl (Proposed Rule)</td>
<td>0.00030 lb/mmBtu</td>
<td>98%</td>
</tr>
<tr>
<td>HCl (Final Rule)</td>
<td>0.0020 lb/mmBtu</td>
<td>89%</td>
</tr>
<tr>
<td>HF (Proposed Rule)</td>
<td>0.00020 lb/mmBtu</td>
<td>93%</td>
</tr>
<tr>
<td>HF (Final Rule)</td>
<td>0.00040 lb/mmBtu</td>
<td>87%</td>
</tr>
</tbody>
</table>

**Table 3: HCl/HF Removal: Comparison of Proposed & Final MATS Rule**

With its final ruling, the EPA allowed an interesting and substantial surrogate for HCl and HF emissions. In place of meeting HCl/HF emissions, the surrogate allowed for fuel moisture concentrations of less than 1%. The EPA reasoned that the purpose of this surrogate was to acknowledge that chlorine is not a compound that is typically present in oil however it was...
repeatedly showing up in the EPA ICR data. The belief is that HCl and HF were showing up in the fuel as a result of contamination during shipment. One specific example cited was the ballasting of tanker ships with sea water when the tankers were empty. By placing a moisture-content cap on the fuel, the thought was that it would encourage handling and transport practices to limit salt water contamination and in turn limit the HCl and HF emissions. In order to qualify for the surrogate, the moisture content must be measured daily if fuel is delivered continuously, per shipment if fuel is delivered on a batch basis or a fuel moisture content certification may be provided by the fuel supplier.

For the project Siemens was involved in, the moisture content was less than the 1% cap, allowing a surrogate for the HCl and HF emissions.

PROJECT BACKGROUND
Siemens was awarded the contract for the above referenced project. The utility is located in the Southeastern U.S. and consists of four 800 MW boilers burning No.6 fuel oil with the capability of fuel switching to natural gas. Siemens’ scope consisted of the design, supply and installation of ESPs, ductwork, ash handling, power distribution as well as demolition/modification services of the existing ductwork and modification of the existing mechanical collector.

PROJECT CHALLENGES
Process
The inherent process challenge for ESP collection of oil-fired flyash is mainly due to the large amount of fine particulate at low resistivity. The majority of the particulate exiting the boiler is less than 2.5 micron with as much as 80% < 1 micron. This fine particulate coupled with low resistivity presents a potential particulate collection issue for any ESP as well as possible flyash re-entrainment during rapping. Also, because of the hygroscopic nature of oil flyash, the rapping intensities and frequencies need to be carefully designed as hygroscopic ash can lead to removal issues affecting the ESP secondary power.

On top of the challenges with flyash collection, Siemens had to design for additional particulate loading from potential activated carbon and dry sorbent injection systems. The net result of this additional loading was estimated to increase the particulate loading to the ESP by about 25%.

Site Constraints
The site layout was perhaps the most difficult challenge. The layout was not conducive for retrofit work with only minimal space available, multiple underground equipment and limited ID fan capability. These constraints, coupled with a relatively short outage window created quite a challenge.
Figure 1 below shows the existing site arrangement which consisted of mechanical collectors followed by ID fans and a short run of ductwork connecting the ID fans to the stack. Any relocation of the ID fans was quickly ruled out due to the outage time concerns and cost. For these same reasons, simply replacing the mechanical collector with an ESP was also ruled out. Next, Siemens investigated the area between the ID fans and stack. In addition to the limited amount of room available between the ID fans and stack, there was a lot of existing equipment in this area both above-grade and below-grade. Siemens settled on placing the ESP in this location. As shown in Figure 2, the ductwork between the ID fans and stack were demolished and in its place the ESP was installed.

The ESP was essentially “shoe-horned” into this location with the inlet nozzles almost directly over the ID fans and the outlet nozzles tight around the stack. This location was deemed the best possible location for the ESP as other locations in the plant were ruled out due to outage duration, cost and the multitude of existing structures and underground equipment. This location allowed some of the civil work to be done while the unit was still on-line and minimized the modifications required to the existing system, allowing a relatively short outage.

**Existing Undergrounds**

One of the major challenges was working around the large amount of below-grade equipment in the area; this equipment included electrical ductbanks, large recirculating water lines, drain piping, process piping, tanks, lift stations and existing foundations. A site survey was done very early in the project to determine the impact that these undergrounds would have on the ESP location; the results of the survey are shown in the isometric drawing in Figure 3 below.
Unfortunately, much of this underground equipment was in the area of potential ESP support columns and could not be moved for various reasons. Typically, support columns on an ESP are located at central load points where vertical ESP casing columns transfer the load down to the support structure. Moving the support columns away from these central load points caused significant load distribution issues. In addition to the existing underground equipment, the ESP support structure had to be high enough to allow truck access underneath the hoppers for ID fan rotor removal and other plant truck access.

In lieu of relocating the underground equipment, Siemens developed a solution that dropped the support columns to grade at intervals where no undergrounds existed. The ESP load distribution issues caused by moving support columns off of central load point locations were alleviated by designing the structure to incorporate a large trussed section into the support structure (shown in Figure 4 below). The resulting support structure was 50ft tall and consisted of a truss section approximately 20ft high to accommodate the load re-distribution with the remaining 30ft to allow for clearance under the ESP. In the end, this solution allowed minimal underground equipment modification / relocation.
**Gas Distribution & Pressure Drop**

With the ESP situated so close to the ID fans and stack, achieving acceptable flue gas distribution was difficult. On top of this challenge, the unit was ID fan limited so there was concern with pressure drop increasing from the existing arrangement.

When the model was first set up, baseline results were poor. Pressure drop was high and the flow distribution was nowhere near ICAC EP-7 guidelines. Siemens ran different models to arrive at a solution which changed the geometry of the nozzles and included different types of internal gas distribution devices. On the inlet nozzle, multiple horizontal and vertical blast plates, perforated plates and vaning were required in order to spread the flue gas evenly to the full height and width of the ESP in the short span of the nozzle. On the outlet nozzle, large sweeping turning vanes were necessary in addition to the vertical channel outlet gas distribution devices. The end result yielded a design that was close to the ICAC EP-7 criteria providing confidence for Siemens to guarantee to meet the emissions requirements. The resultant nozzle configuration is shown in Figure 5 below.

![Fig 5: Final Inlet (left) and Outlet Nozzle Arrangements](image)
In order to accommodate the additional pressure drop of the ESP, the existing mechanical collector needed to be modified. The existing mechanical collector was a UOP design with a side-inlet and a top-outlet, with a tubesheet slanted from inlet to outlet for gas distribution. The UOP design is shown pictorially in Figure 6 below.

![Fig 6: Existing Mechanical Collector Configuration](image)

The internals of the mechanical collector consisted of vaned tubes for dust collection (Figure 7). This type of mechanical collector operates such that the inlet vanes guide the flue gas into the tubes, creating a centrifugal force. This centrifugal force induces a spinning gas stream in the tube, pushing the dust to the outer wall of the tube. The ends of the tube are open to allow dust to fall out the bottom of the tube by gravity and to allow the clean flue gas to exit through the top of the tube.

![Fig 7: Mechanical Collector Internals](image)

In order to obtain high particulate removal, these types of dust collectors generally require high system pressure drop. For Siemens’ project, the goal was to reduce this system pressure drop in order to allow for the needed pressure drop through the new ESP. Many different CFD models were analyzed to accomplish this. Pressure drop was the first priority, however obtaining sufficient velocity through the modified mechanical collector was also important in order to minimize ash dropout.
The resulting configuration is shown in Figure 8 below. With this arrangement, minimum modifications needed to be done to the mechanical collector and only a small amount of steel was being added. The existing tubesheet was cut-away, internals were removed and replaced with baffles to direct the flow, keep the pressure drop low and maintain the velocity in an acceptable range. The mechanical collector was essentially converted to a piece of ductwork; the rest of the mechanical collector casing was reused so no additional structural steel was required. With this modification, approximately 5” of pressure drop was gained for the ESP system.

![Fig 8: Mechanical Collector: Existing (left) and Modified (right)](image)

Pass-Through Insulator Failure
One unexpected challenge that arose during the project was multiple failures of high voltage pass-through insulators during initial startup. Pass-through insulators, or sometimes referred to as “feed-through” insulators, provide a positive separation of the clean and dirty flue gas side while still allowing the high voltage bus to enter the ESP casing. These insulators typically have high alumina content and include a steel flange for mounting.

At startup of the ESP, high spark rates were observed on many electrical bus sections and upon closer inspection, multiple failures of the pass-through insulators were observed. The failures occurred at the steel flange of the insulator (Figure 9). The initial thinking was that excess moisture was causing the arcing and subsequent failures as the weather enclosure roof had not been installed yet. However, this phenomenon was repeated with replacement pass-through insulators after installation of the roof.

![Fig 9: Pass-Through Insulator Failures](image)
Siemens’ pass-through insulator design utilizes a bus bar that travels through the core of the insulator. This design was previously successful on all of our installations of this type. The only difference between this installation and others was that the high voltage source was a high-frequency T/R in lieu of line frequency T/R. In discussions with Siemens’ suppliers for this project, this issue had not been encountered before by the T/R supplier or the insulator supplier. So Siemens sought to replicate this phenomenon in the shop under controlled conditions mimicking the actual installation.

As can be seen in Figure 10 below, arcing begins to occur inside the insulator between the bus bar and the steel flange as the T/R ramps up. The flashover in the picture on the right arcs through the thickness of the insulator to the metal flange, cracking the insulator. The shop testing replicated exactly what was happening in the field.

Most alumina insulators have a dielectric strength of at least 200 v/mil at room temperature. However the dielectric strength is inversely proportional to frequency and temperature such that as frequency and temperature increase, the dielectric strength decreases. The ceramic can actually self-heat due to this dielectric strength loss. So at a frequency of 25 kHz, the dielectric strength was reduced to the point that the bus voltage exceeded the insulator shielding voltage and the insulator could no longer shield the high voltage from the grounded steel flange.

Siemens’ solution for this challenge was to replace the existing bus bar with a shielded cable (Figs 11&12). This insulated cable provided an additional 20 kV of shielding on top of the insulator rating. After this fix was installed, there have not been any more repeated failures.
ESP PERFORMANCE
At the time of this paper, two of the four units have been installed with successful performance for both units as shown in Table 4. During performance testing of the first unit, the ESP was still encountering the problems with the pass-through insulators, and as such, limited the T/R power into the ESP. However the first unit was still able to achieve successful performance despite the issues. For the second unit, the pass-through insulator issue was rectified and the T/R power consumption was increased to about 75% of the T/R design rating as is evident in the much lower emissions results. Also note that the increase in T/R power did not necessarily improve the already-low, 6-minute average opacity however the increase in power did help to reduce the instantaneous opacity spikes considerably. The pressure drop across the system was actually reduced from the baseline condition by 1.5”-2” w.c.; this was remarkable considering the additional equipment and modification of the existing equipment.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>1st Unit</th>
<th>2nd Unit</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissions (FPM)</td>
<td>0.010 lb/mmBtu</td>
<td>0.0022 lb/mmBtu</td>
<td>0.010 lb/mmBtu</td>
</tr>
<tr>
<td>Opacity (6-min ave)</td>
<td>2%</td>
<td>2%</td>
<td>5%</td>
</tr>
<tr>
<td>Opacity (instantaneous)</td>
<td>6%</td>
<td>2%</td>
<td>10%</td>
</tr>
<tr>
<td>Power Consumption</td>
<td>½ of Expected</td>
<td>Expected</td>
<td>-</td>
</tr>
<tr>
<td>Pressure Drop</td>
<td>Approx 1.5” savings from baseline</td>
<td>Approx 2” savings from baseline</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 4: ESP Performance (2 of 4 Units)

SUMMARY
In summary, there are multiple avenues available to oil-fired utilities for achieving MATS compliance. In most cases, specifying the water content in the fuel will allow utilities to only have to meet the filterable particulate matter limit. In order to do this, upgrades to existing ESP equipment may be possible however would have to be reviewed on a case-by-case basis. Mechanical collectors will likely need replaced with ESP(s). The Siemens project detailed above shows one such project where the mechanical collector was unable to achieve MATS compliance reliably, and required replacement with an ESP. This project shows one example of a cost-effective way to achieve MATS compliance in a short outage time frame with a plant that was not conducive to air pollution control expansion.
REFERENCES

