Novel Mercury Control Strategy Utilizing Wet FGD in Power Plants Burning Low Chlorine Coal

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ABSTRACT

Several processes have been developed to cost effectively remove mercury and other heavy metals from combustion gas of coal-fired power stations. Preferred technologies utilize the synergies of existing air pollution control equipment, specifically wet flue gas desulfurization (FGD) for sulfur dioxide (SO_2) control. However, several power stations cannot convert enough elemental mercury (Hg^0) to ionic/oxidized mercury (Hg^{2+}) to achieve the desired mercury removal efficiencies. This could be caused by the lack of a Selective Catalytic Reduction (SCR) system for NO_X control upstream of the wet FGD or the type of coal burned in the unit, for example low-halogen coals such as Powder River Basin (PRB), lignite. To ensure almost quantitative oxidation of mercury, Evonik extended its patented mercury capture process to achieve the desired removal rates of greater 90% by utilizing a second patented technology, an additive to the coal. The patented addition of calcium bromide ($CaBr_2$) is a well known low cost method to oxidize mercury for facilitating its absorption in the wet FGD slurry. The absorbed mercury is captured by adsorption onto powdered activated carbon (PAC) suspended within the FGD slurry and separated in the FGD waste water treatment system.

The first step of the process is Vosteen Consulting's patented technology[14] of bromide addition to the coal prior to combustion in order to maximize the oxidation of mercury in the combustion gas. Once the mercury, which is released from the coal as elemental Hg^0 in the gas phase, is oxidized to Hg^{2+}, it can be easily absorbed into the wet FGD slurry, to which submerged PAC has been added. The absorbed, oxidized mercury dissolved in the FGD slurry adsorbs onto the suspended PAC. This increases the total capture rate of Hg in the wet FGD absorber, and prevents re-emission issues otherwise often associated with wet FGD's. The mercury laden PAC is removed from the FGD slurry during the normal gypsum separation and processed with the FGD blowdown in the FGD's waste water treatment system.

The PAC laden with mercury and other dissolved heavy metals, such as for example selenium halogenide, remains in the FGD waste water stream, which is treated in a two stage FGD waste water treatment system. The FGD waste water treatment system is designed such that it generates two distinctly different types of filter cakes. One filter cake, which amounts to approximately 97%wt of the combined filter cake, is the virtually mercury and heavy metal free fraction. The second filter cake accounts for the remaining balance and consists of a mercury and heavy metal rich fraction.

Evonik's patented mercury control technologies include the addition of PAC to the wet FGD absorber as well as the selective mercury removal in a specially designed two stage FGD waste water treatment system. Work began in 2004 and was extended in 2009 to include the addition of $CaBr_2$. Extensive full scale testing in Evonik's coal-fired power plants revealed a Hg oxidation of well over 95% as well as a total mercury capture rate of greater 95%. This paper discusses the technologies, equipment used including measurement equipment and details of the test results.

INTRODUCTION

In addition to the commonly regulated emissions of coal-fired power plants (particulate, SO_2, NO_X), mercury is becoming an increasingly greater concern. Mercury is a potent neurotoxin that can have a significant effect in the aquatic environment and thus the food chain. Coal-fired power plants have been identified as one of the major sources of anthropogenic mercury emissions and with the new Clean Air Rule recently released for comment by the EPA, it must be expected that coal-fired power stations will be required to reduce their mercury emissions by more than 90%.

Mercury enters the power plant process as a trace component contained in the coal combusted. As shown in Figure 1, there are only four possible paths for mercury to leave the power plant process, namely with the ash, with the flue gas cleaning byproducts (for example gypsum), with the waste water, and with the flue gas.
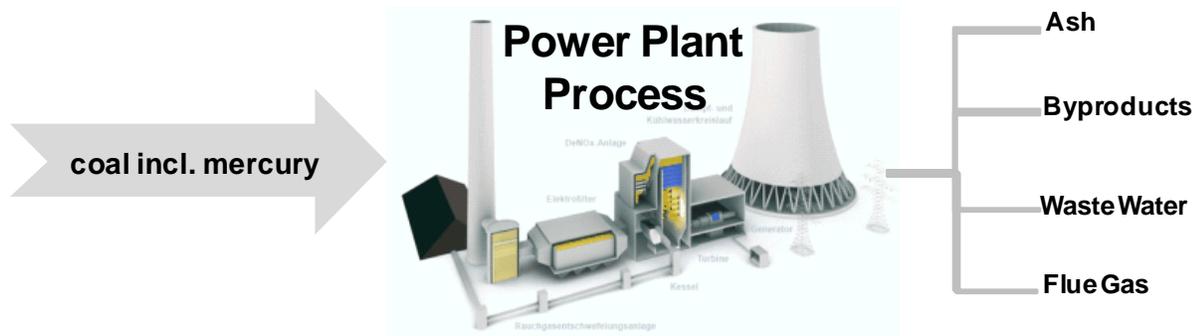
Figure 1: Four different ways of mercury to be emitted to the ecosystem

To achieve a consistently greater 90% mercury emission reduction, several possibilities exist and have been explored. These include preventing the mercury from entering the process including cleaning the coal before it is combusted. Other, economically more reasonable possibilities include:

- Adsorbing the mercury onto the fly ash – mainly on its unburned carbon if present – or onto a carbonaceous adsorbent, if additional PAC, injected upstream into the flue gas and removed again in a particulate collection device downstream, for example a baghouse.
- Absorbing the mercury in a liquid, usually in a wet FGD system and chemically binding it in a solid form, in which it often ends up in the FGD byproduct, i.e. partially in the gypsum and mainly at the waste water treatment sludge.

The concern with these processes is that they may transfer most of the mercury from the flue gas stream to other streams to be discharged from the power plant. These other discharge streams then must be treated for mercury again in order to fully prevent the mercury from entering the biosphere. Mercury captured in ash might leach out from the disposal area, i.e. from the ash pond into the aquatic environment or evaporate from there into the atmosphere. Mercury in solid byproducts such as gypsum also has the potential to limit their use and/or disposal as such use or disposal may result in the mercury being emitted back to the atmosphere in a later applied process, i.e. during thermal calcination of the gypsum (calciumsulfate-dihydrate) to form plaster (calciumsulfat-halfhydrate) for wallboard manufacture. Mercury washed out of the coal before burning (pre-combustion treatment) will be found in the washing solutions, which must be treated in order to avoid discharge into the aquatic environment. Mercury dissolved in the FGD waste water released from the power plant process without treatment will also enter the aquatic environment directly. Mercury emitted into the atmosphere with the flue gas will be washed out by rain into the aquatic environment. Without any additional efforts, all these described pathways are undesirable. Therefore, it is vital to find the most efficient and cost effective method that will not allow mercury to be released back into the ecosystem, but sequester it in a controlled fashion.

There are two conventional methods for capturing mercury in a coal-fired power plant. The first method employs PAC injection into the flue gas followed by a particulate collection device, for example a baghouse. Such PAC injection systems utilize large amounts of non-halogenated PAC or a somewhat smaller amount of halogenated PAC and therefore will become quite expensive for power plant operators. In addition, the PAC and mercury is captured in a particulate control device and will – if no other means are chosen (e.g. the TOXECON II process of US EPRI) – be removed with the fly ash, which can potentially inhibit ash use and/or make ash disposal difficult. The second method utilizes the co-benefit of a wet FGD system installed for SO_2 control. Oxidized mercury is highly water soluble and absorbs willingly into the wet FGD slurry, thus being removed from the flue gas. However, the absorbed oxidized mercury can not only contaminate the gypsum but can also be reduced back to the volatile elemental mercury. Reduction of previously absorbed oxidized mercury followed by desorption from the wet FGD slurry back into the flue gas is a phenomenon commonly referred to as re-emission of mercury.

In order to be absorbed into the FGD slurry, the mercury must be oxidized. Mercury can be oxidized by means of several processes. This can be accomplished after the combustion process during boiler passage via a reaction with gaseous halogens, preferably bromine, but also some chlorine. The halogenation of mercury can be greatly enhanced when passing also across the catalyst of a SCR system. Unfortunately, many coal-fired units are unable to convert enough elemental mercury to oxidized mercury to enable the desired high overall capture rate. This is typically due to firing low-halogen coals such as PRB coal or lignite or the lack of a SCR system upstream of the wet FGD to assist in oxidizing the mercury.

In order to ensure complete oxidation, minimize the cost of PAC, eliminate re-emission issues associated with a FGD and sequester the captured mercury in a controlled fashion, a novel control technology was developed. Combining Vosteen Consulting's bromide addition to the coal prior to combustion, with Evonik's patented PAC injection into the FGD absorber, and Evonik's patented selective two stage FGD waste water treatment system, mercury is not only captured and removed effectively from the flue gas but also sequestered in a controlled fashion via the FGD waste water treatment system. During the FGD waste water treatment process, the mercury is chemically desorbed from the PAC and then selectively precipitated out in a very small fraction of filter cake that is finally disposed off in a hazardous waste landfill unless recycled. This allows the operator to know at all times where the captured mercury resides at the end of the process and it does not affect the use and/or disposal of any of the other coal-combustion byproducts.

DISCUSSION

Oxidization of Mercury

It is well known that oxidized gaseous mercury is highly water soluble and therefore can be effectively removed from the flue gas in a wet FGD while elemental mercury is not water soluble and cannot be removed easily.

During the combustion of coal and other mercury containing fuels, mercury is first released as elemental mercury due to the high temperatures of combustion. However, as the combustion gas cools in the boiler, chlorine and bromine begin to oxidize mercury (Hg^0 to Hg^{2+}). In the case of chlorine a greatly simplified summary reaction may be described as:

$$4HCl + O_2 \rightleftharpoons 2H_2O + 2Cl_2$$

$$Hg + Cl_2 \rightleftharpoons HgCl_2$$
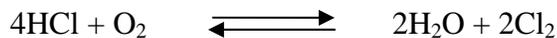
In the case of bromine the corresponding, greatly simplified summary reaction may be described accordingly as:

$$4HBr + O_2 \rightleftharpoons 2H_2O + 2Br_2$$

$$Hg + Br_2 \rightleftharpoons HgBr_2$$
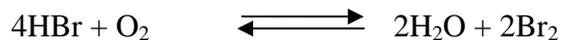
Detailed, more correct reaction sequences, as developed more recently by Niksa [19], consider very large sets of reaction sequences, including reactions with atomic halogens rather than only diatomic molecular halogens as reflected here for simplicity reasons. Of course, such detailed models for calculating mercury oxidation and mercury capture cannot be designed for the purpose of being easily understood. Thus the basic differences in mercury halogenation behaviors at elevated temperatures, as discovered and made plausible by Vosteen almost ten years ago, are presented here once gain.

The first equation of each simplified summary reaction refers to the so-called Deacon equilibrium. In case of chlorine the equilibrium lies mainly on the left side, meaning the preferred species is HCl, which, however, as such is not effective in mercury oxidation. While in case of bromine, the equilibrium lies far on the right side with Br_2 as the preferred species. It may be noted that in case of coal-born fluorine the corresponding Deacon equilibrium calls for the formation of nearly 100 % HF only, which again is not effective in mercury oxidation. Finally, the small amount of coal-born iodine is also highly effective for mercury oxidation – theoretically even more than bromine. However, iodine is rather expensive and shows considerable disadvantages in wet mercury capture, because HgI_2 has the highest vapor pressure of all halogenated Hg^{2+}-species.[5]

The presence of a sufficient concentration of halogens in the combustion gas is critical for the effective oxidation of elemental mercury. Coals that have low native halogen contents do not provide the necessary amount of halogen molecules to the combustion gas for achieving the wanted mercury oxidation. As explained above, "chlorine" is not a very effective oxidizing agent for mercury, because most of it is present in the form of HCl. Higher SO_2 levels in the combustion gas affect the ability of chlorine to oxidize mercury, since SO_2 will consume the intermediately formed chlorine again further down the boiler, thus preventing mercury from becoming sufficiently oxidized. The effect of SO_2 consuming formed Cl_2 again was demonstrated experimentally in large scale tests at a hazardous waste incinerator while SO_2 will not consume molecular (or atomic) bromine within the temperatures range in a boiler. [15, 16, 17, 18]

To summarize: When combustion gas cools to below approximately 1,400°F and direct halogenation of the metallic mercury Hg0 becomes thermodynamically favored, there will be only a very small supply of Cl2. Whereas, if the bromine content of the coal is high enough, there will be ample supply of Br2 (typically 1 to 10 ppm in coal) for oxidizing those varying amounts of mercury:

$$Br_2 / Hg \gg 1$$

$$Hg + Br_2 \Rightarrow HgBr_2$$
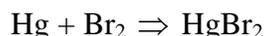
Putting these facts together, it is easily understood that bromine is a crucial factor in mercury oxidation, as first advanced at *Air Quality IV*, 2003[15]. This notion has the important practical corollary that for coals that show low mercury oxidation, this can be changed by addition of small amounts of bromine compounds to the coal or the hot side of the boiler, whereby a

predictable halogenation of mercury will be achieved during boiler passage down to the cold end of the boiler.

Vosteen Consulting owns a patented process to ensure sufficient oxidation of mercury, where a bromine containing compound is added to the coal prior to or during its combustion[14]. In North America, Vosteen Consulting has licensed the technology to ALSTOM, which markets $CaBr_2$ as KNX™ for addition to the coal prior to combustion.

Figure 2 provides a graph based on large scale test results as achieved already in 2001 at the hazardous waste incinerator of CURRENTA in Germany [15, 17, 18]. The combustion gas was continuously spiked with mercury to about 160 µg/dscm. As shown in the graph, a significantly greater amount of chlorine as compared to bromine is needed to provide the desired oxidation.
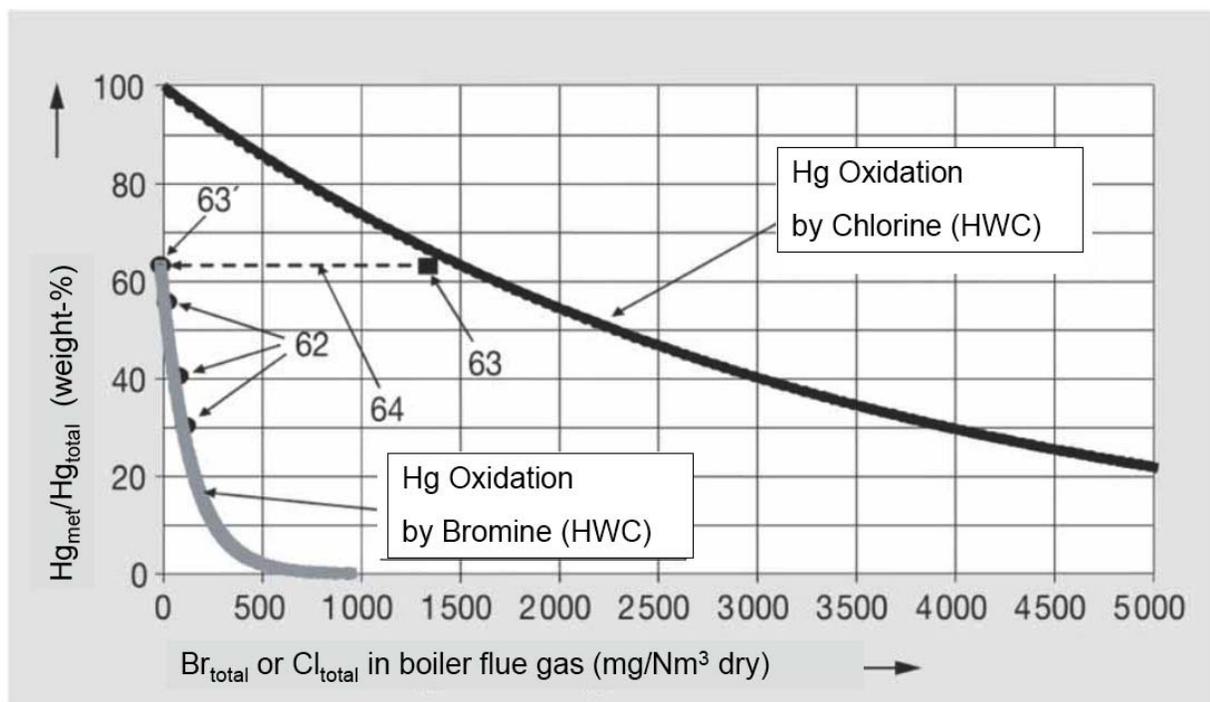

Figure 2: Mercury oxidation by chlorine and bromine [16].

In addition to the halogen content of the coal, the presence of a SCR system upstream of the wet FGD will greatly facilitate the oxidation of mercury in the flue gas. The reason is that the SCR catalyst promotes all reactions involved, at least after completion of the desired DeNOx reaction.

Mercury in the Scrubber

Because oxidized mercury is water soluble, a wet FGD is ideal for its capture from the flue gas. A wet FGD is often an already installed piece of air pollution control equipment at the plant and already inevitably utilized at least for partial mercury control. However, there are typically two issues associated with this more or less coincidental mercury capture.

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The first issue is the problem of possible re-emissions of mercury. This phenomenon occurs when absorbed oxidized mercury in the FGD slurry is reduced back to elemental mercury caused by sulfites. It was observed during mercury speciation testing in the flue gas that greater concentrations of elemental mercury were measured at the outlet of the wet FGD than at the FGD inlet. Because elemental mercury is not water soluble and highly volatile, it desorbs from the FGD slurry back into the flue gas again. Mercury reduction and re-emissions are typically a result of the distribution and the relative quantities of the oxidizing and reducing components within the absorber slurry, which are characterized as the oxidation reduction potential (ORP) of the absorber slurry. The second issue is the problem of simply transferring the mercury from the flue gas via absorption into the absorber slurry to the FGD byproducts, such as gypsum and waste water treatment sludge. Numerous power stations sell their gypsum, either to cement or gypsum wallboard manufacturers, where it is heated in the related processes. This can result in a release of the mercury contained in the gypsum to the cement kiln or calcination flue gases. This results in a mercury emissions problem for the cement or wallboard manufacturer. Any transfer of mercury from coal combustion flue gases to other thermal treatment process flue gases should be avoided. Mercury emission reduction at such plants is an important issue as well.

In order to enhance Hg^{2+} absorption into the FGD slurry as well as preventing re-emissions and other associated issues, Evonik developed and patented a process in which PAC is injected either into the flue gas, prior to the wet FGD absorber, or directly into the absorber slurry itself. The absorbed, oxidized mercury does not remain dissolved in the slurry, but is rather adsorbed in the absorber slurry onto the surface of the suspended PAC, thus preventing the mercury from being reduced and re-emitted back into the flue gas again. Other absorbed and at least partially dissolved heavy metals such as selenium are also adsorbed onto the PAC, which offers a significant potential co-benefit of the technology. The heavy metal laden PAC can then be quantitatively separated from the gypsum and transferred to a two stage FGD waste water treatment system. There, the mercury can be chemically desorbed into the liquid phase again, selectively precipitated and removed from the discharged waste water to be concentrated in a very small fraction of the filter cake.

Solution

In order to prevent all of the issues associated with low halogen coals and wet FGD systems, Vosteen Consulting and Evonik jointly conducted a full scale test to apply and optimize the combination of their technologies. The goal was to prove the benefits of this combination for plants that either burn low halogen coals, or that do not have a SCR system upstream of their ESP and scrubbers. In order to accomplish this, Vosteen Consulting and Evonik selected Evonik's Marl Cogeneration Plant in Marl, Germany. The Marl Cogeneration Plant's 375 MW, pulverized bituminous coal-fired Unit 5 is equipped with a conventional cold-side ESP, a wet limestone, forced oxidation FGD and a tail-end SCR. The unit also burns some small amounts of liquid wastes from the various facilities around the chemical park, in which the plant is located and which it supplies with process steam and electric power. This causes a wide range of inlet mercury concentrations and oxidation rates. The testing utilized both bituminous coal only and varying blends of coals and liquid waste streams. A general schematic of Marl's Unit 5 flue gas path is shown in Figure 3.
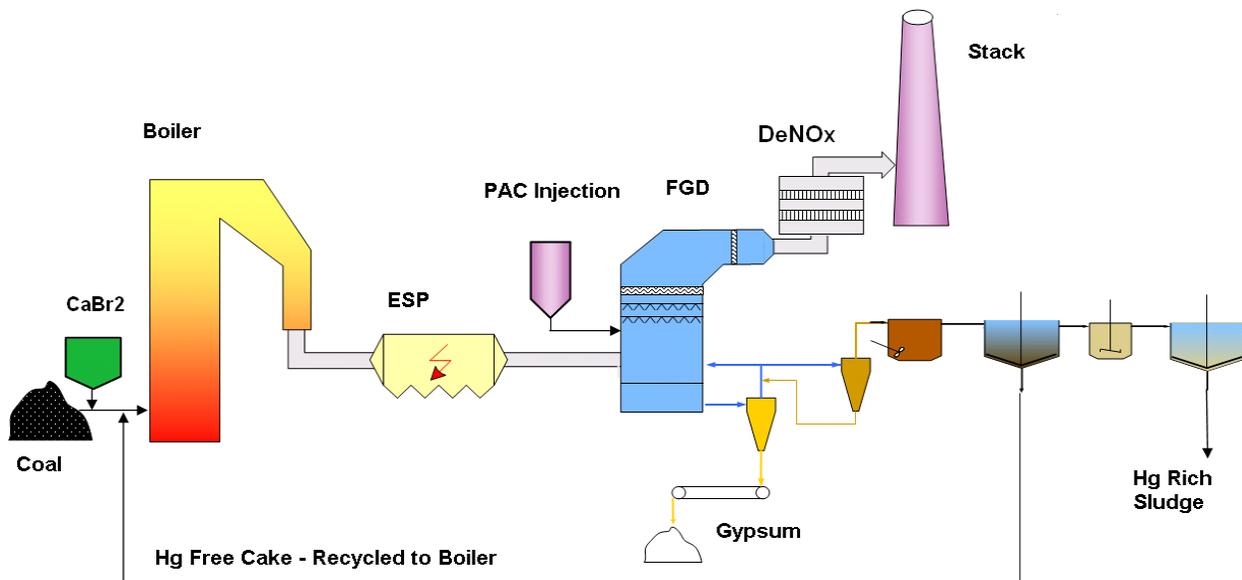
Figure 3: Total mercury removal process with $CaBr_2$ addition, PAC addition to the wet FGD and a two-stage FGD WWT system

The first step of the process is the addition of calcium bromide ($CaBr_2$) to all the coal feeders prior to the mills. To ensure maximum mercury oxidation with a minimal amount of $CaBr_2$, a proper additive distribution must be achieved. Therefore, the $CaBr_2$ solution was added equally onto each of the three coal feeder belts. The total $CaBr_2$ addition was designed for a Br/Hg-mass ratio of only 250 ppm of bromine per ppm of mercury in coal, see also former publications[14, 17]. In Marl, this equates to adding approximately one gallon per hour of the 52 % $CaBr_2$-solution to the coal. This was accomplished by installing three metering pumps on top of a 275 gallon (1 m^3) tote. Figure 4 shows the metering pumps (left) and addition points onto the coal feeder belts (right). The dosing and addition arrangement is designed to achieve a homogeneous distribution of bromine relative to the mercury within the furnace, which is necessary for a complete Hg oxidation while minimizing the addition of bromine.

The second step of the process is the injection of PAC either into the flue gas upstream of the wet FGD scrubber or into the scrubber slurry itself, which is the preferred method. The PAC added to the absorber slurry allows the absorbed, oxidized mercury as well as some other dissolved heavy metals, such as for example selenium-halogenide in the slurry to adsorb onto the PAC particles. Hence, the adsorbed mercury removed from the slurry can no longer be reduced and cause re-emission issues often associated with wet FGDs. The PAC laden with the adsorbed mercury and other heavy metals is removed from the absorber slurry via the scrubber blowdown system. To compensate for the removed PAC, fresh PAC is added to the absorber slurry by means of a simple dosing system that adds a mixture of water and a predetermined amount of PAC to the suction side of an absorber recycle pump. This ensures a relatively constant concentration of PAC in the absorber slurry. Tests revealed that the described PAC addition has been able to maintain dissolved mercury concentrations in the slurry of less than 30 ppb, while not more than 2 lb/h of PAC were used in the 375 MW plant.

Figure 4: CaBr$_2$ addition from totes to coal feeders underneath the day bunkers

Figure 5: PAC dosing station and injection point into the suction side of a absorber recycle pump

The heavy metal laden PAC suspended in the scrubber blowdown is separated from the gypsum in primary hydrocyclones. The PAC is sized appropriately such that it is quantitatively separated from the gypsum (along with the adsorbed mercury and some other heavy metals) in the primary dewatering hydrocyclones and passed on with the overflow to the FGD waste water treatment

system. It is critical to ensure that the primary hydrocyclones' cut point is adjusted properly to ensure complete PAC separation from the gypsum.

To verify the amount of mercury removed by the process, four Lumex RA-915+ type continuous mercury emissions monitors were installed at two locations with two analyzers operating in parallel at each location. The first location was at the outlet of the electrostatic precipitator upstream of the wet FGD. The second location was just downstream of the wet FGD scrubber outlet and upstream of the tail-end SCR's regenerative gas-gas-reheater. On both measuring locations, Hg^0 and Hg_{total} were measured continuously. The obtained values were randomly validated using method DIN EN 13211 Hg, which is comparable to the Ontario Hydro method.

In a conventional, single stage FGD WWT system, the heavy metal laden PAC is precipitated along with other particles such as gypsum, fly ash, etc. and dewatered to a filter cake that is then landfilled. The concern with this conventional process is that the vast majority of the filter cake consists of inert compounds such as sulfates, fluorides, fly ash compounds (silicates, aluminates, iron oxides, etc.) which are environmentally uncritical. Yet, because of the comparatively small amount of mercury and other heavy metals contained in the filter cake, it cannot be recycled back to the coal pile, but must be disposed of in Europe as a hazardous waste.

Evonik developed and patented a two stage FGD waste water treatment process, which allows for the selective separation of mercury from the waste water filter cake by effectively splitting the filter cake into two fractions. The first fraction, which typically accounts for approximately 97%, is largely mercury and heavy metal free. The second, very small remaining fraction of typically less than 3% has a relatively high mercury and heavy metal concentration. The advantage of this process is that the large, virtually heavy metal free, inert fraction of the filter cake can be recycled within the plant internally by simply putting it back on the coal pile. Only the very small fraction of less than 3% containing the higher concentrations of mercury and heavy metals must be disposed off in a special landfill. Figure 6 shows a schematic of Evonik's patented FGD wastewater treatment process.
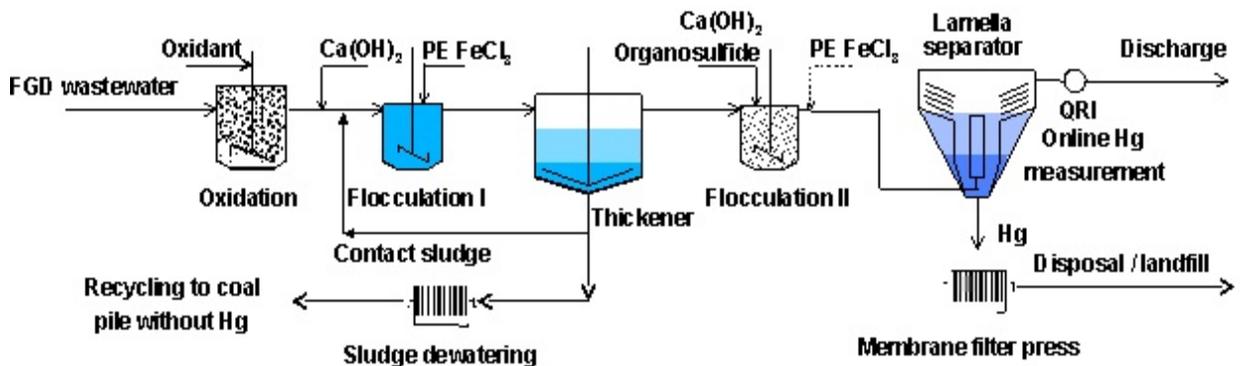

Figure 6: Evonik's patented 2-stage FGD waste water treatment process
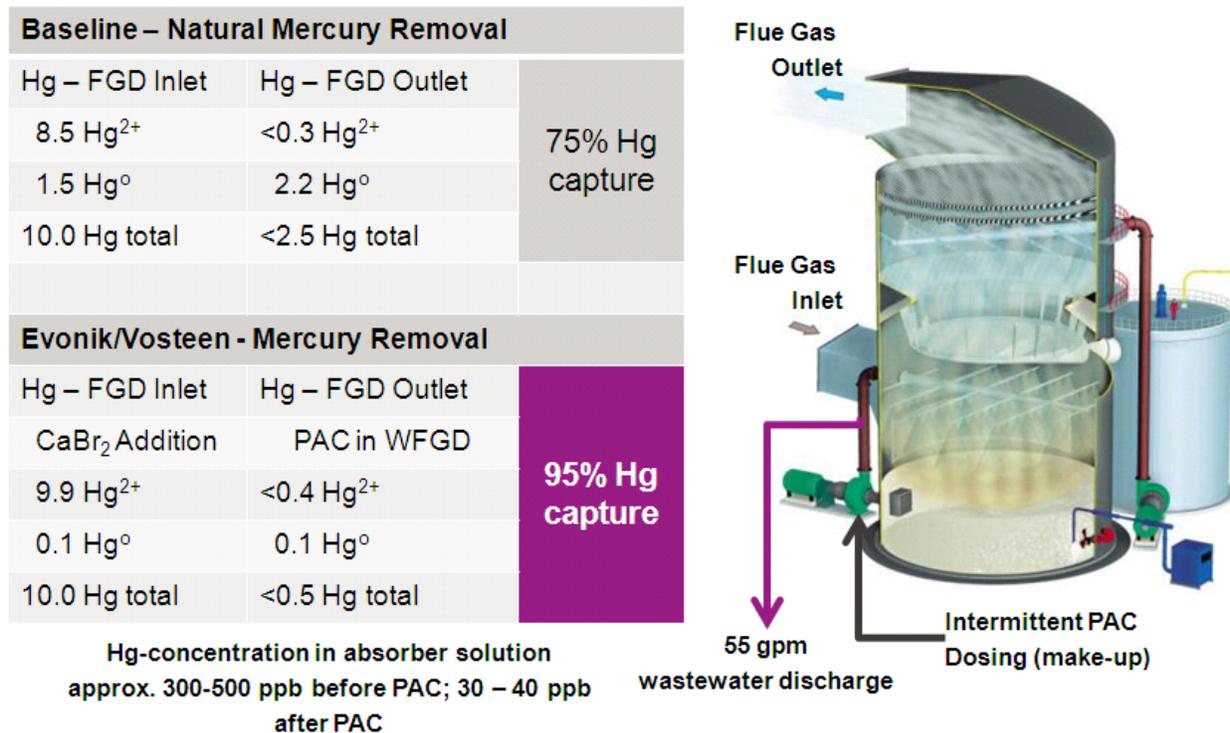
In order to ensure that the mercury adsorbed on the PAC is properly separated from the PAC in the FGD WWT system, it is first chemically desorbed from the PAC. The virtually mercury free

PAC is then precipitated in the first stage of the FGD WWT system and becomes part of the virtually mercury free filter cake, which is recycled back to the coal pile. The desorbed mercury and other heavy metals are precipitated in the second stage of the FGD waste water treatment system and then disposed off with the small fraction of the filter cake.

This process was first installed at Evonik's 1,150 MW coal-fired Herne Cogeneration Station in 2000 and has been in successful operation ever since. Several other Evonik power stations were also retrofitted with this two stage FGD waste water treatment process due to the associated economic benefits including Europe's most modern supercritical 800 MW unit Walsum 10.

RESULTS

Vosteen Consulting and Evonik demonstrated that the combination of their patented technologies work very well together. The addition of the $CaBr_2$ solution resulted in a consistently greater than 95% oxidation rate of the mercury upstream of the wet FGD, starting from between 60 and approximately 80% baseline oxidation without the solution (depending on co-combustion of wastes). These results were confirmed by both the continuous Hg monitors and the sorbent traps and are displayed in Figure 7.


Baseline – Natural Mercury Removal

Hg – FGD Inlet	Hg – FGD Outlet	
$8.5\ Hg^{2+}$	$<0.3\ Hg^{2+}$	75% Hg capture
$1.5\ Hg^o$	$2.2\ Hg^o$	
10.0 Hg total	<2.5 Hg total	

Evonik/Vosteen - Mercury Removal

Hg – FGD Inlet	Hg – FGD Outlet	
$CaBr_2$ Addition	PAC in WFGD	95% Hg capture
$9.9\ Hg^{2+}$	$<0.4\ Hg^{2+}$	
$0.1\ Hg^o$	$0.1\ Hg^o$	
10.0 Hg total	<0.5 Hg total	

Hg-concentration in absorber solution approx. 300-500 ppb before PAC; 30 – 40 ppb after PAC

Flue Gas Outlet

Flue Gas Inlet

55 gpm wastewater discharge

Intermittent PAC Dosing (make-up)

Figure 7: Results before $CaBr_2$ and PAC addition (baseline) and after combining both technologies

Prior to the $CaBr_2$ and PAC additions, the scrubber removed less than 70% of the total mercury, with a significant amount of re-emissions. In addition, the mercury concentration in the absorber slurry was measured to be between 300 and 500 ppb. After the PAC addition to the required level, the total mercury capture rate was greater than 95% on a continuous basis with the detection limits of the Hg monitors being the limiting factor for the reported Hg removal efficiency. The mercury concentration in the FGD slurry was brought down to below 30 ppb.

The next task was to test the hydrocyclones to ensure that the gypsum was not contaminated with PAC or mercury. First, the hydrocyclones were tested and their cut point was adjusted to ensure that PAC would not enter the gypsum with the underflow but rather be carried out to the FGD waste water treatment system with the overflow. During a test performed at the hydrocyclones manufacturer's lab the cut point was set to be sufficient to ensure a proper separation of gypsum and PAC. Subsequent field tests were conducted to confirm that there was no negative impact neither in terms of residual mercury in the gypsum nor the gypsum whiteness.

Finally, the hydrocyclones' overflow containing the heavy metal/mercury laden PAC was treated in the plant's FGD two stage waste water treatment system. In the first stage of the FGD waste water treatment system, more than 85 % of the adsorbed mercury was chemically desorbed from the PAC and brought back in solution. While keeping the heavy metals in solution during this process, all of the non-heavy metal containing particles including the now "mercury free" PAC were precipitated out to become harmless filter cake, which was recycled back to the coal pile. The mercury desorbed from the PAC remained in solution and transferred with the largely solids free waste water treated in the first stage to the second stage. In the second stage, the heavy metals and remaining very fine ash particles were precipitated out in an environmentally inert form (such as for example HgS using TMT15 or PRAVO) and were dewatered to the very small fraction of the filter cake that is disposed off in a special landfill. Figure 8 provides an analysis of each of the filter cake's composition.

First stage filter cake (recycle back to coal pile)   Second stage filter cake (for landfill/disposal)
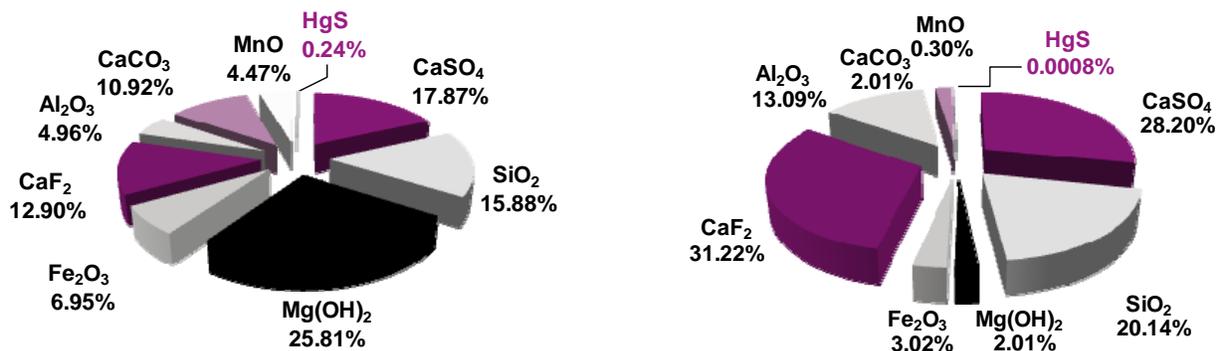
Figure 8: Composition of FGD waste water treatment filter cake fractions

SUMMARY

The effective control of the fate of mercury contained in coal is becoming more important and will have a significant impact on the operation of coal-fired power plants. The key to effective mercury control is not only the removal of the mercury from the flue gas, but also the control of its fate in order to prevent its discharge to the environment through another pathway. For mercury control utilizing the co-benefit of a wet FGD to be effective, the mercury must be in the oxidized state. Some power stations can achieve complete mercury oxidation based on the fired coals' native halogen contents, especially when there is a SCR system available upstream of the wet FGD absorber. For plants that are unable to achieve the required mercury oxidation, a technology such as bromide addition to the coal prior to its combustion must be employed to ensure that the mercury is quantitatively oxidized.

Once the mercury is oxidized, it can be easily captured in a wet FGD. However, traditional systems of dry and wet mercury capture have their associated issues. Conventional PAC injection into the flue gas upstream of a particulate collection device (for example a baghouse) can result in ongoing long term expenses and poses an additional residue disposal issue for any utility. Units that utilize their wet FGDs for mercury emission control can experience re-emission issues and mercury contaminated gypsum. Mercury emissions as part of the FGD waste water discharge result in more and more stringent FGD waste water discharge regulations. Neither is desirable and must be addressed.

In order to achieve the required oxidation needed and the complete capture of mercury, the combination of the two patented technologies was tested full scale and successfully placed in commercial operation at Evonik's Marl Cogeneration Plant. Vosteen Consulting's patented addition of a bromide solution prior to combustion is a simple, cost effective method for ensuring quantitative mercury oxidation, which then can be captured in downstream air pollution control equipment. The patented Evonik process utilizes existing air pollution control (wet FGD and waste water treatment system), thus reducing the overall capital investment and O&M costs. By injecting less than 0.3 lb/MMacfm PAC into the wet FGD absorber, absorbed mercury can be effectively removed from the scrubbing slurry by means of adsorption. Finally, Evonik's patented FGD waste water treatment for selective mercury removal allows concentrating the captured mercury into a very small amount of residue to be disposed off in an environmentally inert form. By combining these technologies to oxidize and remove the total mercury from the flue gas and the FGD waste water, power plants can cost effectively capture and sequester mercury from their flue gas, waste water and by-product streams.

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KEYWORDS

Mercury Control, Bromide Addition to Coal ($CaBr_2$), Powdered Activated Carbon Addition to FGD (PAC), Waste Water Treatment, Selective Precipitation