Enhanced Fine Particle and Mercury Emission Control Using the Indigo Agglomerator

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Abstract: Fine particles are a major health issue as they remain suspended in the atmosphere for extended periods, are able to penetrate deep into the human lung and contain significant concentrations of heavy metals, such as Arsenic. They are also a significant component of the smog that limits the visibility in many cities and even in some national parks plus scientists believe they have an effect on global weather patterns. The Indigo Agglomerator enhances fine particle collection by attaching the fine particles to the larger particles. These large agglomerated particles are easily collected in existing control devices, such as Electrostatic Precipitator (ESP), fabric filters, scrubbers and cyclones. This paper concentrated on PM2.5 particles, that is particles less than 2.5 μm in diameter, including data that was collected on particles down to 50 nm in diameter. It was found that the reduction in fine particle emission from an Electrostatic Precipitator provided by installing an Indigo Agglomerator increases with reducing particle size from a factor of 5 at 2 μm to a factor of 10 at 100 nm. Reductions of this magnitude will have a significant effect on the impact of fine particles on both visibility and health. It will also result in a reduction in heavy metal emissions.Recent regulations in the US require Mercury emission control on coal fired power stations. Mercury is considered a major health hazard because it concentrates in the food chain and, in particular, may result in very high concentrations in some fish. The Indigo Agglomerator enhances Mercury collection by increasing the interaction between the Mercury, in the form of elemental or ionic molecules contained in the gas stream, and the adsorbent, either injected Activated Carbon or using the LOI from the combustion process. Initial tests have shown a factor of four enhancement of the Mercury removal when an Indigo Agglomerator is installed in front of an Electrostatic Precipitator. This is in compliance with the long term EPA requirements in the US.

Keywords: Agglomerator, PM2.5, Mercury, Indigo

1 THE FINE PARTICLE PROBLEM

Extensive research has been carried out on the health effects of Particulate Matter and it is universally accepted that the main cause of health problems are the PM2.5 particles with a diameter less than 2.5 μm, by current convention known as fine particles. The EU Working Group on Particulate Matter in its Second Position Paper on Particulate Matter recommended that PM2.5 should be used "as the principal metric for assessing exposure to particulate matter". This was based on a report by the World Health Organization identifying PM2.5 as the key component of particulate that impacts on health issues.

Although small in terms of mass, the sub-micron fraction contains a very high proportion of the heavy metals, which are initially volatilized in the furnace area and then condense in the cooler region of the plant. This condensation will coat the surface of existing particles and form some fine particles. Because most of the surface area is in the fine particles, this is where most of the heavy metals condense. Also the surface area to volume is high in fine particles, so the concentration of the condensed heavy metals will be higher in the fine particles. The sub-micron particles are respirable and in passing into the lungs can be retained in the alveoli, which are small sacks through which oxygen is extracted by the blood stream and carbon dioxide released. Any heavy metals particles reaching the alveoli can eventually become absorbed by the blood stream and being accumulative can lead to various health problems.

The US EPA has carried out a number of studies that identify the following health issues[1]:

- Premature death;
- Respiratory related hospital admissions and emergency room visits;
- Aggravated asthma;
- Acute respiratory symptoms, including aggravated coughing and difficult or painful breathing;
- Chronic bronchitis;
- Decreased lung function that can be experienced as shortness of breath;
- Work and school absences.

The EPA believes that the recent reduction in fine particle ambient air quality levels from 65 $\mu g/m^3$ to 35 $\mu g/m^3$ will:

- Save 15 000 lives per year;
- Reduce hospital admissions by thousands each year due to reduced heart and lung diseases;
- Improved visibility.

There are two factors that cause the greatly increased contribution of fine particles to the plume visibility, which is what is measured by Opacity:

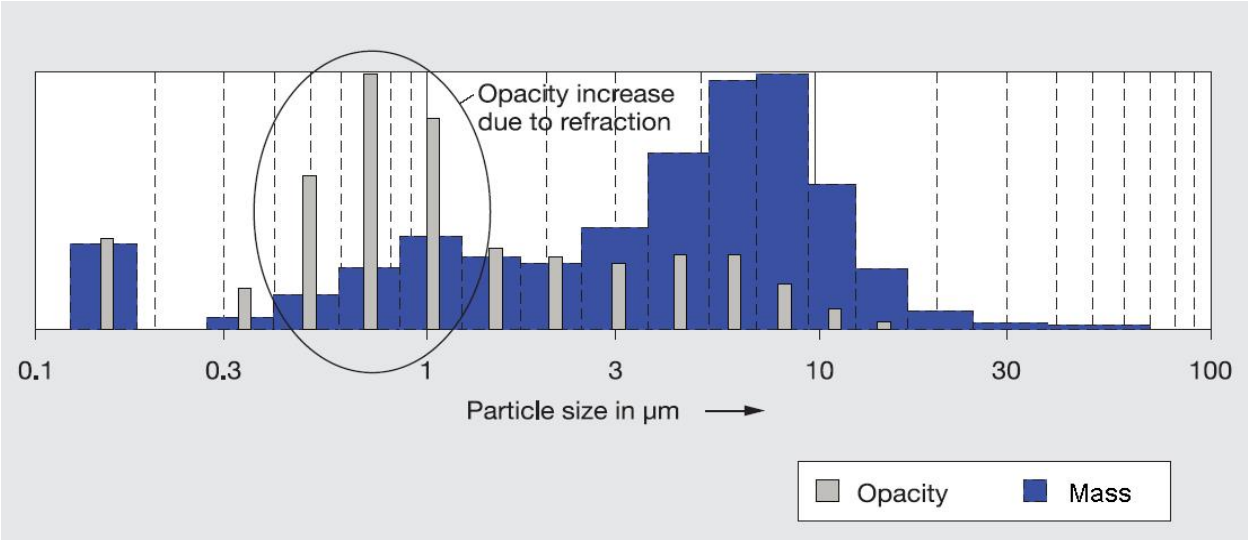


Fig. 1 ESPM Model estimates of Opacity and Mass Emissions.

The first factor is the increase in obscuration of a given mass of particles as the particle size reduces. This is because the mass is dependent upon volume, which is proportional to the cube of the particle diameter, while the obscuration is proportional to the cross sectional area, which is proportional to the square of the particle diameter. For given mass of particles, as size reduces from say 10 microns to 1 micron, the amount of obscuration will increase by a factor of 10.

The second factor contributing to the increased obscuration of fine particles is the fact that white light has a wave length of about 0.8 microns. Thus particles about this size will have a significantly increased obscuration due to refraction of the light. This results in these particles being over three times as visible.

Thus the emission of 0.8 micron particles will be over thirty times as visible as the emission of the same mass of eight micron particles. This effect is shown in Figure 1, a graphic from a simulation of the Watson ESP using the EPRI ESPM performance modelling program. It can be seen that although the majority of the particulate mass is in the 5um to 10 µm size range the main contributor to the plume visibility or Opacity are the 0.5 µm to 1 µm size particles. It is these fine particles that also contribute most to the reduced visibility in our cities and nature reserves. See Fig. 1.

Finally there is increasing evidence that fine particles are a major contributor to global warming, generally referred to as the Greenhouse Effect. Scientists carrying out research in this area suggest that up to 30% of global warming may be due to fine black particles carried into the upper atmosphere.

2 THE ELECTROSTATIC PRECIPITATOR PROBLEM

The ESP is very efficient (>99.9%) at collecting large particles, those greater than 10um, but as the particle size falls below 2 µm the ESP efficiency falls off dramatically. In extreme cases the collection efficiency can drop below 50% but will generally be less than 90% for particles between 0.5 µm and 2 µm. This is greater than two orders of magnitude (that is over 100 times) increase in the emission of this particle size range.

A typical ESP dust emission for particle sizes from 0.05um to 10um is given in Fig. 2. This data was collected using two particle size measurement instruments, namely:

- The Process Metrix, Model PCSV-P, dual beam forward scatter laser particle size analyser was used to measure particle size distribution from 0.5 µm to 50 µm. This analyser has a water cooled probe that is inserted into the gas flow to measure the particles suspended in the gas. The particle size was adjusted slightly, a factor of 0.7 was applied, on the data collected by the PCSV analyser so that the data coincided with the SMPS analyser data, see Fig. 2.

- Sub-micron particle tests were carried out at Plant Watson by the Southern Research Institute using a TSI Model 371A SMPS Analyser, which uses electrostatic mobility to measure particle distribution from 0.03 µm to 0.85 µm. The TSI Model 371A SMPS Analyser uses an extraction system that removes the larger particles followed by an electrostatic mobility based particle size selector that is used to scan and count the sub-micron particles.

Fig. 2 shows the number of particles per cubic centimetre that the ESP emissions are worst in the particle size range where the particles are most visible and most dangerous for human health, namely from 0.2 µm to 2 µm. Because of their small size, these particles will have a very low mass but a very high visibility. ESP mass emissions of less than 10 mg have been measured using the US Method 17 at Hammond Power Station while still measuring Opacity levels approaching 20%. Opacity levels below about 8% are normally invisible to the human eye. This shows that very visible plumes can result from high fine particle emissions even with extremely low mass emissions.

3 THE MERCURY EMISSION PROBLEM

Mercury is a toxic, persistent pollutant that accumulates in the food chain. Mercury in the air is a global problem.

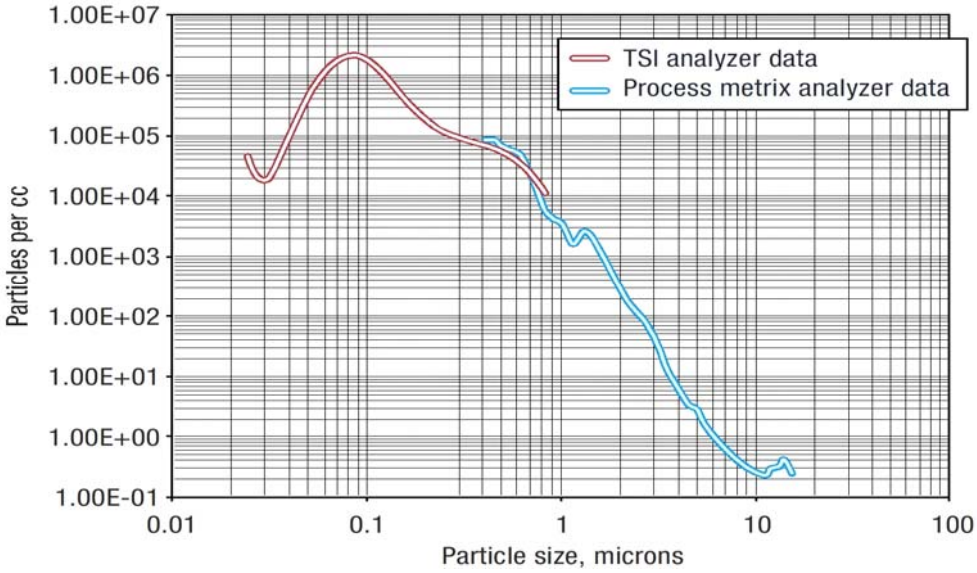


Fig. 2 ESP Emissions

While fossil fuel-fired power plants are the largest remaining source of human-generated mercury emissions in the United States, they contribute only a small amount (about 1 percent) of total annual Mercury emissions worldwide.

The Clean Air Mercury Rule (CAMR) in the USA has been struck down; however this makes all power stations in the USA Hazardous Air Polluters (HAPS). This will force the federal EPA to enact strict rules to restrict the emission of Mercury and other pollutants soon. A number of U.S. states have also enacted or plan to enact regulations to require even greater reductions in Mercury emissions; many require a 90% reduction.

Mercury emitted from coal-fired power plants comes from mercury in coal, which is released when the coal is burned. Coal-fired power plants emit mercury in three different forms: oxidized mercury (likely to deposit locally); elemental mercury, which travels hundreds and thousands of miles before depositing to land and water; and mercury that is in particulate form. Because mercury can be transported thousands of miles in the atmosphere, and because many types of fish are caught and sold globally, effective exposure reduction will require reductions in global emissions.

Concentrations of mercury in the air are usually low. However, atmospheric mercury falls to Earth through rain, snow and dry deposition and enters lakes, rivers and estuaries. Once there, it can transform into, methylmercury, and can build up in fish tissue. We are exposed to methylmercury primarily by eating contaminated fish. Because the developing foetus is the most sensitive to the toxic effects of methylmercury, women of childbearing age are regarded as the population of greatest concern. Children who are exposed to methylmercury before birth may be at increased risk of poor performance on neurobehavioral tasks, such as those measuring attention, fine motor function, language skills, visual-spatial abilities and verbal memory [2].

Environmental protection agencies around the world are looking at the Mercury problem and developing strategies to regulate the emission of Mercury to the atmosphere. The United States is the first country to regulate Mercury emissions but others will soon follow their lead, Mercury emission control from coal fired power stations will be the focus for future regulation in many countries. The EU are currently reviewing the effects of current EU law on Mercury emissions, providing information to support further Mercury emission cuts in Member States and studying the implications of additional control of releases from coal burning power stations.

Power stations with ESP's generally collect between 20% and 50% of the Mercury in the coal, depending upon the coal properties and, in particular, the level of un-burnt carbon in the form of soot emitted from the boiler. As the level of un-burnt carbon increases more Mercury is adsorbed by the carbon and the Mercury emissions will be reduced. Mercury removal can be increased up to about 70% by adding Activated Carbon to the exhaust gas following the Air-heater; Mercury is effectively adsorbed by carbon at low temperatures, generally below 160 ℃. Removal efficiencies of 90%, as required in some U.S. states, are difficult to achieve with an ESP, even using Activated Carbon injection.

4 THE INDIGO AGGLOMERATOR SOLUTION

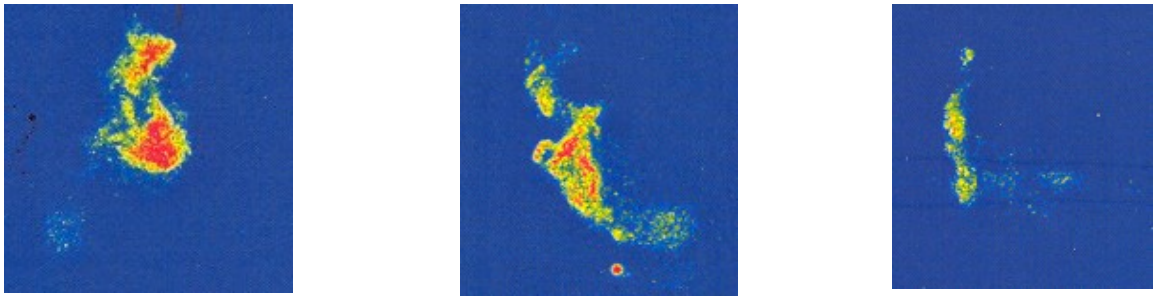
The Indigo Agglomerator is a new technology initially developed five years ago in Australia. It has been tested on a range of Australian, U.S. and South American coals with significant success in reducing fine particles emissions. The Indigo Agglomerator is installed in the inlet duct immediately prior to the ESP. Fine particles entering the Indigo Agglomerator are attached to the larger particles by a combination of electrostatic and fluidic processes. These large agglomerates are then easily collected in the ESP that follows the Indigo Agglomerator.

The Indigo Agglomerator utilizes two patented processes that cause the fine particles to attach to the large particles,

which are easily captured by the ESP. The first process is the Fluidic Agglomeration Process (FAP), a physical process that occurs without the need for electrical energisation. The Bipolar Electrostatic Agglomeration Process (BEAP) requires electrical energisation to charge the particles. It is the combination of these two processes that result in the massive reduction in fine particles shown in the test data.

The **Fluidic Agglomeration Process** (**FAP**), which uses enhanced fluidic based particle size selective mixing to increase the physical interaction between the fine particles and the large particles. This increased interaction vastly increases collisions between the fine and large particles resulting in the formation of agglomerates, which significantly reduces the number of fine particles. Extensive testing at the University of Adelaide using Laser Induced Fluorescence (LIF) has confirmed that FAP greatly reduces the number of fine particles. One micron water droplets, doped with a chemical that fluoresces when it passes through a laser sheet, were introduced into the gas flow in a wind tunnel. The intensity of the fluorescence, which is proportional to the total volume of fine particles passing through the laser sheet, was measured using a digital video camera with a filter set at the wavelength of the fluorescence. A computer was used to analyse this video data by averaging over time then scaling and colour coding the fine particle spatial distribution from blue, indicating no fine particles, through the spectrum to red, as the number of fine particles increases. Larger un-doped droplets, of about ten microns, could be injected as required but appear blue in the LIF analysis due to the filter. When the fine droplets collide with the large droplets they are absorbed and cease to fluoresce, due to the high dilution of the un-doped large droplets.

Fig. 3(a), the colour coded distribution (Blue-no 1 μm droplets through to Red – maximum concentration of 1 μm droplets) of fine droplets without any large droplets or FAP, is the base condition for fine droplet mass comparison. Fig. 3(b), the distribution of fine droplets with large droplets injected but no FAP, shows increased fine droplet dispersion but little change in total fine droplet mass. Fig. 3(c), the distribution of fine droplets with large droplets injected and FAP operating shows a greatly reduced fine droplet mass.



(a) Fine Particles Only (b) Fine and Large Particles (c) Fine and Large Particles with FAP

Fig.3 Colour Coded LIF Analysis of Fine Particle Mass Density: Color Code - Blue – No. 1 μm droplets; Red – maximum concentration of 1 μm droplets

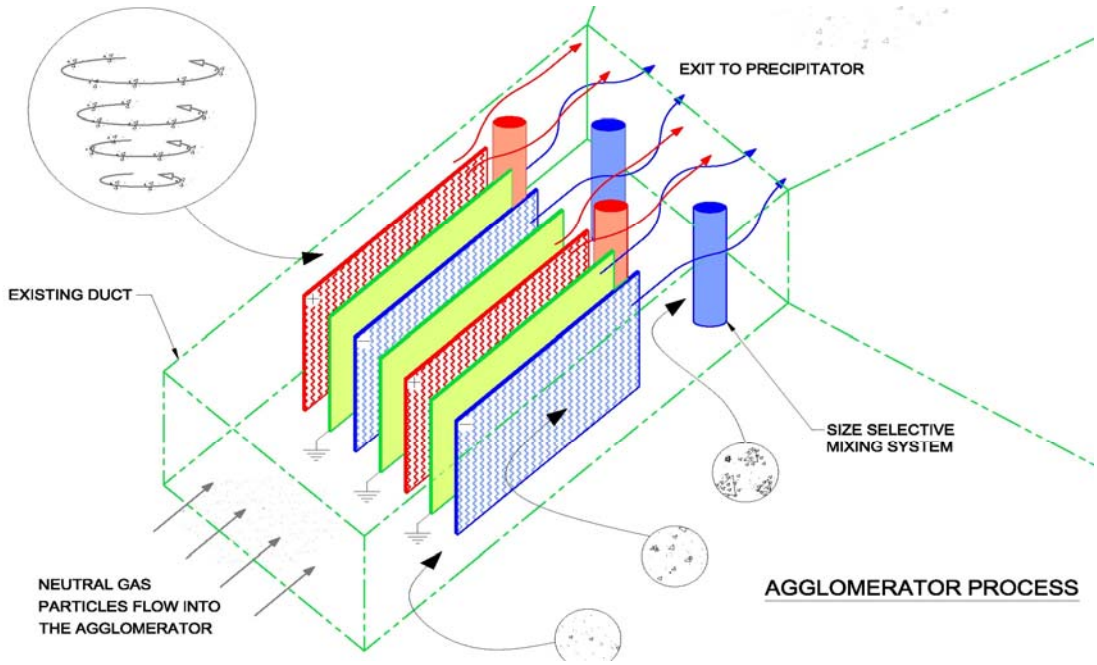


Fig. 4 The Bipolar Electrostatic Agglomeration Process (BEAP)

This data proves FAP greatly increases the collisions between fine and large droplets thereby significantly reducing the number of fine droplets. The percentage of collisions that result in agglomeration is, as yet unknown, but site test have shown FAP reduces fine particle count by more than half on the full size installation.

The **Bipolar Electrostatic Agglomeration Process** (BEAP) uses two key processes to reduce fine particle emissions. A Bi-polar Charger is used to charge half of the dust with a positive charge and half negatively. The Bipolar Charger has a series of alternating positive and negative parallel passages that the gas and dust pass through to acquire a positive or negative charge. The second key process is a specially designed size selective mixing system that causes the fine positive particles to be carried by the gas and mixed with the large negative particles emitting from the adjacent negative passage. The mixing system also causes the fine negatively charged particles to mix with the large positive particles, as shown in Fig. 4. Because electrostatic force decreases rapidly with distance, the mixing system is essential as it brings the fine particles close to the oppositely charged large particles so that the electrostatic force is sufficient to cause them to attach forming agglomerates. Plant tests have shown that BEAP also reduces fine particles by more than half on the full size installation.

5 FINE PARTICLE TEST DATA FROM WATSON POWER STATION

Tests performed at the Indigo Agglomerator trial installation at Watson Power Station show a huge reduction in fine particle emissions when an Indigo Agglomerator was installed in front of an existing ESP. Watson Power Station, located in Gulfport, Mississippi in the USA, is a 250 MW wall fired pulverized coal boiler with two air-heaters connected to two separate ESP's. An Indigo Agglomerator was installed in front of the "B" ESP and particle size tests were performed on both "A" and "B" ESP's. Fig. 5 shows a comparison of the Slip, the percentage of the dust entering the ESP that is emitted to the atmosphere, from both "A" and "B" ESP, for particle sizes from 0.05 μm to 10 μm. These tests were performed using the two probes described above.

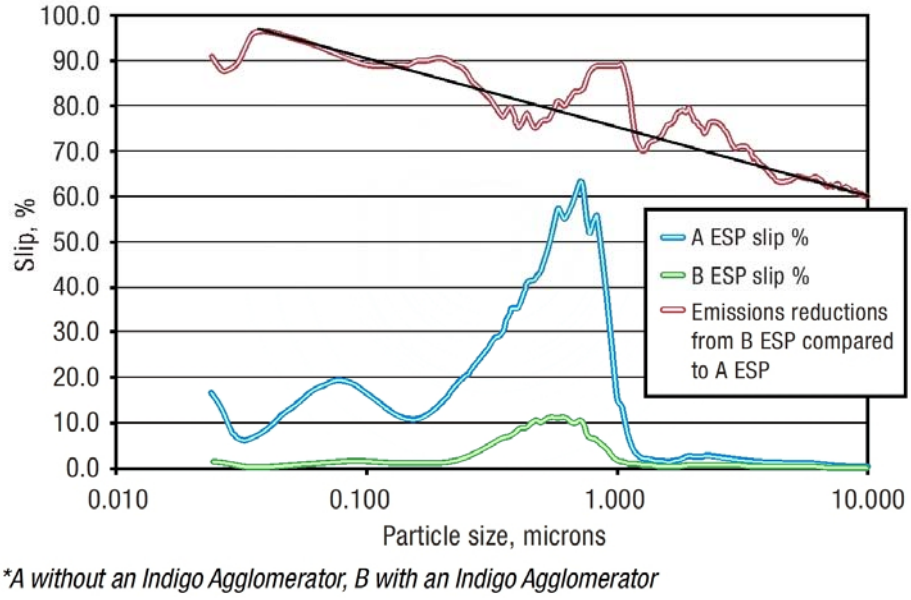


Fig.5 Comparison of dust emitted to the atmosphere with and without the Indigo

The collection efficiency of "A" ESP decreases rapidly below 2um particle size, as indicated by the increasing slip (Slip (%) =100-Efficency (%)). Over 50% of the particles in the key 0.6 μm to 1um size range are not captured by "A" ESP. The "B" ESP captures 90% of those particles, resulting in a greatly reduced visible emission as measured by Opacity.

It can be seen that the reduction in fine particle emissions provided by the Indigo Agglomerator increases with reducing particle size, as indicated by the improvement trend line in Fig. 5. This shows a 60% improvement at 10 μm increasing to 75% at 1um and 90% at 0.1 μm. Thus, the fine particle emission reduction provided by the Indigo Agglomerator increases from a factor of 2 at 10 μm to a factor of 10 at 0.1 μm. The average reduction in PM2.5 emissions is about a factor of 5 or 80%.

6 FINE PARTICLE TEST DATA FROM TARONG POWER STATION

Tests performed at Tarong Power Station show an increase in fine particles collected in the ESP hoppers and an increase in Arsenic concentration in the collected dust on Pass 1, with an Indigo Agglomerator installed before the ESP,

compared to Pass 2, without an Indigo Agglomerator. Both Pass 1 and Pass 2 treat gas from Air-heater A while Pass 3 and Pass 4 treat gas from Air-heater B. Tarong Power Station is located near Brisbane, Queensland in Australia and has four by 350 MW units. Each ESP pass at Tarong Power Station has six Zones or Sections with a separate hopper for each with a total of 260s ec/m SCA. Ash was taken from hoppers 1, 2, 4 and 6 for particle size and/or Arsenic concentration measurement are representative of the dust collected in the 1, 2, 4 and 6 ESP zones.

Fig. 6 shows the particle size distributions for Hoppers 1, 4 and 6. The larger particles are mainly captured in the in the front of the ESP. Most of the larger particles are found in the front hopper, Hopper1, however there are more fine particles captured in this hopper on Pass 1. The fine particles are captured in the in the rear of the ESP, as is evident from the rear hopper particle size distribution. There are less large particles in the rear hoppers of Pass 1 but there are more fine particles. The agglomeration of the fine particles to the larger particles will result in the larger agglomerates being captured in the front of the Pass 1 ESP with the Indigo Agglomerator, hence the reduced number of larger particles in the rear hoppers. The agglomeration of fine particles to slightly larger particles will increase the number of fine particles collected in the rear of the ESP, hence the increased number of fine PM2.5 particles in the rear hoppers.

Arsenic vaporizes in the combustion process but condenses in the colder rear section of the boiler. The condensation will preferentially form on the surface of existing particles on the basis of surface area. Some may also condense to form ultra-fine particles. Because the vast majority of the surface area is in the fine particles, most of the condensed Arsenic ends up in the fine particles. The concentration of Arsenic will also be higher in the fine particles because the ratio of surface area to volume is inversely proportional to particle size.

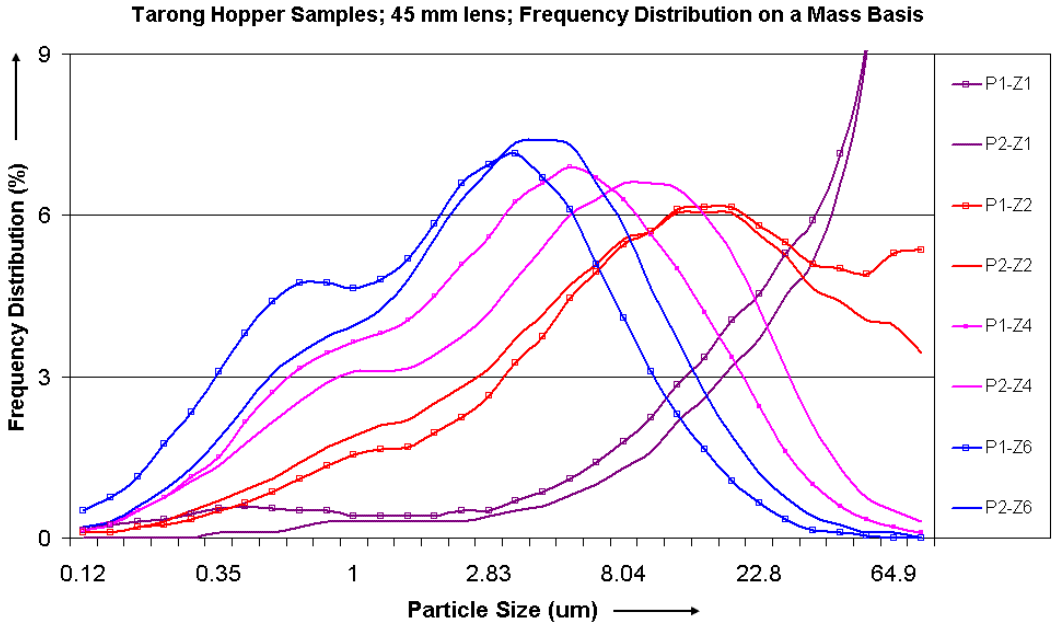


Fig. 6 Hopper particles size distribution

Table 1 7 shows the Arsenic concentration in the ash samples from Hoppers 1, 2, 3 and 4. The Arsenic concentration is consistently higher on the Pass 1 ESP, with the Indigo Agglomerator, as this ESP consistently collects more fine particles, as shown in Figure 6. As the fine particles are preferentially collected in the rear of the ESP, the concentration of Arsenic is largest in the rear hoppers. The increase in the fine particle collection on Pass 1 provided by the Indigo Agglomerator has less of an impact on the Arsenic concentration because there is already a high concentration of fine particles and Arsenic. The ESP preferentially collects large particles in the front section, where most of the dust is collected (up to 90%), hence the concentration of Arsenic is lower, due to the dilution of the large particles, and the improvement is lower, due to the large mass of dust collected. The improvement is greatest in Hopper 2, which represents the dust collected in Zone 2 of the ESP. The amount of dust collected in ESP Zone 2 is a lot less, up to an order of magnitude, than that collected in Zone 1 and therefore there is a lot less dust in Hopper 2 than Hopper 1. The increase in fine particles and, hence Arsenic concentration, is therefore more significant.

Table 1 Arsenic Concentration in the Ash

	Hopper 1	Hopper 2	Hopper 4	Hopper 6
ESP Pass 1	2.98 mg/kg	7.94 mg/kg	20.3 mg/kg	24.7 mg/kg
ESP Pass 2	1.7 mg/kg	2.78 mg/kg	14.1 mg/kg	20.2 mg/kg
Pass 1 Increase	75%	186%	45%	22%

7 MERCURY TEST DATA FROM WATSON POWER STATION

A single set of Mercury tests at full load were carried out at the Mississippi Power's Plant Watson on Indigo Agglomerator trial installation on Unit 4 in January, 2004. The plant was burning Columbian CMC coal, which had a LOI level of between 9% and 16% and NO sorbent, such as Activated Carbon, was injected. The CMC coal was selected because it normally produced a high level of LOI, which is the prime Mercury sorbent produced by the combustion process. Coal ash samples taken from the three ESP ash hoppers during the Mercury tests were analysed and the un-burnt carbon measurements are given in Table 2.

Table 2 Percentage un-burnt carbon measured in each ESP hopper

	Front Hopper	Middle Hopper	Rear Hopper
A Side Hoppers	8.7%	9.7%	14.3%
B Side Hoppers	7.0%	13.6%	23.0%

Much of the un-burnt carbon from this coal is in the form of soot, very fine carbon particles formed from the incomplete combustion of heavy hydrocarbons (oils) in the coal. The soot, being very fine particles, is mainly collected in the rear of the ESP, as can be seen from Figure 8 The Indigo Agglomerator increases the ESP fine particle collection efficiency, hence the higher carbon found in the rear hoppers on B Side. The lower carbon level in the front hopper indicates a lower un-burnt carbon level on B Side and therefore one would expect less Mercury removal.

Total Mercury trap sampling in triplicate was performed by the Southern Research Institute at:

- Both Air-heater Outlets;
- The Indigo Agglomerator Outlet;
- Both ESP Outlets.

Three separate samples were taken at the A Side Air-heater Outlet concurrently with four samples at the A Side ESP outlet on the 27 th January, 2004. Six samples were taken at the B Side Air-heater Outlet, three concurrently with the three at the Indigo Agglomerator Outlet and three concurrently with three at the A Side ESP outlet on the 28th January, 2004. The 19 sealed Mercury Traps along with the Plugs or Pre-filters were sent to Frontier Science for analysis. The Total Mercury results measured by Frontier Science, as supplied by the Southern Research Institute, are given in Table 3.

The coal was also analysed and was found to contain Mercury equivalent to 4.5 $\mu g/m^3$ at the Air-heater Outlet. Although most of the results looked reasonable, the total Mercury in the B Side Air-heater Outlet Traps (0.79 $\mu g/m^3$) was very low compared to that expected based on the coal analysis (4.5 $\mu g/m^3$) and the A Side Air-heater Outlet analysis results (4.25 $\mu g/m^3$). After consideration, it was thought likely that the Mercury may have been trapped by the LOI carbon particles captured in the Plugs or Pre-filters. After some weeks it was decided to have Frontier Science analyse the Plugs or Pre-filters to determine the level of Mercury present. This was found to be very high on B Side and lifted the Total Mercury concentration at the Air-heater Outlet from 0.79 $\mu g/m^3$ to 2.64 $\mu g/m^3$, there was more than twice the Mercury in the Plug or Pre-filter than there was in the actual Mercury Trap. The main variation was at the B Side Air-heater Outlet and the Indigo Agglomerator Outlet, the variation in the other results was quite small, as little Mercury was found in the Plug or Pre-filter. This data shows a 65.5% reduction in Mercury emission on B Side with the Indigo Agglomerator compared to a 20.6% reduction across the ESP on A Side. This is a 70% improvement in Mercury removal on B Side ESP with the Indigo Agglomerator compared to the A Side ESP.

There is still a large difference in the Mercury concentration at the B Side Air-heater Outlet (2.64 $\mu g/m^3$) compared to A Side Air-heater Outlet and the coal data (4.5 $\mu g/m^3$). Because the Plugs or Pre-filters were not stored in sealed containers during the period between the sampling and the analysis, some weeks later, it is certain that some of the Mercury in the Plugs or Pre-filters would have escaped, since Mercury will evaporate at normal temperatures. By assuming a similar percentage loss from all Plugs or Pre-filters, the Plugs or Pre-filters Mercury can be adjusted until both A Side and B Side Air-heater Outlets are about the same. This indicated that the loss of Mercury from the Plugs or Pre-filters was about 54%, which is reasonable given the extended time between sampling and analysis. As shown in Table 4, the reduction in Mercury emission on B Side with the Indigo Agglomerator is 78% compared to a 16% reduction across the ESP on A Side. This is an 80% improvement in Mercury removal on B Side ESP with the Indigo Agglomerator compared to the A Side ESP.

The effect of Mercury adsorption by the carbon caught in the per-filter was very small at the ESP outlet. If the inlet Mercury concentration was the same, the collection trap measurements at the ESP outlet show almost a 75% improvement in Mercury removal on B Side ESP (0.82 mg/m^3) with the Indigo Agglomerator compared to the A Side ESP (3.2 mg/m^3). The Mercury emissions from the A Side ESP are four times that emitted from the B Side ESP equipped with an Indigo Agglomerator. The results are almost the same if the Mercury adsorbed in the per-filter is included. This shows a significant reduction in Mercury emissions from the B Side ESP even though the un-burnt carbon level in the front hopper is lower, which should indicate a lower level of Mercury adsorption as there is less un-burnt carbon to adsorb the Mercury.

Table 3 Mercury test results supplied by The Southern Research Institute for Plant Watson, Unit 4

Date	Start time	End time	SRI Sample Vol (litres)	SRI blank corrected (μg/m^3)	Test position	Total Mercury (μg/m^3)	Revised averages with plugs (μg/m^3)
1/27/2004	1420	1445	15.45	4.88			
1/27/2004	1508	1540	15.40	3.80	A side A-H outlet	4.25	4.51
1/27/2004	1607	1647	15.14	4.06			
1/27/2004	1420	1446	15.02	3.58			
1/27/2004	1513	1537	15.02	3.32	A side ESP outlet average	3.20	3.58
1/27/2004	1613	1632	15.04	3.02			
1/27/2004	1720	1747	15.02	2.89			
1/28/2004	803	847	15.17	1.08			
1/28/2004	913	950	15.04	0.44	B side A-H outlet	0.79	2.64
1/28/2004	1015	1103	15.16	0.84			
1/28/2004	805	836	15.03	0.74			
1/28/2004	858	930	15.08	0.83	B side ESP outlet average	0.82	0.91
1/28/2004	1020	1052	15.02	0.89			
1/28/2004	1202	1247	15.28	0.50			
1/28/2004	1330	1410	15.20	0.39	B side A-H outlet	0.53	2.50
1/28/2004	1430	1510	15.35	0.72			
1/28/2004	1200	1244	15.04	0.36			
1/28/2004	1329	1408	15.03	0.66	B side Indigo AGG outlet overage	0.51	2.08
1/28/2004	1430	1510	15.04	0.50			

Note: Significant problems on B side with high unburned carbon levels and loading of pre-filters which had to be changed out at east once per test

Table 4 Mercury measurement correction and analysis from Watson generating plant, with LOI, burning CMC c oal

	Mercury in Collection Trap μg/m^3	Mercury in Filter and Collector μg/m^3	Mercury in Filter μg/m^3	Mercury in Filter with 54% Loss μg/m^3	Total Mercury with 54% Loss μg/m^3	Removal Efficiency %
A Side A-H Outlet	4.25	4.51	0.26	0.57	4.82	16.4%
A Side ESP Outlet	3.2	3.58	0.38	0.83	4.03	
B Side A-H Outlet	0.79	2.64	1.85	4.02	4.81	78.9%
B Side ESP Outlet	0.82	0.91	0.09	0.20	1.02	
B Side A-H Outlet	0.53	2.5	1.97	4.28	4.81	18.5%
B Side AGG Outlet	0.51	2.08	1.57	3.41	3.92	

Note: Estimate of Mercury from Coal analysis is 4.5 μg/m^3.
Increased Mercury emissions from A Side ESP 481.4%;

Mercury removal improvement with Agglomerator is 77.5%.

8 CONCLUSIONS

Fine particles, in particular PM2.5, are an acknowledged health hazard and government environmental protection organizations around the world are now focusing on controlling the emission of these fine particles. ESP's are poor collectors of fine particles, particularly between 0.5 μm and 2 μm. The ESP collection efficiency, normally around 99.9% for larger particles, is generally less than 90% in this particle size range and can fall below 50% in worst case conditions. This results in the emission of large numbers of very fine but very visible particles. Although these emissions may have a very low mass emission, in some cases less than 10 mg/m^3, the Opacity, the measurement of visibility will be very high.

The Indigo Agglomerator provides a significant reduction in fine particle emissions by attaching the fine particles to the large particles, which are easily collected in the ESP. The reduction in fine particles provided by the Indigo Agglomerator technology increases from 60%, about a factor of 2, at 10 μm to 90%, about a factor of 10, at 0.1 μm. PM2.5 emissions may be reduced by up to 80% with the installation of an Indigo Agglomerator in front of an ESP. This will provide a significant reduction in visible emissions, as measured by Opacity.

The hopper ash tests carried out at Tarong Power Station show increased fine particle collection and a significantly increased Arsenic concentration in the ash. This supports both the relationship between fine particles and heavy metal concentration plus the enhanced fine particle removal provided by the Indigo Agglomerator. Thus the Indigo Agglomerator also will significantly reduce heavy metal emissions by reducing fine particle emissions.

Despite problems with the Mercury measurement and analysis at the B side Air-heater Outlet and the Indigo Agglomerator Outlet sample points, the test data measured at both ESP outlets was consistent and reliable, since the LOI levels were much lower and the Mercury caught by the Plug or Pre-filter was minimal. The Mercury emissions were much lower, 0.9 $\mu g/m^3$ to 1.0 $\mu g/m^3$, on B Side with the Indigo Agglomerator compared to A Side with just the ESP, 3.6 $\mu g/m^3$ to 4.0 $\mu g/m^3$. This indicates a consistent 75% reduction in Mercury emissions with the Indigo Agglomerator installed. The data shows a removal efficiency of between 65% and 79% with the Indigo Agglomerator and the ESP compared to 16% to 21% with the ESP alone. This indicates a huge 300% to 500% increase in Mercury emissions from the A Side ESP, without the Indigo Agglomerator installed, compared the B Side ESP, with an Indigo Agglomerator installed at the inlet.

REFERENCES

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