

## Emission reduction and Availability improvement in old Electrostatic Precipitators at Gold Roaster – A Case Study

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### Abstract.

Industrial plants are one of the major users of Electrostatic Precipitators (ESPs) for particulate emission control. These are primarily Cement, Metallurgy, Pulp & Paper and Aluminium industries. The paper generally speaks about the challenges that we face with the old Industrial Precipitators to cope with stringent emission norms in spite of Physical dimensional and plant layout Restrictions.

The Precipitators in such Industrial applications are used not only for emission control but also to recover the dust either to recycle or to use as end product.. Today's technology has advanced, particularly in the area of High Voltage & Controls and shows extremely promising results beginning usually at 30 % emission reduction, but commonly much better than this .

In this paper we specifically discuss about a Case Study on ESPs in a Gold Roaster application in Western Australia and compare the emission performance enhancement with few upgrades

### Key Words

ESP, electrostatic precipitator, emission, pollution, upgrade, control system, high voltage power supply, HFPS, Transformer Rectifier, TR

### Introduction

KCGM Gidgi plant has two roasters designed and build by an OEM other than Alstom. The flue gases from the circulating fluidized bed roaster are passed thru primary cyclone collector followed by Electrostatic Precipitator for controlling the particulate emission.

The ESP have one casing with three fields (zones) per roaster with following configuration as explained in Table . The first two zones have 100 kV/800mA T/R sets and the third zone has 100kV/1000mA T/R set.

The ESP was experiencing problems such as :

- High Emission levels & Poor performance/Power (kVA) drop
- Heavy built up of product on discharge electrodes which Rapping not able to dislodge thus requiring frequent manual cleaning
- Damage to some components due to excessive cleaning

### Design Specifications

Table 1- General Configuration of ESP

No of units	2
No of casings per unit	1
No of electrical Zones per casing	3
Zone Length x width	4.54 M x 5.2 M
Collecting electrode Height	7.5 M
Collecting electrode spacing	400 mm

Table 2- Process Parameters

Parameters	Unit	Design	Present Operating	Variation %
Gas Flow	M3/s	44.4	63.22	+42%
Gas Temp	°C	350	350	-
Gas Moisture	% v/v	46.4	46.4	-
Inlet Dust	g/Nm3	34	180	+529%
Outlet Emission	mg/Nm3	70	250	+350%
SCA	m2/m3/s	79.75	56	-30%
Gas velocity	m/s	1.14	1.62	+42%

**Inspection Report**

The dirty inspection was conducted and some of the comments are reproduced here for reference.

**Mechanical**

All 3 Fields did not reveal any mechanical faults significant enough except

- Some discharge electrodes are coming loose due to the excessive stress of accumulation & cleaning, some have already been removed from service to prevent shorting.
- Moderate dust accumulation was found on collecting plates
- Extensive dust accumulation was found on emitter ribbons in all Fields with 1 being the worst affected.

**Electrical**

The controllers for zone 2 & 3 appeared to be working ok, both registering approximately 10 sparks / min and recorded peaks of 63kV/120mA and 75kV/600mA respectively.

Zone 1 kV was fluctuating between 10-50kV as if it was detecting sparks however none were being

recorded, all three controllers were set to 80kV limit

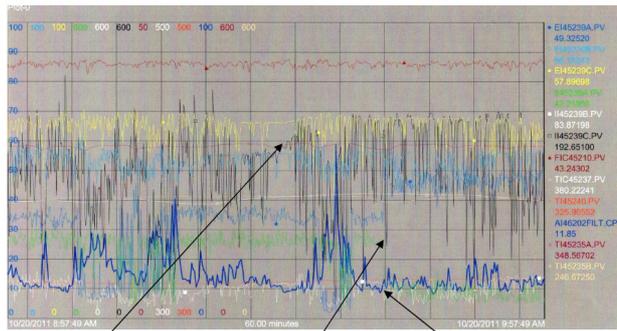
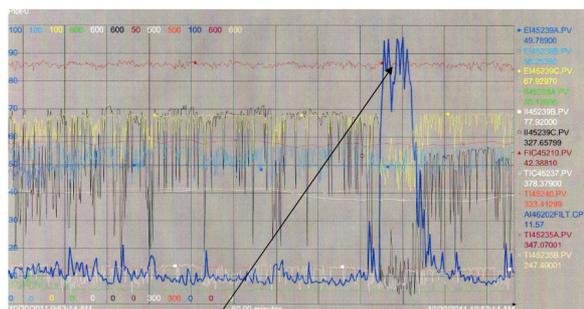


Figure 1- Unit 2 Zone 1- Screen Shot

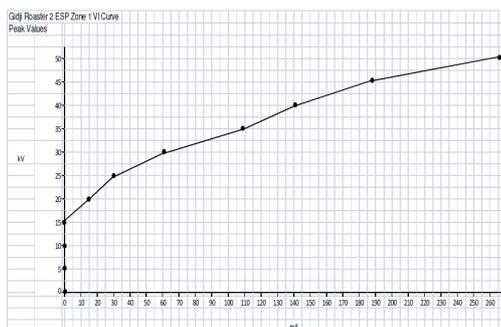
- Limiting the kV did not affect the average over time, but did provide a smoother operation, in the case of zone 1 the average kV increased markedly while the mA decreased.
- Although the emissions were now trending lower than in previous weeks they need to be monitored with any necessary adjustments made to the TR settings.



Spike caused by rapping

Figure 2- Unit 2 Emission Level

- The chart above shows the emission level and TR output over a 1hr period following limiting of the kV, the spike in emissions is due to rapping in the outlet zone. Below shows the VI curve taken from R2 zone 1, no back corona is indicated.



## ICESP XIII, September 2013, Bangalore, India

Figure 3- Unit 2 Zone 1 VI Curve

Zones 2 & 3 returned similar graphs.

### Sample Testing

#### Dust Analyses

Following analyses of the dust samples have been performed:

1. Resistivity analyses of field 1& field 3 dust
2. Stickiness test of field 1 and field 3 samples
3. Total sulphur in samples from fields 1-3
4. Water soluble sulphur in samples
5. SEM/EDX analyses of sample from field
6. Resistivity Measurement

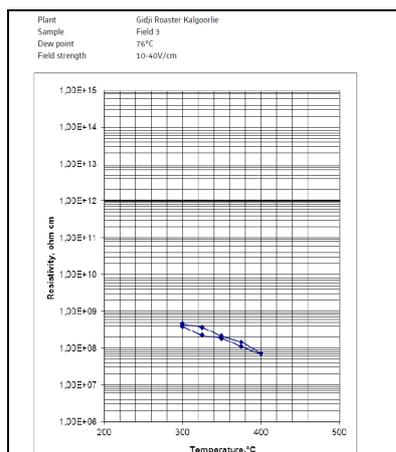


Figure 4- Resistivity Filed 1 dust

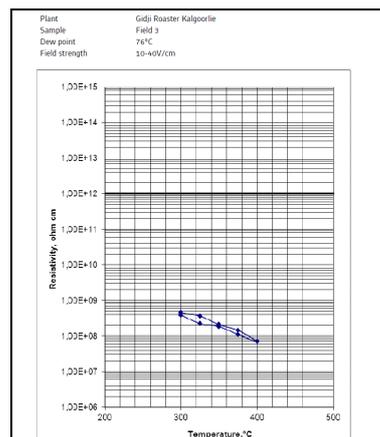


Figure 5- Resistivity Field 3 dust

As seen from the above the resistivity of the samples is in the range of  $10^8 - 10^9$  Ohm-cm. The results confirm that it is a low resistivity dust. The electrical discharge of the particles through the dust layer on the collection plates would therefore not be a limiting factor for the collection efficiency.

#### Test of stickiness

The same two samples as used in the resistivity measurements (field 1 and field 3) were exposed for a temperature of  $380^\circ\text{C}$  and a moisture content of 40 % by volume for several hours. The open containers with dust were removed from the hot and moist air and a visual assessment was made of the dust nature.

None of the two samples showed a sticky structure. It did not stick at all to the spoon. Both samples had a quite dense and compact nature. The compacting of the dust samples may be a sign of a slight sintering between the particles when exposed to high temperature levels during longer periods of time.

The test was, of course, not fully representative as the samples were inserted in an air environment instead of a gas environment having a high concentration of  $\text{SO}_2$  and  $\text{SO}_3$ . However, the conclusion is that, the samples in the state they were delivered don't have a tendency to melt despite the high temperature.

#### Total Sulphur

The total sulphur content of all three samples (fields 1-3) was analyzed in a LECO analyzer.

Table 3- Total Sulphur % by weight

Stot ( % By Weight)	
Field 1	14.6
Field 2	11.2
Field 3	13.5

As can be seen in the table, the total sulphur content is high in all the samples.

#### Water soluble Sulphur

The water-soluble sulphur generally occurs in the form of sulphate. In the table below, the result of the analysis of water-soluble sulphate (IC, Ion Chromatography) is compared with the amount of sulphate received by recalculating total sulphur (LECO analyzer) to sulphate.

Table 4-Soluble Sulphur

	SO4 (mg/g)	SO4 (mg/g)
	IC	LECO
Field 1	352	437
Field 2	304	336
Field 3	376	404

As can be seen, the amount of sulphate based on water-soluble sulphur is only somewhat less than the amount of sulphate calculated from the content of total sulphur. The conclusion is that most of the sulphur present in the dust samples exists in the form of sulphate.

#### SEM/EDX Analysis

The dust sample from field 1 was brought for analysis in their SEM (Scanning Electron Microscope). Photos were taken of the sample at lower as well as higher magnifications to get an overview of the sample and to look at specific details.

EDX (Energy-Dispersive X-ray spectroscopy) analyses were performed for the overview sample as

well as for specific particles. The EDX is a half-quantitative analyses method, which gives the content of elements in the sample.

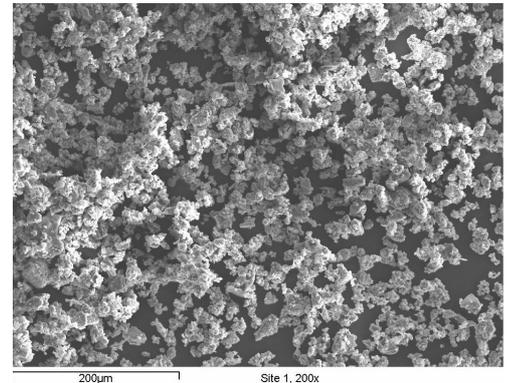


Figure 6- Sample Overview

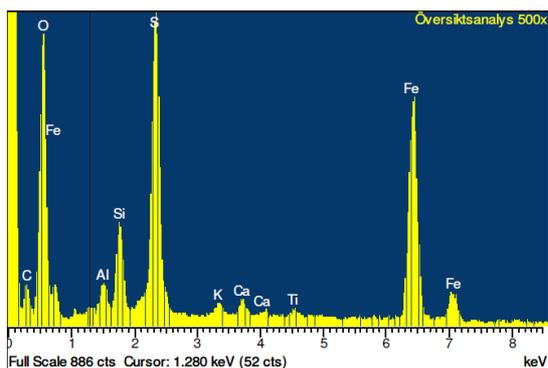


Figure 7- Spectrum Of Sample Overview

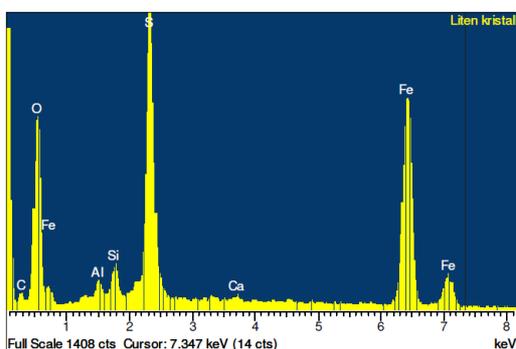


Figure -9 Spectrum on Small Crystal

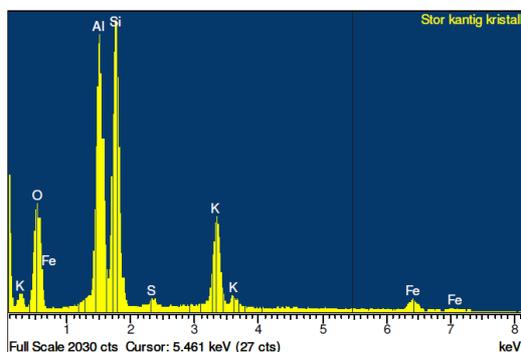


Figure 10-Spectrum on Large crystal

The SEM photos show that the particles are comparatively large. It means that the space-charge effect causing suppressed current would be less problematic than what could be expected based on the very high dust concentration.

According to the SEM photos and the EDX analyses it is obvious that the dust contains two different fractions. One fraction consists of larger, angular mineral particles that are composed of Si, Al, K and O. The other fraction consists of very irregular crystals with high concentrations of Fe, S and O, i.e.

most likely a mixture of iron oxide ( $Fe_2O_3$ , as colour of sample is dark red) and iron sulphate.

As can be seen on the detail picture below, the irregular particles look sintered. In few cases it seems as the irregular fraction acts as the cement in concrete, forming a binding phase between the particles.

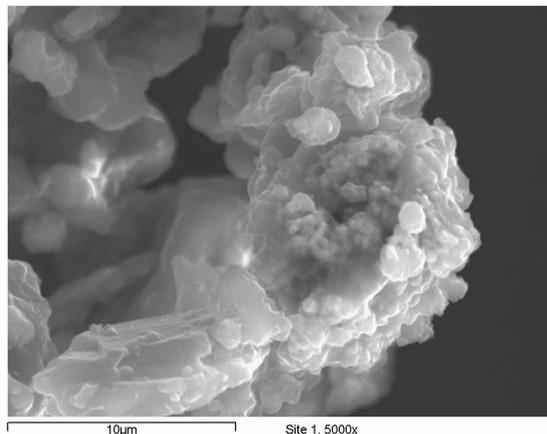


Figure 11- SEM photo

The formation of a binding phase typically occurs due to sintering between particles. The sintering effect is enhanced by high temperature, high moisture content and chemical reactions. When particles sinter, adjacent particles will exchange material with each other.

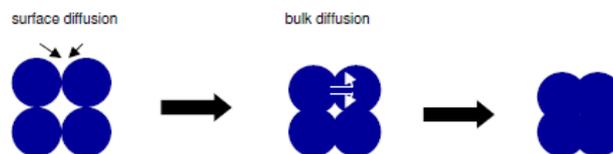


Figure 12- Sintering

Due to the high concentration of sulphur in the samples and a  $SO_2$  level in the flue gas around 8% by volume, it is reasonable to assume that sintering has occurred during the reaction between iron oxide in the dust and  $SO_2/SO_3$  in the gas phase.

Sintering due to chemical reactions doesn't necessarily result in sticky dust. The only negative effect may be that single particles adhere and bind to each other forming larger aggregates. During such conditions it is typical that the worst dust accumulations occur around the discharge electrodes, because a shell of sintered particles is formed. As long as the dust is dry and solid, the hold forces between the dust layer and the metal surface

## ICESP XIII, September 2013, Bangalore, India

in the collection plates will not become much stronger due to the sintering between the particles.

### Test Conclusions

From the analyses made, it appears as the process related disturbances above all are due to dust accumulation problems caused by sintering between the dust particles. The most likely reason for the sintering is the reaction between iron oxide particles and SO<sub>2</sub>/SO<sub>3</sub> in the flue gas.

The dust does not appear to be physically sticky at normal operating temperature and normal moisture content. However a slight sintering may occur due the exposure for high temperature during longer periods.

The very high dust concentration at the precipitator inlet will most likely result in reduced current levels in the front-end fields. Due to a comparatively coarse dust character, the negative effect is judged to be limited.

The resistivity of the dust cake is quite low, hence there would be no problem to discharge the collected dust particles.

### Rapping

#### Collecting System

The collecting rapping system is as follows;

Table 5- Rapping time

Zones	ON time ( sec )	OFF time ( min)
Z1	230	1
Z2	600	2
Z3	230	90

The rapping speed is 0.28 rpm.

#### Discharge System

The discharge electrode rapping is as follows;

Rapping speed Z1 = 1.40 rpm

Rapping speed Z2 & Z3 = 0.62 rpm

The zone 1 hammer size has been increased in both roasters R1 & R2.

The rapping is continuous.

#### Analysis

The collecting rappers have all the speed 0.28 rpm or 1 rev/3min 34 sec.

The emitting rapper in Z1 has the speed 1.40 rpm or 1 rev/ 43 sec. and operated continuously

The emitting rappers in Z2 & Z3 have the speed 0.62 rpm or 1 rev/1 min 37 sec. and operated continuously.

The collecting plate rapper settings given in the table above can be "translated" as follows:

Z1: The shaft will make 1.07 rev. in 230 sec. and each collecting plate will get one hit every 4 min 45 sec. based on 1 min OFF time

Z2: The shaft will make 2.8 rev. in 600 sec and each collecting. plate will get one hit every 4 min 17 sec based on 2 min OFF time, i.e. more often than Z1.

Z3: The shaft will make 1.07 rev. in 230 sec. and each collecting plate will get one hit every 94 min 45 sec. based on 90 min OFF time.

The emitting rappers are then acting as follows:

Z1: The shaft is operated continuously with 1.4 rpm or one hit every 43 sec. i.e. very often.

Z2 & 3: The shaft is operated continuously with 0.62 rpm or one hit every 1 min 37 sec.

With this low speed on the collector shaft the only



Figure 8- DE dust coating

way to reduce frequency is to extend the OFF time from 0 min (continuously) up to maybe 60 min.

The problem is to introduce PCR (Power control rapping/ power down rapping) when you have a slow speed on the collecting shaft as the power OFF time will be longer per hit of the plate.

## DISCUSSIONS

### Process parameters

As seen from

Table 2- Process **Parameters**, the gas flow has increased by 42% to 63.2 m<sup>3</sup>/s and the inlet dust concentration has increased more than five times the design values to 180 g/m<sup>3</sup>.

Increase in the inlet dust concentration has not only increased the outlet emission but also has created difficulty in first zone collection and accumulation.

### Low resistive dust

The resistivity of the dust was tested in the laboratory and was clearly a low resistive dust.

### Rapping

As identified, the discharge electrodes have been coated with thick layer of dust which points towards ineffectiveness of rapping particularly with changed process conditions.

It was observed during site inspection, due to excessive rapping some of the components have

started failing (like missing DE's). It indicates that even after discharge electrodes were rapped excessively the cleaning was not adequate.

During the inspection the discharge electrodes were found to be coated with dust especially in the first field.

## HFPS –High Frequency Power Supply

Conventional Electrostatic Precipitator rectifiers generate peak voltage which can be as much as 25% above the average voltage. The peak voltage triggers the sparking in the Electrostatic Precipitator zone. Sparking quenches the ionization and effectively limits the average voltage applied to the electrodes and thus the efficiency of Electrostatic Precipitator. To overcome such an occurrence it is prudent to inject more power in ESP.

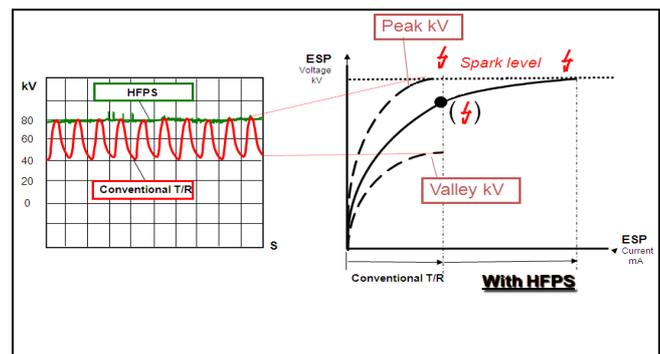


Figure 9- HFPS

HFPS is a High Frequency DC rectifier with integral switching and rectifying unit. High frequency DC output provided by this new technology rectifiers, gives almost ripple free DC output compared to the conventional T/R's. This allows the Electrostatic Precipitator to operate at full voltage up to the point at which sparking occurs. This increases useful Electrostatic precipitator current which provides substantial Electrostatic Precipitator emission reduction.

Switching technology used in the HFPS unit loads the main power line very smoothly. It also distributes the load evenly as all three phases of the AC are utilized. This technology also has a good power factor (  $\cos \phi$  ).

### Power down Rapping (PDR)

HFPS units have the inbuilt algorithm that enables the controller to disconnect the power supply during

## ICESP XIII, September 2013, Bangalore, India

the rapping cycle and make the rapping more effective.

The above is effective also in case of dust collected on discharge electrodes.

### Recommendations

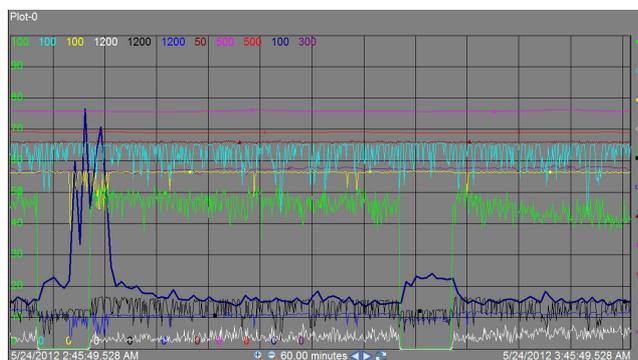
- 1 Installation of HFPS units specifically in the front zone
- 2 Tuning of the ESP
- 3 Checking and repairs of the existing casing/baffles/rapping etc.
- 4 Change of Rapper motors from 0.28 to 1RPM.
- 5 Change of discharge electrodes with Ribbons having peaks
- 6 Installation of additional rapping on upper level of DE frame on the opposite side of the existing rapping.
- 7 Installation of outlet GD screen

### Implementation

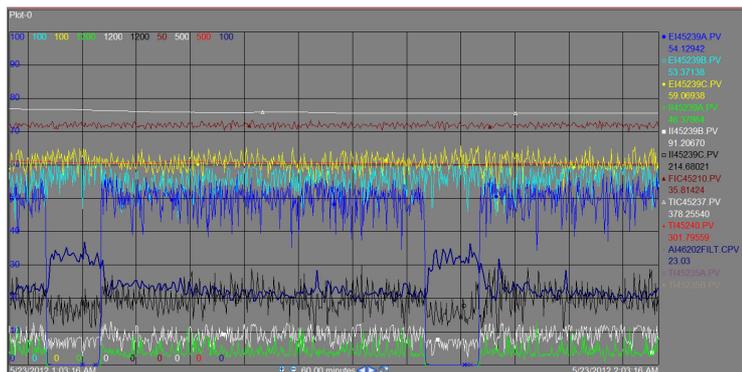
To start with as Phase 1 the following Recommendations are implemented :

- 1 Installed 70 Kv / 1700 mA HFPS units at the front zone
- 2 Tuning of the ESP
- 3 Installed additional rapping on upper level of DE frame with 1 RPM Motor
- 4 Repaired / Fixed most of the leakages

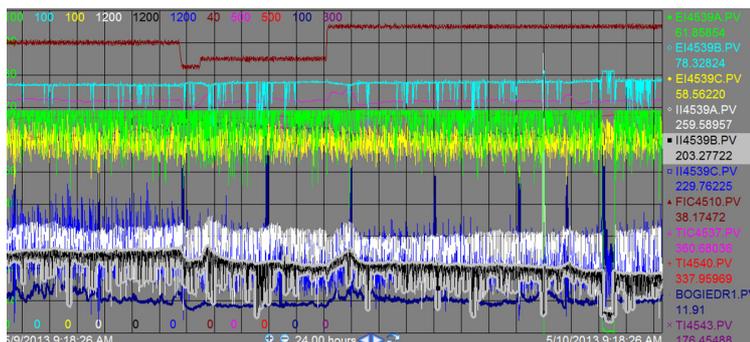
### Result



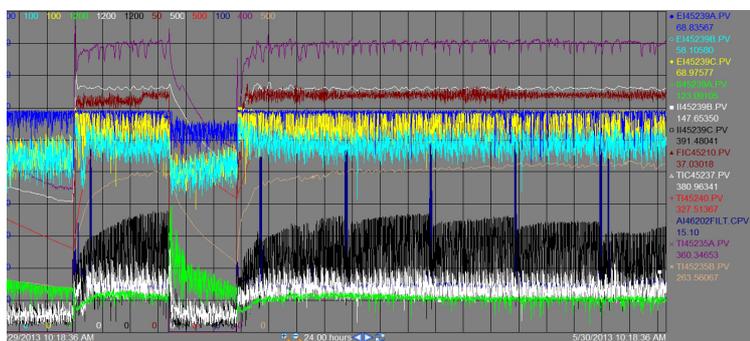
Roaster #1 pre-HFPS installation typical trend May 2012. 1 hour period.



Roaster #2 pre-HFPS installation typical trend May 2012. 1 hour period.



Roaster #1 typical trend May 2013. 24 hour period.



Roaster #2 typical trend May 2013. 24 hour period.

From the 2013 trends it can be seen that secondary voltage and current in all fields has increased significantly from the 2012 pre-HFPS trends, while the production rate (FIC4510.PV & FIC45210.PV) has increased and the emissions (BOGIER1.PV & AI46202FILT.CPV) have reduced.

It is interesting to note the trend for Roaster #2 outlet field secondary current (I145239C.PV). This trend gives an indication of rapping effectiveness. Directly after a rapping event the current is reduced indicating clean collector plates and as the dust gradually builds up on the collectors the current increases until the next rap. This sort of behaviour was not there prior to the HFPS installation.

## ICESP XIII, September 2013, Bangalore, India

With the installation of the HFPS units and the additional rapping, KCGM were able to lift production from around 15t/h to 19t/h which equates to an extra 2500oz/annum. In addition to higher production rates, due to improved collecting and rapping efficiency, there are fewer outages due to fouling; down from 34/year to an estimated 15/year. This has resulted in lower operating costs and less exposure of workers and the environment to toxic chemicals. Overall, this project has delivered not only financial benefits but also health and safety benefits. (ref: Continuous Improvement 2012 - Gidji Roaster ESP build up – KCGM)

At the time of commissioning time did not allow for any real tuning to be carried out under normal operating conditions so it is possible that further improvements can be achieved.

### Conclusion

The above results with HFPS indicate that for aging Industrial precipitators HFPS certainly provides a unique solution, Not only can the overall ESP efficiency improve, the collection efficiency can increase to a point, that minor mechanical defects on the ESP internal parts may become permissible without exceeding emission limits. The above ESPs after a cement kiln and a recovery boiler are only examples from a long list of various process Industrial ESPs that Alstom has successfully upgraded with HFPSs. The number of HFPSs installed on industrial plants are now reaching c:a 900 units.

In comparison with other available means to reduce emission, HFPSs certainly give great value for money and the relative payback period may be very short indeed.

As a HFPSs installation is made only outside of the ESP, a big shutdown is never needed, which usually totally eliminates any plant production loss.

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