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ELECTROSTATIC PRECIPITATOR ENHANCEMENT THROUGH GAS AND DUST FLOW OPTIMISATION

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1. INTRODUCTION

The recent projects conducted by Eskom Technology Servises International in applying the electrostatic precipitator Skew Gas Flow Technology have demonstrated that significant reductions in emissions can be achieved by low cost flow modifications.

The technology has been successfully applied on behalf of Eskom, SA Industry, a copper smelter plant and to utilities in Australia (brown coal). The improvement in performance obtained has demonstrated that the Skew Gas Flow Technology is applicable to a wide verity of dusts, is beneficial when combined with SO_3 injection and can reduce emissions by up to 80% (BCL Ltd. Botswana).

This enhancement technology is attracting international attention and changes to the well-established standard (ICAC) which advocate uniform flow distributions, are being considered by the international authority.

TSI is continually developing the technology. Presently research projects are being conducted on two phase flow modelling with the aim of manipulating the dust distribution before entry to the collection chamber. By combining both the manipulation of the dust and gas distribution it is believed that this will lead to further improvement in ESP efficiencies.

Computational Fluid Dynamic (CFD) modelling has been extensively used to evaluate the flow modifications required to develop the skew flow optimisation. Further developments to the CFD modelling are carried out, which will incorporate full collection dynamics and re-entrainment of the dust particles. Such a model will allow improved predictions of the gain in performance and evaluation of modifications, which will reduce re-entrainment losses.

By combing the manipulation of the dust and flow distribution and reducing re-entrainment losses it is expected that the performance of an electrostatic precipitator can be further improved.

This paper will briefly summarise the applications of the skew gas flow technology and details the present research projects, which are being conducted.

2. SUMMARY OF SKEW GAS FLOW APPLICATIONS [1,2,3]

2.1. Principle of the SGFT

Due to re-entrainment and the effect of gravity a higher dust concentration is developed at the bottom of the treatment zone as the flow progresses from inlet to outlet, Figure 1. The principle of the SGFT is that the flow distribution throughout the collection chamber is altered from that of uniform flow to an inlet and outlet skew distribution, Figure 2. This manipulation of the gas distribution produces lower than average gas velocities in the area where the dust distribution is the highest and reduces re-entraiment losses, especially during the rapping cycle. Thus the overall performance of the ESP is increased.

The skew gas flow technology considers the effects of re-entrainment and thus the non-uniformity of the dust distributions.

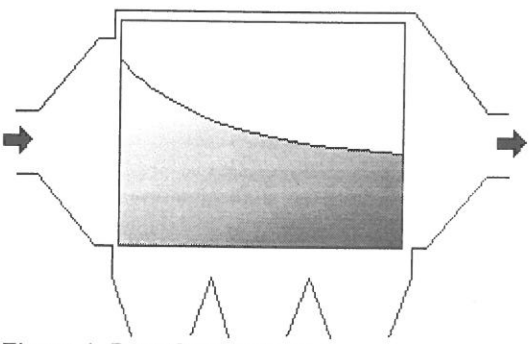

Figure 1. Dust Concentration

Table 1. lists the applications that have been conducted by Eskom. In addition to these the technology has also been successfully applied in the pulp industry.

Table 1: SGFT Applications

Application	Type of application	% reduction	Aspect ratio
Matimaba Power Station	Ash from Black Coal	53	1.4
Lethabo Power Station	Ash from Black Coal	25	2.4
Arnot Power Station	Ash from Black Coal	45	1.2
Tutuka Power Station	Ash from Black Coal	20	1.7
Kriel Power Station	Ash from Black Coal	30	1.3
SASOL South Africa	Ash from Black Coal	48	1.4
BCL Ltd. Botswana	Copper/Nickel product	78	1.1
Hazelwood Power Australia	Ash from Brown Coal	24	1.4

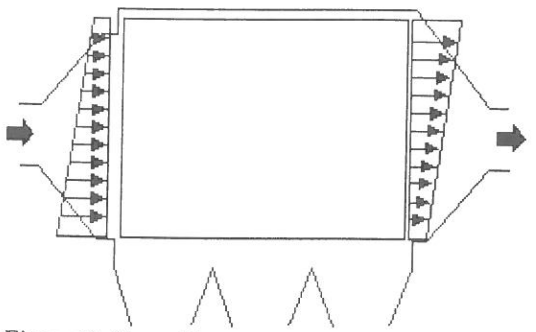

Figure 2. Skew Flow

The above projects have demonstrated that the technology is applicable to a verity of dusts and is beneficial when used in conjunction with flue gas conditioning (SO_3).

The variation in the reduction that can be achieved is dependent on a number of factors:

- The geometry of the inlet/outlet ducting.
- The aspect ratio of the collection chamber (L/H).
- The size distribution of the particles.
- The initial flow/particle distribution.

A comparison between Matimba and Lethabo ESPs shows the influence of the Aspect ratio and the outlet duct geometry. In the case of Lethabo the aspect ratio is 2.4 in comparison to Matimba ESPs, which is only 1.4. Due to a lower aspect ration the dust has a longer dis-tance to fall into the hoppers and hence re-entrainment losses are higher, which renders SGFT more effective. In addition the outlet ducting of the Lethabo ESPs is above the centre line of the collection chamber and this promotes a natural outlet skew which reduces the benefit of applying the skew gas flow technology, Figure 3.

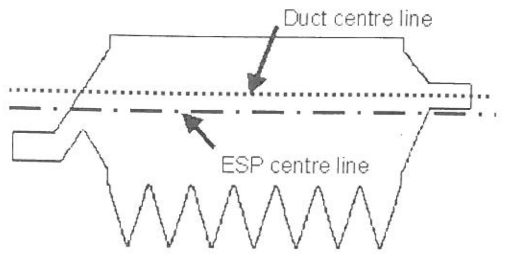

Figure 3. Side view of Lethabo ESP

The investigations conducted on behalf of Hazelwood Power, Australia were successful in reducing emissions by 24%. Although the aspect ratio is quite low the brown coal produces a very fine dust distribution and thus the particles more easily follow the path of the gas flow, which reduces the effect of the skew distributions.

2.2 Cost Benefits

Cost benefits for SGFT implementation within Eskom are mostly derived from deferring or avoiding more expensive emission control technologies. The most modifications were carried out at Kriel Power Station. The ESPs are approximately 20 years old and were the first to be equipped with an SO_3 conditioning plant. However, the deterioration of the internal mechanical condition resulted in difficulties to adhere to present emission limits. The implementation of the SGFT has successfully reduced the the emissions by 30%, which has deferred the costly immediate refurbishment of the ESPs. The project demonstrated the effectiveness of combining SO_3 conditioning technology an SGFT.

The SGFT application at the copper-nickel smelter plant at BCL in Botswana achieved a payback for the cost for the full investigation and the installation within one month due to the reduction in product emissions.

The payback period from SGFT implementation at Hazelwood Power Station was 3 month as confirmed with the station. Due to the reduction in emissions the station was able to run at full load as compared to the reduced load operation, which increased the stations revenue

3. DUST MANIPULATION

From the projects that have been conducted it has been observed from the CFD models that the dust distribution also plays a significant role in the collection efficiency. The dust distribution can be affected by the geometry of the inlet ducting which in some instances can increase the dust loading at the bottom of the collection chamber. In latter projects emphasis has been placed on the manipulation of the dust particles. From experience suitable modifications have been applied with the aim of increasing the dust loading at the bottom of the collection chamber. However, the effectiveness of such modifications has not been quantifiable. Present research is conducted to develop dust manipulation systems in the inlet duct of an ESP and to quantify their effect on the ESP efficiency. A newly commissioned two-phase flow wind tunnel has been specifically designed for this purpose. The work also aims at modelling the dust flow in the wind tunnel using computational fluid dynamics. The cross referencing of these results to that of the CDF simulations will ensure that future field application can be carried out with enhanced accuracy and confidence to implement suitable modifications.

4. CFD MODELLING OF A COMPLETE ESP [4,5,6,7,8]

The application of skew gas flow technology within Eskom plant has assisted in reducing emissions. This technology necessitates the optimisation of the flow distribution within ESPs. The control of flow distribution at the inlet and the outlet of the ESPs are carried out by modification of existing screens and the implementation of additional screens. In order to reduce plant downtime and to establish cost effective modi-fications CFD has been applied. Site measurements showed that CFD predicts the gas flow distribution accurately before and after the implementation of the modifications. To this effect

Eskom has embarked on an extensive research project in order to ensure accu-rate modelling. Figure 4 shows an example of a detailed ESP model with guide vanes, baffles and electrodes.

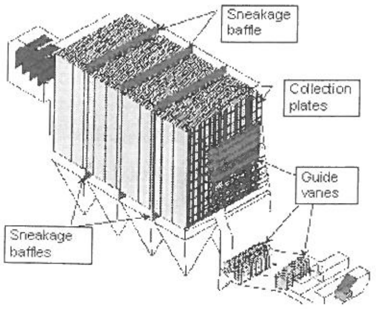

Figure 4. Detailed ESP model

4.1 CFD Research Programme

Research has been focussed on modelling all dynamic aspects of ESP performance using Computational Fluid Dynamics (CFD). A full modelling capability creates the opportunity to investigate the different influencing factors, which govern the dust collection efficiency and lead to improved ESP performance. The dust collection within an ESP is influenced by a number of factors, namely:

- gas distribution
- duct geometry
- inlet geometry
- ash distribution
- gas temperature
- ash quality
- gas composition
- electrostatic forces
- electrode geometry
- collection plate geometry
- rapping
- resistivity

The initial research conducted concentrated primarily on the modelling of the fluid flow within ESPs. World-wide only a few attempts had been made to model the gas flow within ESPs. Initial results were not accurate and the industry did not trust the use of CFD to establish flow patterns within ESPs. This was mainly due to the steep angles of the inlet flares. Flow correctional devices were not modelled adequately which caused unacceptable inaccuracies in the development of the flow within the casing of the ESP. In addition, where internal structures were not modelled with sufficient care, further inaccuracies became evident.

The results of the work conducted by Eskom has resulted in an accurate modelling methodology for ESPs, which was internationally recognised as an important achievement. CFD can now be applied with sufficient accuracy, which has reduced plant down time considerably.

For the development and implementation of the collection dynamics a two-dimensional model was used which represents the geometry of the Arnot inlet and outlet flare and casing.

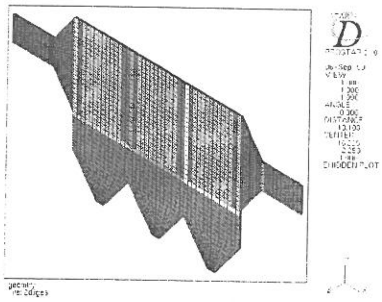

Figure 5. Computational mesh of the Arnot ESP geometry

The model consists of a single gas path. Particle are counted at the inlet and outlet of each field thus calculating the efficiency of the ESP.

4.1.1 Gravity Effects

The effect of gravity on the particles plays an important role in the performance of an ESP. The particle trajectory seen in Figure 7a shows that the particles closely follow the gas distribution shown in Figure 6. Due to the forces of inertia larger particles tent to deviate from the gas path. Incorporation of the effect of gravity leads to fallout of the larger particles, Figure 7b. Fly ash particles smaller than 10mm are hardly affected by gravity and follow the gas flow.

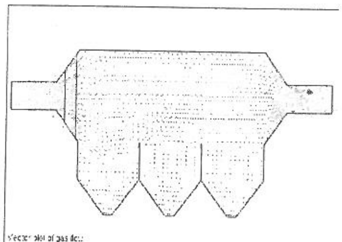

Figure 6. Gas flow distribution

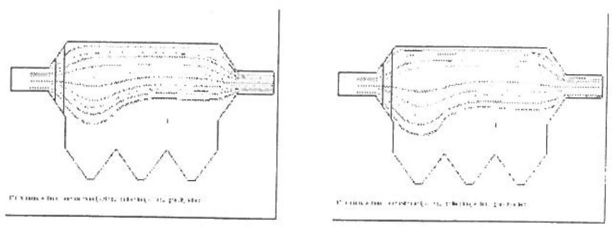

Figure 7a. Trajectory for 100□m and 10□m particles without collection, no gravity

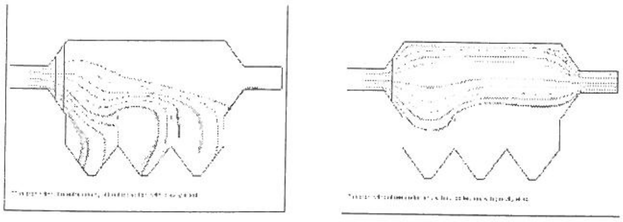

Figure 7b. Trajectory for 100□m and 10□m particle without collection and gravity

4.1.2 Effect of Particle Collection

To simulate the particle collection, particle charge and Coulomb forces are added to the momentum equation of the moving particle. Figure 8 indicates the effect of the particle charge and the presence of the electrostatic field. Although the acceleration forces for the large particles are much lower than for the small particles, they are collected within a few meters into the first field. Smaller particles tend to penetrate the ESP much further and sometimes escape collection entirely.

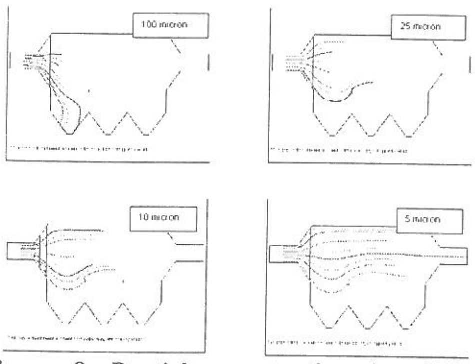

Figure 8. Particle penetration for different size particles

Large particles are less influenced by the moving gas and can follow the collection forces with much less resistance. The collection behaviour shown by the various runs agree with the collection behaviour observed in an ESP i.e. larger particles collect in the first field.

Particle collection is indicated by the interrupted particle trajectory. The end of each trajectory represents the point of collection of the individual particle. Continuous lines of trajectory through to the outlet show non-collection. Sweepage is indicated by particles sweeping through the hopper and re-entering the collection zone of the following field where they may or may not be collected.

4.1.3 Particle Reentrainment Model

Particle reentrainment is one of the most important parameters that influence the performance of an ESP. Reentrainment may be caused by direct scouring of the collection electrode surfaces by the gas stream, by re-dispersion of collected particles during a rapping of the electrodes, and by sweepage of collected dust from hoppers.

It is not uncommon for example that an ESP efficiency of 85% under poor flow conditions can be raised to 95% to 98% by the correction of flow to uniform flow. A further improvement to 99% could be achieved by further flow optimisation i.e. controlled gas flow technology.

The current work introduced a reentrainment mechanism, which models some of the important factors causing reentrainment. Although the mechanism does not consider all possible causes, it can be calibrated more closely to the individual ESP under consideration. The main focus of the reentrainment lies in the effect of rapping.

A number of different reentrainment modeling methods have been considered for the incorporation into the model, of which one has proven to be the most accurate.

This method displaces all particles after collection back into the gas stream according to a given vertical and horizontal distance, Figure 9.

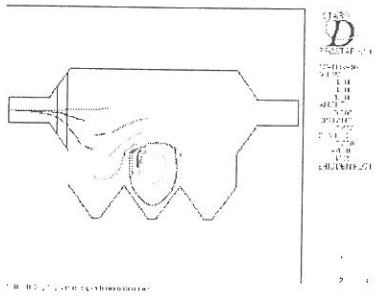

Figure 9. Particle reentrainment by displacement method

The actual displacement value needs to be established for every ESP individually and depends on the operational parameters of the ESP. The falling particle curtain accelerates according to the length of the vertical drop.

The final drop velocity is calculated as follows:

During this process it is assumed that the particle has lost it's charge and a new charging process is initiated. However, the second charging process is delayed by a certain factor, to account for the fact that the recharge of a particle is less effective than the initial charge at entry to the ESP.

In order to achieve reentrainment effects close to those experienced at the plant a calibration of the current model is necessary.

The method applied does not consider all possible reentrainment mechanics but greatly assist in the investigation of ESP performance behavior. By establishing accurate flow patterns within the ESP using CFD, the performance of the ESP can be qualitatively judged regarding the potential behavior of reentrained dust.

Currently work is being carried out to calibrate the reentrainment model against measurements taken on site at Lethabo Power Station.

5. CONCLUSIONS

- The skew gas flow technology has proven to be cost effective ESP enhancement technology.
- The technology is applicable to a wide variety of dusts and in conjunction with SO3 flue gas conditioning.
- To further improve the benefit of this technology continued research is being conducted with the emphasis on the manipulation of the dust particles before entry to the collection chamber
- The application of the skew gas flow technology has been greatly enhanced by the CFD simulations. The combination of the manipulation of both the flow and dust and the reduction of reentrainment will results in the full optimisation of the ESP collection efficiency.
- The application of CFD modelling has substantially reduced the outage time required to successfully implement the technology.
- The returns of investments are substantial in comparison to other available enhancement technologies.

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BRAZIER DESIGN FOR MINIMUM SMOKE EMISSION

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1. INTRODUCTION

Smoke from braziers (imbawula's, paola's) has been a thorn in the flesh of officials doing air pollution control in urban areas for many years. Everybody has seen the bellowing smoke from these imbawula's during winter mornings in the CBD of Johannesburg. It sometimes even reduces the visibility so much that even the road cannot be seen which is a traffic hazard. This pollution is especially bad during during the mealie season when informal traders braai mealies to sell it to the passing trade. Informal traders cooking food in fact has become part of the everyday life in most urban areas in South Africa. Braziers are also used in former black townships and in informal settlements for domestic cooking.

2. LAW ENFORCEMENT

Law enforcement as far as braziers is concerned is and was always very difficult if not impossible. The Atmospheric Pollution Prevention Act prohibits smoke from fuel-burning appliances with a certain density depending on whether the appliance is in an industrial or a residential area. Normally the appliance is on a premises where an occupier or an owner can be prosecuted if necessary. Informal traders use a piece of the sidewalk in the CBD or a vacant piece of government or provincial land where nobody can be prosecuted. Some even sell hot embers to other informal traders. Confiscation of braziers may even lead to attacks on officials and is counterproductive as this is their livelihood. These arguments however do