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<b>Subject:</b>	<b>Interim SO<sub>2</sub> mitigation for Medupi Power Station – Duct Sorbent Injection</b>

## 1. Introduction

The focus of this memorandum is to inform Project Development of the outcome from a desktop evaluation relating to direct sorbent injection technology for the partial abatement of SO<sub>2</sub> emissions to meet the existing plant limit (3500 mg/Nm<sup>3</sup>) as an interim solution at Medupi until the WFGD retrofit is realised.

The plant would require between 4% and 25% SO<sub>2</sub> removal efficiency when operating with the worst design case and rejection coal sulphur quantities respectively. The interim measure however will not be required continuously, but only when emissions are expected to exceed the legislated limits.

## 2. Technology Definition

Direct sorbent injection was originally developed to treat acidic gasses such as SO<sub>3</sub> (due to the introduction of selective catalytic reduction processes), HCl and HF. The process can successfully be used for the reduction of SO<sub>2</sub>, however this will be in competition of the other acidic gasses.

Direct Sorbent Technology is typically implemented for utilities and industrial applications that require low removal efficiencies and/or with a short remaining plant life. The potential advantages include ease of retrofit and low associated capital investment.

The sorbent (calcium/sodium based) can be pneumatically injected anywhere in the flue gas path from the furnace to the stack, however elevated temperatures are best suited for SO<sub>2</sub> control. Common injection points include; in the furnace (Furnace Sorbent Injection - FSI), in the economizer region (Economiser Sorbent Injection - ESI) and upstream and/or downstream of the air preheater (Duct Sorbent Injection - DSI). The absorption of SO<sub>2</sub> results in the formation of a dry waste that can be removed from the flue gas in the particulate control system (i.e. Fabric Filter Plant (FFP) at Medupi) and then landfilled either in the ash dump or separate landfill facility. For the sake of this desktop review, DSI and ESI is combined into a single process and referred to as DSI.

### 2.1. Furnace Sorbent Injection

The dry sorbent (e.g. limestone) is injected in the upper part of the furnace where the temperature is in the range of 750-1250°C. The sulphation reaction practically ceases at temperatures below 750°C and the sorbent active surface area is reduced at temperatures above 750-1250°C.

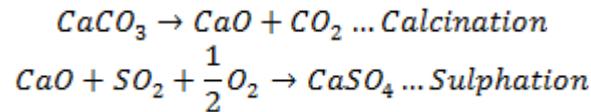
Alternatively, sorbent can be injected through the burner system (e.g. LIMB - Limestone Injection Multi-Stage Burners technology). The limestone is injected at high temperatures (above 950°C) to allow calcination for the limestone to quicklime for partial removal of SO<sub>2</sub>.

### 2.2. Duct Sorbent Injection

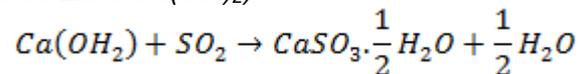
Sorbent (e.g. hydrated lime or trona) can either be injected into the flue gas stream near the economizer zone where the temperature is in a range of 300°C to 650°C or into the duct after the air preheater where the temperature is approximately 150°C.

### 3. Basic Chemical Reactions and Typical Removal Efficiencies

*FSI (Sorbent – Limestone CaCO<sub>3</sub>)*



*FSI, DSI (Sorbent – Hydrated Lime Ca(OH)<sub>2</sub>)*



Removal efficiencies of up to 50% and 80%<sup>1</sup> can be achieved with FSI and DSI respectively however this is highly dependent on the flue gas properties (i.e. temperature, moisture content and concentration of other competing acid gases) the reagent properties such as specific surface area (SSA), porosity and particle size as well as the configuration of the system including injection location, residence time, reagent mixing, particulate control system.

### 4. Factors that Impact DSI System Effectiveness

#### 4.1. Flue Gas Properties (temperature, moisture content and concentration of other competing acidic gases)

Generally speaking, temperatures over 580°C are required to ensure pure thermal dissociation of calcium hydrate for removal efficiencies higher than 60%. Below 580°C the reaction depends on the amount of moisture in the flue gas since the reaction with SO<sub>2</sub> takes place in the liquid phase and not the gas phase therefore further conditioning of the flue gas would be required to obtain higher removal efficiencies. Water can be injected onto the hydrated lime prior to injection into the duct as a thin mist to create a hydration layer around the particles. Below 150°C, a significant portion of water would be required to aid the reaction and removal efficiencies of only 20% would be expected even with the additional residence time contributed by the FFP. In this case, better suited technologies such as circulating dry scrubbing technology have been developed.

Furthermore, at low temperatures (around 150°C) hydrated lime has the affinity to react quicker with SO<sub>3</sub>, HF and HCl than with SO<sub>2</sub>. In this case the hydrated lime would react with all the SO<sub>3</sub>, HF and HCl before it reacts with the SO<sub>2</sub> therefore limiting the possible SO<sub>2</sub> removal efficiencies and increasing the sorbent requirements.

#### 4.2. Reagent Properties

Theoretically SO<sub>2</sub> removal efficiencies of between 20% and 30% may be achieved with the use of normal hydrated lime with an excess Ca/S nett stoichiometric ratio (NSR) of between 2 and 4, a specific surface area of 20m<sup>2</sup>/g and a porosity of approximately 0.7 cm<sup>3</sup>/g; assuming the other conditions (i.e. flue gas temperature and moisture content, reagent mixing, residence time) are favourable. The removal efficiency can be increased through the utilisation of an optimised technical hydrated lime sorbent (e.g. SORBACAL) with a specific surface area greater than 40m<sup>2</sup>/g and porosity of ~0.23 cm<sup>3</sup>/g. The production of such technical hydrated lime sorbents involves a very specific and proprietary slaking process which increases the cost of the reagent and is currently not available in South Africa.

DSI with the use of sodium based sorbents (i.e. sodium bicarbonate or sodium sesquicarbonate – TRONA) can achieve high removal efficiencies of up to 80% with similar NSR as hydrated lime however this has been excluded from the evaluation due to the environmental implications

<sup>1</sup> This can only be achieved in nearly perfect conditions and with optimal sorbent quality and properties

associated with the high leachability of the sodium ions and the cost implications to the ash disposal facilities.

### 4.3. System Configuration

For DSI technology the SO<sub>2</sub> removal efficiency can be improved through the following:

- Longer sorbent particle residence time.
- Good distribution of sorbent particles over the cross-section of the duct.
- Further reaction of the unreacted hydrated lime on the bags of the FFP with the remaining SO<sub>2</sub> in the flue gas.

Multiple injection trains with strategically positioned nozzles based on flow conditions, longer duct length post sorbent injection and the presence of a FFP (as opposed to ESP) are beneficial for the reduction of SO<sub>2</sub>.

## 5. Practical Implications for Application at Medupi Power Station

### 5.1. Sorbent Sourcing

Hydrated lime with maximum specific surface area and porosity that can be achieved with conventional slaking may be acceptable to achieve the low removal efficiency required for Medupi in the interim. Proprietary sorbents sourced internationally may be required if the desired removal efficiency cannot be achieved. The reduction efficiency of South African hydrated lime needs to be evaluated on a pilot basis first to establish the exact characteristics for removal efficiency. The mineralogy of South African limestones is not favourable for the calcination process. Therefore there is uncertainty with respect to the characteristics of the burnt lime and therefore also the hydrated lime and its suitability for the DSI process.

Should normal hydrated lime be acceptable, it would be easier to source burnt lime and hydrate the lime on site in a slaking process. Current knowledge suggests that burnt lime is only available from the Northern Cape area and will therefore have to be delivered to site via truck/rail over extended distances.

Assumptions regarding the sorbent quality and reactivity had to be made to calculate an expected sorbent utilisation amount. These can only be confirmed during a concept design and once pilot testing has taken place. The expected hydrated lime requirement for a 25% reduction is approximately 1000 tons per day per unit if the DSI unit is running on a continuous basis.

### 5.2. Infrastructure Requirements

In the case of DSI, the following new plant would be required:

- Sorbent trucks and off-loading facilities,
- Burnt lime silo/s for the storage of burnt lime,
- Lime slaker to hydrate the burnt lime,
- Hydrated lime silo/s to store hydrated lime,
- Pneumatic pipelines for transportation of hydrated lime,
- Sorbent injection ports,
- Flue gas conditioning/additional water before hydrated lime injection into the duct, and
- Bulk Materials Handling infrastructure and waste management systems (to be evaluated).

### 5.3. Continuous versus batch-wise operation

The SO<sub>2</sub> emissions at Medupi should be within the existing plant emission standards when operating with design coal. Operation of the DSI system would only be required when receiving coal quality

between the worst case and rejection point for sulphur. Additional instrumentation should be installed to monitor this in real time to ensure timeous starting of the injection process.

#### 5.4. Bulk Materials Handling and Waste Management

Implementation of any of the DSI variations would increase the solids loading through the FFP and the Dust Handling Plant (DHP). The composition of the fly-ash will also be altered and will include the by-product (CaSO<sub>4</sub> and CaSO<sub>3</sub>.1/2H<sub>2</sub>O) as well as a significant amount of unused sorbent (since it is added in excess). The solid loading to be transported by the DHP will not be able to be transported in the current pneumatic handling systems and have to be increased by approximately 35%. The flow ability of the material is not yet understood and the impact to the conditioning plant, transport to the silos and the impact on the rest of the materials handling value chain up to the current ash dump has not been considered. The pulsing system for Medupi FFP will have to increase over its current capability. These will all need to be evaluated in detail. The current ash dump was designed to cater for fly ash for the first 20 years of the station life. The lifetime will be reduced due to the increase in loading.

#### 5.5. Erosion and fouling

The implementation of FSI will result in a significant increase in entrained solids throughout the boiler due to the NRS required for neutralisation. This is largely negative as it will take place before the convective sections within the boiler. This will increase the fly-ash erosion rate and the slagging propensity may be affected. LIMB technology will result in more alkaline slags, which will significantly increase the slagging ratio of the ash produced and present in the radiant furnace section. The capacity and operability of the milling system would have to be checked based on the properties of the limestone. The Medupi boiler is currently experiencing significantly high erosion rates and therefore FSI would not be preferred. The combustion system at Medupi has not been specifically developed to be able to feed additional limestone through the burners and a thorough technology review needs to be conducted to review its feasibility.

Sorbent injection upstream of the air preheater will probably lead to abrasion, by-product (CaSO<sub>4</sub>, CaSO<sub>3</sub>.1/2H<sub>2</sub>O and unused sorbent) solids deposits and blockage over time. However, neutralisation of SO<sub>3</sub> may be beneficial to low temperature acid condensation plugging of the air preheater.

For DSI at low temperatures (150°C and below) where further conditioning of the flue gas is required care should be taken to avoid liquid water carryover to the FFP which would cause clogging of the filter bags.

#### 5.6. EIA requirements

The ash dump is currently lined with a Class C liner for the first four years followed by the installation of another Class C liner to cater for the WFGD gypsum by-product for years 5 to 20. The DSI waste (i.e. fly ash and DSI by-products) would require an environmental classification which has not been completed. It is likely that this waste would require a Class A liner. This will require that the 5-20 year liner need to be upgraded (at least a portion) to a Class A liner to suit the DSI application.

The implementation of DSI would require an amendment to the Water Use License due to change in water balance (i.e. raw water users). An environmental impact assessment would also be required based on construction of new plant, processing of chemical sorbents, and change in quantity and quality of the FFP waste stream and the handling and disposal thereof.

The duration of the EIA process is approximately 12-18 months.

## 6. Costs

The capital cost of a DSI system (technology cost only) is conceptually estimated at approximately R50m per unit. The cost for lime is approximated to R1.5m per unit per day for a 25% removal efficiency. This cost needs to be evaluated further to ensure that the transportation costs are catered for completely and the other operational expenditures associated to the plant infrastructure and operating is added. A high level net present cost for one unit at a seven year operational life is estimated at approximately R3.3bn. This value includes modifications to the DHP and FFP. Greater cost accuracy should be obtained through further engineering analysis.

## 7. Conclusion

Out of the DSI options presented above hydrated lime injection in the duct before the air preheater seems to be the most suitable technology choice to achieve removal efficiencies of up to 30% due to the temperature requirement. This is highly dependent on the temperature profiles and distribution, moisture content in the flue gas, residence time through the duct and FFP and the reactivity of the sorbent. The effect on the air preheater and associated fouling and plugging should not be underestimated and requires investigation to ensure suitability of the technology selection. The removal efficiency achievable with DSI is not an exact science and the optimum design should be developed based on pilot plant testing due to the amount of variables currently present.

The implementation of DSI at Medupi is therefore seen as questionable due to the technical concerns relating to the air preheater. The environmental concerns and timelines need to be addressed as well as the sorbent reactivity and achievable reduction efficiency proven. Furthermore, the technical capability of the current installed plant (i.e. the air heater, FFP, DHP and road infrastructure) needs to be confirmed during a conceptual engineering phase as part of a business case development process.

The cost of sorbent is prohibitively high. In addition there are logistical challenges to source and bring the sorbent to Medupi site. The mass balance indication shows that a significant amount of sorbent will be required for a limited abatement of SO<sub>2</sub> in the flue gas. 20 to 30 truckloads of sorbent per unit per day may be required if the plant is continuously running with higher sulphur levels. This can be optimised during a conceptual design phase for a batch-wise operation; however the figure is not expected to reduce significantly. Consideration to the time requirements for installation needs to be critically reviewed against the overall FGD installation program if DSI is considered to be implemented.

Direction from Project Development is required for Plant Engineering to consider further work on the topic.

Yours Sincerely



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Leon van Wyk, Pr. Eng

**AIR QUALITY ENGINEERING MANAGER**

Plant Engineering: Power Plant  
Group Technology Engineering

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