Title: Large scale Implementation of WFGD in Eskom: The Medupi Power Station WFGD Plant Retrofit Project

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Outline

1. Introduction

2. Compliance to $\text{SO}_2$ emissions legislation

3. Medupi WFGD Retrofit Project

4. Conclusions & Current Work
1. Introduction

- Eskom: largest producer of electricity in Africa
- 13 existing and 2 new build coal-fired power stations
- Installed coal fired generation capacity of 39.5 GW (Base load and Return To Service)

![Figure 1: Electricity produced in 2013 232 479 GWh (total net production)](image1)

![Figure 2: Contributors to SO$_2$ emissions in the Highveld Priority Area](image2)
1. Introduction

1.1. SO$_2$ emissions legislation in South Africa

- Sulphur Oxides classified as a “criteria pollutant”
- National Environmental Management: Air Quality Act, 2004 (Act No. 39)

**Table 1: Minimum Emissions Standards for SO$_2$ Emissions**

<table>
<thead>
<tr>
<th>SO$_2$ Emissions Limit</th>
<th>Applicable to</th>
<th>Compliance Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>500 mg/Nm$^3$ at 10% O$_2$</td>
<td>New Plants</td>
<td>2010</td>
</tr>
<tr>
<td>3500 mg/Nm$^3$ at 10% O$_2$</td>
<td>Existing Plants</td>
<td>2015</td>
</tr>
<tr>
<td>500 mg/Nm$^3$ at 10% O$_2$</td>
<td>Existing Plants</td>
<td>2020</td>
</tr>
</tbody>
</table>

**Table 2: National Ambient Air Quality Standard for SO$_2$ Emissions**

<table>
<thead>
<tr>
<th>Averaging Period</th>
<th>Concentration</th>
<th>Frequency of Exceedence (per annum)</th>
<th>Compliance Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 minutes</td>
<td>50µg/m$^3$ (191ppb)</td>
<td>526</td>
<td>Immediate</td>
</tr>
<tr>
<td>1 hour</td>
<td>359µg/m$^3$ (134ppb)</td>
<td>88</td>
<td>Immediate</td>
</tr>
<tr>
<td>24 hours</td>
<td>125µg/m$^3$ (48ppb)</td>
<td>4</td>
<td>Immediate</td>
</tr>
<tr>
<td>1 year</td>
<td>50µg/m$^3$ (19ppb)</td>
<td>0</td>
<td>Immediate</td>
</tr>
</tbody>
</table>
2. Compliance to SO$_2$ Emissions Legislation

2.1. National Ambient Air Quality Standard

- **Declared Priority Areas**
  - a) Highveld (Kendal, Matla, Arnot, Hendrina, Duvha, Camden, Majuba, Tutuka, Komati, Grootvlei, Kriel, Kusile)
  - b) Vaal Triangle (Lethabo)
  - c) Waterberg (Matimba, Medupi)

- **Atmospheric Dispersion Modelling for SO$_2$ concentration levels**
  - Areas of non-compliance in the Highveld
  - NAAQS being achieved in Vaal Triangle and Waterberg areas
2. Compliance to SO₂ Emissions Legislation

2.2. Minimum Emissions Standard (SO₂)

Table 3: Compliance to Minimum Emissions Standards for SO₂ Emissions for Eskom Coal-fired Power Stations

<table>
<thead>
<tr>
<th>Station Type</th>
<th>Station sub-type</th>
<th>Station Name</th>
<th>Complaince with 2015 existing plant standards</th>
<th>Current compliance with 2020 standards</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>New Build</td>
<td>Kusile</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Coal-fired power stations</td>
<td>Medupi</td>
<td>Y</td>
<td></td>
<td>N (Will comply 6 years after commissioning)</td>
</tr>
<tr>
<td></td>
<td>Existing</td>
<td>Station 1</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Station 2</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Station 3</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Station 4</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Station 5</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Station 6</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Station 7</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Station 8</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Station 9</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Station 10</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td>Existing, Return to service</td>
<td>Station 11</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Station 12</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Station 13</td>
<td>Y</td>
<td>N</td>
</tr>
</tbody>
</table>

15/10/2014
3. Eskom Large Scale FGD Retrofit- Medupi WFGD Retrofit Project

3.1. Background

- Currently under construction
- 6 X 800MW Units (4800MW)

![Flue Gas Path with WFGD for Medupi Power Station](Medupi PS May 2013)

- WFGD (Limestone, Forced Oxidation- LSFO) Retrofit: 6 Absorbers and one common plant for limestone preparation, gypsum dewatering and wastewater treatment
3. Eskom Large Scale FGD Retrofit- Medupi WFGD Retrofit Project

Figure 4: General overview of a typical wet FGD plant.
3.2. WFGD “Ready” Concept

- Increased margin on ID Fans
- Lining of chimney flues with corrosion resistant liner
- Rotation of chimneys to 180° to ensure clean gas duct tie-in
- Lining of ash dump
- Spatial provisions for Absorber Island and Common Plants
- Raw Water Storage and Pumping System

Figure 5: Notable provisions made for WFGD retrofit.
3.3. Design Criteria & Process Design Basis

- **Sulphur in coal range**: 1.2-1.8% a.d
- **85-96% CaCO₃ Limestone range**
- **Attemperation Air upstream of the FFP**
- **Required SO₂ clean gas concentration**: 400mg/Nm³
- **Varying Raw Water Source**: Mokolo Dam and Crocodile West Scheme

*Figure 6: Process Design Basis Considerations

*Figure 7: Location of limestone deposits in relation to Medupi Power Station*
3.4. Key Design Features & Considerations

a. Absorber Design

<table>
<thead>
<tr>
<th>Table 4: Medupi FGD Absorber Characteristics.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSORBER CHARACTERISTICS (per unit)</td>
</tr>
<tr>
<td>Materials of Construction</td>
</tr>
<tr>
<td>Flue Gas Volume</td>
</tr>
<tr>
<td>SO₂ Removal Efficiency (%)</td>
</tr>
<tr>
<td>Absorber Height</td>
</tr>
<tr>
<td>Absorber Diameter</td>
</tr>
<tr>
<td>Reaction Tank Diameter</td>
</tr>
<tr>
<td>No. of Spray Banks</td>
</tr>
<tr>
<td>Recirculation Pumps (m³/hr)</td>
</tr>
<tr>
<td>Mist Eliminator</td>
</tr>
<tr>
<td>No. of Reaction Tank Agitators</td>
</tr>
<tr>
<td>Absorber Gas Velocity</td>
</tr>
</tbody>
</table>

Figure 8: Medupi FGD Absorber Overview and Render of Absorber from Medupi WFGD 3D Model
b. Low quality limestone

a. Effects on plant design
   • Increases in equipment sizing, auxiliary power requirements and investment cost

Table 5: Design changes as a result of low quality limestone evaluated.

<table>
<thead>
<tr>
<th></th>
<th>Concept Design</th>
<th>Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>Absorber Reaction Tank Diameter (m)</td>
<td>20.5</td>
<td>21.5</td>
</tr>
<tr>
<td>Absorber Reaction Tank Height (m)</td>
<td>8</td>
<td>7</td>
</tr>
<tr>
<td>Absorber Recirculation Pump Size (m³/h)</td>
<td>9100</td>
<td>9600</td>
</tr>
<tr>
<td>Limestone Consumption</td>
<td>8.8% increase</td>
<td></td>
</tr>
<tr>
<td>Raw Water Consumption</td>
<td>3.5% increase</td>
<td></td>
</tr>
<tr>
<td>Gypsum Production</td>
<td>5.6% increase</td>
<td></td>
</tr>
</tbody>
</table>

b. Potential Process Effects
   • Preliminary sample analyses: High levels of magnesium and inert material (dolomite, quartz and layered crystals)
   • Higher milling costs and gypsum dewatering costs. Effects on limestone solubility.
c. Water Consumption Optimisation

- Design Features to reduce WFGD Raw Water consumption
  - Absorber make-up through ME flushing
  - Introduction of Wastewater hydro-cyclone to reduce wastewater
  - Reclaim and recycle of all process streams
  - Zero Liquid Effluent Discharge Plant (ZLED) Plant: 10% reduction in overall water consumption
  - Provision for future retrofit of Gas Cooler for raw flue gas cooling: approx. 30% reduction in raw water consumption
    - Unit 2 and 5 absorbers rotated by 30° to allow for uniform flue gas distribution
    - Flue Gas inlet duct to absorber constructed using carbon steel with perfluoroalkoxy (PFA) lining
c. Water Consumption Optimisation

Figure 9: Medupi FGD Absorber Inlet Duct with Gas Cooler

Figure 10: Medupi FGD Unit 4-6 Process Area Arrangement with Gas Cooler
3.5. Challenges associated with Construction and Commissioning Sequence

a. Construction
3. Eskom Large Scale FGD Retrofit- Medupi WFGD Retrofit Project

Figure 12: Render of Medupi WFGD 3D Model

- Unit 1
- Unit 2
- Unit 3
- Unit 4
- Unit 5
- Unit 6

ZLD Wastewater Treatment Plant

Gypsum Dewatering Plant

Limestone Preparation
3. Eskom Large Scale FGD Retrofit- Medupi WFGD Retrofit Project

- Construction of Unit 4 in planned sequence may impact the erection schedule, cost and safety.

Figure 13: Render of Medupi WFGD 3D Model Unit 4-6 (Absorber Cluster 2)
• Temporary facilities and laydown areas situated on WFGD footprint preventing geotechnical studies.
b. Operational Challenges
3. Eskom Large Scale FGD Retrofit- Medupi WFGD Retrofit Project

Figure 15: Schematic of Medupi WFGD Limestone Slurry Loop Lines

Total Length of Piping: ≈ 3.2 km
4. Conclusions and Current Work

- Medupi WFGD Retrofit FEED Studies
  - Challenges associated with large scale retrofit
  - Lessons learned related to Arrangement Design and Constructability
  - Integration with existing plant systems is vital to ensure successful retrofit
  - Comprehensive limestone characterisation essential for design
  - Flue Gas Cooling to reduce water consumption
  - Basic Design Concluded- preparations for detailed design underway

- Current Work:
  - Kusile WFGD Plant under construction
  - Fleet Technology Evaluation taking into account:
    - Evaluation of a suite of FGD Technologies (Wet & Semi-Dry)
    - Site Layout
    - Capacity of and impacts on existing plant facilities (draught systems, electrical, control & instrumentation, raw water, compressed air, materials handling systems and chimneys) to support FGD retrofit
    - Waste management
    - Lessons learned from Kusile and Medupi WFGD.

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- Eskom, Group Technology, Sustainability
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  - Environmental
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