# INTHUU MEASUREMENTS CC

VAT REG NO.: 4960254359 REG NO.: 2009/190265/23

P.O. Box 14769
Bredell, 1623

Plot 2/410 Seventh Road
Bredell A/H, Kempton Park,
1619

Tel: +27 (0)82 572-2380
Fax: +27 (0)86 659-2231


Eskom Holdings SOC Ltd
Majuba Power Station
***Attention: Mr. Lindani Madonsela***
Private Bag 9001
Volkrust
2470

| Date | Your Reference | Our Reference | Enquiries |
|---|---|---|---|
| 04 May 2016 | Order No.: 4502289115 | RCCS247 | CC Scheepers<br>Cell: 082 572 2380<br>e-mail: coen@inthuu.co.za |

**REPORT – 2016/04/26/RCCS247**
**PARTICULATE EMISSION MONITOR CORRELATION ON UNIT 2 AT MAJUBA POWER STATION**

Herewith the report for the particulate emission monitor correlation measurements carried out between the 01st and 03rd of April 2016. Tests were carried out on Unit 2 in Stack 1.

We thank you for the opportunity to be of service and trust that your requirements have been interpreted correctly. If you have any queries, please contact us at the above numbers, we will gladly assist.

Yours faithfully
Inthuu Measurements cc

CC Scheepers

| INTHUU MEASUREMENTS CC | | |
|---|---|---|
| Stack tester<br>**AV Makama** | Prepared by:<br>Signature:.....<br>**MT Matlou** | Issued by:<br>Signature:.....<br>**CC Scheepers** |

# REPORT

| | | |
|---|---|---|
| **CUSTOMER** | **:** | ESKOM MAJUBA POWER STATION |
| **OPERATING COMPANY** | **:** | MAJUBA POWER STATION |
| **TYPE OF MEASUREMENT** | : | PARTICULATE EMISSION MONITOR CORRELATION |
| **TITLE** | : | PARTICULATE EMISSION MONITOR CORRELATION ON UNIT 2 IN STACK 1 AT MAJUBA POWER STATION |
| **ORDER No's.** | : | 4502289115 |
| **REPORT No.** | : | 2016/04/26/RCCS247 |
| **REPORT DATE** | : | 04 MAY 2016 |

# Index




Summary:

| | | |
|---|---|---|
| Plant | : | Majuba Power Station |
| Operating times | : | 24 hours |
| Emission source | : | Power generation - fossil fuel boilers |
| Measured components | : | Particulate Matter |
| Date of measurement | : | 01 to 03 April 2016 |
| Emission source No. | : | Unit 2 in Stack 1 |
| Atmospheric Emission Limit | | 100mg/Nm$^3$ (d) at 10% $O_2$ |

**Measurement results**

1. Nine measurements at 500 MW showed emission concentrations between 15.5 and 28.7 mg/Nm$^3$ (d) at 10% $O_2$
2. PM function as found for AO2, y = 25.2564*mA - 100.8546
3. PM function as found for AO3, y = 9.4711*mA - 37.7138
4. PM function recommended for AO2, y = 8.2083*mA - 32.6625
5. PM function recommended for AO3, y = 12.6282*mA - 50.3419
6. Gas flow function, g = 1.3492*Total air flow + 0.9037

Where:

| | | | |
|---|---|---|---|
| y | = | Particulate emissions | [mg/Nm$^3$ (d) at 10% $O_2$] |
| mA | = | Monitor output, AO1 or AO2 | [mA] |
| g | = | Gas flow rate | [Nm$^3$/s (d) at 10% $O_2$] |
| Total air flow | | | [kg/s] |

## GLOSSARY

Some of the following abbreviations were used in the text, figures and Tables:

| | |
|---|---|
| AMS | Automated Measurement System |
| SRM | Standard Reference Method |
| CEM | Continuous Emission Monitor |
| ESP | Electrostatic Precipitator |
| FFP | Fabric Filter Plant |
| MCR | Maximum Continuous Rating |
| °C | Degrees Celsius |
| Pa (g) | Gauge pressure in Pascal |
| kPa (abs) | Absolute pressure in kilo Pascal |
| % v/v | Percentage on a Volume-by-Volume basis |
| $Am^3$ | **Actual** Cubic Metres |
| $Nm^3$ | **Normal** Cubic Metres |
| $Am^3(w)$ | **Actual** Cubic Metres on a wet basis |
| $Nm^3(w)$ | **Normal** Cubic Metres on a wet basis |
| $Am^3(d)$ | **Actual** Cubic Metres on a dry basis |
| $Nm^3(d)$ | **Normal** Cubic Metres on a dry basis |
| ATPD | Actual Temperature and Pressure – Dry |
| NTPD | Normalised Temperature and Pressure - Dry |
| g/s | Grams per second |
| mg/s | Milligrams per second |
| dP | Differential pressure |
| AO | Analogue Output |

- **'Actual'** refers to the measured temperature and pressure conditions of the gases in the duct.
- **'Normal' or 'Standard'** refers to the actual conditions being normalised to 0 °C and 101,325 kPa.

## 1 MEASUREMENT OBJECTIVE

Inthuu Measurements CC was contracted by Majuba Power Station, to perform the Particulate Emission Monitor correlation from which monthly reports are generated.

The objective was to determine a linear regression allowing the reporting of emissions from an Automated Measurement System (AMS). Constants are derived from the gravimetric measurements by a Standard Reference Method (SRM) and the corresponding AMS signal.

The correlation function must report emissions at normal running condition, but must at the same time be able to indicate excursions over the Ambient Emission Limit when plant problems occur.

Tests were carried out between the 01st and 03rd of April 2016.

## 2 PLANT DESCRIPTION AND MATERIALS HANDLED

The power station currently operates six power generation units, each consisting of a steam driven turbine and a boiler supplying the steam. The boilers are specially designed to burn low grade coal, which contains high percentages of ash and sulphur.

Each unit is equipped with particulate matter abatement technology. Majuba uses Fabric filters (FFPs) to clean the boiler waste gases. Currently, no further emission abatement technology is implemented at Majuba Power Station.

## 3 DESCRIPTION OF THE MEASUREMENT SITE

The measuring site is located inside the multi-flue stack.

The stack consists of a concrete outer windshield with three flues inside the windshield. The height of the 250m tall stack is divided into 8 levels, level 8 being the last platform before the “roof” of the stack. Each level is a concrete slab through which the three flues enter from the bottom. The bottom flue fits into the flue above it without significant flow disturbance. The flue above each level is supported by that level. This arrangement allows for the expansion and contraction of the flue of one unit without being influenced by the other flues when one of the boilers is switched on or off. Expansion and contraction of the flues do not influence the level of the concrete floor.

The ports are positioned at a height above the floor so that neither the ports nor the alignment of the instruments are influenced by the expansion and contraction of the flue. The alignment of the monitors is therefore very stable. The particulate AMS is situated on the fourth level. In Stack 1 (Units 1, 2 and 3), the sampling ports are situated on level 8. In Stack 2 (Units 4, 5 and 6), the ports are situated on the sixth level.

The three flues being encompassed by the wind shield require the use of one probe of 9.5m to traverse one complete diameter (Traverses A and B) and another 3.5m probe to traverse the two radii (traverses B and C) at 90° to traverses A and B.

The sampling ports being situated on the very top level in Stack 1, made it impossible to rig the 9.5m probe onto the measuring platform. It was agreed with the customer to perform three out of four traverses on the flues of Units 1, 2 and 3.

## 4 MEASUREMENT AND ANALYTICAL METHODS AND APPARATUS

| Compound | Method | Comment |
|---|---|---|
| Particulate Matter | BS EN 9096:2003 | - |
| Low mass concentrations | BS EN 13284-1:2002 | - |
| Correlation function | VDI 2066, Part 4 | Statistical procedures for establishing confidence and tolerance bands |
| Eskom's Emissions Monitoring and Reporting Standard | 240-56242363 | - |

## 5 PLANT OPERATING CONDITION DURING THE MEASUREMENTS

Normal operating conditions were maintained for the duration of the emission survey. The tests were carried out at a constant load for the full duration of nine consecutive tests for 3 days. Low, Mid and High loads were arranged to achieve a spread in the emission concentrations. The low and mid loads were arranged for the weekend, but Majuba was experiencing wet coal and they couldn't load further. The poor performance of mills further contributed to the inability to increase load.

The tests were carried out at a condition which represents the normal state of power production. The coal which was burnt during the test period was the normal supply.

The economiser outlet oxygen levels were representative of normal running excess air levels. Air ingress, in the form of in-leakage, may be expected at the air heaters and the FFPs under normal running conditions. The FFP bags are protected against high temperatures by an attemperating system, which allows ambient air into the main gas stream to cool the flue gas down. No abnormal ingress air was noticed from the $O_2$ readings in the stack.

Additional operating data is tabulated in the Appendices.

## 6 PRESENTATION OF MEASUREMENT RESULTS AND DISCUSSION

### 6.1 EVALUATION OF THE OPERATING CONDITIONS DURING THE MEASUREMENTS

It is an Eskom standard that, if it is not possible to vary the loads, that the correlation tests are carried out at a load most commonly experienced. Tests are carried out without soot blowing and oil support in each case.

Below is a summary of the main relevant plant and test parameters.

| Test No. | Actual Boiler load during test | Load condition | Measured Gas flow | Total Air flow | Standard deviation of air flow | Dust Concentration | Average face velocity | % Isok | Nozzle diameter | Comment |
|---|---|---|---|---|---|---|---|---|---|---|
| | MW | - | [$Am^3$/s (d)] at 10% $O_2$ | [kg/s] | kg of Total Air flow | mg/$Nm^3$ (d) at 10% $O_2$ | cm/s | % | mm | |
| 1 | 500.00 | 80% MCR | 1308.5 | 588.8 | 14.0 | 20.5 | 3.86 | 98.0 | 4.2 | |
| 2 | 500.00 | 80% MCR | 1439.7 | 620.3 | 9.7 | 21.7 | 4.23 | 98.6 | 4.2 | |
| 3 | 500.00 | 80% MCR | 1389.1 | 599.7 | 8.4 | 21.8 | 4.12 | 98.5 | 4.2 | |
| 4 | 500.00 | 80% MCR | 1370.4 | 581.0 | 13.1 | 15.5 | 4.04 | 96.9 | 4.2 | |
| 5 | 500.00 | 80% MCR | 1386.8 | 584.9 | 6.9 | 28.7 | 4.08 | 98.7 | 4.2 | Not included |
| 6 | 500.00 | 80% MCR | 1425.0 | 585.1 | 8.9 | 17.6 | 4.12 | 97.6 | 4.2 | |
| 7 | 500.00 | 80% MCR | 1374.1 | 591.8 | 7.3 | 18.1 | 4.03 | 99.2 | 4.2 | |
| 8 | 500.00 | 80% MCR | 1363.2 | 577.3 | 5.2 | 17.2 | 4.01 | 98.7 | 4.2 | |
| 9 | 500.00 | 80% MCR | 1364.7 | 583.0 | 16.1 | 17.3 | 4.00 | 99.0 | 4.2 | |

All the face velocities were above 3 cm/s specified in the Eskom Standard

The isokineticities were all between the 95 – 105% as per the allowed range in the Eskom Standard. Test 5 was not included in the linear regression. The test falls outside the tolerance bands for this correlation. Test error is expected. Due to the low emissions, it was not possible to know from the available information whether the final dust concentration was acceptable or not and consequently Test 5 was not repeated. It was considered unnecessary to conduct further tests, since all eight the other tests were carried out at the same load.

## 6.2 MEASUREMENT RESULTS

One test was omitted from the calculations. The correlation function was determined from eight parallel measurements.

The function yields the emission in mg/$Nm^3$ (d) at 10% $O_2$ corrected for temperature, pressure, moisture and oxygen.

The following table gives the pertinent monitor information and correlation parameters for the “as found” conditions.

| **Plant:** | **Unit 2** | |
|---|---|---|
| Location of Monitor | Stack 1 | |
| Make: | SICK | |
| Model: | DHT200 | |
| Monitor serial number: | 12068626/12068634 | |
| Reflector serial number: | 12068602 | |
| Channel | **Analogue Output AO 2:** | **Analogue Output AO 3:** |
| Measuring range (mg/$m^3$) | 0.0 - 0.8 | 0.0 - 0.3 |
| DCS measuring range (mg/$Nm^3$) at 10 %$O_2$ | 404.3 | 151.7 |
| Output range (mA): | 4 - 20 | 4 - 20 |
| **Info for DCS** | | |
| mA | Emission | Emission |
| 4.00 | 0.2 | 0.2 |
| 5.97 | 50.0 | 18.9 |
| 9.26 | 133.0 | 50.0 |
| 20.00 | 404.3 | 151.7 |
| % Output | Emission | Emission |
| 0.00 | 0.2 | 0.2 |
| 12.33 | 50.0 | 18.9 |
| 100.00 | 404.3 | 151.7 |
| **Constants for Linear function (mA)** | | |
| $m_{mA}$ = | 25.2564 | 9.4711 |
| $c_{mA}$ = | -100.85 | -37.71 |
| **Constants for Linear function (%)** | | |
| $m_{\%}$ = | 4.0410 | 1.5154 |
| $c_{\%}$ = | 0.1708 | 0.1708 |

Detailed results from the sampling process:

| **Test No.** | | 1 | 2 | 3 |
|---|---|---|---|---|
| **Stack tester:** | | AVM | AVM | AVM |
| **Date** | dd-mm-yy | 2016-04-01 | 2016-04-01 | 2016-04-01 |
| **Start Time** | HH:mm | 11H00 | 13H59 | 15H37 |
| **End Time** | HH:mm | 12H24 | 15H13 | 16H46 |
| **Boiler load** | MW | 500 | 500 | 500 |
| **Outlet Conditions.** | | | | |
| Gas Temperature | °C | 107.6 | 112.7 | 107.7 |
| Barometric pressure | kPa (g) | 81.1 | 80.7 | 80.5 |
| Duct pressure | kPa (abs) | 80.8 | 80.5 | 80.4 |
| Moisture | %v/v | 5.5 | 4.9 | 5.9 |
| Oxygen (O2) | % | 8.6 | 8.6 | 8.6 |
| Velocity | m/s | 23.45 | 25.64 | 24.99 |
| Duct area | m2 | 52.43 | 52.43 | 52.43 |
| Gas Volume Flow (Qact) | Am3/s | 1229.44 | 1344.23 | 1310.35 |
| Gas Volume Flow (Qad 10 %O2) | Am3/s | 1308.48 | 1439.70 | 1389.11 |
| Gas Volume Flow (Qnd 10 %O2) | Nm3/s | 748.83 | 810.11 | 790.28 |
| Gas flow rate | kg/s | 900.13 | 965.06 | 954.27 |
| Sampling time | Minutes | 60 | 60 | 60 |
| Dust mass | mg | 14.31 | 16.49 | 16.13 |
| Gas Volume Sampled (Vnd) | Nm3 (d) | 0.6200 | 0.6745 | 0.6572 |
| Dust Concentration | mg/Nm3 (d) | 23.1 | 24.5 | 24.5 |
| Correction factor 10% | | 0.9 | 0.9 | 0.9 |
| Dust Concentration Normalised to 10% O2 | mg/Nm3 (d) @ 10% O2 | 20.5 | 21.7 | 21.8 |
| Outlet Dust Flowrate | mg/s | 15343.4 | 17585.6 | 17224.1 |
| Moisture Concentration | g/Nm3 (d) | 46.8 | 41.5 | 50.2 |
| Average Face velocity | cm/s | 3.9 | 4.2 | 4.1 |
| Isokineticity | % | 98.0 | 98.6 | 98.5 |
| | | | | |
| Average O/M Signal AO1 | mA of output | 4.87 | 4.96 | 4.93 |
| Average O/M Signal AO1 | % of output | 5.44 | 5.98 | 5.79 |
| | | | | |
| AO1 Ext range | | 0.70 | | |
| Measured Extinction | Ext | 0.0380 | 0.0419 | 0.0405 |
| AO2 Ext range | | 0.80 | | |
| Average O/M Signal AO2 | mA of output | 4.76 | 4.84 | 4.81 |
| Average O/M Signal AO2 | % of output | 4.76 | 5.23 | 5.06 |

| **Test No.** | | 4 | 5 | 6 |
|---|---|---|---|---|
| **Stack tester:** | | AVM | AVM | AVM |
| **Date** | dd-mm-yy | 2016-04-02 | 2016-04-02 | 2016-04-02 |
| **Start Time** | HH:mm | 9H15 | 10H40 | 12H04 |
| **End Time** | HH:mm | 10H24 | 11H45 | 13H09 |
| **Boiler load** | MW | 500 | 500 | 500 |
| **Outlet Conditions.** | | | | |
| Gas Temperature | °C | 102.2 | 104.3 | 107.1 |
| Barometric pressure | kPa (g) | 81.0 | 80.9 | 80.9 |
| Duct pressure | kPa (abs) | 80.9 | 80.8 | 80.7 |
| Moisture | %v/v | 6.1 | 6.8 | 5.9 |
| Oxygen (O2) | % | 8.5 | 8.4 | 8.3 |
| Velocity | m/s | 24.51 | 24.80 | 25.04 |
| Duct area | m2 | 52.43 | 52.43 | 52.43 |
| Gas Volume Flow (Qact) | Am3/s | 1284.97 | 1300.27 | 1312.65 |
| Gas Volume Flow (Qad 10 %O2) | Am3/s | 1370.45 | 1386.79 | 1424.97 |
| Gas Volume Flow (Qnd 10 %O2) | Nm3/s | 796.03 | 800.18 | 815.84 |
| Gas flow rate | kg/s | 957.81 | 954.54 | 956.40 |
| Sampling time | Minutes | 60 | 60 | 60 |
| Dust mass | mg | 11.41 | 21.52 | 13.33 |
| Gas Volume Sampled (Vnd) | Nm3 (d) | 0.6463 | 0.6563 | 0.6567 |
| Dust Concentration | mg/Nm3 (d) | 17.7 | 32.8 | 20.3 |
| Correction factor 10% | | 0.9 | 0.9 | 0.9 |
| Dust Concentration Normalised to 10% O2 | mg/Nm3 (d) @ 10% O2 | 15.5 | 28.7 | 17.6 |
| Outlet Dust Flowrate | mg/s | 12376.2 | 22928.7 | 14358.4 |
| Moisture Concentration | g/Nm3 (d) | 51.8 | 58.7 | 50.2 |
| Average Face velocity | cm/s | 4.0 | 4.1 | 4.1 |
| Isokineticity | % | 96.9 | 98.7 | 97.6 |
| | | | | |
| Average O/M Signal AO1 | mA of output | 4.76 | 4.88 | 4.95 |
| Average O/M Signal AO1 | % of output | 4.77 | 5.52 | 5.97 |
| | | | | |
| AO1 Ext range | | | | |
| Measured Extinction | Ext | 0.0334 | 0.0387 | 0.0418 |
| AO2 Ext range | | | | |
| Average O/M Signal AO2 | mA of output | 4.67 | 4.77 | 4.84 |
| Average O/M Signal AO2 | % of output | 4.17 | 4.83 | 5.22 |

| **Test No.** | | 7 | 8 | 9 |
|---|---|---|---|---|
| **Stack tester:** | | AVM | AVM | AVM |
| **Date** | dd-mm-yy | 2016-04-03 | 2016-04-03 | 2016-04-03 |
| **Start Time** | HH:mm | 9H25 | 10H50 | 12H16 |
| **End Time** | HH:mm | 10H33 | 11H57 | 13H25 |
| **Boiler load** | MW | 500 | 500 | 500 |
| **Outlet Conditions.** | | | | |
| Gas Temperature | °C | 96.5 | 99.5 | 98.5 |
| Barometric pressure | kPa (g) | 81.6 | 81.6 | 81.6 |
| Duct pressure | kPa (abs) | 81.5 | 81.5 | 81.5 |
| Moisture | %v/v | 6.2 | 6.0 | 6.4 |
| Oxygen (O2) | % | 8.4 | 8.5 | 8.4 |
| Velocity | m/s | 24.49 | 24.36 | 24.30 |
| Duct area | m2 | 52.43 | 52.43 | 52.43 |
| Gas Volume Flow (Qact) | Am3/s | 1283.75 | 1277.10 | 1274.14 |
| Gas Volume Flow (Qad 10 %O2) | Am3/s | 1374.15 | 1363.16 | 1364.75 |
| Gas Volume Flow (Qnd 10 %O2) | Nm3/s | 816.81 | 803.27 | 806.42 |
| Gas flow rate | kg/s | 970.65 | 956.75 | 958.20 |
| Sampling time | Minutes | 60 | 60 | 60 |
| Dust mass | mg | 13.95 | 12.94 | 13.16 |
| Gas Volume Sampled (Vnd) | Nm3 (d) | 0.6756 | 0.6643 | 0.6639 |
| Dust Concentration | mg/Nm3 (d) | 20.6 | 19.5 | 19.8 |
| Correction factor 10% | | 0.9 | 0.9 | 0.9 |
| Dust Concentration Normalised to 10% O2 | mg/Nm3 (d) @ 10% O2 | 18.1 | 17.2 | 17.3 |
| Outlet Dust Flowrate | mg/s | 14775.6 | 13778.6 | 13966.8 |
| Moisture Concentration | g/Nm3 (d) | 53.3 | 51.2 | 55.0 |
| Average Face velocity | cm/s | 4.0 | 4.0 | 4.0 |
| Isokineticity | % | 99.2 | 98.7 | 99.0 |
| | | | | |
| Average O/M Signal AO1 | mA of output | 4.75 | 4.72 | 4.75 |
| Average O/M Signal AO1 | % of output | 4.70 | 4.50 | 4.66 |
| | | | | |
| AO1 Ext range | | | | |
| Measured Extinction | Ext | 0.0329 | 0.0315 | 0.0326 |
| AO2 Ext range | | | | |
| Average O/M Signal AO2 | mA of output | 4.66 | 4.63 | 4.65 |
| Average O/M Signal AO2 | % of output | 4.11 | 3.94 | 4.08 |

Detailed information is given in the Appendices:

**Appendix A** – Figures
1. Emission Monitor Correlation Certificate [Normal dry at 10 %$O_2$]
2. Stack Gas Flow Correlation Certificate [Normal dry at 10 %$O_2$]

**Appendix B** – Plant parameters
**Appendix C** – Monitor calibration certificates
**Appendix D** –Correlation functions and parameters

# APPENDIX A

## Correlation Function

Figure 1 – As found

Figure 2 – Air to gas flow correlation

# MAJUBA POWER STATION

## Emission Monitor Correlation Certificate

**Plant:** Unit 2
**Location of monitor:** Stack 1
**Monitor information:**
Make of Monitor: Sick
Model: DHT200
Serial Numbers:
Optical head: 12068626/12068634
MCU 12068602

**Limits of validity:**
Lower limit 15.55 mg/Nm3 (d) [as an hourly average]
Upper limit 21.79 mg/Nm3 (d) [as an hourly average]

**Operational data:**
Path length: N/A mm [Stack flange to Stack flange]
Monitor range: 4 - 20 mA
Analogue Output AO 2: 0.0 - 0.8 mg/m$^3$ Measuring Range: 0.8 - 404.3 mg/Nm$^3$ at 10 %$O_2$
Analogue Output AO 3: 0.0 - 0.3 mg/m$^3$ Measuring Range: 0.3 - 151.7 mg/Nm$^3$ at 10 %$O_2$
AEL Limit 100 mg/Nm3 @ 10% $O_2$

**Dates:**
Calibration date: 09-Feb-16
Correlation dates: 01-03 April 2016

| mA | Analogue Output AO 2: | Analogue Output AO 3: |
|---|---|---|
| 4.00 | 0.2 | 0.2 |
| 7.95 | 100.0 | 37.6 |
| 14.54 | 266.4 | 100.0 |
| 20.00 | 404.3 | 151.7 |

**Linear function:**
$E_{AO2}$ = 25.2564x - 100.8546 Correlation coefficient(R) = 0.99
$E_{AO3}$ = 9.4711x - 37.7138
where: E = Emission [mg/Nm$^3$(d)@ 10% $O_2$]
x = Monitor output [mA]

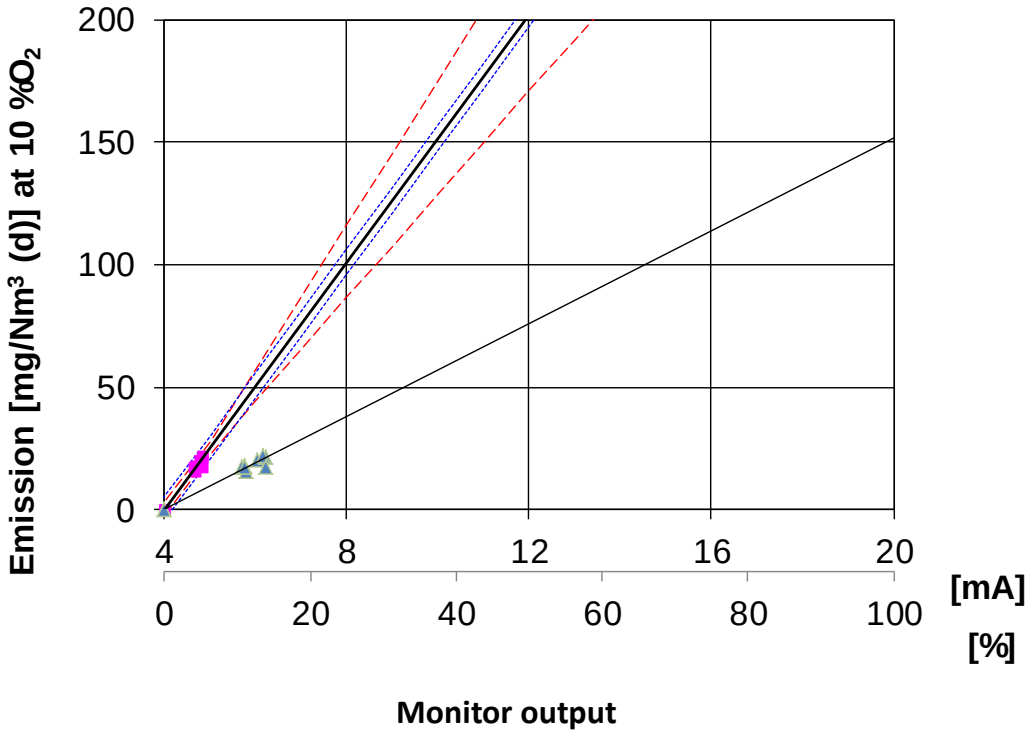


**FIGURE 1**

Prepared by: Inthuu Measurements

# MAJUBA POWER STATION

## Stack Gas Flow Correlation Certificate

**Plant:** Unit 2
**Location of monitor:** Stack 1
**Monitor information:**
Make of Monitor: Sick
Model: N/A
Serial Numbers:
N/A
N/A

**Limits of validity:**
Lower limit 748.38 $Nm^3/s$ (d) at 10 $\%O_2$ [as an hourly average]
Upper limit 816.81 $Nm^3/s$ (d) at 10 $\%O_2$ [as an hourly average]

**Operational data:**
Stack internal diameter 8.1702 m
Monitor range: N/A -

**Dates:**
Calibration date: N/A
Correlation dates: 01 - 03 April 2016

**Linear function:**
g = 1.3492a + 0.9037 Correlation coefficient(R) = 1.00

where: g = Stack exit gas flow [$Nm^3/s$ (d) at 10 % $O_2$]
a = Total air flow from DCS [Kg/s]

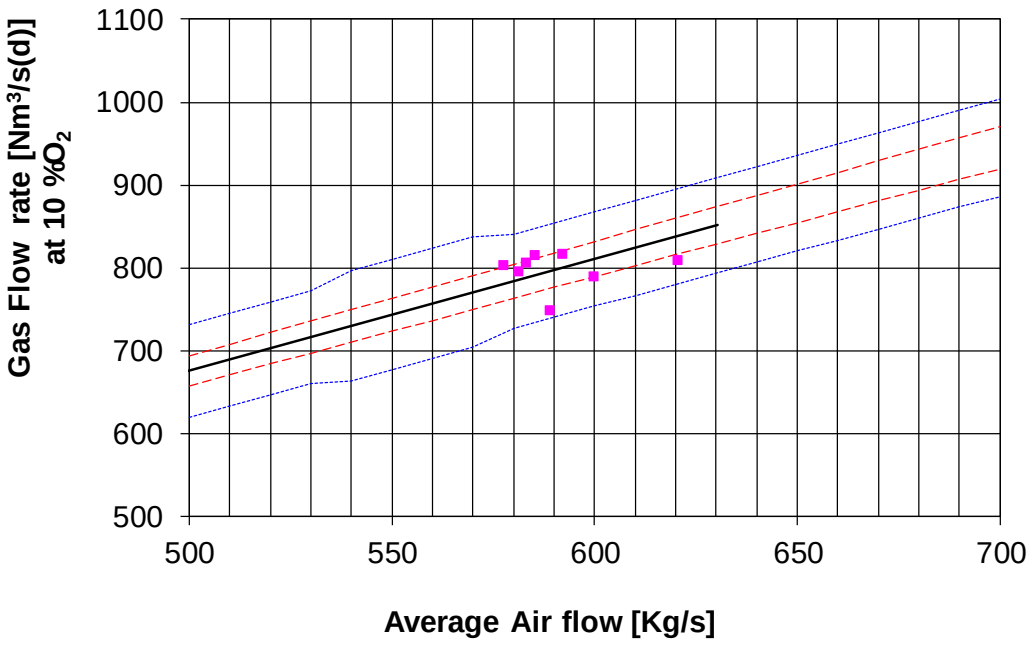


**FIGURE 2**

Prepared by: Inthuu Measurements

# APPENDIX B

## Plant Parameters

Plant parameters for the duration of the tests:

| **Test No.** | 1 | 2 | 3 |
|---|---|---|---|
| **Stack tester:** | AVM | AVM | AVM |
| **Date** | 2016-04-01 | 2016-04-01 | 2016-04-01 |
| **Start Time** | 11H00 | 13H59 | 15H37 |
| **End Time** | 12H24 | 15H13 | 16H46 |
| **Boiler load** | 500 | 500 | 500 |
| | | | |
| **Outlet Conditions.** | | | |
| SO2 EMISSION | 669.79 | 674.47 | 694.93 |
| NOX EMISSION | 523.37 | 541.57 | 542.91 |
| DUCT PRESSURE | 826.51 | 824.24 | 823.98 |
| LH AFT ATT AVE T | 113.80 | 117.56 | 111.09 |
| RH AFT ATT AVE T | 107.68 | 112.30 | 105.67 |
| DUST EMISSION | 4.94 | 5.42 | 5.31 |
| MAX MAIN DIFF PRESS | 1.75 | 1.96 | 1.81 |
| FFP PLANT RUNNING H | 72.16 | 75.04 | 76.65 |
| CELLS IN SERVICE | 8.00 | 8.00 | 8.00 |
| PLSAIR SUPPLY PRESS. | 74.97 | 75.08 | 74.99 |
| BLOW OFF CTRL VLV | 78.85 | 74.12 | 76.36 |
| TARGET LD SET POINT | 500.00 | 500.00 | 500.00 |
| UPPER LOAD LIMIT | 500.00 | 500.00 | 500.00 |
| LOWER LOAD LIMIT | 400.00 | 400.00 | 400.00 |
| DUST IN MG/SM3 | 6.20 | 6.79 | 6.67 |
| DUST VELOCITY | 23.80 | 25.22 | 24.18 |
| BLR LOAD DEM | 500.00 | 500.00 | 500.00 |
| LH A/H OUT F/GAS T | 116.85 | 120.74 | 114.36 |
| LH A/H OUT F/GAS T | 116.75 | 120.52 | 113.40 |
| TOTAL FUEL FLOW | 67.38 | 85.35 | 81.17 |
| ML MAIN MTR KW | 0.00 | 0.00 | 0.00 |
| GENERATOR MW | 503.59 | 503.35 | 503.95 |
| O2 CONTROL RATIO | 0.36 | -0.13 | 0.14 |
| LH A/H INL F/GAS O2 | 4.08 | 4.49 | 4.04 |
| LH ID FAN IN F/GAS T | 111.47 | 114.71 | 109.71 |
| RH A/H INL F/GAS O2 | 3.85 | 4.36 | 3.88 |
| RH ID FAN IN F/GAS T | 105.32 | 108.98 | 103.99 |
| TOTAL AIR FLOW | 588.84 | 620.26 | 599.68 |
| FUEL/AIR SET POINT | 0.90 | 0.77 | 0.79 |
| TOTAL FEED WATER F | 417.71 | 414.44 | 415.33 |

| **Test No.** | 4 | 5 | 6 |
|---|---|---|---|
| **Stack tester:** | AVM | AVM | AVM |
| **Date** | 2016-04-02 | 2016-04-02 | 2016-04-02 |
| **Start Time** | 9H15 | 10H40 | 12H04 |
| **End Time** | 10H24 | 11H45 | 13H09 |
| **Boiler load** | 500 | 500 | 500 |
| | | | |
| **Outlet Conditions.** | | | |
| SO2 EMISSION | 701.90 | 719.52 | 725.01 |
| NOX EMISSION | 521.43 | 533.59 | 536.83 |
| DUCT PRESSURE | 827.25 | 827.49 | 826.76 |
| LH AFT ATT AVE T | 108.99 | 110.77 | 113.08 |
| RH AFT ATT AVE T | 103.24 | 105.27 | 108.02 |
| DUST EMISSION | 4.36 | 5.07 | 5.46 |
| MAX MAIN DIFF PRESS | 1.72 | 1.77 | 1.83 |
| FFP PLANT RUNNING H | 94.31 | 95.67 | 97.06 |
| CELLS IN SERVICE | 8.00 | 8.00 | 8.00 |
| PLSAIR SUPPLY PRESS. | 74.94 | 75.09 | 75.00 |
| BLOW OFF CTRL VLV | 79.29 | 76.81 | 72.84 |
| TARGET LD SET POINT | 500.00 | 500.00 | 500.00 |
| UPPER LOAD LIMIT | 500.00 | 500.00 | 500.00 |
| LOWER LOAD LIMIT | 400.00 | 400.00 | 400.00 |
| DUST IN MG/SM3 | 5.44 | 6.36 | 6.86 |
| DUST VELOCITY | 23.39 | 23.60 | 23.72 |
| BLR LOAD DEM | 500.00 | 500.00 | 500.00 |
| LH A/H OUT F/GAS T | 112.20 | 113.74 | 116.46 |
| LH A/H OUT F/GAS T | 111.76 | 113.47 | 115.96 |
| TOTAL FUEL FLOW | 79.21 | 81.97 | 84.02 |
| ML MAIN MTR KW | 0.00 | 0.00 | 0.00 |
| GENERATOR MW | 504.33 | 502.81 | 504.29 |
| O2 CONTROL RATIO | -0.13 | -0.12 | 0.01 |
| LH A/H INL F/GAS O2 | 3.87 | 3.86 | 3.78 |
| LH ID FAN IN F/GAS T | 106.20 | 107.98 | 110.14 |
| RH A/H INL F/GAS O2 | 3.72 | 3.72 | 3.58 |
| RH ID FAN IN F/GAS T | 100.22 | 102.20 | 105.02 |
| TOTAL AIR FLOW | 580.97 | 584.93 | 585.11 |
| FUEL/AIR SET POINT | 0.83 | 0.81 | 0.79 |
| TOTAL FEED WATER F | 406.57 | 407.66 | 413.54 |

| **Test No.** | 7 | 8 | 9 |
|---|---|---|---|
| **Stack tester:** | AVM | AVM | AVM |
| **Date** | 2016-04-03 | 2016-04-03 | 2016-04-03 |
| **Start Time** | 9H25 | 10H50 | 12H16 |
| **End Time** | 10H33 | 11H57 | 13H25 |
| **Boiler load** | 500 | 500 | 500 |
| | | | |
| **Outlet Conditions.** | | | |
| SO2 EMISSION | 712.10 | 700.08 | 675.06 |
| NOX EMISSION | 520.51 | 505.11 | 500.14 |
| DUCT PRESSURE | 833.75 | 833.57 | 832.92 |
| LH AFT ATT AVE T | 102.63 | 103.86 | 104.30 |
| RH AFT ATT AVE T | 97.31 | 98.31 | 98.98 |
| DUST EMISSION | 4.34 | 4.24 | 4.39 |
| MAX MAIN DIFF PRESS | 1.64 | 1.57 | 1.66 |
| FFP PLANT RUNNING H | 118.45 | 119.86 | 121.32 |
| CELLS IN SERVICE | 8.00 | 8.00 | 8.00 |
| PLSAIR SUPPLY PRESS. | 74.97 | 75.02 | 75.09 |
| BLOW OFF CTRL VLV | 82.77 | 81.24 | 80.16 |
| TARGET LD SET POINT | 500.00 | 500.00 | 500.00 |
| UPPER LOAD LIMIT | 500.00 | 500.00 | 500.00 |
| LOWER LOAD LIMIT | 400.00 | 400.00 | 400.00 |
| DUST IN MG/SM3 | 5.45 | 5.33 | 5.51 |
| DUST VELOCITY | 23.36 | 22.96 | 23.20 |
| BLR LOAD DEM | 500.00 | 500.00 | 500.00 |
| LH A/H OUT F/GAS T | 105.53 | 107.54 | 107.77 |
| LH A/H OUT F/GAS T | 104.48 | 106.36 | 106.70 |
| TOTAL FUEL FLOW | 82.82 | 82.41 | 83.92 |
| ML MAIN MTR KW | 0.00 | 0.00 | 0.00 |
| GENERATOR MW | 501.84 | 502.67 | 496.83 |
| O2 CONTROL RATIO | -0.22 | 0.12 | -0.08 |
| LH A/H INL F/GAS O2 | 4.18 | 3.92 | 4.10 |
| LH ID FAN IN F/GAS T | 100.09 | 101.66 | 102.19 |
| RH A/H INL F/GAS O2 | 4.02 | 3.63 | 3.79 |
| RH ID FAN IN F/GAS T | 94.90 | 96.16 | 96.76 |
| TOTAL AIR FLOW | 591.81 | 577.31 | 582.98 |
| FUEL/AIR SET POINT | 0.81 | 0.79 | 0.79 |
| TOTAL FEED WATER F | 408.81 | 409.40 | 408.22 |

# APPENDIX C

## Monitor Calibration certificate

SICK Automation
Southern Africa (PTY) Ltd

1011 Katrol Ave, Robertville Ext
Roodepoort, Gauteng
South Africa 1709
www.sickautomation.co.za
TEL : 27 11 472 3733
FAX : 27 11 472 3078

# Electronic Calibration Certificate:

# DHT200

| Customer data: | | Certificate: | T200-EC02-09022016-RM002 |
|---|---|---|---|
| Customer: | Eskom Majuba | Customer no: | |
| Country: | South Africa | City: | |
| Plant: | Majuba | Location: | Stack 1 (Unit 2) |

| 1. Device data: | | | |
|---|---|---|---|
| Device type : | DHT200 | Device type MCU: | NW0DNO 1000 NNNE |
| Serial no: | 12068626/12068634 | Serial No: | 12068602 |
| Firmware no. : | 01.08.14/01.02.01 | Firmware no. MCU: | 01.06.00 |
| Measuring Units: | Ext | AO Measuring Range AO1/AO2/AO3: | 0.7/0.8/0.3 |

| 2. Filter linearity Check: SN: 0-T059 – 80-T059 | | | |
|---|---|---|---|
| Filter [%] | Measured value [%] | Deviation [%] | Allowable deviation [%] |
| 83.3 | 82.9 | -0.4 | 2.0 |
| 58.9 | 58.7 | -0.2 | 2.0 |
| 38.1 | 37.6 | -0.5 | 2.0 |
| 20.5 | 20.3 | -0.2 | 2.0 |
| 0.0 | -0.3 | -0.3 | 2.0 |

| Remarks: | | | |
|---|---|---|---|
| | | | |
| Date : | 09-02-2016 | Name: | Signed: |
| Valid until: | 09-02-2017 | Engineer: Reentseng Molapo | |

# APPENDIX D

## RECOMMENDED CORRELATION CURVE

# MAJUBA POWER STATION

## Emission Monitor Correlation Certificate

**Plant:** Unit 2
**Location of monitor:** Stack 1
**Monitor information:**
Make of Monitor: Sick
Model: DHT200
Serial Numbers:
Optical head: 12068626/12068634
MCU 12068602

**Limits of validity:**
Lower limit 15.55 mg/Nm3 (d) [as an hourly average]
Upper limit 21.79 mg/Nm3 (d) [as an hourly average]
Hourly cycle checks are included in linear regression

**Operational data:**
Path length: N/A mm [Stack flange to Stack flange]
Monitor range: 4 - 20 mA
Analogue Output AO 2: 0.0 - 0.26 mg/m$^3$ Measuring Range: 0.26 - 131.5 mg/Nm$^3$ at 10 %$O_2$
Analogue Output AO 3: 0.0 - 0.4 mg/m$^3$ Measuring Range: 0.4 - 202.2 mg/Nm$^3$ at 10 %$O_2$
AEL Limit 100 mg/Nm3 @ 10% $O_2$

**Dates:**
Calibration date: 09-Feb-16
Correlation dates: 01-03 April 2016

| mA | Analogue Output AO 2: | Analogue Output AO 3: |
|---|---|---|
| 4.00 | 0.2 | 0.2 |
| 16.16 | 100.0 | 153.8 |
| 11.91 | 65.1 | 100.0 |
| 20.00 | 131.5 | 202.2 |

**Linear function:**
$E_{AO2}$ = 8.2083x - 32.6625 Correlation coefficient(R) = 0.99
$E_{AO3}$ = 12.6282x - 50.3419
where: E = Emission [mg/Nm$^3$(d)@ 10% $O_2$]
x = Monitor output [mA]

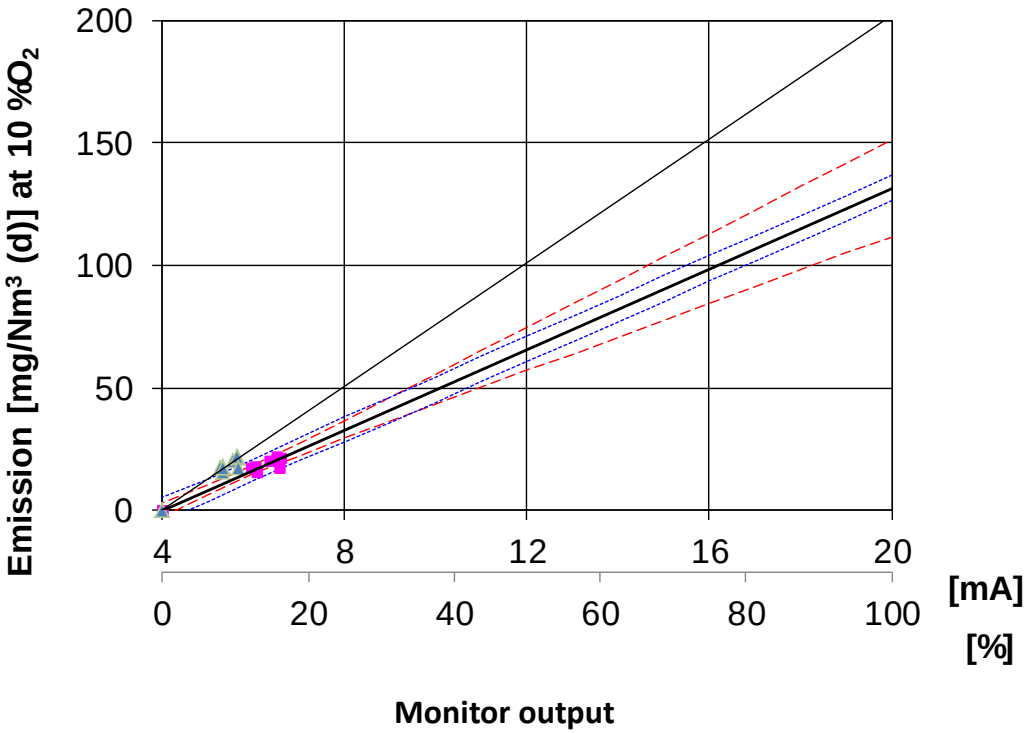


**FIGURE 3**

Prepared by: Inthuu Measurements

| **Plant:** | **Unit 2** | |
|---|---|---|
| Location of Monitor | Stack 1 | |
| Make: | SICK | |
| Model: | DHT200 | |
| Monitor serial number: | 12068626/12068634 | |
| Reflector serial number: | 12068602 | |
| Channel | **Analogue Output AO 2:** | **Analogue Output AO 3:** |
| Measuring range ($mg/m^3$) | 0.0 - 0.26 | 0.0 - 0.4 |
| DCS measuring range ($mg/Nm^3$) at 10 $\%O_2$ | 131.5 | 202.2 |
| Output range (mA): | 4 - 20 | 4 - 20 |
| **Info for DCS** | | |
| mA | Emission | Emission |
| 4.00 | 0.2 | 0.2 |
| 10.07 | 50.0 | 76.8 |
| 7.95 | 32.6 | 50.0 |
| 20.00 | 131.5 | 202.2 |
| % Output | Emission | Emission |
| 0.00 | 0.2 | 0.2 |
| 37.94 | 50.0 | 76.8 |
| 100.00 | 131.5 | 202.2 |
| **Constants for Linear function (mA)** | | |
| $m_{mA}$ = | 8.2083 | 12.6282 |
| $c_{mA}$ = | -32.66 | -50.34 |
| **Constants for Linear function (%)** | | |
| $m_{\%}$ = | 1.3133 | 2.0205 |
| $c_{\%}$ = | 0.1708 | 0.1708 |

## 7 DISTRIBUTION LIST

| | |
|---|---|
| L Madonsela | Majuba Power Station - BPE |
| CC Scheepers | Inthuu Measurements CC |