Ankerlig Unit 43

Emissions Report

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1. Intent

The intent of this report is to provide Siemens with the results of isokinetic gravimetric measurement of particulate matter (PM) for the determination of the factor required to correlate the Durag 320 units. The Durag 320 units employ the principle of light scattering in order to infer the concentration of particulate matter. However, because light scattering may be affected by the proximity of nearby structures within the stack, the size and geometry of the particles, and stray light; it is necessary to correlate the electrical signal obtained from these devices back to a gravimetric weight of particulate matter. The gravimetric weight of particulate matter must be representative by virtue of its isokineticity and the location of the sampling points within the cross sectional geometry of the stack.

2. Executive Summary

On the 04th of September 2015, Yellow Tree conducted emissions testing on Unit 43 at the Ankerlig Power Station. The following emissions were measured by Yellow and Eskom's Ultramat 23 continuous emissions monitor:

Table 1: Unit 43 Emissions and Limits

Pollutant (mg/Nm^3 at 15 % O_2)	Unit 43	Limit
Yellow Tree		
Particulate Matter (PM)	1.3	75
Sulphur Dioxide (SO_2)	< 29 mg/Nm^3	3 500
Oxides of Nitrogen (NO_x)	193	250
Carbon Monoxide (CO)	0.1	None
Ultramat 23		
Sulphur Dioxide (SO_2)	12	3 500
Oxides of Nitrogen (NO_x)	169	250
Carbon Monoxide (CO)	1.9	None

All emissions measured were within the limits as specified in the Air Emissions License (AEL) for the site.

3. Introduction

Emissions testing was conducted so that the new Durag 320 Continuous Emissions Monitoring Systems, installed on each stack at Ankerlig, could be calibrated against an accurate, gravimetric measurement of particulate matter (PM).

Additionally, all units at Ankerlig are required to comply with emissions limits of 75 mg/Nm^3 for PM, 250 mg/Nm^3 for NO_x and 3 500 mg/Nm^3 for SO_2 as specified in the Air Emissions License (AEL) for the site.

4. Test Method

4.1. Procedures

The stack was sampled as per US EPA methods 1, 2, 3, 4, 6c, 7e, and 17. Three tests of 90 minutes each were conducted on the stack as per Eskom's Emissions Monitoring and Reporting Standard (document number 240-56242363).

The testing of the particulate matter (PM) and the gases (O_2, CO, NO, NO_2 and SO_2) consisted of 24 sampling points across the diameter of the stack through four sampling ports as shown in Figure 1 below.

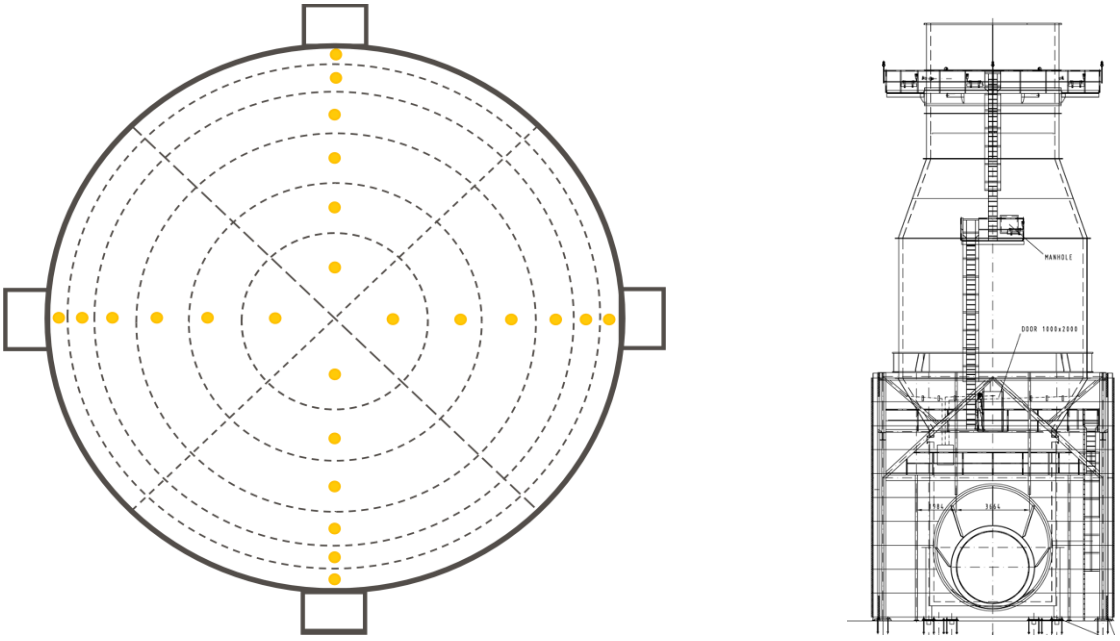

Figure 1: Cross Section of the Stack Divided into Equal Cross-Sectional Areas

The gas concentrations were logged every 10 seconds.

As per Eskom's Emissions Monitoring and Reporting Standard, flat plane filters were used to collect PM. Furthermore, it was ensured that isokinetic deviations were within ± 5 % for each test which is a requirement in Eskom's Standard.

4.2. Equipment

The measurement of PM was performed using the Isostack G4 which is manufactured by Tecora. The Isostack G4 is completely automatic and digital. The elimination of manual calculations and adjustments makes this instrument one of the most accurate machines available globally. The machine was purchased for the purpose of testing the Ankerlig and Gourikwa Power Stations. It features the largest pump configurable in a Tecora isokinetic testing machine. This is necessary when sampling gases with low PM concentrations. The unit was calibrated on the 20th May 2015.

The measurement of the gases: sulphur dioxide, nitric oxide, nitrogen dioxide, carbon monoxide and oxygen was performed using the ECOM J2KN gas analyser. This unit is certified as fit for legal compliance measurement. It is equipped with a peltier cooler so that it measures on a dry basis as

required by South African legislation. It measures to ± 2% accuracy which supersedes the industry standard of ± 5%. The J2KN was manufactured in Germany and was purchased for the purpose of testing Ankerlig and Gourikwa.

Additionally, Yellow Tree purchased an integrated testing probe for the purpose of testing at Ankerlig and Gourikwa. Temperature and velocity measurement, gas analysis and a filter holder for PM measurement are all incorporated into the single probe.

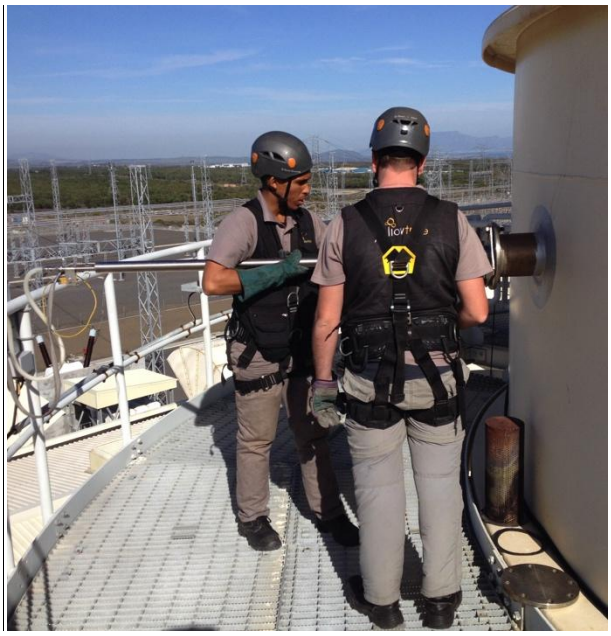

Figure 2: Yellow Tree's Testing Equipment

5. Legislation

The open cycle gas turbines (OCGTs) at Ankerlig are classified as Listed Activities under Subcategory 1.2 of the Listed Activities legislation. As a result, emissions from the OCGTs are required to comply with the emissions limits shown in Table 2.

Table 2: Legislated Limits Applicable to Liquid Fuel Combustion Installations

(2) *Subcategory 1.2: Liquid Fuel Combustion Installations*

Description:	Liquid fuels combustion installations used primarily for steam raising or electricity generation.		
Application:	All installations with design capacity equal to or greater than 50 MW heat input per unit, based on the lower calorific value of the fuel used.		
Substance or mixture of substances		**Plant status**	**mg/Nm³ under normal conditions of 3% O_2, 273 Kelvin and 101.3 kPa.**
Common name	**Chemical symbol**		
Particulate matter	N/A	New	50
		Existing	75
Sulphur dioxide	SO_2	New	500
		Existing	3500
Oxides of nitrogen	NO_X expressed as NO_2	New	250
		Existing	1100

(a) The following special arrangements shall apply –

(i) Reference conditions for gas turbines shall be 15% O_2, 273K and 101.3kPa

As per the legislation, plant that was in operation before April 2010 is required to comply with the limits for "existing" activities. The OCGTs at Ankerlig were commissioned between 2007 and 2009 and are thus classified as "existing" activities. The OCGTs are therefore required to comply with the more lenient limits for "existing" plant shown in Table 2. In April 2020, activities which are classified as "existing" activities, will be required to comply with the stricter limits applicable to activities which are classified as "new" activities.

NEMAQA does, however, provide provincial and municipal Air Quality Officers with the authority to impose air emissions regulations that are stricter, but not more lenient, than the requirements of the national legislation. As such, the Air Quality Officer (AQO) for Ankerlig Power Station requires NO_x emissions from the OCGTs to comply with a limit of 250 mg/Nm^3 instead of the limit of 1 100 mg/Nm^3 which is stipulated in the national legislation shown in Table 2. A summary of the limits applicable to the OCGTs, as per the Air Emissions Licenses (AELs) is shown in Table 3.

Table 3: Air Emissions Licenses' Limits (mg/Nm^3 at 15 % O_2)

	Ankerlig		Gourikwa	
Pollutant	**Normal**	**Abnormal**	**Normal**	**Abnormal**
Particulate Matter (PM)	75	150	50	75
Sulphur Dioxide (SO_2)	3 500	3 500	500	3 500
Oxides of Nitrogen (NO_x)	250	400	250	1 100
Carbon Monoxide (CO)	-	-	100	-

6. Results

As per Yellow Tree's Field Testing Procedure, each filter was weighed separately, before and after sampling. Because the mass of the particulates that were sampled is low, the combined mass of the filters, before and after sampling, was also recorded. By combining the filters, and weighing them together, the accuracy of the measurement is enhanced. This is because a single error associated with the scale is distributed across three filters.

The combined filter measurements are shown in the last column of the results table, and these results tie up closely with the average of the three filters weighed individually.

Table 4: Detailed Emissions Results

Test Number	1	2	3	Average	1, 2, 3
Date	04-Sep-15	04-Sep-15	04-Sep-15		04-Sep-15
Start Time	13H49	15H56	17H51		13H49
End Time	15H38	17H37	19H37		19H37
Sample Time	90 mins	90 mins	90 mins		270 mins
Sampled Vol - Wet Actual Conditions (m^3)	6.2689	6.3222	6.3870		18.9781
Sampled Vol - Dry, STP (Nm^3)	2.0832	2.0993	2.1212		6.3037
Gas Flow Rate - Wet Actual Conditions (Am^3/s)	1261.4	1269.5	1283.8		
Gas Flow Rate - Dry Actual Conditions (Am^3/s)	1214.8	1222.5	1236.3		
Gas Flow Rate - Wet, STP (Nm^3/s)	434.7	437.3	442.2		
Gas Flow Rate - Dry, STP (Nm^3/s)	418.6	421.1	425.8		
Moisture mass (g)					175
Moisture (% v/v)					3.34
Isokinetic Deviance (%)	-0.5	-0.4	-0.1		
Stack Diameter (m)	6.2	6.2	6.2		
Stack Area (m^2)	30.19	30.19	30.19		
Nozzle Size (mm)	6	6	6		
Port No.	1, 2, 3 & 4	1, 2, 3 & 4	1, 2, 3 & 4		
Filter No.	KW	KX	KY		
Average Velocity (m/s)	41.678	41.944	42.416		
Average Stack Temp (° C)	512.95	513.50	512.10[1]		
Average Stack Pressure (kPa)	100.491	100.452	100.453		
Average Ambient Temperature (°C)	21.4	22.7	20.3		
Average Barometric Pressure (kPa)	100.572	100.508	100.496		
Cake Mass (g)	0.0025	0.0016	0.0030		0.0067
Particulate Matter (mg/m^3) - Actual Conditions	0.4	0.3	0.5	0.4	0.4
Particulate Matter (mg/Nm^3) - STP	1.2	0.8	1.4	1.1	1.1
Particulate Matter (mg/Nm^3) - STP, 15% O_2	**1.4**	**0.9**	**1.8**	**1.4**	**1.3**
Particulate Matter Flow Rate (g/s)	0.5	0.3	0.6	0.5	
Gas Analysis					
O_2 Average	16.0%	15.8%	16.3%	16.0%	16.0%
CO Average (15% O_2) mg/Nm^3	0.2	0.0	0.0	0.1	0.1
SO_2 Average (15% O_2) mg/Nm^3	0	0	0	0	0
NO Average (15% O_2) mg/Nm^3	116	108	116	113	113
NO_2 Average (15% O_2) mg/Nm^3	18	19	22	20	20
NO_x Average (15% O_2) mg/Nm^3	195	184	200	193	193

[1] Temperature measurements were not recorded by Yellow Tree due to a thermocouple connection error. The temperature measurements listed were recorded by the Ultramat 23.

Ultramat 23 Gas Analysis	
Date	04-Sep-15
Start Time	14H00
End Time	20H00
SO_2 Average (15% O_2) mg/Nm^3	12
CO Average (15% O_2) mg/Nm^3	1.9
NO_x Average (15% O_2) mg/Nm^3	169

A gas volume of ± 19 m^3 at stack conditions was sampled on Unit 43. Isokinetic deviations measured during the tests were low and are below the Eskom standard of ± 5 %. It must be noted that the error is calculated by halving the isokinetic deviance. An isokinetic deviance of 1 % for example equates to an error of 0.5 %.

PM emissions were low at 1.3 mg/Nm^3. These emissions are well below the limit of 75 mg/Nm^3 specified in the AEL. Low emissions are expected from the OCGTs which are operated at a constant load during emissions testing and exhibit no visual smoking. It was not possible to weigh the three filters together as was done in the testing of the other units, because the one filter run was voided due to a detached sampling nozzle and an additional filter had to be used.

CO emissions were 0.1 mg/Nm^3 as measured by Yellow Tree and 1.9 mg/Nm^3 as measured by the Ultramat 23. There are no limits applicable to CO at Ankerlig. However, the CO limit applicable to Gourikwa is 100 mg/Nm^3 and may be used as a guideline of good practice for Ankerlig. Unit 43 at Ankerlig is below this guideline.

SO_2 emissions were measured as 0 ppm. A mass balance reveals that when combusting diesel with 500 ppm of sulphur, SO_2 emissions of 24 mg/Nm^3 are expected when normalized to 15% oxygen. A measurement of 24 mg/Nm^3 is equivalent to 8 ppm. Yellow Tree engaged with the instrument manufacturer in Germany and it was ascertained that electrochemical cells for SO_2 measurement have a detection limit of 10 ppm (29 mg/Nm^3). As the SO_2 concentrations in the OCGT stacks are anticipated to be ± 24 mg/Nm^3, SO_2 is not detected by the electrochemical cell. Yellow Tree also engaged with two other emissions testing companies who confirmed that SO_2 is unpredictable to measure at concentrations below 10 ppm using instrumental analysis. Occupational exposure limits are within this order of magnitude and are generally set at between 0.5 – 5 ppm depending on the duration. This further reiterates the dilution of these concentrations.

While Non Dispersive Infrared (NDIR) and Fourier Transform Infrared (FTIR) may be able to accurately measure SO_2 at lower concentrations, to perform accurate analysis, advanced sample preparation and conditioning is required, as is used in the Ultramat. As such, the best way to calibrate the Ultramat system at such low concentrations is with calibration gases.

Wet chemistry, in accordance with EPA Method 6, may provide accurate measurements of SO_2, however calibration gases are the ideal verification for the Ultramat 23.

To verify that the limitations pertaining to the SO_2 measurement did not lie elsewhere, Yellow Tree's CO and SO_2 cells were referenced to certified gases, and were found to be performing accurately.

Additionally, because SO_2 is highly soluble in water, any water condensate which is present in the gas train will absorb SO_2 and thus the electrochemical cell will measure lower, or negligible, concentrations of SO_2. In order to combat this, the gas analysis line was made as short as possible (± 670 mm) and was traced with a 121 °C heating element. This intervention did not effect any change in SO_2 measurement again verifying the difficulty of measurement at sub 10 ppm levels.

SO_2 emissions were 12 mg/Nm^3 as measured by the Ultramat 23.

Average NO_x emissions were within the limit of 250 mg/Nm^3.

Yellow Tree would like to thank Siemens for the opportunity to be of service. Yellow Tree's passion is to assist clients in quantifying their emissions accurately, to advise clients about engineering solutions to air emissions problems, and to help clients in making improvements in keeping with their environmental policies while constraining the costs of such solutions.

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