INTHUU MEASUREMENTS CC

VAT REG NO. 4960254359 Reg No. 2009/190265/23

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Eskom Holdings SOC Ltd
Arnot Power Station
Attention: Ms. Nomathemba Mpulo
Private Bag X2
Rietkuil
1097

Date	Your Reference	Our Reference	Enquiries
21 January 2015	Order No.: 3070214665	RCCS224	CC Scheepers Cell: 082 572 2380 e-mail: coen@inthuu.co.za

REPORT – 2014/12/27/CCS224
CORRELATION OF THE EMISSION MONITOR SITUATED ON THE SOUTH STACK AT ARNOT POWER STATION

Herewith the draft report for the monitor calibration and full correlation tests carried out on the South stack. Tests on the emission monitor, situated on the South Stack, were carried out between the 27th of November and the 1st of December 2014.

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

Submitted by:	Checked by	Approved by
		
Signature:.....	Signature:.....	Signature:.....
AV Makama	**NPL Siluma**	**CC Scheepers**

REPORT

CUSTOMER	**:**	ARNOT POWER STATION
TITLE	:	CORRELATION OF THE EMISSION MONITOR SITUATED ON THE SOUTH STACK AT ARNOT POWER STATION
ORDER No's.	:	3070214665
REPORT No.	:	2014/12/27/CCS224
REPORT DATE	:	27 DECEMBER 2014

Index

Summary:

See Summary on next page.

Summary:

Inthuu Measurements were contracted by Arnot Power Station to perform full correlation tests on the Particulate Emission Monitor on the South Stack.

Inthuu Measurements witnessed the calibration, which was carried out by Sick Automation South Africa on the 26th of November 2014. The full correlation tests on South Stack were carried out between the 27th of November and the 1st of December 2014.

The particulate emissions for the South Stack are reported from the monitor's Analogue Output channel No. 1 and is described by the formula, $y_1 = m_1x_1 + c_1$. The monitor's Analogue Output channel No. 2 is not in use. Emissions reported from this channel will be described by, $y_2 = m_2x_2 + c_2$ when the channel is linked to the DCS. The gas flow of Units 4, 5 and 6 through the South stack is described by the formula, g = na + k.

South Stack	**Emissions correlation curve constants at 10 %O_2**			
	m_1	**c_1**	**m_2**	**c_2**
As found	0 – 200 mg/m^3		50 – 200 mg/m^3	
	4.748	-18.319	N/A	N/A
Correlation co-efficient	R = 0.99			

South Stack	**Curve constants for Gas flow correlation** [Nm^3/s on dry basis at 10 %O_2]	
	n	**k**
Based on Average Air Flow	0.7732	836

Where

y_1 = Emission for Output 1 [mg/Nm^3 (d) at 10 %O_2]
y_2 = Emission for Output 2 [mg/Nm^3 (d) at 10 %O_2]
x_1 = Monitor Analogue Output 1 [mA]
x_2 = Monitor Analogue Output 2 [mA]
g = Normal Gas flow on dry basis [m^3/s (w)] at 10 %O_2
a = Control Room indication of Average air flow [kg/s]

South Stack Atmospheric Emissions License limit: 175 mg/Nm^3 (d) at 10 %O_2

GLOSSARY

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

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. INTRODUCTION

Inthuu Measurements were contracted by Arnot Power Station to perform full correlation tests on the Particulate Emission Monitor situated on the South Stack.

Inthuu Measurements witnessed the calibration, which was carried out by Sick Automation South Africa on the 26th of November 2014. The full correlation tests on South Stack were carried out between the 27th of November and the 1st of December 2014.

This report shows the Emission monitor correlation as well as the correlation between the Control Room indication of Average Air flow and the measured flow in the stack. The gas flow correlation is expressed in terms of Normal temperature and pressures in the stack on a dry basis and at 10 $\%O_2$.

2. METHOD OF MEASUREMENT

Particulate emission measurements were carried out employing procedures and equipment which comply with the requirements of EN 13284-1 (Reference 9.1).

Eskom's Technical note (Reference 9.2) is incorporated in Eskom's standard for Emission Monitoring and Reporting (Reference 9.3). Reference 9.3 was followed with particular reference to the Quartz micro-fibre high purity thimble filters.

The VDI correlation procedure (Reference 9.4) was followed in the determination of the linear regression.

3. PROCEDURES

Inthuu Measurements were contracted to provide the service of isokinetic dust sampling and reporting of results only. The plant was set up by Arnot Power Station personnel and tested at the conditions presented and tabulated in this report.

For the recording of the monitor signal during the sampling, a data logger was connected to AO1 as well as AO2 of the emission monitor. The range of AO1 was set to 0 - 200mg/m^3. The range of AO2 was set to 50 - 200mg/m^3. AO2 is not in use. The data logger was verified on site using the CALOG milliamp source and compared with the signal displayed on the Monitor Control Unit (MCU).

<u>South Stack</u>
Twelve isokinetic tests were carried out in accordance 3.7.3 (m) of Eskom's standard for Emission Monitoring and Reporting (Reference 9.3).

The conditions under which the tests were carried out were as follows:

- 3 tests at 280 MW per Boiler and High emission conditions.
- 2 tests at 300 MW per Boiler and normal conditions.
- 4 tests between 266 - 300 MW per Boiler and normal conditions.
- 3 tests at Varied Boiler loads. Unit 5 tripped and returned during the test period.

This report shows the function for AO1 and monitor settings "As found" to be used for back fitting emission data if required.

4. MONITOR INFORMATION AND CALIBRATIONS

South Stack
The Table below shows the settings as found for AO1 Normalised to 10 $\%O_2$.

Plant:	**Units 4, 5 and 6**
Location of Monitor	South Stack
Make:	SICK
Model:	Dust Hunter SB100
Monitor serial number:	10168556
Reflector serial number:	N/A
Channel	**Analogue Output AO 1:**
Measuring range	0.00 - 200
DCS measuring range (mg/Nm3) at 10 $\%O_2$	76.6
Output range (mA):	4 - 20
Info for DCS	
mA	Emission
4.00	0.7
10.00	29.2
15.00	52.9
20.00	76.6
% Output	Emission
0.00	0.7
37.50	29.2
68.75	52.9
100.00	76.6
Constants for Linear function (mA)	
m_{mA} =	4.748
c_{mA} =	-18.319
Constants for Linear function (%)	
$m_{\%}$ =	0.7597
$c_{\%}$ =	0.673

The calibration of the monitor was witnessed by Inthuu Measurements. The certificate was obtained and is included in **Appendix A**.

5. RESULTS

Table 5.1 below shows the test parameters. The test parameters include the requirements for iso-kineticity and face velocity in accordance Reference 9.3. Eskom's standard is in conflict with the International standard regarding face velocity and nozzle size. Reference 9.1 does not prescribe a face velocity, but specifies that the nozzle diameter must be ≥ 8 mm.

South Stack

Table 5.1 – Test Parameters during South Stack correlations

Test No.	Nominal Boiler Load per Boiler	Sum of Units 4, 5 & 6 GEN MW OUTPUT 1	Load condition	Measured Gas flow	Total Air flow	SOUTH STACK OPACITY	Dust Concentration	Average face velocity	% Isok	Comment
	[MW]	[MW]	-	[Nm^3/s (d)] at 10 %O_2	[kg/s]	[%]	[mg/Nm^3 (d)] at 10 %O_2	[cm/s]	[%]	
1	284	851	Max %MCR	1595.7	927.8	60.49	65.3	5.47	98.2	Excluded from linear regression
2	279	835	Max %MCR	1540.1	919.9	62.18	49.4	5.26	97.9	
3	251	752	Max %MCR	1423.9	850.7	68.83	62.3	5.21	96.9	Excluded from linear regression
4	308	923	Max %MCR	1638.4	1027.6	30.46	27.1	5.39	98.2	
5	308	923	Max %MCR	1644.0	1031.5	31.25	24.2	5.37	98.2	
6	310	930	Max %MCR	1612.4	1032.0	31.76	26.3	5.32	98.8	
7	282	844	Max %MCR	1614.9	962.8	33.52	23.3	5.26	98.5	Excluded from linear regression
8	272	815	Max %MCR	1587.9	958.9	37.51	28.0	5.24	99.2	
9	266	798	Max %MCR	1390.9	930.2	46.10	27.6	5.06	98.7	Excluded from linear regression
10	283	850	Max %MCR	1426.2	945.7	51.54	35.9	4.93	98.2	
11	Varied	633	Max %MCR	1381.9	837.8	31.49	26.3	4.78	97.6	Excluded from linear regression
12	Varied	558	Max %MCR	863.3	763.0	15.46	17.4	3.65	99.8	Excluded from linear regression

The face velocities were within ±10 % of the required 5 cm/s. The isokineticities were all between the 95 – 105% as per the allowed range in the Eskom Standard. Quartz filters were used throughout.

Tests 1, 3, 7, 9, 11 and 12 were excluded from the linear regression in accordance Reference 9.4. During these tests one of the three units changed load drastically causing a change in the emission during the test (see discussion).

Test 10 was additionally omitted in the determination of the air to gas correlation.

South Stack

South Stack	**Emissions correlation curve constants at 10 %O_2**			
	m_1	**c_1**	**m_2**	**c_2**
As found	0 – 200 mg/m^3		50 – 200 mg/m^3	
	4.748	-18.319	N/A	N/A
Correlation co-efficient	R = 0.99			

South Stack	Curve constants for Gas flow correlation [Nm^3/s on dry basis at 10 $\%O_2$]	
	n	k
Based on Average Air Flow	0.7732	836

Where

y_1 = Emission for Output 1 [mg/Nm^3 (d) at 10 $\%O_2$]
y_2 = Emission for Output 2 [mg/Nm^3 (d) at 10 $\%O_2$]
x_1 = Monitor Analogue Output 1 [mA]
x_2 = Monitor Analogue Output 2 [mA]
g = Normal Gas flow on dry basis [m^3/s (w)] 10 $\%O_2$
a = Control Room indication of Average air flow [kg/s]

Figures:

- Figure 1 - The 'As Found' Emission Monitor Correlation Certificate at 10 $\%O_2$
- Figure 2 - The relationship between Air flow and gas flow at Normal conditions on dry basis and 10% O_2

Appendices:

- Appendix A - Monitor Calibration Certificate
- Appendix B - Detailed Correlation Test Results
  - Tables B1 to B4
- Appendix C – Charts of omitted tests
- Appendix D - Plant parameters

6. DISCUSSION

The correlation curve for the dust monitor has a correlation coefficient of 0.99, complying with the requirements of the Eskom Standard.

AO2 of the monitor is not connected to the DCS. The measuring range of AO2 will be determined at a later stage.

The three units do not emit the same concentrations. If one unit changes load the rate of emission changes accordingly which results in an increased or decreased concentration of the particulate emissions. If the unit had a good performing FFP, the contribution by this unit is equivalent to dilution while it is running. When this unit reduces load the dilution effect is less, giving higher emissions and vice versa.

7. RECOMMENDATIONS

South Stack
It is recommended that:

- Back dating of recorded emissions prior to the correlation tests is done using the formulae in Section 5.

- The emissions are reported to D.E.A.T. using the formulae given in Sections 4 and 5.

- The gas flow correlation curve given in Figure 2 is used for determining the emission rates.

8. ACKNOWLEDGEMENTS

The author expresses appreciation for the co-operation and assistance provided by Mr Fred Hofmann and the operating personnel of Arnot Power Station during the test period.

9. REFERENCES

9.1 BS EN 13284-1: 2002, Stationary source emissions – Determination of low range mass concentration of dust.

9.2 TRR/M85/006, Hansen, RS 1985, Iso-kinetic Dust Sampling Train as Developed by Mechanical Test & Research Rosherville.

9.3 240-56242363, Alternative Reference Number: 474-187, March 2013, Standard for Emission Monitoring and Reporting: Revision 1

9.4 VDI 2066, Part 4, January 1989, Measurement of Particulate Matter in Flowing Gases – Determination of Dust load by Continuous Measurement of optical Transmission

ARNOT POWER STATION

Emission Monitor Correlation Certificate

Plant: Units 4, 5 and 6
Location of monitor: South Stack
Monitor information:

Make of Monitor: Sick
Model: Dust Hunter SB100
Serial Numbers:
Optical head: 10168556
Reflector: N/A
MCU: 9278513

Limits of validity:

Lower limit 24.2 mg/Nm3 (d) at 10 %O_2 [as an hourly average]
Upper limit 49.4 mg/Nm3 (d) at 10 %O_2 [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 1: 0.00 - 200 mg/m^3 Measuring Range: 0.6 - 76.6 mg/Nm^3 at 10 %O_2
Analogue Output AO 2: N/A - Measuring Range: N/A
AEL Limit 175 mg/Nm^3 @ 10% O_2

Dates:

Calibration date: 26-Nov-14
Correlation dates: 27 Nov - 01 Dec 2014

Linear function:

E_{AO1} = 4.748x - 18.319 Correlation coefficient(R) = 0.99
E_{AO2} = Not operational
where: E = Emission [mg/Nm^3(d)@ 10% O_2]
x = Monitor output [mA]

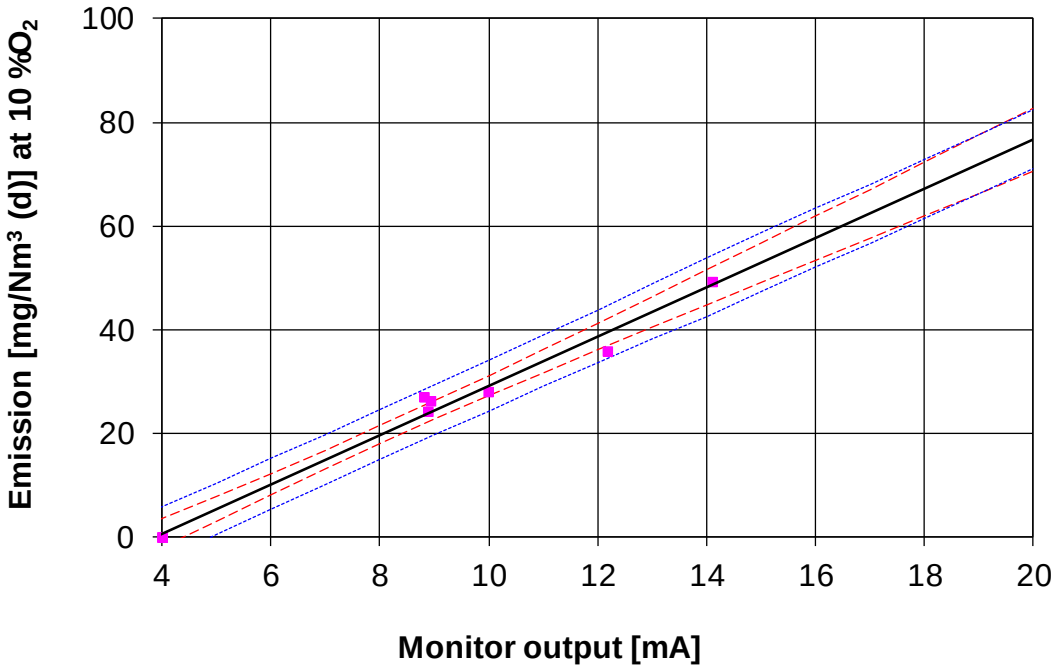


FIGURE 1

Prepared by:

Inthuu Measurements

ARNOT POWER STATION

Stack Gas Flow Correlation Certificate

Plant: Units 4, 5 and 6
Location of monitor: South Stack
Monitor information:
Make of Monitor: Arnot DCS
Model: N/A
Serial Numbers:
N/A
N/A

Limits of validity:
Lower limit 1540.1 Nm^3/s (d) at 10 $\%O_2$ [as an hourly average]
Upper limit 1644.0 Nm^3/s (d) at 10 $\%O_2$ [as an hourly average]

Operational data:
Stack internal diameter 14.5 m
Monitor range: N/A -

Dates:
Calibration date: N/A
Correlation dates: 27 Nov to 01 Dec 2014

Linear function:
g = 0.7732a + 836 Correlation coefficient(R) = 0.94

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

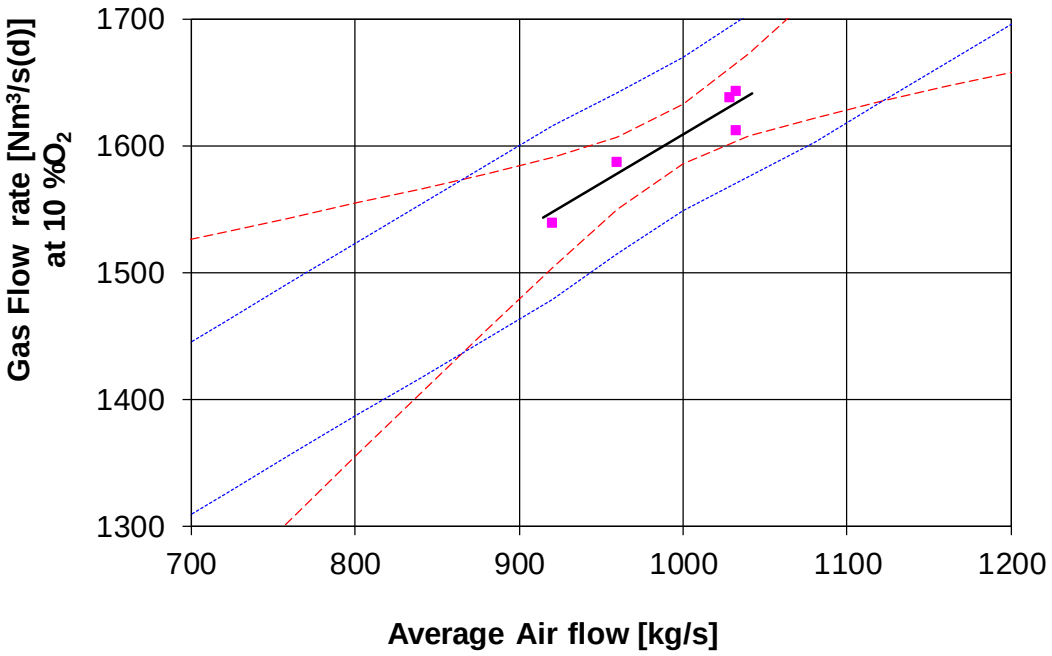


FIGURE 2

Prepared by:

Inthuu Measurements

APPENDIX A
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: DUSTHUNTER SB100

Customer data:		**Certificate:**	**SB100-EC01-26112014-DN001**
Customer:	Eskom Arnot	Customer no:	
Country:	South Africa	City:	
Plant:	Arnot Power Station	Location:	South Stack

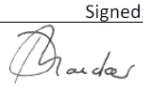
1. Device data:			
Device type DH:	SB100	Device type MCU:	DUSTHUNTER S Display: yes
Serial no:	10168556	Serial no:	09278513
Firmware no. DH:	01.03.10	Firmware no. MCU:	01.06.01
Measuring Units: AO1/AO2	Conc a.c. (SL) / SL	Measuring Range: AO1/AO2	0- 200 / 50 - 200

2. Filter linearity Check: SN S0-80 S158

	Filter [%]	Measured value [%]	Difference [%]	Allowable difference [%]
	79.0	78.4	-0.6	2.0
	58.4	58.9	0.5	2.0
	41.7	42.3	0.6	2.0
	21.3	21.6	0.3	2.0
	0.0	0.1	0.1	2.0

Remarks:

The above calibration checks were witnessed by Inthuu Measurements

Date :	26/11/2014		Name	Signed:
Valid Unit:	26/11/2015	Engineer:	Dustin Naicker	

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

Service Report

Client : **Eskom Arnot**
Instrument : **SB100**
Location : **North and South Stacks**
Date : **26 November 2014**
Service Engineer : **Dustin Naicker**

Request

- Perform electronic calibrations on North and South stack SB100 dust monitors.
- Install the ordered MCU on the South Stack and remove the SICK loan unit

Findings/Actions

North Stack

- The lift was not operational. No further work was possible

South Stack

- The monitor was serviced and an electronic calibration was performed.
- The SICK loan MCU was not removed due to delays in isolating the power from the customers side. It was agreed upon with Mahlatse that SICK will retain the ordered MCU and Arnot will retain the currently installed unit permanently. There is no difference in the units and will work exactly the same
- Inthuu Measurements were present to witness the electronic calibration.
- The CAN cable connection was found to be incorrectly wired, however the monitor was in operation. The wires were correctly connected thereafter
- The ranges were not altered. The MCU display was updated accordingly.

Comments/Recommendations

- It is recommended to ensure all communication and arrangements be made prior to the service trip to avoid unnecessary delays
- The cycle check is currently set to 1hr. We recommend this be set to 4hr or 8hr depending on the engineering team decision.

Dustin Naicker
Service Engineer
Process Automation

APPENDIX B

DETAILED RESULTS: ISOKINETIC DUST SAMPLING

TABLE B1
South Stack
Detailed Test Results Tests 1 to 3

Test No.		1	2	3
Stack tester:		AVM	AVM	AVM
Date	dd-mm-yy	2014/11/27	2014/11/27	2014/11/27
Start Time	HH:mm	11H15	13H22	15H22
End Time	HH:mm	12H45	14H40	16H48
Boiler load	MW	270	270	270
Outlet Conditions.				
Gas Temperature	°C	143.8	142.2	139.5
Barometric pressure	kPa (g)	83.0	82.9	82.8
Duct pressure	Pa	-111.5	-131.8	-175.5
Duct pressure	kPa (abs)	82.9	82.7	82.6
Moisture Mass	mg	47.0	48.0	42.0
Moisture	%v/v	6.9	7.3	6.5
Oxygen	%	7.6	7.6	8.7
Velocity	m/s	15.96	15.35	15.21
Duct area	m2	165.13	165.13	165.13
Gas Volume Flow (Qact)	Am3/s	2635.73	2534.39	2512.24
Gas Volume Flow (Qnw)	Nm3/s	1411.93	1360.88	1355.96
Gas Volume Flow (Qnd)	Nm3/s	1314.30	1260.89	1268.34
Gas Volume Flow (Qnd 6 %O2)	Nm3/s	1170.16	1129.40	1044.18
Gas Volume Flow (Qnd 10 %O2)	Nm3/s	1595.68	1540.10	1423.88
Gas flow rate	kg/s	1801.26	1727.65	1713.62
Thimbles used		PB1	PB2	PB3
Gas density in duct	kg/m3	0.683	0.682	0.682
Sampling time	Minutes	60	60	60
Nozzle diameter	mm	6.0	6.0	6.0
Dust mass	mg	63.1	45.9	53.0
Gas Volume Sampled (Vact)	Am3 (w)	1.5963	1.5301	1.5002
Gas Volume Sampled (Vnw)	Nm3 (w)	0.8551	0.8216	0.8097
Gas Volume Sampled (Vad)	Am3 (d)	1.4870	1.4188	1.4033
Gas Volume Sampled (Vnd)	Nm3 (d)	0.7966	0.7619	0.7574
Dust Concentration	mg/Am3 (w)	39.5	30.0	35.3
Dust Concentration	mg/Nm3 (w)	73.8	55.9	65.5
Dust Concentration	mg/Am3 (d)	42.4	32.4	37.8
Dust Concentration	mg/Nm3 (d)	79.2	60.3	70.0
Dust Concentration Normalised to 6% O2	mg/Nm3 (d) @ 6% O2	89.0	67.3	85.0
Dust Concentration Normalised to 10% O2	mg/Nm3 (d) @ 10% O2	65.3	49.4	62.3
Outlet Dust Flowrate	mg/s	104228.0	76071.8	88779.0
Moisture Concentration	g/Nm3 (d)	59.0	63.0	55.5
Average Face velocity	cm/s	5.5	5.3	5.2
Isokineticity	%	98.2	97.9	96.9
Average O/M Signal Output 1 (0 - 200mg/m^3)	mA	13.55	14.11	14.75
Average O/M Signal Output 1 (50 - 200mg/m^3)	mA	11.65	12.42	13.25

TABLE B2
South Stack
Detailed Test Results Tests 4 & 5

Test No.		4	5
Stack tester:		AVM	AVM
Date	dd-mm-yy	2014/11/29	2014/11/29
Start Time	HH:mm	9H10	11H10
End Time	HH:mm	10H40	12H35
Boiler load	MW	271	271
Outlet Conditions.			
Gas Temperature	°C	142.0	144.0
Barometric pressure	kPa (g)	83.3	83.5
Duct pressure	Pa	-167.0	-129.9
Duct pressure	kPa (abs)	83.2	83.4
Moisture Mass	mg	46.0	45.5
Moisture	%v/v	6.7	6.7
Oxygen	%	7.2	7.1
Velocity	m/s	15.73	15.67
Duct area	m2	165.13	165.13
Gas Volume Flow (Qact)	Am3/s	2597.33	2588.15
Gas Volume Flow (Qnw)	Nm3/s	1402.77	1393.99
Gas Volume Flow (Qnd)	Nm3/s	1308.15	1300.36
Gas Volume Flow (Qnd 6 %O2)	Nm3/s	1201.52	1205.59
Gas Volume Flow (Qnd 10 %O2)	Nm3/s	1638.43	1643.99
Gas flow rate	kg/s	1786.47	1773.83
Thimbles used		PB5	PB6
Gas density in duct	kg/m3	0.688	0.685
Sampling time	Minutes	60	60
Nozzle diameter	mm	6.0	6.0
Dust mass	mg	26.9	24.1
Gas Volume Sampled (Vact)	Am3 (w)	1.5730	1.5674
Gas Volume Sampled (Vnw)	Nm3 (w)	0.8496	0.8442
Gas Volume Sampled (Vad)	Am3 (d)	1.4669	1.4622
Gas Volume Sampled (Vnd)	Nm3 (d)	0.7923	0.7876
Dust Concentration	mg/Am3 (w)	17.1	15.4
Dust Concentration	mg/Nm3 (w)	31.6	28.5
Dust Concentration	mg/Am3 (d)	18.3	16.5
Dust Concentration	mg/Nm3 (d)	33.9	30.6
Dust Concentration Normalised to 6% O2	mg/Nm3 (d) @ 6% O2	36.9	33.0
Dust Concentration Normalised to 10% O2	mg/Nm3 (d) @ 10% O2	27.1	24.2
Outlet Dust Flowrate	mg/s	44358.5	39743.2
Moisture Concentration	g/Nm3 (d)	58.1	57.8
Average Face velocity	cm/s	5.4	5.4
Isokineticity	%	98.2	98.2
Average O/M Signal Output 1 (0 - 200mg/m^3)	mA	8.81	8.88
Average O/M Signal Output 1 (50 - 200mg/m^3)	mA	5.40	5.51

TABLE B3
South Stack
Detailed Test Results Tests 6 to 9

Test No.		6	7	8	9
Stack tester:		AVM	AVM	AVM	AVM
Date	dd-mm-yy	2014/11/30	2014/11/30	2014/11/30	2014/11/30
Start Time	HH:mm	9H22	11H10	12H54	14H33
End Time	HH:mm	10H43	12H25	14H11	15H49
Boiler load	MW	270	270	270	270
Outlet Conditions.					
Gas Temperature	°C	144.8	145.0	144.2	142.9
Barometric pressure	kPa (g)	83.5	83.5	83.5	83.3
Duct pressure	Pa	-140.5	-157.5	-149.2	-153.3
Duct pressure	kPa (abs)	83.3	83.3	83.4	83.1
Moisture Mass	mg	47.0	38.0	45.0	39.0
Moisture	%v/v	7.0	5.7	6.7	6.1
Oxygen	%	7.2	7.2	7.2	8.6
Velocity	m/s	15.54	15.35	15.29	14.77
Duct area	m2	165.13	165.13	165.13	165.13
Gas Volume Flow (Qact)	Am3/s	2566.83	2535.05	2525.04	2438.69
Gas Volume Flow (Qnw)	Nm3/s	1379.74	1361.91	1359.58	1313.79
Gas Volume Flow (Qnd)	Nm3/s	1283.60	1283.86	1267.97	1233.91
Gas Volume Flow (Qnd 6 %O2)	Nm3/s	1182.42	1184.25	1164.47	1019.98
Gas Volume Flow (Qnd 10 %O2)	Nm3/s	1612.40	1614.88	1587.91	1390.89
Gas flow rate	kg/s	1755.29	1742.25	1739.22	1678.76
Thimbles used		PB7	PB8	PB9	PB10
Gas density in duct	kg/m3	0.684	0.687	0.689	0.688
Sampling time	Minutes	60	60	60	60
Nozzle diameter	mm	6.0	6.0	6.0	6.0
Dust mass	mg	25.8	22.8	27.2	23.3
Gas Volume Sampled (Vact)	Am3 (w)	1.5637	1.5389	1.5445	1.4831
Gas Volume Sampled (Vnw)	Nm3 (w)	0.8405	0.8267	0.8316	0.7990
Gas Volume Sampled (Vad)	Am3 (d)	1.4548	1.4509	1.4405	1.3930
Gas Volume Sampled (Vnd)	Nm3 (d)	0.7820	0.7794	0.7756	0.7504
Dust Concentration	mg/Am3 (w)	16.5	14.8	17.6	15.7
Dust Concentration	mg/Nm3 (w)	30.7	27.6	32.7	29.2
Dust Concentration	mg/Am3 (d)	17.8	15.7	18.9	16.7
Dust Concentration	mg/Nm3 (d)	33.0	29.3	35.1	31.1
Dust Concentration Normalised to 6% O2	mg/Nm3 (d) @ 6% O2	35.9	31.7	38.2	37.6
Dust Concentration Normalised to 10% O2	mg/Nm3 (d) @ 10% O2	26.3	23.3	28.0	27.6
Outlet Dust Flowrate	mg/s	42425.3	37580.5	44479.4	38322.3
Moisture Concentration	g/Nm3 (d)	60.1	48.8	58.0	52.0
Average Face velocity	cm/s	5.3	5.3	5.2	5.1
Isokineticity	%	98.8	98.5	99.2	98.7
Average O/M Signal Output 1 (0 - 200mg/m^3)	mA	8.93	9.34	10.00	11.38
Average O/M Signal Output 1 (50 - 200mg/m^3)	mA	5.60	6.13	7.10	8.88

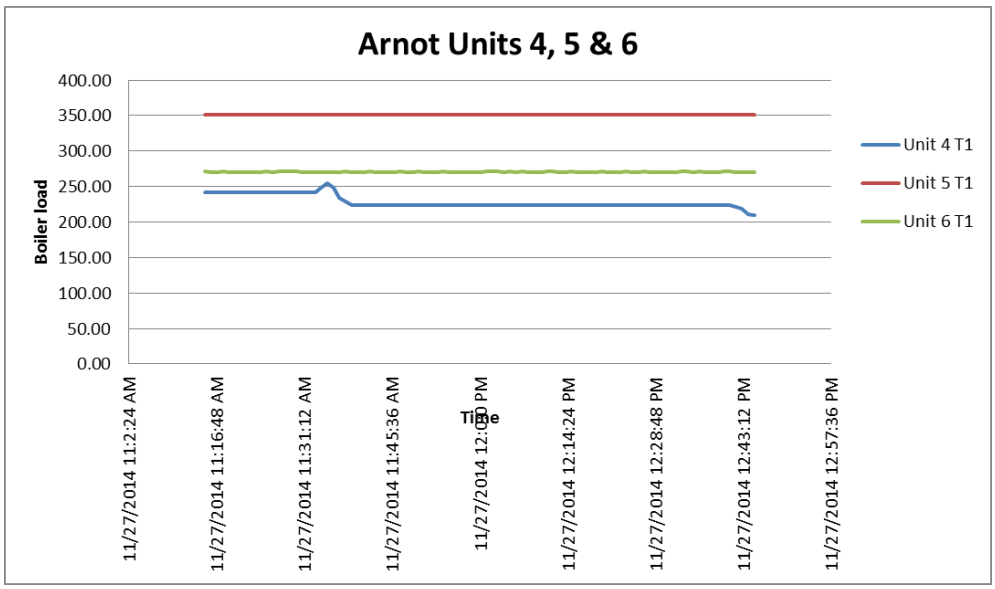
TABLE B4
South Stack
Detailed Test Results Tests 10 to 12

Test No.		10	11	12
Stack tester:		AVM	AVM	AVM
Date	dd-mm-yy	2014/12/01	2014/12/01	2014/12/01
Start Time	HH:mm	12H28	14H13	15H46
End Time	HH:mm	13H45	15H27	17H04
Boiler load	MW	270	270	270
Outlet Conditions.				
Gas Temperature	°C	142.5	142.4	134.7
Barometric pressure	kPa (g)	83.5	83.4	83.3
Duct pressure	Pa	-162.8	-151.8	-132.2
Duct pressure	kPa (abs)	83.3	83.2	83.2
Moisture Mass	mg	41.0	37.5	30.5
Moisture	%v/v	6.6	6.2	6.6
Oxygen	%	7.9	8.0	10.5
Velocity	m/s	14.40	13.94	10.67
Duct area	m2	165.13	165.13	165.13
Gas Volume Flow (Qact)	Am3/s	2377.54	2302.46	1761.36
Gas Volume Flow (Qnw)	Nm3/s	1284.30	1243.57	968.06
Gas Volume Flow (Qnd)	Nm3/s	1199.91	1165.96	904.01
Gas Volume Flow (Qnd 6 %O2)	Nm3/s	1045.85	1013.38	633.11
Gas Volume Flow (Qnd 10 %O2)	Nm3/s	1426.15	1381.88	863.34
Gas flow rate	kg/s	1639.28	1581.69	1233.01
Thimbles used		PB12	PB13	PB14
Gas density in duct	kg/m3	0.689	0.687	0.700
Sampling time	Minutes	60	60	60
Nozzle diameter	mm	6.0	6.0	6.0
Dust mass	mg	31.0	21.9	9.3
Gas Volume Sampled (Vact)	Am3 (w)	1.4396	1.3856	1.0880
Gas Volume Sampled (Vnw)	Nm3 (w)	0.7776	0.7483	0.5979
Gas Volume Sampled (Vad)	Am3 (d)	1.3451	1.2991	1.0189
Gas Volume Sampled (Vnd)	Nm3 (d)	0.7266	0.7017	0.5600
Dust Concentration	mg/Am3 (w)	21.5	15.8	8.6
Dust Concentration	mg/Nm3 (w)	39.9	29.3	15.6
Dust Concentration	mg/Am3 (d)	23.1	16.9	9.1
Dust Concentration	mg/Nm3 (d)	42.7	31.2	16.6
Dust Concentration Normalised to 6% O2	mg/Nm3 (d) @ 6% O2	49.0	35.9	23.8
Dust Concentration Normalised to 10% O2	mg/Nm3 (d) @ 10% O2	35.9	26.3	17.4
Outlet Dust Flowrate	mg/s	51221.9	36377.8	15080.5
Moisture Concentration	g/Nm3 (d)	56.4	53.4	54.5
Average Face velocity	cm/s	4.9	4.8	3.6
Isokineticity	%	98.2	97.6	99.8
Average O/M Signal Output 1 (0 - 200mg/m^3)	mA	12.19	8.64	6.30
Average O/M Signal Output 1 (50 - 200mg/m^3)	mA	9.93	6.27	4.39

NOTE:
PLEASE REFER TO GLOSSARY FOR THE INTERPRETATION OF THE ABBREVIATIONS USED IN THE ABOVE TABLES.

APPENDIX C

Boiler Load Charts of omitted tests


Arnot Units 4, 5 & 6
Boiler load
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
11/27/2014 11:2:24 AM
11/27/2014 11:16:48 AM
11/27/2014 11:31:12 AM
11/27/2014 11:45:36 AM
11/27/2014 12:0:0 PM
11/27/2014 12:14:24 PM
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11/27/2014 12:43:12 PM
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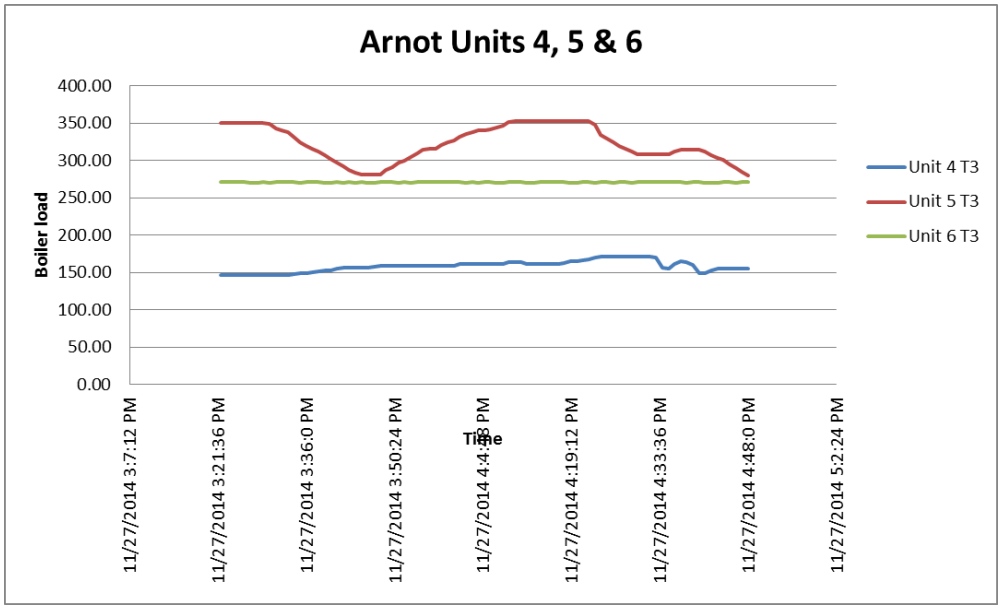
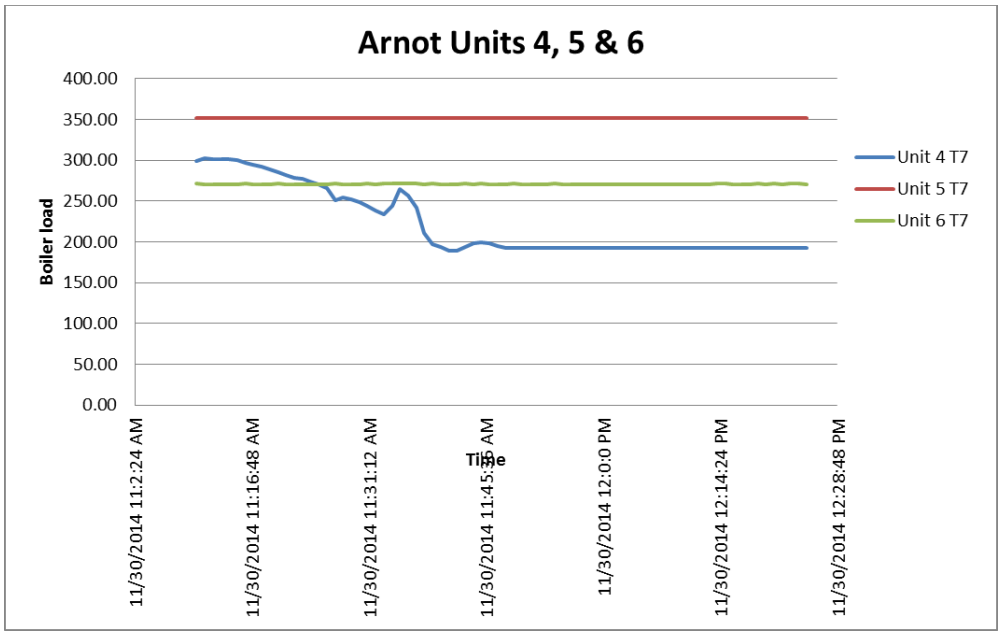
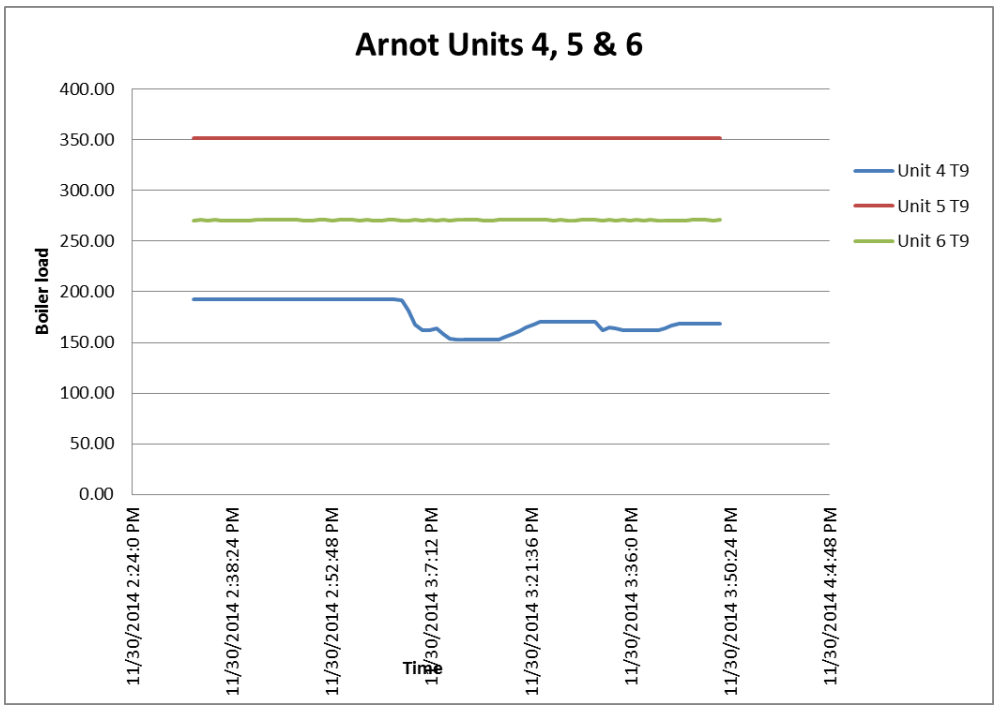
Time
Unit 4 T1
Unit 5 T1
Unit 6 T1


Arnot Units 4, 5 & 6
Boiler load
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
11/27/2014 3:7:12 PM
11/27/2014 3:21:36 PM
11/27/2014 3:36:0 PM
11/27/2014 3:50:24 PM
11/27/2014 4:4:48 PM
11/27/2014 4:19:12 PM
11/27/2014 4:33:36 PM
11/27/2014 4:48:0 PM
11/27/2014 5:2:24 PM
Time
Unit 4 T3
Unit 5 T3
Unit 6 T3


Arnot Units 4, 5 & 6
Boiler load
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
11/30/2014 11:2:24 AM
11/30/2014 11:16:48 AM
11/30/2014 11:31:12 AM
11/30/2014 11:45:36 AM
11/30/2014 12:0:0 PM
11/30/2014 12:14:24 PM
11/30/2014 12:28:48 PM
Time
Unit 4 T7
Unit 5 T7
Unit 6 T7


Arnot Units 4, 5 & 6
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
Boiler load
11/30/2014 2:24:0 PM
11/30/2014 2:38:24 PM
11/30/2014 2:52:48 PM
11/30/2014 3:7:12 PM
11/30/2014 3:21:36 PM
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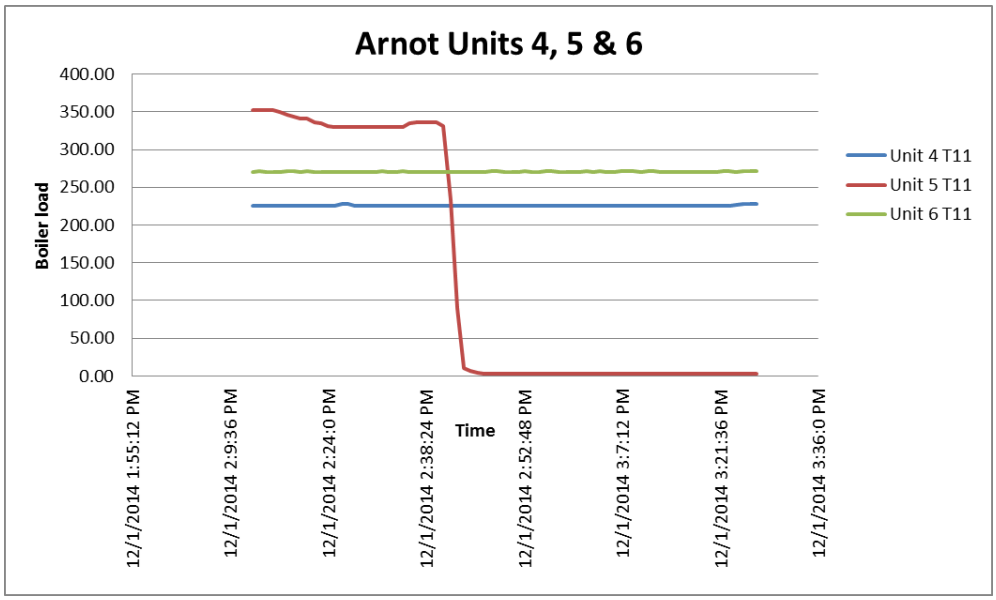
Time
Unit 4 T9
Unit 5 T9
Unit 6 T9


Arnot Units 4, 5 & 6
400.00
350.00
300.00
250.00
200.00
150.00
100.00
50.00
0.00
Boiler load
12/1/2014 1:55:12 PM
12/1/2014 2:9:36 PM
12/1/2014 2:24:0 PM
12/1/2014 2:38:24 PM
12/1/2014 2:52:48 PM
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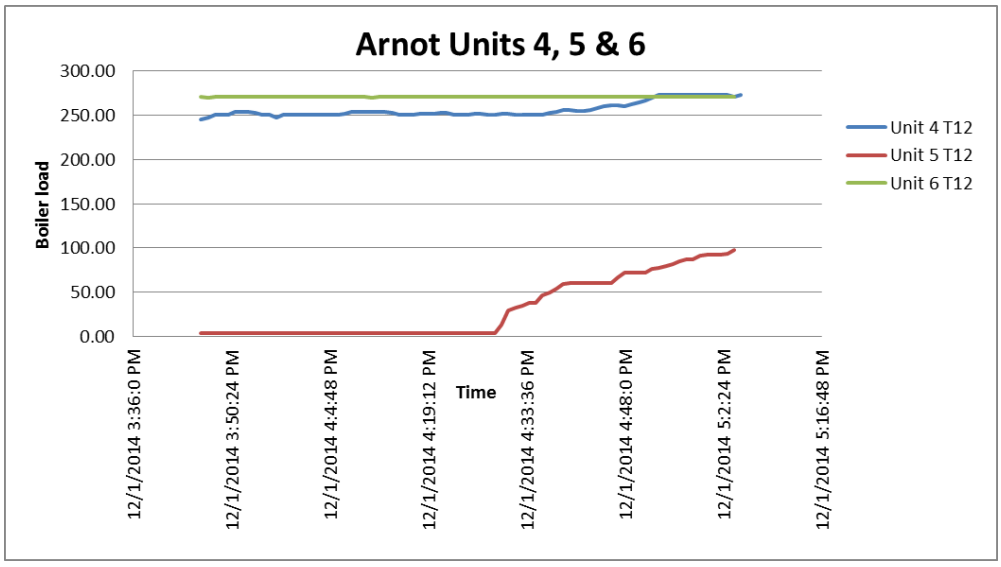
Time
Unit 4 T11
Unit 5 T11
Unit 6 T11


Arnot Units 4, 5 & 6
300.00
250.00
200.00
150.00
100.00
50.00
0.00
Boiler load
12/1/2014 3:36:0 PM
12/1/2014 3:50:24 PM
12/1/2014 4:4:48 PM
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12/1/2014 4:33:36 PM
12/1/2014 4:48:0 PM
12/1/2014 5:2:24 PM
12/1/2014 5:16:48 PM
Time
Unit 4 T12
Unit 5 T12
Unit 6 T12

APPENDIX D

Plant Parameters

Table E1

South Stack

Plant Parameters Tests 1 – 12

Test No.		1	2	3	4	5	6	7	8	9	10	11	12
Stack tester:		AVM	AVM	AVM	AVM	AVM	AVM	AVM	AVM	AVM	AVM	AVM	AVM
Date	dd-mm-yy	2014/11/27	2014/11/27	2014/11/27	2014/11/29	2014/11/29	2014/11/30	2014/11/30	2014/11/30	2014/11/30	2014/12/01	2014/12/01	2014/12/01
Start Time	HH:mm	11H15	13H22	15H22	9H10	11H10	9H22	11H10	12H54	14H33	12H28	14H13	15H46
End Time	HH:mm	12H45	14H40	16H48	10H40	12H35	10H43	12H25	14H11	15H49	13H45	15H27	17H04
Boiler load	MW	270	270	270	271	271	270	270	270	270	270	270	270
Unit 4													
GEN MW OUTPUT 1	MW	228.54	212.97	158.67	306.19	306.14	307.55	222.32	192.36	175.39	227.11	226.15	256.47
TOTAL BOILER FUEL FLOW	%	67.10	56.66	45.11	76.85	76.61	80.37	73.39	70.92	58.14	66.58	65.52	64.30
LH/RH TOT AIR FLOW	kg/sec	238.89	219.82	164.60	337.45	341.09	339.46	270.84	252.09	223.59	233.79	231.93	267.58
LH O2 ANALIZER ON ECON	%	2.43	2.04	4.23	1.65	1.57	1.56	4.27	5.09	5.53	1.90	1.59	1.46
LH ECONOMISER OUTBRD O2	%	4.44	4.25	5.97	2.94	2.91	2.89	5.76	6.70	7.47	4.03	3.75	3.67
RH O2 ANALISER ON ECON	%	2.42	3.13	4.33	1.36	1.35	1.51	3.98	5.14	4.79	2.54	2.36	1.71
RH ECONOMISER OUTBRD O2	%	3.74	4.27	5.30	2.88	2.99	2.94	5.20	6.38	6.18	3.88	3.83	2.92
T LH AH GAS INL 3v4	DegC	263.38	244.93	246.23	306.44	306.64	306.49	287.25	279.89	272.25	284.18	284.18	281.67
T RH AH GAS INL 3v4	DegC	272.09	254.05	249.93	310.55	310.55	309.61	294.20	288.10	283.78	292.38	293.16	290.25
LH BAGFILTER INL TMP AVE	DegC	133.17	126.09	122.06	147.22	150.98	151.61	144.12	136.60	133.26	145.48	146.45	140.94
RH BAGFILTER INL TMP AVE	DegC	149.38	143.83	145.12	147.34	150.01	149.69	154.80	157.26	160.30	158.83	159.41	151.75
LH FD FAN CCT AMPS	A	136.78	132.95	122.75	158.49	159.00	159.39	142.40	137.75	132.54	132.51	130.93	139.27
RH FD FAN CCT AMPS	A	139.80	134.23	122.60	162.73	162.48	162.59	145.30	141.72	134.11	136.95	136.42	145.23
LH ID FAN MTR CCT AMPS	A	116.29	114.80	108.05	151.75	156.54	154.73	123.16	116.63	111.27	115.46	114.67	121.20
RH ID FAN CCT AMPS	A	126.54	124.23	112.38	162.76	165.62	164.13	136.05	131.42	126.16	126.17	126.31	135.28
AMPS MILL F FEEDER	A	-4.95	-4.93	-4.91	-4.91	-4.91	-4.91	-4.91	-4.91	-4.91	-4.91	-4.91	-4.91
AMPS MILL A FEEDER	A	12.05	12.00	12.31	11.91	11.90	12.07	12.15	13.24	13.47	13.17	12.40	12.08
AMPS MILL E FEEDER	A	13.07	11.24	-1.96	11.63	11.74	12.71	1.66	-5.00	-5.00	11.76	11.38	11.16
AMPS MILL B FEEDER	A	12.43	7.82	11.88	11.94	12.00	12.21	12.16	12.16	12.06	12.13	12.07	12.03
AMPS MILL D FEEDER	A	12.11	12.48	12.81	11.82	11.81	12.26	12.53	13.03	12.77	13.76	12.04	12.14
AMPS MILL C FEEDER	A	0.08	0.10	3.88	9.43	9.44	9.48	10.51	11.18	5.00	-5.01	-5.01	-3.96
DP LH FFP	mbar	10.27	9.76	8.96	15.31	15.48	14.98	11.26	10.68	9.60	9.96	9.91	10.84
DP RH FFP	mbar	10.54	10.41	8.85	15.39	15.97	16.65	12.83	11.78	10.97	11.35	11.48	13.09
P LH BAGFILTER PULSING	kPa	553.71	578.19	567.41	594.37	596.19	592.20	607.85	601.62	601.31	599.13	605.98	618.55
P RH BAGFILTER PULSING	kPa	530.95	539.81	537.34	571.96	563.57	558.26	576.75	574.74	579.39	556.54	574.24	588.88
LH FFP PULSE TREND CNTL	%	63.61	80.77	135.83	6.48	7.28	8.41	109.88	76.39	198.48	46.91	34.33	19.78
RH FFP PULSE CNTL	%	8.95	8.10	21.97	4.76	4.77	4.18	5.64	5.34	6.98	4.94	5.02	4.80
MAIN FEED WATER FLOW 2v3	kg/s	203.72	185.18	143.13	283.23	284.95	279.99	201.75	173.05	157.94	201.28	201.97	223.49
Unit 5													
GEN MW OUTPUT 1	MW	351.64	351.75	322.95	346.36	346.36	351.24	351.40	351.40	351.40	351.88	136.53	30.92
TOTAL BOILER FUEL FLOW	%	87.24	88.91	80.74	85.95	85.70	87.39	88.72	88.45	87.77	87.82	33.68	6.38
LH/RH TOT AIR FLOW	kg/sec	362.79	371.08	354.97	358.33	356.65	355.20	354.45	368.98	372.80	373.86	269.81	160.67
LH 02 ANAL ON ECON	%	2.04	2.18	2.88	2.63	2.56	1.97	1.81	2.48	2.74	2.59	14.37	16.22
LH ECONOMISER OUTBRD 02	%	2.81	2.58	2.89	2.43	2.45	2.73	2.65	2.37	2.55	2.38	14.17	16.30
RH 02 ANAL ON ECON	%	1.08	1.28	1.92	1.36	1.24	1.24	1.07	1.31	1.33	1.50	12.89	13.35
RH ECONOMISER OUTBRD 02	%	2.09	2.10	2.53	2.53	2.42	2.18	2.12	2.39	2.16	2.21	13.30	15.21
T LH AH GAS INL 3v4	DegC	326.90	327.08	322.60	323.24	323.24	323.49	323.49	323.49	323.49	326.66	303.48	269.86
T RH AH GAS INL 3v4	DegC	332.28	332.28	327.28	332.28	332.28	327.39	328.89	332.45	332.52	332.80	308.31	273.75
LH BAGFILTER INL TMP AVE	DegC	145.45	145.16	144.63	141.26	144.10	145.34	145.51	142.92	141.82	141.14	144.73	131.29
RH BAGFILTER INL TMP AVE	DegC	153.39	152.70	150.92	150.42	154.55	155.08	155.29	153.54	152.34	150.83	134.51	123.49
LH FD FAN CCT AMPS	A	174.72	181.26	174.16	171.92	170.77	168.98	170.15	178.21	179.64	180.58	137.61	113.28
RH FD FAN CCT AMPS	A	176.61	182.89	177.15	174.94	174.30	171.67	173.44	181.83	183.52	183.64	152.18	120.12
LH ID FAN MTR CCT AMPS	A	172.97	172.80	162.38	173.31	172.35	172.16	172.37	172.90	171.87	172.62	133.55	103.87
RH ID FAN CCT AMPS	A	182.02	181.94	169.39	183.06	182.28	181.87	182.13	182.87	181.65	181.91	136.83	101.90
AMPS MILL F FEEDER	A	10.34	10.29	10.11	10.30	10.33	10.34	10.31	10.04	10.32	10.42	4.07	4.96
AMPS MILL A FEEDER	A	11.25	11.23	11.08	11.58	11.50	11.61	11.29	11.23	11.16	11.13	4.40	0.80
AMPS MILL E FEEDER	A	9.61	9.62	9.62	9.45	9.45	9.85	9.78	9.34	9.34	9.32	3.65	0.06
AMPS MILL B FEEDER	A	8.70	6.57	0.13	8.82	8.87	8.67	8.55	8.56	8.55	8.61	3.48	0.08
AMPS MILL D FEEDER	A	11.92	11.93	12.00	11.51	11.47	11.62	11.63	11.63	11.71	11.70	4.58	0.10
AMPS MILL C FEEDER	A	0.03	7.02	13.46	0.05	0.05	0.05	0.05	0.05	0.05	0.06	0.06	0.06
DP LH FFP	mbar	14.70	14.85	14.73	14.57	14.48	14.49	14.48	14.90	15.02	15.41	11.82	8.51
DP RH FFP	mbar	15.57	16.14	16.62	14.76	14.53	14.48	14.46	15.03	15.27	16.76	13.01	8.78
P LH BAGFILTER PULSING	kPa	460.71	462.33	461.84	595.85	597.90	586.17	592.61	593.66	592.25	591.86	603.29	621.90
P RH BAGFILTER PULSING	kPa	460.85	462.99	462.43	593.13	595.90	584.48	591.06	592.08	592.44	591.48	604.01	622.43
LH FFP PULSE CNTL	%	14.05	13.29	12.67	14.35	15.86	15.26	13.76	12.09	10.87	8.62	94.70	396.05
RH FFP PULSETREND CNTL	%	7.38	7.79	8.54	8.34	9.10	11.83	10.40	8.69	8.44	7.70	215.43	393.50
MAIN FEED WATER FLOW 2v3	kg/s	329.06	328.67	303.80	330.17	325.70	331.31	330.29	329.68	329.77	329.99	144.39	36.30
Unit 6													
GEN MW OUTPUT 1	MW	270.76	270.74	270.77	270.74	270.72	270.73	270.75	270.77	270.75	270.77	270.79	270.77
TOTAL BOILER FUEL FLOW	%	67.64	68.11	67.83	66.90	67.85	68.01	67.38	68.35	68.01	68.35	67.77	67.99
LH/RH TOT AIR FLOW	kg/sec	326.12	329.02	331.09	331.79	333.80	337.37	337.47	337.83	333.78	338.07	336.07	334.80
LH 02 ANAL ON ECON	%	2.06	2.18	2.35	1.63	1.98	2.11	2.03	2.07	1.76	2.03	1.99	1.94
LH ECONOMISER OUTBRD 02	%	2.23	2.29	2.48	2.55	2.86	2.70	2.62	2.72	2.58	2.60	2.55	2.54
RH 02 ANAL ON ECON	%	1.85	1.75	1.61	1.48	1.37	1.43	1.40	1.37	1.62	1.45	1.52	1.61
RH ECONOMISER OUTBRD 02	%	2.51	2.57	2.41	2.40	2.18	2.04	2.01	1.99	2.18	2.02	2.10	2.19
T LH AH GAS INL 3v4	DegC	311.45	311.84	312.33	308.22	309.25	310.62	311.56	311.72	310.94	312.33	311.77	311.26
T RH AH GAS INL 3v4	DegC	305.87	306.14	306.26	304.48	306.54	303.15	303.35	304.19	303.04	304.19	303.61	303.22
LH BAGFILTER INL TMP AVE	DegC	141.60	141.93	140.68	132.25	134.08	135.80	137.43	137.59	137.10	136.65	136.37	136.47
RH BAGFILTER INL TMP AVE	DegC	136.40	138.36	134.90	130.18	131.29	130.60	130.57	131.35	130.28	129.65	130.54	130.47
LH FD FAN CCT AMPS	A	151.22	151.47	151.98	154.76	154.90	156.06	155.99	156.55	155.51	156.08	155.45	155.44
RH FD FAN CCT AMPS	A	162.39	162.75	163.24	165.60	165.96	167.51	167.55	167.95	167.42	168.09	167.84	168.00
LH ID FAN MTR CCT AMPS	A	125.08	124.96	125.93	126.40	126.00	127.17	126.66	126.78	125.29	126.39	124.82	124.34
RH ID FAN CCT AMPS	A	122.78	123.32	123.17	124.40	125.06	125.54	124.77	124.89	123.98	124.51	124.21	124.29
AMPS MILL F FEEDER	A	12.74	12.68	10.80	10.85	10.89	10.79	10.92	11.44	10.79	10.90	10.83	10.84
AMPS MILL A FEEDER	A	8.28	8.40	8.35	0.11	0.11	9.10	9.64	9.27	9.51	9.08	9.00	9.07
AMPS MILL E FEEDER	A	15.87	15.74	14.35	13.75	14.44	13.09	13.70	13.19	12.34	12.88	12.83	12.72
AMPS MILL B FEEDER	A	-4.99	-4.99	-4.99	-4.99	-4.99	-4.99	-4.99	-4.99	-4.99	-4.99	-4.99	-5.00
AMPS MILL D FEEDER	A	11.58	12.04	11.15	11.13	11.28	0.09	0.09	0.09	0.09	0.09	0.09	0.09
AMPS MILL C FEEDER	A	8.11	8.09	8.08	8.07	8.07	8.09	8.12	7.98	8.06	7.60	7.87	7.98
DP LH FFP	mbar	13.62	13.72	13.79	13.80	13.85	13.94	13.95	13.98	13.86	13.99	13.93	13.88
DP RH FFP	mbar	13.62	13.73	13.79	13.78	13.85	13.96	13.96	13.97	13.85	13.97	13.90	13.87
P LH BAG FILT PULLS	kPa	366.19	364.80	383.13	372.32	367.38	361.74	358.89	362.59	373.47	379.27	379.51	379.15
P RH BAGFILT PULLS	kPa	351.80	354.17	359.05	362.33	367.64	363.92	360.96	365.34	374.12	376.94	378.90	380.65
LH FFP PULSE TREND CNTL	%	71.94	73.36	59.28	67.47	71.46	75.50	77.68	74.88	66.51	62.19	62.00	62.20
RH FFP PULSE TREND CNTL	%	85.12	84.35	78.99	77.75	75.66	75.98	76.04	73.61	66.06	63.98	62.62	61.04
MAIN FEED WATER FLOW 2v3	kg/s	250.85	250.67	249.82	251.01	251.54	251.66	252.39	251.99	252.66	251.73	252.10	251.55
SOUTH STACK OPACITY	%	60.49	62.18	68.83	30.46	31.25	31.76	33.52	37.51	46.10	51.54	31.49	15.46

10. DISTRIBUTION LIST

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