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Testing of the OekoTube Electrostatic Precipitator on Coal Emissions

Customer: **West Coast Regional Council**
PO Box 66
Greymouth 7840

Report 14/2660 **January 2014**

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Attention: **Lillie Sadler**

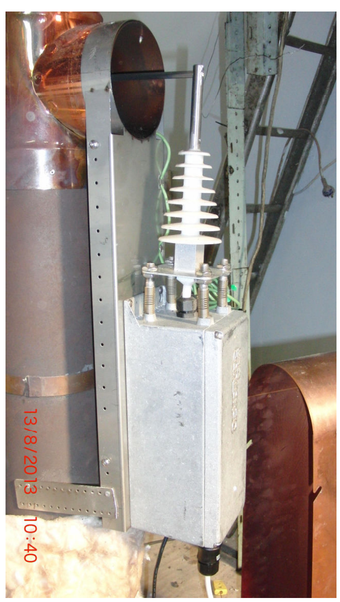
Testing of the OekoTube Electrostatic Precipitator on Coal Emissions

1.0 Introduction

Flue gas emissions of a sample of the appliance described below were tested using the procedures in Appendix 1. An OekoTube electrostatic precipitator (ESP) was installed in the flue and emissions were measured before and after the device. The ESP is designed to place a charge on particles in the flue gases which causes them to be attracted to the flue and deposited there as a coarse dust. The dust either falls into the fire or is removed when the flue is swept. Testing was carried out by George Looman and Pete Wilkie at our Beatty Street Laboratory in January 2014. Dr Rene Haeberli from Envirosolve Ltd, Mr Jim Foster from The Reefton Airshed Committee, Mr Mike Meehan from West Coast Regional Council, Mr Terry Archer from West Coast Regional Council, and Mr Rob Whitney from the Coal Association were present for some or all of the testing.

Appliance	Freestanding Multifuel Heater	OekoTube
Manufacturer		OekoSolve
Type of Appliance		Electrostatic precipitator

Figure 1 OekoTube installed in flue (protective cover removed from device)



2.0 Experimental Details

2.1 Heater

The heater used for the test was a freestanding multifuel heater. The firebox dimensions were from side to side 470mm, door shut to rear firebrick was 430mm and the height from the grate in the firebox floor to the secondary air tube was 317mm.

2.2 Electrostatic Precipitator

During these tests the OekoTube unit was protected against heat off the flue by a sheet of Micore 160 placed between the flue and the control unit. As noted above the OekoTube is designed to be installed above the roof where the control unit will be separated from the flue by flue liners.

The ESP was installed by Dr Rene Haeberli. The ESP is designed to be installed above roof level. For testing, the ESP was installed in the flue above the calorimeter room. The ESP had an electrode that was inserted into the flue above the heater so that the top of the electrode was 4.08m above the floor of the calorimeter room. The electrode was approximately 1.6m long made up of two thin metal strips suspended in the flue with a weight on the bottom of the strips. The top of the strips was attached to a hexagonal bar that protruded from the flue and was clamped in an insulator above the electronics of the device.

A thermostat controls the OekoTube in normal use, but for this testing it was attached to a laptop computer and manually switched on and off. The laptop also functioned as a data logger for collecting information on the functioning of the OekoTube during the testing.

2.3 Fuel

Fuel was supplied by Mr Jim Foster from the Reefton Airshed Committee as follows

- Sub Bituminous coal from Giles Creek Mine, and RedDale Cosycoal
- Bituminous Coal – a mix of Strongman and Echo Coals
- Typical West Coast firewood (Beech) with moisture content approximately 33% ww.

Fires were started with kindling and small pieces of firewood before adding coal. Various coals and coal mixes were used at various times (see Appendix 1) during the testing:

- 100% Giles Creek coal
- Bituminous - 50% Strongman 50% Echo coals
- Blend 3 – 25% Strongman, 25% Echo, 50% Giles Creek coals
- 50% Reddale Coal and 50% West Coast firewood

2.4 Test Equipment

Tests were carried out using equipment specified in the joint Australian/New Zealand Standards 4012:1999 and 4013:1999. Portable Emission Samplers developed by Applied Research Services were installed in the flue above and below the ESP. The samplers cool and dilute the flue gases in the same way as the dilution tunnel used for testing to AS/NZS 4013 prior to collecting particulates on filters. The samplers are described in more detail in Appendix 3. The estimated uncertainty in emissions rates obtained with these samplers is 20%. The samplers were calibrated against the emissions rig.

2.5 Heater Operation

The heater was operated following the procedures set out in Appendix 1. This involved 5 phases on each day; a start up phase, 2 high burn phases, and 2 low burn phases. The test was run on 4 days and portable samplers (see section 2.6) were used to analyse the emissions before and after the

ESP. Two Samba brand fire starters were used to light the kindling. The fire starter was placed within the kindling stacked in a criss-cross pattern.

2.6 Fuel Analysis

Calculations using coal gross calorific value (GCV) and moisture content used figures from "The Analysis of New Zealand Industrial Coals" produced by the Coal Research Association of New Zealand. Wood GCV was based on analytical data from wood samples submitted to CRL Energy Ltd. Analysis and moisture content was determined by oven drying according to AS/NZS4014.2 Appendix A. For day 2 the moisture content used was the average for the Giles Creek coal and Wood at 29.9%.

3.0 Results and Discussion

3.1 Calibration of Portable Emissions Samplers

Figure 3a shows the correlation between the emissions rates obtained from the portable sampler above the OekoTube (Sampler 1) and the emissions rig dilution tunnel. Figure 3b shows the same data broken down by day and phase.

Figure 3a Correlation between the emissions rates obtained from the portable samplers and the emissions rig dilution tunnel.

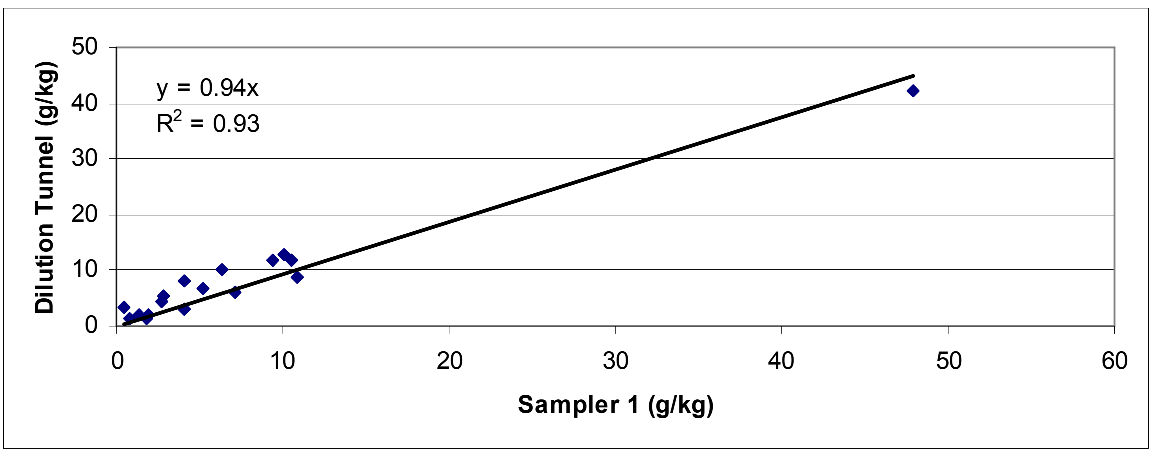
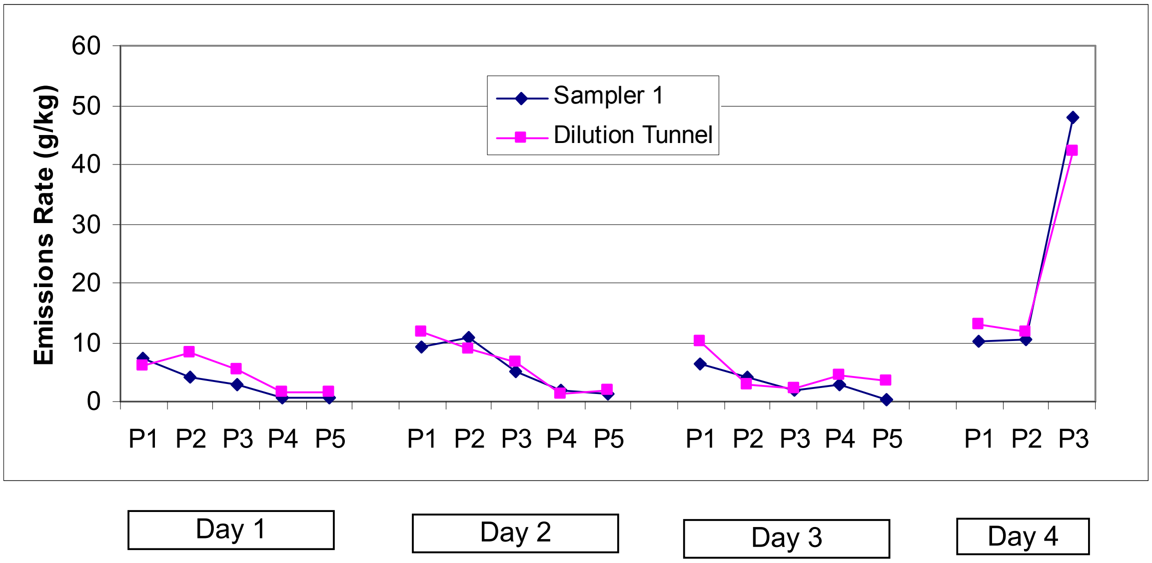


Figure 3b Emissions rates obtained from the portable samplers and the emissions rig dilution tunnel.

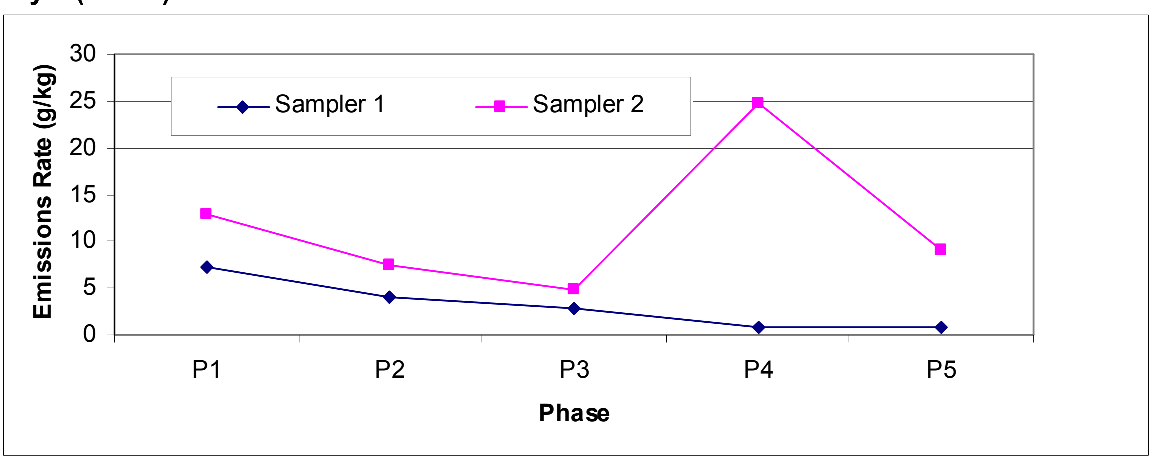


3.2 Particulate Emissions before and after the OekoTube

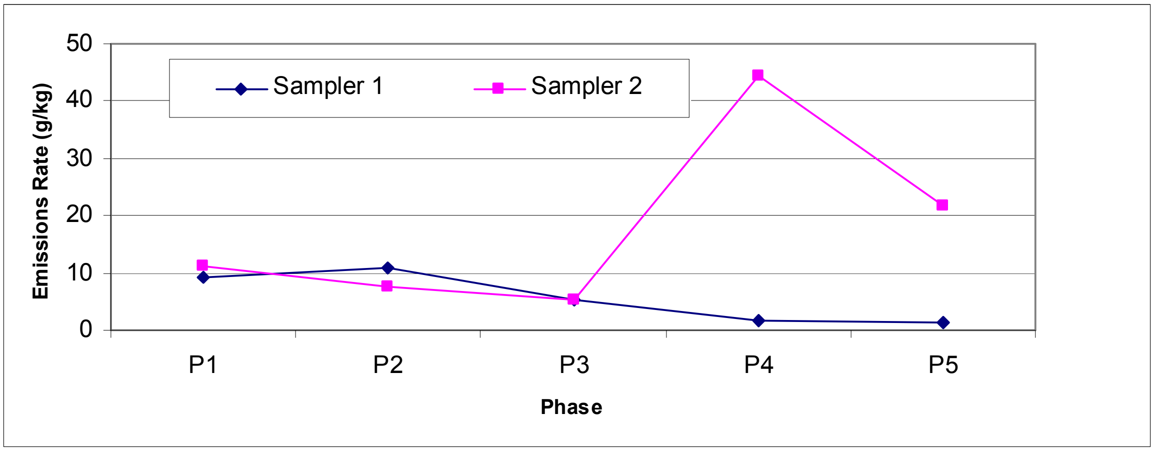
The portable emissions samplers were placed before (Sampler 2) and after (Sampler 1) the OekoTube ESP. Results are summarised in the graphs in figure 4.

Figure 4 Emissions Rates before (Sampler 2) and after (Sampler 1) the OekoTube ESP

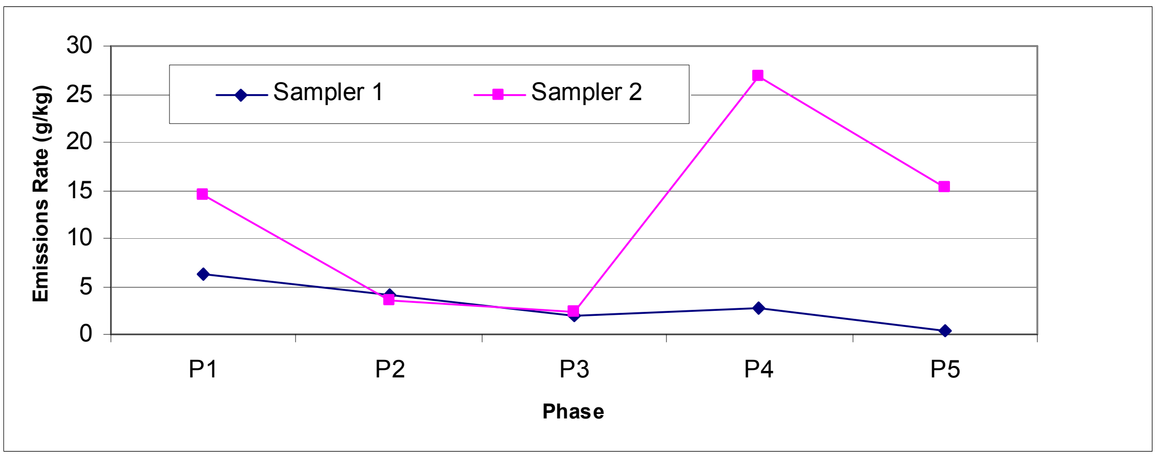
Day 1 (6/1/14)



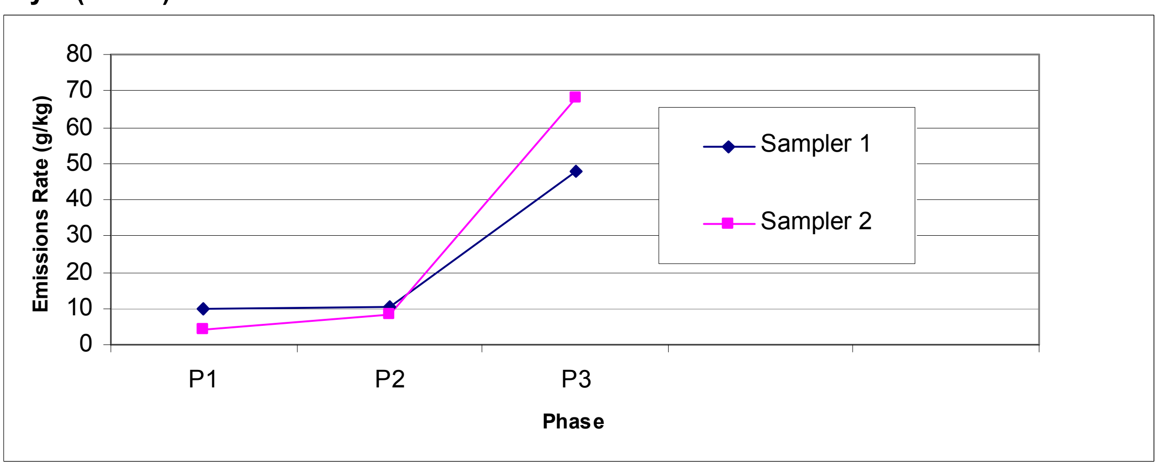
Day 2 (7/1/14)



Day 3 (8/1/14)

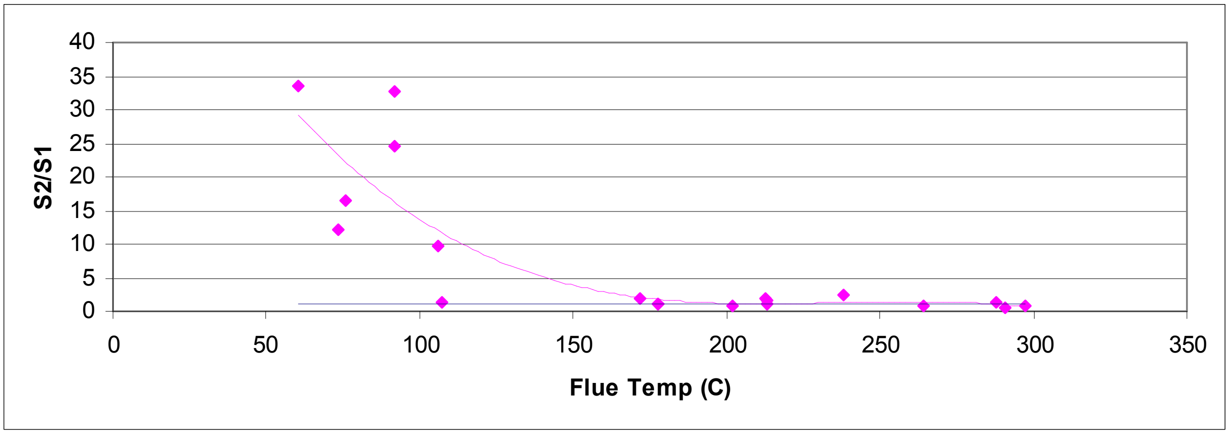


Day 4 (9/1/14)



An electrostatic precipitator such as the OekoTube will collect materials which have condensed into particles. When flue temperatures are high a significant proportion of the emissions from the fire do not condense into particles until after the flue gases have left the flue. Figure 5 indicates that the efficiency of the Oekotube increases significantly as the flue temperature drops below 180 ^{o}C

Figure 5 Ratio of Emissions Rates as a function of flue temperature



3.3 Collection of Soot

The OekoTube is designed to precipitate particulates onto the flue wall. At the end of each test day the flue including the OekoTube and its electrode was swept and the sweepings were collected and weighed. A deposit of a tarry substance was also collected from the flue collar this was also weighed. The total weight of particulates emitted by the flue can be calculated from the dilution tunnel data and added to the weight of the sweepings and flue collar deposit, this gives an indication of the total mass of particulates emitted by the wood burner.

	Mass of Sweepings	Description of sweepings	Flue collar deposit	Description of collar deposit	Mass Emitted from Flue	Total Mass produced by burner	Proportion Retained in Flue
	(g)		(g)		(g)	(g)	%
Test Day 1	8	Powdery	6	Thick tarry gunge	48.9	62.9	22
Test Day 2	16	Gritty	3	Granular tarry gunge	78.4	97.4	20
Test Day 3	62	Coarse flake	1	Granular tarry gunge	59.5	122.5	51
Test Day 4	28	Soft powder	0	none	95.0	123.0	23

These results indicate that the ESP is removing on average 29 % of the particulate emissions.

3.4 Filters

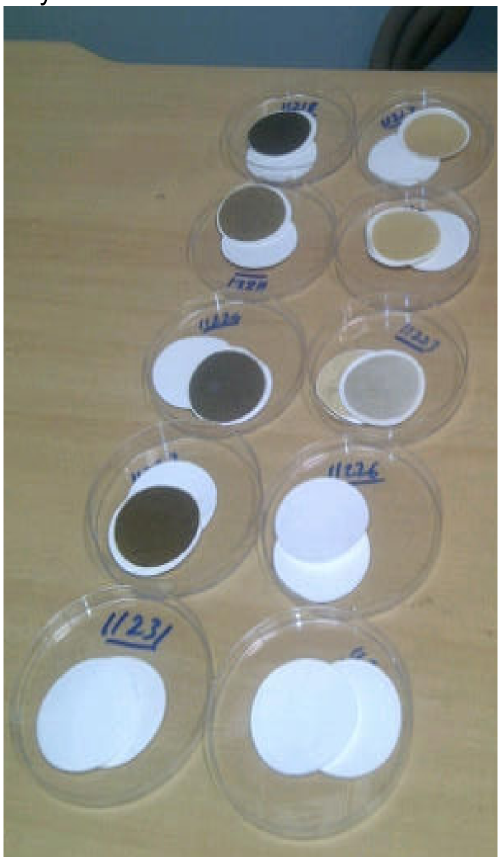
Coal combustion generates soot particles and volatile organic compounds (VOCs) some of which condense into droplets when cooled. An ESP will collect substances which have condensed into particles by the time they pass through the ESP. The dilution tunnel is designed to cool the flue gases in a similar way to what happens when they are released into the atmosphere. The filters that collect particulates from the dilution tunnel typically catch soot particles on their front surface while the condensed VOCs form a yellow oily deposit that penetrates through the filter.

The filters took several weeks to reach a stable weight as required by clause 6.9 of AS/NZS4013.

The photographs in Figure 5 show the front face of the filters. These suggest that the ESP is removing the bulk of the soot but is much less effective in removing VOCs from the flue gases.

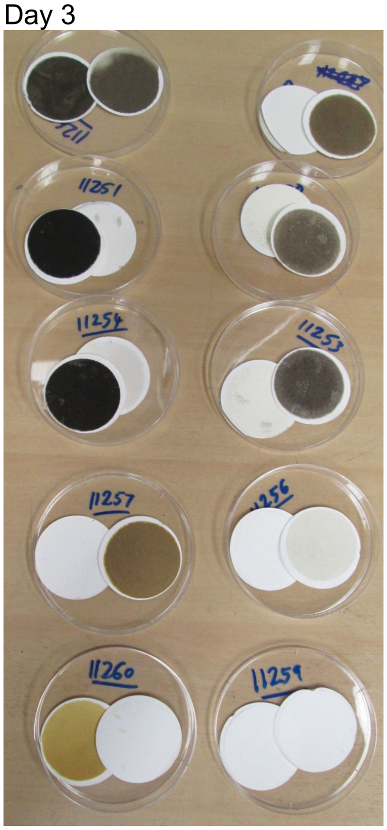
Figure 5 Filter deposits - Sampler 2 on Left (before ESP) Sampler 1 on Right (after ESP), first phase at top last phase at bottom of photographs

Day 1

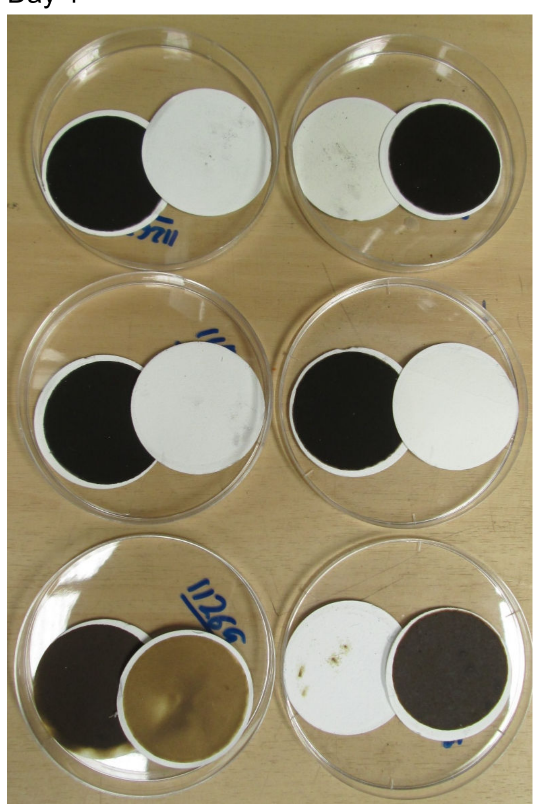


Day 2

Day 3



Day 4



4.0 Summary

These results indicate that the effectiveness of the OekoTube increases markedly as the flue temperature drops. At higher flue temperatures it appears that the OekoTube removes soot while allowing uncondensed material to pass through.

This Report:

Report: 14/2660

Prepared by: G. Looman

Approved by: W.S. Webley

Release Date: 24/2/14

Appendix 1 Procedure

Day 1: Five phases - each one hour long - operation with Giles Creek Coal.

Ph1 - start up and operation at high

Heater set on high
Start up on kindling using approximately 1.5kg of kindling each piece weighing approximately 75g. Use 2 firelighters. When well alight add 3 pieces of wood at 300g each.
When well alight add 3 kg coal

Ph2 - high burn

Add approximately 3kg coal

Ph3 - high burn

Add approximately 3 kg coal

Ph4 - low burn

Add approximately 3kg coal

Ph5 - low burn

Add sufficient coal to bring back to start weight of Phase 3

Day 2: Five phases - each one hour long - operation with wood and Giles Creek Coal (50:50 mix approximately).

Heater set on high
Start up on kindling using approximately 1.5kg of kindling each piece weighing approximately 75g. Use 2 firelighters. When well alight add 3 pieces of wood at 300g each.
When well alight add 3 kg coal and wood mix (50/50)

Ph2 - high burn

Add approximately 3 kg coal and wood mix (50/50)

Ph3 - high burn

Add approximately 3 kg coal and wood mix (50/50)

Ph4 - low burn

Add approximately 3 kg coal and wood mix (50/50)

Ph5 - low burn

Add sufficient coal and wood mix (50/50) to bring back to start weight of Phase 3

Day 3: Five phases - each one hour long

Re fuel loading as and when required based on usual operation within a home.
This shouldn't be seen as totally prescriptive, however. For example if the fire is not responding to a fuel load when under low burn then increase the temperature setting until the fire is burning properly and then reduce to low burn (i.e., undertake whatever reasonable measures are required to make sure the burn cycle does not deviate too much from what would be reasonably done in a home).

Just operate the burner as it might be used in a home type setting.
Phase 1 still includes a cold start. Operation with Reddale Cosycoal and wood.

Phase 2 - operation as normal - but make a note of the percentage of time at different settings. Operation with Reddale Cosycoal.

Phase 3 - operation as normal - but make a note of the percentage of time at different settings. Operation with Reddale Cosycoal and wood.

Phase 4 - operation as normal - but make a note of the percentage of time at different settings. Operation with Reddale Cosycoal.

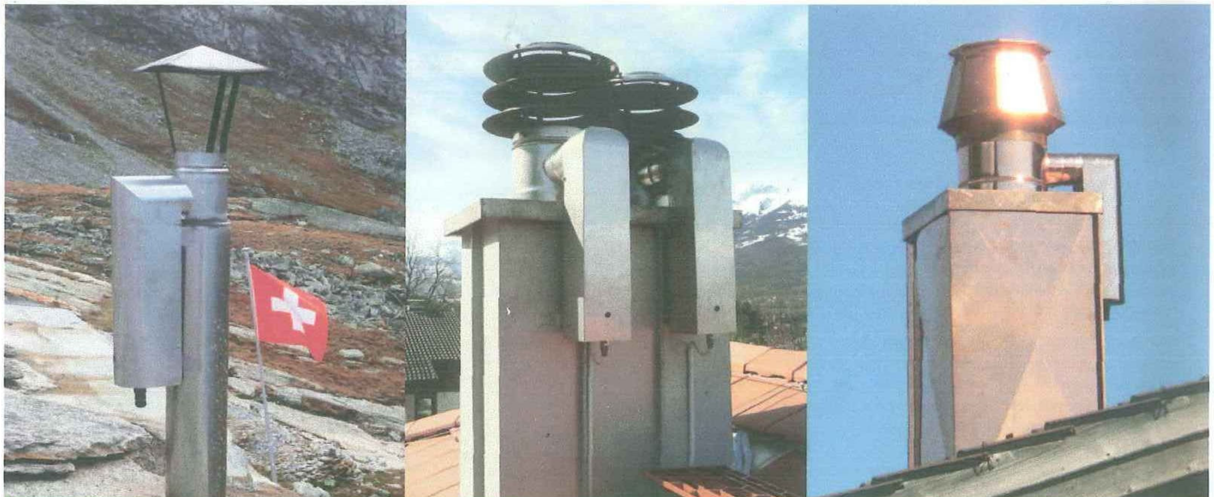
Phase 5 - operation as normal - but make a note of the percentage of time at different settings Operation with Reddale Cosycoal and wood.

Day 4: same as Day 1 but using bituminous coal. Only one low burn i.e. 4 phases.
Phase 1 Bituminous Coal and wood at start up
Phase 2 Bituminous Coal
Phase 3 Blend 3
Phase 4 Blend 3

Filter changes at end of each phase

Appendix 2 OekoTube Manufacturer's brochure

OekoSolve
Environment. Energy.



OekoTube – the micro-dust filter for your wood fire.

The OekoTube is an electrostatic filter which substantially reduces your micro-dust soot emissions from small wood-fired stoves like open fireplaces, free standing wood stoves and pellet stoves.

The micro-dust filter OekoTube is suitable for all wood fires with a capacity below 40 kW and is mounted on top of the chimney. According to laboratory tests for wood fired heating facilities, the OekoTube has an officially tested efficiency of 95 % and therefore meets all the requirements of the Official Swiss Air Pollution Control Ordinance (CAO/LRV).

The OekoTube micro-dust filter can easily be fitted to both new and existing wood-heating and burning systems. No structural changes are necessary inside an existing building, because the micro-dust filter is mounted outside, on top of the chimney.

OekoTube facts

- Suitable for all small wood fire facilities like open fireplaces, free standing wood stoves, central heating systems fuelled with wood logs, shavings or wood chips below the capacity of 40 kW
- Proven and officially tested efficiency of 95 % of particulate matter
- Massively increased air quality
- Can easily be fitted on any kind of chimneys (steel or brick)
- Automatically functions and regulates
- No alterations on existing chimneys
- Easy cleaning by the chimney sweeper
- Robust, sturdy and built to last long
- Available in New Zealand through the official agency EnviroSolve Ltd for New Zealand and Australia – Dr Rene Haeberli

Requirements for the installation of the OekoTube micro-dust filter

- A minimum of two metres vertically downward length from the top of the chimney
- Availability of a direct power supply (230 V AC)

OekoSolve
Environment. Energy.

EnviroSolve Ltd
Dr Rene Haeberli
Official agency for OekoSolve Switzerland
www.envirosolve.co.nz

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phone +64 6 385 48 71
fax +64 6 385 48 72
mobile 021 24 24 211

OT 02.2012

Wood as an energy source and micro-dust. Wood is a traditional energy and heating source in New Zealand. It is efficient, renewable and wood fuels do not incur any carbon charge. The use of wood as and energy source for heating purpose is CO_2 neutral and promotes the added value chain within the regional economy. The New Zealand Government has confirmed its on-going commitment to encouraging the use of this renewable energy. Unfortunately, burning wood is releasing hazardous micro-scoping dust into the atmosphere.

For several years the micro-dust emissions created by wood fires has been a daily topic of conversation, especially during winter months. During inverted atmospheric conditions (a stable warm layer of air above a cold ground layer), the legal limits of fine particulate matter in the air are regularly and massively exceeded. Scientific studies show that these micro-particles (especially smaller than 1 micron in diameter) are a serious health hazard. These micro-particles are passing through your respiratory track into the alveoli of the lungs and then enter the bloodstream. Therefore not only the lungs but also other organs can be affected by these micro-particles. Coughing, bronchitis, asthma, cardio-vascular diseases and sometimes even lung cancer could be severe health consequences.

Installing an OekoTube on chimneys is an active and effective contribution to local and global air quality. The micro filter is ecologically and economically beneficial because older heating systems can be used longer and are more environmentally friendly.

Installation und operation. The OekoTube is fitted between the cover and the top of the chimney. The height of the chimney will be increased by 25 cm due to the installation of the so-called divider. The flue draft will not be affected by this alteration. In order to install the electrode there has to be a minimum vertically downward length from the top of the chimney of two metres. There is also a direct power supply of 230 VAC needed nearby to operate the electrode.

When the fire is lit, the OekoTube automatically turns on and it switches to a standby mode after the fire has gone out. Less than 30 W of electrical power is needed for the operation of the OekoTube. During the operation the micro-dust particles are collected on the inside wall of the chimney and clog together into coarse flakes, which are not hazardous or dangerous to the environment.

Easy cleaning. The OekoTube filter will be easily cleaned by a professional chimney sweeper at your annual chimney inspection. The coarse flakes of fine particulate matter will be removed with a common chimney broom. The chimney sweeper can clean the chimney from the top or from underneath, without removing the electrode of the OekoTube.

Agencies and sales. The OekoTube is available from the official agency EnviroSolve Ltd for New Zealand and Australia – Dr Rene Haeberli. Please check out our website www.envirosolve.co.nz for more info.

Operation principle

The OekoTube filter functions on the electrostatic principle. The operational principle of the OekoTube is schematically illustrated in the following pictures.

01 The micro-dust particles are flowing with the used air through the air channel of the OekoTube filter

02 The high voltage electrode is releasing electrons into the chimney space containing the micro-dust particles.

03 Due to the electrostatic force the electrons move towards the chimney wall. During this process the micro-dust will get electrostatic polarized and are also moving towards the chimney wall.

04 The micro-dust particles are collected on the inside wall of the chimney and clog together into coarse flakes. This particulate matter will be removed by the chimney sweeper at the annual chimney inspection.

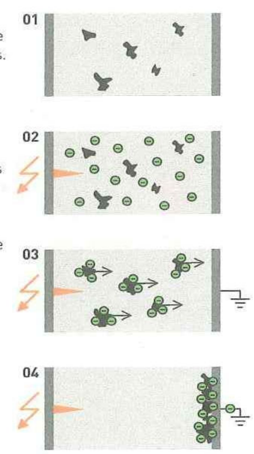
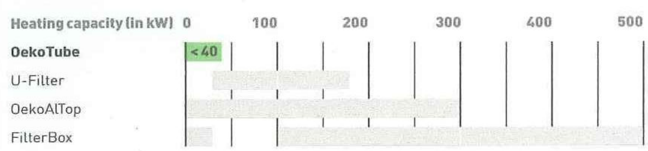
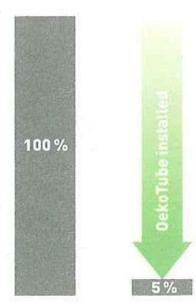


Diagram of all OekoSolve micro-dust filters on offer



Your micro-dust soot emission



Appendix 3 Information on the Portable Emissions Sampler

APPLIED RESEARCH SERVICES LIMITED

Technical Bulletin 72

Portable Emissions Sampler

The portable emissions sampler captures particulate emissions using a method based on Oregon Method 41 (OM41). This method is also known as the Condar Method.

Principle of Operation

The sampling head includes a dilution system to dilute and cool the flue gas. This simulates the dilution and cooling that occurs when flue gases mix with ambient air and results in condensation of oily compounds such as polyaromatic hydrocarbons which can then be captured on the filter.

In practice, flue gases are drawn into a manifold through the sample probe. Dilution air is also drawn into the manifold through small holes in its face. The diluted gases are then drawn through two filters which collect the particulate emissions.

Details of the Sampler

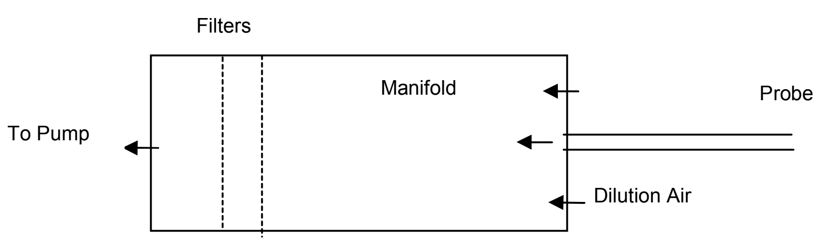
General

The sampler includes a sampling head (detailed below) which captures the sample of particulates. In addition flue temperature is measured, flue gases are analysed continuously for oxygen and carbon dioxide content and the carbon dioxide content of the diluted gas stream is analysed. The sampler also contains gauges to monitor and set gas flows through the sample head and flue gas analysers, canisters of drying agent to remove water vapour from the gas streams, a gas meter to quantify the sample flow and a vacuum sensor to monitor filter loadings. The sampler is interfaced to a laptop computer which activates the sampling pump when the heater is operated and the flue temperature rises. The computer is also used to log data.

Sampling Head

The sampling head consists of a stainless steel dilution manifold (length 100 mm, internal dia 49 mm) fitted with two end caps. One end cap is fitted with a short probe with a glass insert. The probe is inserted into the flue so that the inlet is near the flue center. Dilution air is admitted to the manifold via 12 x 1 mm dia holes in the face of the end cap. The sample is collected on two 47 mm glass fibre filters (Gelman Type A/E Cat No 61631) mounted on two filter holders fitted to the other end cap of the manifold.

Figure 1. Schematic Of Sampling Head



Apart from the probe and manifold assembly the sampling assembly is the same as used in AS/NZS 4012/3. As with NZS4013 two glass fibre filters are used to collect the particulate materials. The flue gas composition is also measured and is used to calculate the total volume of gas which has passed up the flue per kg of fuel burnt. The total emissions can then be calculated from rate at which material is collected on the filter and the dilution ratio.

Comparison of Results Obtained with AS/NZS 4012/3

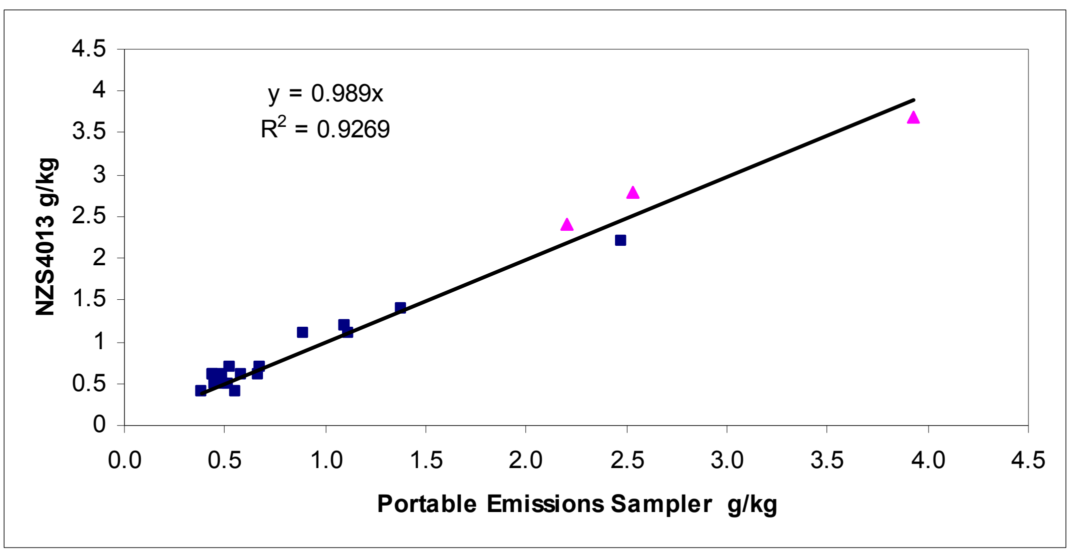
Laboratory tests of wood burners for compliance to particulate emissions standards in New Zealand are currently carried out according to methods set out in the joint Australian/ New Zealand standard AS/NZS 4012/3. The test involves capture of the entire gas stream exiting the flue which is then passed to a dilution tunnel where it is mixed with room which provides dilution and cooling. The particulate sample is drawn from the end of the dilution tunnel. Because the velocity of gas in the dilution tunnel is more easily measured than that in the flue the amount of particulate generated is relatively easily calculated.

During the comparative tests the portable emissions sampler was set up in the test room and run at the same time as the laboratory test rig.

Results

The graph below shows the results of nineteen runs carried out on a range of heaters. Of these seventeen (squares) were obtained during tests where fuelling was carried out in accordance with the requirements of AS/NZS 4012/3 and three (triangles) were carried out during five hour runs and a "real life" fuelling regime in accordance with SMF Contract Application Number 2205. Results are particulate emissions in g/kg.

Figure 2 Comparison of Results Obtained with Portable Emissions Sampler and AS/NZS 4012/3



The results show that a good correlation exists between results obtained with the two methods.

Appendix 4 Test Data

		Emissions Rate (g/kg)				Flue Temp (°C)		
		Sampler 1	Sampler 2	Ratio S2/S1	Dilution Tunnel	Sampler 1	Sampler 2	Tav
Day 1	P1	7.15	12.84	1.80	6.08	142.30	200.80	172
	P2	4.12	7.35	1.78	8.12	133.80	291.00	212
	P3	2.86	4.85	1.70	5.50	141.50	285.00	213
	P4	0.76	24.76	32.69	1.47	57.00	127.00	92
	P5	0.75	9.09	12.18	1.49	47.00	99.80	73
Day 2	P1	9.34	11.12	1.19	11.83	125.40	229.60	178
	P2	10.83	7.71	0.71	8.81	140.60	263.10	202
	P3	5.22	5.23	1.00	6.72	145.80	280.50	213
	P4	1.81	44.53	24.62	1.24	50.90	132.80	92
	P5	1.31	21.58	16.46	1.89	43.00	109.10	76
Day 3	P1	6.32	14.59	2.31	10.25	170.70	305.90	238
	P2	4.10	3.54	0.86	2.94	181.60	412.70	297
	P3	1.95	2.42	1.24	2.12	174.80	401.00	288
	P4	2.76	26.95	9.76	4.44	58.60	154.00	106
	P5	0.45	15.21	33.63	3.43	39.80	81.00	60
Day 4	P1	10.08	4.36	0.43	12.90	202.00	379.00	291
	P2	10.52	8.32	0.79	11.81	175.00	353.00	264
	P3	47.86	68.22	1.43	42.12	64.50	150.00	107

Fuel loads

Note: Start up phase uses wood for kindling and Intermediate 1 loads each day
Sampling time is the time the sampling was taking place, the burn times for each phase were 2-3 minutes longer
Average burn rate is on a dry weight basis

Day 1 - Coal only

	6/01/2014 Giles Creek Coal	Bed weight at loading kg	Fuel Load kg	Moisture Content	Flue Temp at loading ºC	Ave Flue Temp ºC	Fuel burnt kg Fuel load + ember bed weight difference	Sampling Time min	Ave burn rate kg/h	Fuel dry weight kg
				%ww						
P1	Start-up Phase kindling	0.00	1.472	14	20	206	3.741	60	3.74	2.86
	Intermediate 1	0.95	0.919	31	331					
	Intermediate 2	0.93	3.040	28.7	230					
P2	High Burn Rate	1.69	3.066	28.7	281	295	3.056	60	3.06	2.18
P3	High Burn Rate	1.70	3.022	28.7	292	326	2.832	60	2.83	2.02
P4	Low Burn Rate	1.89	3.002	28.7	289	140	1.432	62	1.39	1.02
P5	Low Burn Rate	3.46	1.422	28.7	124	109	1.132	60	1.13	0.81
	End	3.75								
		Total fuel added	15.943				12.193	302	2.42	8.89

Day 2 - Coal and wood mix

	7/01/2014 Giles Creek Coal and Beech (50/50)	Bed weight at loading kg	Fuel Load kg	Moisture Content	Flue Temp at loading ºC	Ave Flue Temp ºC	Fuel burnt kg Fuel load + ember bed weight difference	Sampling Time min	Ave burn rate kg/h	Fuel dry weight kg
				%ww						
P1	Start-up Phase kindling	0.00	1.462	14	25	258	4.276	60	4.28	3.22
	Int 1	0.89	0.963	31	406					
	Int2	1.15	3.121	29.9	351					
P2	High Burn Rate	1.27	3.340	29.9	269	300	3.27	60	3.27	2.29
P3	High Burn Rate	1.34	3.094	29.9	289	306	3.034	60	3.03	2.13
P4	Low Burn Rate	1.40	3.047	29.9	292	147	1.767	60	1.77	1.24
P5	Low Burn Rate	2.68	3.079	29.9	134	118	1.809	60	1.81	1.27
	End	3.95								
		Total fuel added	18.106				14.156	300	2.83	10.15

Day 3 - first high burn coal, second high burn coal and wood, first low burn Coal, second low burn coal and wood

	8/01/2014	Bed weight kg	Fuel Load kg		Moisture Content		Flue Temp at loading ºC	Ave Flue Temp ºC	Fuel burnt kg Fuel load + ember bed weight difference	Sampling Time min	Ave burn rate kg/h	Fuel dry weight kg
			Wood	Coal	%ww wood	%ww coal						
P1	Start-up Phase kindling	0.00	1.453		14		20	307	4.961	60	4.96	3.99
	Intermediate 1	0.38	0.975		31		341					
	Intermediate 2	0.76		3.076		18.4	252					
	Intermediate 3	3.16		2.957		18.4	206					
P2	High Burn Rate	3.50		2.995		18.4	386	421	3.995	60	4.00	3.26
		5.40		3.030		18.4						
P3	High Burn Rate	5.53	1.474	1.597	31	18.4	534	408	3.201	60	3.20	2.41
P4	Low Burn Rate	5.40		3.006		18.4	390	163	0.856	60	0.86	0.70
P5	Low Burn Rate	7.55	0.53	0.500	31	18.4	108	88	0.31	60	0.31	0.23
	End	8.27										
		Total fuel added	21.593						13.323	300	2.66	10.59

Day 4 – Bituminous coal for start up and first high burn, blend 3 for second high burn and low burn

	9/01/2014	Bed weight kg	Fuel Load kg		Moisture Content	Flue Temp at loading ºC	Ave Flue Temp ºC	Fuel burnt kg Fuel load + ember bed weight difference	Sampling Time min	Ave burn rate kg/h	Fuel dry weight kg
			Wood	Coal	%ww						
P1	Start-up Phase kindling	0.00	1.201		14	20		0.272	60	0.27	2.71
	Intermediate 1	1.08	0.991		31	348					
	Intermediate 2	0.86		2.998	7.5	219					
P2	High Burn Rate	1.92		3.004	7.5	339	393	2.254	52	2.60	2.08
P3	High Burn Rate	2.67		3.000	18.1	291	353	2.76	60	2.76	2.26
P4	Low Burn Rate	2.91		3.000	18.1	299	154	1.200	60	1.20	0.98
	End	4.71									
		Total fuel added	14.194					6.486	232	1.68	8.04