Fairbanks North Star Borough

RFP No. 19047
Wood Stove/Pellet Stove Retrofit Emissions
Control Device for Emissions Reduction Testing

ATTACHMENT B
PROPOSAL TRANSMITTAL FORM

This form is to be completed in full, signed and submitted as the cover sheet of the proposal.

I certify that I am a duly authorized representative of the firm listed below and that information and materials enclosed with this proposal accurately represent the capabilities of the office listed below for providing the services indicated and comply with all provisions in this RFP. In addition, I certify that I am a company officer empowered to bind the company to the requirements of this RFP and to our proposal. The FNSB is hereby authorized to request anyone identified in this proposal to furnish any pertinent information deemed necessary to verify information provided or regarding reputation and capabilities of the firm.

A. Amendments

The Offeror represents to the FNSB that it has relied upon no oral representations from the FNSB or its consultants in the preparation of this proposal. If any amendments are issued to this RFP, Offeror must acknowledge the receipt of such amendments in the space provided on the line below or by signing the amendment and submitting it before the submittal deadline, unless the amendment states otherwise. Proposals that fail to acknowledge receipt of amendments may be considered non-responsive and be eliminated from further consideration.

The Offeror acknowledges receipt of the following Amendments: ________________

B. Original Signature

This Transmittal Form must include an original signature. A proposal shall be considered non-responsive and eliminated from further consideration if an original signature is not included.

[signature]
Signature of Representative

Date: 06/07/2019

Name: H. NICO LAUER

Title: PRINCIPAL

Firm: ONE WORLD RESOURCE MANAGEMENT, LLC

Alaska Business License No.: ________

Email Address: hnicoLauer@gmail.com

Office Address for which this submittal is made:

Street: 1 KILBY ST. #44 HNL.

PO Box: ________

City State Zip: WOBURN, MA 01801 HNL

Phone: (608) 772-0270 HNL
(with area code)

ITEM 2: Minimum Requirements

The OekoTube electrostatic precipitator ("ESP") is a standard product which has been available since its market introduction in 2008. It is specifically designed to be used as an add-on device to mitigate the emissions of harmful fine dust from solid fuel burning devices, such as wood or coal burning stoves. While the basic principle of the ESP is always identical for each unit installed, various models are manufactured by the Swiss company OekoSolve AG to meet the technical specifications of the individual wood (or coal) burning stove and to ensure an ideal fit, such as energy rating of stove, diameter of smoke pipe, and inside/outside installation.

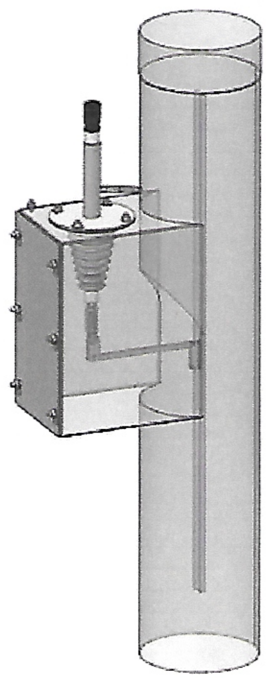

Illustration 1: OekoTube inside model, length = 1000 mm (39") The schematic shows the position of the electrode in the center of the smoke pipe and the insulator in the insulator box which is accessible through a bolted lid cover. The electronic control box is not shown but is connected to the electrode through the insulator.

The technical principle of electrostatic precipitators has been the industry standard for over 100 years and it is considered to be highly effective in the removal of fine dust particulate matter (PM_{10}, $PM_{2.5}$).

has successfully scaled this technology down for domestic or small industrial applications. A further attractive feature of the OekoTube is its very low operating cost, based on the maximum power consumption of 30 W/h, the equivalent of a small light bulb. When on standby mode the power consumption of the unit is 0.7 W/h. The standby mode enables the OekoTube to activate itself when the thermal probe detects a temperature delta in the smokestack.

One World Resource Management, LLC ("OWRM) is the market developer and distributor for the United States.

The Minimum Requirements for the scope of work for this RFP include that the device offered must be:

- In current production
- Installed in residential applications
- An off-the-shelf product.

These shall now be described in more detail.

1. Current Production Information
   ESPs are offered in a range of different sizes, with smaller individual ESPs (OekoTube) specifically designed for the individual residential application (< 350,000 BTU), intermediate size ESPs incorporating several individual electrostatic precipitator tubes in parallel (< 3.5 MMBTU) and large industrial units (< 10 MMBTU). The ESP models offered in this RFP are solely limited to the smaller residential units (OekoTube, < 350,000 BTU). While the basic design remains unchanged, the OekoTubes are offered in different forms to fit the particular physical properties and design of the wood stove (interior and exterior models and the diameter of the smokestack (typically 5-10" diameter).
   As an optional feature the ESPs can be fitted by wireless monitoring devices which provides the ability to monitor their operation, therefore ensuring that their uptime is maximized. The "plug & play" design of the OekoTube makes installation and servicing of the device very user-friendly. The ease of installation of the OekoTube is demonstrated on YouTube at:
   https://www.youtube.com/watch?v=vTgdCj8qKsA

2. Length of Time of Production
   Commercial production of the OekoTube started in 2008 and demand continues to grow on an international level, both in the number of countries that have adapted this proven technology and in the number of units sold in each country. Ongoing R&D has brought further improvements in the product since its market introduction. The basic manufacturer warranty is limited to 24 months. The continuous operation of the units since 2008 has led to a high level of customer satisfaction with the OekoTube.

3. Residential Installation: a) location and b) quantities

Since market introduction approx. 5000 OekoTube units have been sold in mostly European markets. The analysis of the data provided in ITEM 3 shows that there has been a steady yearly growth in the demand of the ESP with a clear preference for the inside ESP model which was first introduced on the market in 2015. While this trend is impressive, it does not reflect the strong demand in the ESP units sold for commercial installations, which have shown a strong growth for boilers in the intermediate 1-3 MMBTU range. The table in ITEM 3 gives a detailed break-down of the annual growth in the demand for the residential OekoTube ESPs.

After an initial testing phase, particularly in Alaska under arctic conditions, the OekoTube model has been installed in the following locations in the United States:

a. Waite Park, Minnesota (1 hydronic boiler, 2017)
b. North Pole, Alaska (1 outside unit on a cordwood stove, 2 inside unit on a pellet and a cordwood stove, 2017-19)
c. Massachusetts (6 units installed on high efficiency wood chip boilers, 2018)

The two units which have been installed in North Pole, AK in November 2017 and February 2018, respectively, have been also used for demonstration purposes. The installed units have been operating without any known technical problems for two winter seasons. Testimonials for select installations in the U.S. are available upon request, subject to owner's approval.

ITEM 3: Number of Existing residential installations (World)

Year	OekoTube-Outside	OekoTube-Inside	SUM/yr.
2008	41		41
2009	150		150
2010	183		183
2011	165		165
2012	249		249
2013	265		265
2014	423		423
2015	446	7	453
2016	415	156	571
2017	380	386	766
2018	423	624	1047
2019	135	392	527
Total	**3,275**	**1,565**	**4,840**

Countries:

New Zealand	18	
France	54	
Italy	143	
Netherlands	149	24
Belgium	103	
Germany	230	1,230
Bulgaria	28	5
USA	1	7
Slovenia	18	
Switzerland	2,531	299

Fairbanks North Star Borough

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Wood Stove/Pellet Stove Retrofit Emissions
Control Device for Emissions Reduction Testing

ATTACHMENT C
NON-COLLUSION AFFIDAVIT

(To be executed prior to and submitted with the Offerors proposal)

STATE OF ALASKA)
)SS
FOURTH JUDICIAL DISTRICT)

I, HANS NIKOLAUS LAUER of ONE WORLD RESOURCE MANAGEMENT, LLC
(printed/typed name) (firm name)

being duly sworn, do depose and state that I (or the firm, association, or corporation of which I am a member), as an Offeror on the contract to be awarded by the FAIRBANKS NORTH STAR BOROUGH for: **RFP 19047**

WOOD STOVE/PELLET STOVE RETROFIT EMISSIONS CONTROL DEVICE FOR EMISSIONS REDUCTION TESTING

in the Fairbanks North Star Borough, have not, either directly or indirectly, entered into any agreement, participated in any collusion, or otherwise taken any action in restraint of free competitive bidding in connection with such contract.

ONE WORLD RESOURCE MANAGEMENT, LLC
Contractor

[signature]
By (signature)

06/05/2019
(date)

PRINCIPAL
Title

(SEAL)

KIRUTHIKA RAMAKRISHNAN
Notary Public, Commonwealth of Massachusetts
My Commission Expires February 13, 2026

Kiruthika .R.

SUBSCRIBED AND SWORN TO before me this 5 day of June, 20 19.

Notary Public in and for the State of MA My commission expires: 02/13/2026.

ATTACHMENT D
Certification of No Conflict of Interest

1. "Organizational Conflict of interest" means that because of other activities or relationships with other persons, a person is unable or potentially unable to render impartial assistance or advice to the FNSB, or the person's objectivity in performing the contract work is or might be otherwise impaired, or a person has an unfair competitive advantage (FAR 2.101).
2. "Person" has the meaning stated in FNSBC and includes a Bidder/Offeror, Contractor, Consultant, or Subcontractor or Sub-Consultant at any tier, including their employees or agents; and also includes any FNSB employee or FNSB agent who has, or will have the authority to control or supervise all or a portion of the work for which a Bid/Proposal is made (§16.04.010).
3. The Bidder/Offeror warrants that, except as disclosed in #4, below, there are no relevant facts of circumstances now giving rise or which could, in the future, give rise to a conflict of interest.
4. The following facts or circumstances give rise or could in the future give rise to a conflict of interest (explain in detail—attach additional sheets if necessary).
5. The Bidder/Offeror agrees that if an actual or potential conflict of interest arises after the date of this affidavit, the Bidder/Offeror shall immediately make a full disclosure in writing to the Fairbanks North Star FNSB Chief Procurement Officer, P.O. Box 71267, Fairbanks, AK 99707 of all relevant facts and circumstances. This disclosure shall include a description of actions which the Bidder/ Offeror has taken and proposes to take to avoid, mitigate, or neutralize the actual or potential conflict of interest. If the contract has been awarded and performance of the contract has begun, the Contractor shall continue performance until notified by the Chief Procurement Officer of any contrary action to be taken.

I DO SOLEMNLY DECLARE AND AFFIRM UNDER THE PENALTIES OF PERJURY THAT THE CONTENTS OF THIS AFFIDAVIT ARE TRUE AND CORRECT TO THE BEST OF MY KNOWLEDGE, INFORMATION, AND BELIEF.

ONE WORLD RESOURCE MANAGEMENT, LLC
Contractor

[signature]
By: (signature)

06/03/2019
(date)

H. NICO LAUER, PRINCIPAL
(Name and Title)

ITEM 6: Existing Testing Data

The OekoSolve electrostatic precipitators have been tested by many accredited laboratories and institutes in several countries. In addition, the ESPs have been tested by independent, licensed testing labs in field tests subject to quantitative gravimetric and qualitative PM-concentration tests as part of the required regular testing routine for woodstoves. The various reports attached below are not exhaustive but list the most important authorities and results. As different countries have different testing standards and methods, the data supplied by the various studies may not be always be comparable to the U.S. standards. It is notable, however, that the testing data supplied by the T.U.V. Austria protocol, was performed pursuant to the EN 303-5 method which closely resembles the EPA method 5 testing protocol.

The most pertinent testing norms and regulations applied for the testing of the OekoSolve ESP include the following (translation of an excerpt of the TUV Austria report, p. 7-8):

1. Norm EN 303-5 “Heating boilers for solid fuels, manually and automatic fed combustion processes up to 500 kW”, November 15, 2012
2. Norm M 5861-1 “Manual determination of dust concentration in flowing gases; gravimetric testing procedure” April 1, 1993
3. VDI 2066, page 1 “monitoring of particles; fine dust measurements in flowing gases; gravimetric determination of the dust load, November 1, 2006
4. Norm EN 13284, Part 1: Determination of dust mass concentrations for low dust concentrations, March 1, 2002
5. Norm EN 14789 “Emissions from stationary sources – determination of volumetric concentrations of oxygen (O_2) referenced procedure: paramagnetism” April 1, 2006
6. Norm EN 15259 “air quality – measurement of emissions from stationary sources- requirements for measuring stations and measuring task”, December 1, 2007
7. VDI / VDE 2640, Page 3, “Measurements in air flow cross sections” November 1983

Report Number: 0407.

Total Pages: 13.

Item Under Test (IUT):

Model:	Oekotube.
Type:	Electrostatic Particle Filter.
Manufacturer:	Oekosolve, Schmelziweg, 28889 Plons, Switzerland.

Client Details:

Attention:	Nadeine Dommisse (Principal Strategy Advisor.)
Company Name:	Environment Canterbury.
Company Address:	17 Sir Gil Simpson Drive, Christchurch.
Phone:	0800 324 636.

Checked by,
Mr. P. Sparrow
Signatory

Tested by,
Mrs. J. Patil.
Engineer

Issue Date 10/03/2016

Test Method Specification:

The method used in included in this report as Appendix 1.

Client Instructions:

The client requested the testing of three batch-loaded solid fuel heaters in accordance to the method shown above; the results along with any observations were to be reported.

The Oekotube test sample was supplied by the local Oekosolve agent Mr. Rene Haeberli from Envirosolve Ltd.

The solid fuel log burners tested were sourced by Environment Canterbury.

The samples were delivered by the relevant manufacturers.

Compliance with the test method:

There are no compliance requirements to meet for this test method, the reported results and observations were to be used by the client to establish the suitability of the Oekotube's installation and use in the Canterbury region.

This testing reports the emissions of the item under test but not the efficiency.

The Oeko Tube:

The Oeko Tube is an electrostatic emissions filter installed within the grounded metal flue pipe system of a solid fuel burning heater.

A high voltage potential is used to create an electric field that originates from the center of the flue through the use of a hanging conductive electrode.

The electrodes high potential voltage supplies free electrons that negatively charge the combustion emission particles as they travel up the flue.

The charged / ionized particles are attracted to the positive charge of the flue while at the same time being repelled by the hanging electrodes negative charge.

In simplified terms the effect is similar to how magnets attract and repel each other depending on their relative polarity or how a static electrical charge on a plastic ruler rubbed against a woolen sweater can be used to lift small pieces of paper.

The voltage used and thus the intensity of the field created is dictated by the flue pipe diameter and the flue gas velocity.

The flue was installed as per the AS/NZS4012:2014 standard but without the water bath that decouples the weight of the flue from the scale, this ensured that it would not influence the results of the real world operation. Increased moisture in the flue may affect the electric field due to a higher conductivity.

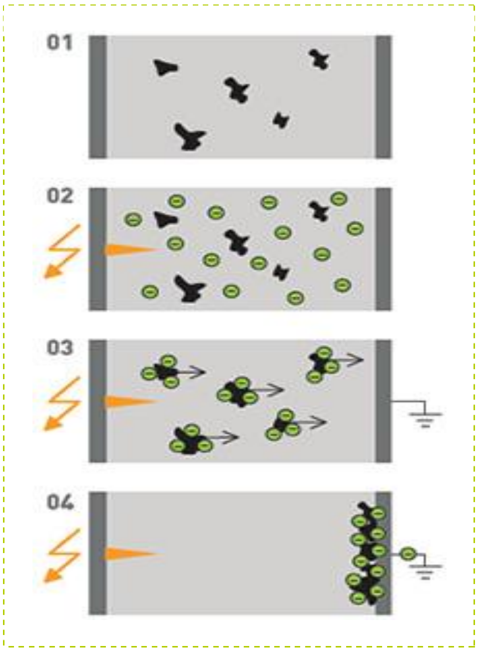
Mr. Rene Haeberli operated the Oeko Tube during the test, he was unable to influence the test results in any way other that the effect the Oeko tube was capable of on the days it was in operation. It could be seen that as it was monitored during the test and the field tuned that it was operating in a near ideal environment.

The Oeko website states the following with respect to how the filter operates.

Simple and Convincing.

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 sweep at the annual chimney inspection.*



Technical Notes / Observations:

The heaters under test were representative of those in mass production and seen as typical heaters installed into the Christchurch air shed.

The calorific room's door was left open to ensure that the heaters were operated at atmospheric pressure during all runs.

A counterweight of equal mass to the Oekotube was installed atop the flue pipe opposite to the location of the Oekotube to assist in alignment an prevent the flue from leaning to one side during the test runs; this is not expected to affect the reported results in any way.

The calorific value and ash content are not known, the variation in fuel and bark means that the exact value cannot be known. This does not affect the testing conducted as the average of each pair of loads has been selected to be as close as possible.

Typical Test Fuel - Both days prepared at the same time.

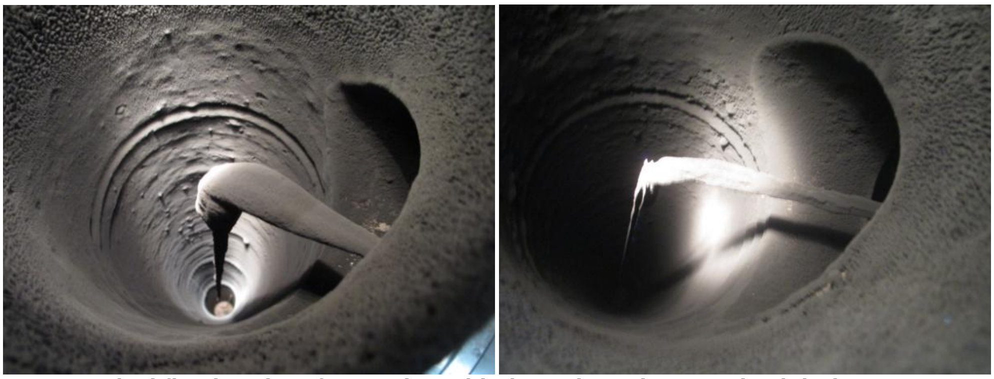
The following photos show the ash recovered daily after the testing was complete, each day started with a clean flue, the Oeko tube ash is shown on the right. The difference may be difficult to see in a photo but the amount recovered when the tube was active was considerably more. The block of wood provides some scale.

Pioneer New Zealand – Model Wee Rad (31st / 1st)

Glen Dimplex – Model R5000 (3rd / 4th)

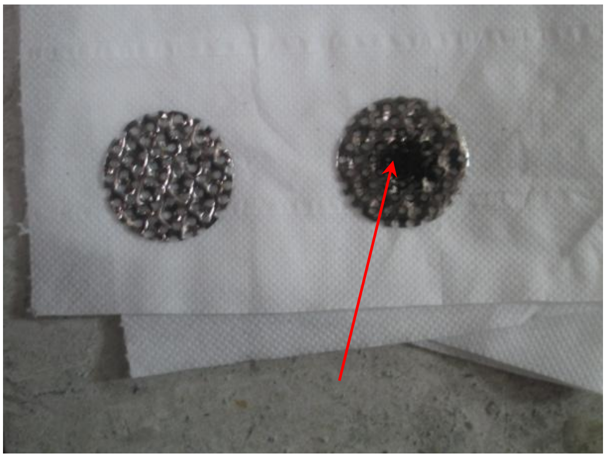
The following photos show the internal flue condition after the test runs.

Typical flue interior __after__ testing without the Oeko Tube in operation during the test



Typical flue interior __after__ testing with the Oeko Tube energized during test

Typical large particulates captured by sample train (During the Pioneer test on the 1st of October), this caused inconsistent emissions results as they contaminate the filter and increase the calculated PM_{10} emissions.
The photo below shows the portion of the re-entrained particulate that was trapped on the filter housing, this is also reference in the note on page 8.



Section 1: Descriptions

Solid Wood Burner Description:

The heaters supplied were as those sold to the public by the following suppliers.

W. H. Harris Limited – Model Novo
Metro Fires Limited – Model Wee Rad
Glen Dimplex New Zealand Limited – Model R5000

Heater Installation:

The heaters were installed as per the method.

A dilution tunnel and sampling train was used as specified in AS/NZS4013:2014.

The Oekotube was installed and operated by Mr. Rene Haeberli under supervision of Spectrum Laboratory staff.

Section 2: Test Conditions and Fuel Loading

Testing was carried out in accordance with the method shown in Appendix 1 as per the client's instructions.

W. H. Harris Limited – Woodsman – Model Novo
Average Moisture Content: 15 %.
Average Calorific Value: 20.1 MJ/kg. (Assumed, refer to technical notes)
Average Ash content: 0.5 %. (Assumed, refer to technical notes)

W. H. Harris Limited - Woodsman Day - 1 - Without Oeko Tube							
Moisture	15%	15%	15%	15%	15%	15%	15%
Fuel Info	**K (kg)**	**I1 (kg)**	**I2 (kg)**	**H1 (kg)**	**H2 (kg)**	**L1 (kg)**	**L2 (kg)**
Wet Load	1.52	1.50	3.01	4.00	4.00	4.02	4.01
Dry Load	1.28	1.27	2.54	3.38	3.38	3.40	3.39
Total Wet			6.02		8.00		8.03
Total Dry			5.09		6.76		6.79

Total Dry Mass	18.64 kg

W. H. Harris Limited - Woodsman Day - 2 - With Oeko Tube							
Moisture	15%	15%	15%	15%	15%	15%	15%
Fuel Info	**K (kg)**	**I1 (kg)**	**I2 (kg)**	**H1 (kg)**	**H2 (kg)**	**L1 (kg)**	**L2 (kg)**
Wet Load	1.50	1.50	3.00	4.00	4.01	4.01	4.01
Dry Load	1.27	1.27	2.54	3.38	3.39	3.39	3.39
Total Wet			6.00		8.01		8.01
Total Dry			5.08		6.78		6.78

Total Dry Mass	18.64 kg

Metro Fires Limited – Pioneer Metro – Model Wee Rad
Average Moisture Content: 15 %.
Average Calorific Value: 20.1 MJ/kg. (Assumed, refer to technical notes)
Average Ash content: 0.5 %. (Assumed, refer to technical notes)

Metro Fires Limited – Pioneer Metro Day - 1 - Without Oeko Tube							
Moisture	15%	15%	15%	15%	15%	15%	15%
Fuel Info	**K (kg)**	**I1 (kg)**	**I2 (kg)**	**H1 (kg)**	**H2 (kg)**	**L1 (kg)**	**L2 (kg)**
Wet Load	1.01	1.23	2.52	3.03	3.03	3.03	3.02
Dry Load	0.85	1.04	2.13	2.56	2.56	2.56	2.56
Total Wet			4.75		6.06		6.05
Total Dry			4.02		5.12		5.12

Total Dry Mass 14.26 kg

Metro Fires Limited – Pioneer Metro Day - 2 - With Oeko Tube							
Moisture	15%	15%	15%	15%	15%	15%	15%
Fuel Info	**K (kg)**	**I1 (kg)**	**I2 (kg)**	**H1 (kg)**	**H2 (kg)**	**L1 (kg)**	**L2 (kg)**
Wet Load	1.01	1.23	2.53	3.05	3.03	3.02	3.02
Dry Load	0.86	1.04	2.14	2.58	2.57	2.56	2.56
Total Wet			4.77		6.08		6.04
Total Dry			4.03		5.14		5.11

Total Dry Mass 14.28 kg

Glen Dimplex New Zealand Limited – Masport – Model R5000
Average Moisture Content: 15 %.
Average Calorific Value: 20.1 MJ/kg. (Assumed, refer to technical notes)
Average Ash content: 0.5 %. (Assumed, refer to technical notes)

Glen Dimplex NZ Limited - Masport Day - 1 - Without Oeko Tube							
Moisture	15%	15%	15%	15%	15%	15%	15%
Fuel Info	**K (kg)**	**I1 (kg)**	**I2 (kg)**	**H1 (kg)**	**H2 (kg)**	**L1 (kg)**	**L2 (kg)**
Wet Load	1.50	1.50	3.00	4.01	4.00	4.00	3.99
Dry Load	1.27	1.27	2.54	3.39	3.39	3.39	3.38
Total Wet			6.00		8.01		8.00
Total Dry			5.08		6.78		6.76

Total Dry Mass 18.62 kg

Glen Dimplex NZ Limited - Masport Day - 2 - With Oeko Tube							
Moisture	15%	15%	15%	15%	15%	15%	15%
Fuel Info	**K (kg)**	**I1 (kg)**	**I2 (kg)**	**H1 (kg)**	**H2 (kg)**	**L1 (kg)**	**L2 (kg)**
Wet Load	1.50	1.53	2.99	4.00	3.98	3.99	4.00
Dry Load	1.27	1.29	2.53	3.38	3.37	3.37	3.38
Total Wet			6.02		7.98		7.99
Total Dry			5.09		6.75		6.76

Total Dry Mass 18.60 kg

Section 3: Raw Results

CALORIMETER TEST DATA SHEET	Start	High 1	High 2	Low 1	Low 2	Overall
Reference file	0407					
Test date	27/08/2015					
Start Time	9:51					
Heater model	Harris Woodsman Novo – Without Oeko Tube					
Weight of Wood charge, kg	6.024	3.998	4	4.02	4.014	22.056
Weight of Wood (Dry mass) kg	5.094798	3.3813085	3.383	3.399915	3.3948405	18.653862
Filter ID - Primary	S1A	MH1A	MH2A	ML1A	ML2A	-
Filter ID - Secondary	S1B	MH1B	MH2B	ML1B	ML2B	-
Main filter Start, g	0.09032	0.09044	0.08937	0.08916	0.09076	0.45005
Backup filter Start, g	0.08985	0.09011	0.08898	0.09038	0.08960	0.44892
Main filter Stop, g	0.10030	0.09425	0.09676	0.09352	0.09673	0.48156
Backup filter Stop, g	0.09008	0.09038	0.08930	0.09067	0.08974	0.45017
Dry gas meter START, cu.m.	1533.95	1534.94	1535.85	1536.72	1538.03	1533.95
Dry gas meter STOP, cu.m.	1534.94	1535.85	1536.72	1538.03	1539.46	1539.46
Dilution tunnel temperature	33.49	35.73	35.88	27.59	25.38	30.62
Dry Gas Meter Average °C	16.39	19.79	21.21	22.02	20.03	20.00
Total Cycle Time (mins)	130.44	120.49	114.08	173.31	202.90	741.23
Average cycle Barometric Pressure, mB	1031.00	1032.00	1032.00	1032.00	1032.00	1031.82
Dilution Tunnel volume, cu.m.	662.22	613.62	579.44	880.41	1042.00	3777.68
Emission (g)	0.010	0.004	0.008	0.005	0.006	0.033
Emission Factor (g/kg)	1.304	0.800	1.500	0.903	1.288	**1.182**
Fuel consumption rate, kg/h	2.34	1.68	1.78	1.18	1.00	1.51
Gas Meter Sample flow rate, L/min.	7.80	7.68	7.72	7.69	7.18	7.57

CALORIMETER TEST DATA SHEET	Start	High 1	High 2	Low 1	Low 2	Overall
Reference file	0407					
Test date	28/08/2015					
Start Time	10:28					
Heater model	Harris Woodsman Novo – With Oeko Tube					
Weight of Wood charge, kg	6.004	4.002	4.01	4.008	4.006	22.03
Weight of Wood (Dry mass) kg	5.077883	3.3846915	3.3914575	3.389766	3.3880745	18.6318725
Filter ID - Primary	S1A	MH1A	MH2A	ML1A	ML2A	-
Filter ID - Secondary	S1B	MH1B	MH2B	ML1B	ML2B	-
Main filter Start, g	0.08967	0.08942	0.08962	0.08925	0.08903	0.44699
Backup filter Start, g	0.08891	0.08896	0.08997	0.08915	0.08975	0.44674
Main filter Stop, g	0.09433	0.09262	0.09082	0.09064	0.09077	0.45918
Backup filter Stop, g	0.08866	0.08918	0.09022	0.08938	0.08997	0.44741
Dry gas meter START, cu.m.	1539.47	1540.45	1541.10	1541.77	1543.13	1539.47
Dry gas meter STOP, cu.m.	1540.45	1541.10	1541.77	1543.13	1544.60	1544.60
Dilution tunnel temperature	31.59	34.83	36.71	25.55	23.73	28.88
Dry Gas Meter Average °C	16.41	18.44	19.24	19.63	19.29	18.69
Total Cycle Time (mins)	138.30	87.27	89.55	178.72	194.20	688.04
Average cycle Barometric Pressure, mB	1031.00	1029.00	1029.00	1029.00	1029.00	1029.40
Dilution Tunnel volume, cu.m.	698.75	439.98	449.09	910.36	991.95	3490.14
Emission (g)	0.004	0.003	0.001	0.002	0.002	0.013
Emission Factor (g/kg)	0.600	0.672	0.280	0.315	0.382	**0.459**
Fuel consumption rate, kg/h	2.20	2.33	2.27	1.14	1.05	1.62
Gas Meter Sample flow rate, L/min.	7.31	7.58	7.65	7.73	7.74	7.62

NOTE: The operator was required to burn 10% of the low setting fuel on the high setting to enable it to get started correctly on the low burn setting. This was done on both tests so the results are comparable.

CALORIMETER TEST DATA SHEET	Start	High 1	High 2	High 3	Low 1	Overall
Reference file	0407					
Test date	31/08/2015					
Start Time	9:35					
Heater model	Pioneer Metro Wee Rad – Without Oeko Tube					
Weight of Wood charge, kg	4.752	3.028	3.028	4.008	4.006	18.822
Weight of Wood (Dry mass) kg	4.019	2.561	2.561	2.563	2.558	14.261
Filter ID - Primary	S1A	MH1A	MH2A	ML1A	ML2A	-
Filter ID - Secondary	S1B	MH1B	MH2B	ML1B	ML2B	-
Main filter Start, g	0.08975	0.08964	0.08944	0.09074	0.08930	0.44887
Backup filter Start, g	0.08838	0.08933	0.08915	0.08873	0.08972	0.44531
Main filter Stop, g	0.09749	0.09110	0.09249	0.09325	0.10671	0.48104
Backup filter Stop, g	0.08860	0.08949	0.09088	0.08934	0.09001	0.44832
Dry gas meter START, cu.m.	1544.60	1545.30	1545.80	1546.39	1546.77	1544.60
Dry gas meter STOP, cu.m.	1545.30	1545.80	1546.39	1546.77	1547.90	1547.90
Dilution tunnel temperature	29.96	34.65	33.79	35.14	23.33	29.77
Dry Gas Meter Average °C	18.62	19.78	19.89	20.02	19.92	19.61
Total Cycle Time (mins)	101.08	67.97	80.09	52.80	148.28	450.22
Average cycle Barometric Pressure, mB	1014	1014	1014	1014	1014	1014
Dilution Tunnel volume, cu.m.	511.86	345.69	405.76	264.26	758.38	2285.95
Emission (g)	0.008	0.002	0.005	0.003	0.018	0.035
Emission Factor (g/kg)	1.457	0.435	1.271	0.851	4.648	**1.708**
Fuel consumption rate, kg/h	2.39	2.26	1.92	2.91	1.03	1.90
Gas Meter Sample flow rate, L/min.	6.88	7.40	7.44	7.16	7.61	7.33

CALORIMETER TEST DATA SHEET	Start	High 1	High 2	High 3	Low 1	Overall
Reference file	0407					
Test date	1/09/2015					
Start Time	9:23					
Heater model	Pioneer Metro Wee Rad – With Oeko Tube					
Weight of Wood charge, kg	4.769	3.048	3.034	3.022	3.022	16.895
Weight of Wood (Dry mass) kg	4.033	2.578	2.566	2.556	2.556	14.289
Filter ID - Primary	S1A	MH1A	MH2A	ML1A	ML2A	-
Filter ID - Secondary	S1B	MH1B	MH2B	ML1B	ML2B	-
Main filter Start, g	0.08995	0.08895	0.08927	0.08933	0.08875	0.44625
Backup filter Start, g	0.08891	0.08961	0.08857	0.08884	0.09051	0.44644
Main filter Stop, g	0.09531	0.08973	0.09775	0.10058	0.10256	0.48593
Backup filter Stop, g	0.08921	0.08981	0.08880	0.08910	0.09090	0.44782
Dry gas meter START, cu.m.	1547.90	1548.62	1549.17	1549.73	1550.19	1547.90
Dry gas meter STOP, cu.m.	1548.62	1549.17	1549.73	1550.19	1551.65	1551.65
Dilution tunnel temperature	30.87	34.80	35.20	46.00	47.65	40.44
Dry Gas Meter Average °C	18.55	20.46	20.78	22.03	24.07	21.71
Total Cycle Time (mins)	100.84	64.86	73.28	61.09	190.60	490.67
Average cycle Barometric Pressure, mB	1006	1006	1006	1006	1006	1006
Dilution Tunnel volume, cu.m.	504.93	325.69	367.88	301.90	961.60	2462.00
Emission (g)	0.006	0.001	0.009	0.012	0.014	0.041
Emission Factor (g/kg)	0.992	0.223	2.280	3.004	3.734	**1.912***
Fuel consumption rate, kg/h	2.40	2.38	2.10	2.51	0.80	1.75
Gas Meter Sample flow rate, L/min.	7.08	8.54	7.47	7.41	7.51	7.54

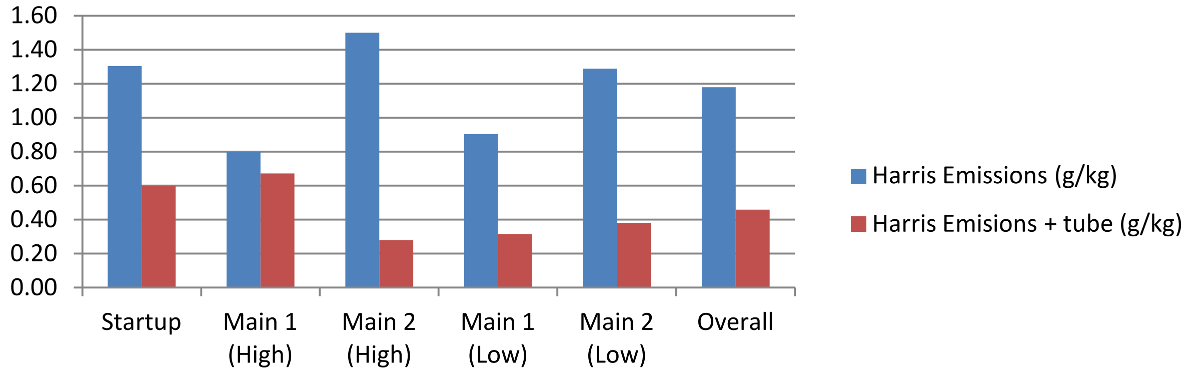
***NOTE:** During testing larger re-entrained particulate matter was observed on the primary filter carrier, this added additional weight to the filters and has likely increased the particulate results for this run. The result of 1.912 g/kg is expected to be a lot lower if the re-entrained matter had not been collected.

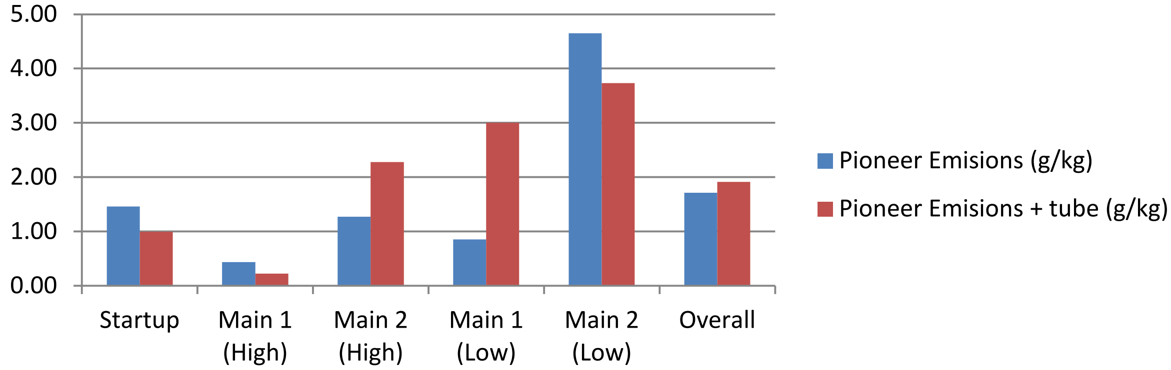
CALORIMETER TEST DATA SHEET	**Start**	**High 1**	**High 2**	**Low 1**	**Low 2**	**Overall**
Reference file	0407					
Test date	3/09/2015					
Start Time	10:02					
Heater model	Glen Dimplex Masport R5000 – Without Oeko Tube					
Weight of Wood charge, kg	6.004	4.010	4.004	4.004	3.992	22.014
Weight of Wood (Dry mass) kg	5.078	3.391	3.386	3.386	3.376	18.618
Filter ID - Primary	S1A	MH1A	MH2A	ML1A	ML2A	-
Filter ID - Secondary	S1B	MH1B	MH2B	ML1B	ML2B	-
Main filter Start, g	0.09149	0.08977	0.08959	0.09034	0.08950	0.45069
Backup filter Start, g	0.08995	0.08980	0.08808	0.08981	0.09088	0.44852
Main filter Stop, g	0.12128	0.09410	0.09207	0.09894	0.11160	0.51799
Backup filter Stop, g	0.09012	0.09002	0.08822	0.09010	0.09124	0.44970
Dry gas meter START, cu.m.	1551.647	1552.126	1552.556	1553.079	1554.278	1551.647
Dry gas meter STOP, cu.m.	1552.126	1552.556	1553.079	1554.278	1555.53	1555.53
Dilution tunnel temperature	31.57	37.76	36.53	23.06	22.06	27.41
Dry Gas Meter Average °C	15.93	17.04	17.29	17.46	17.43	17.15
Total Cycle Time (mins)	81.43	58.07	70.01	159.24	165.82	534.57
Average cycle Barometric Pressure, mB	1004	1004	1004	1005	1009	1006
Dilution Tunnel volume, cu.m.	406.53	292.45	351.99	815.06	848.08	2714.12
Emission (g)	0.030	0.005	0.003	0.009	0.022	0.068
Emission Factor (g/kg)	4.983	0.912	0.521	1.784	4.485	**2.565**
Fuel consumption rate, kg/h	3.74	3.50	2.90	1.28	1.22	2.09
Gas Meter Sample flow rate, L/min.	5.91	7.41	7.47	7.53	7.59	7.28

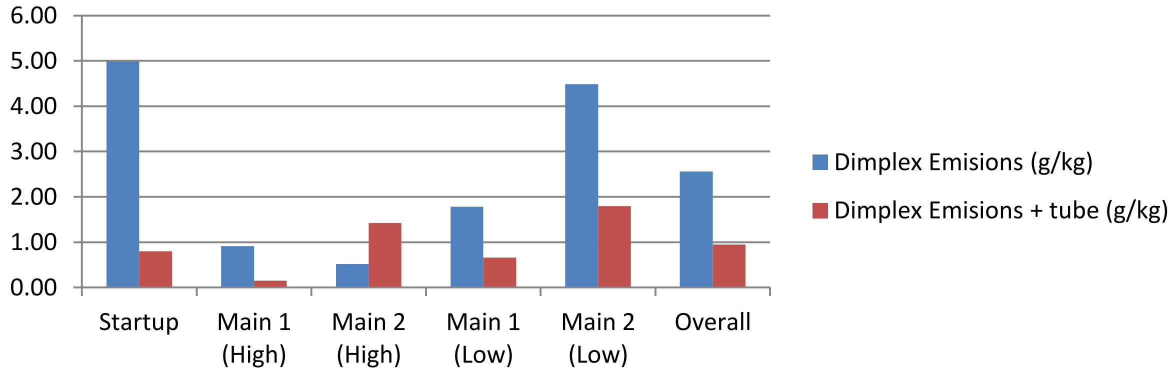
CALORIMETER TEST DATA SHEET	Start	High 1	High 2	Low 1	Low 2	Overall
Reference file	0407					
Test date	4/09/2015					
Start Time	9:50					
Heater model	Glen Dimplex Masport R5000 – With Oeko Tube					
Weight of Wood charge, kg	6.020	3.998	3.980	3.990	4.002	21.990
Weight of Wood (Dry mass) kg	5.091	3.381	3.366	3.375	3.385	18.598
Filter ID - Primary	S1A	MH1A	MH2A	ML1A	ML2A	-
Filter ID - Secondary	S1B	MH1B	MH2B	ML1B	ML2B	-
Main filter Start, g	0.08939	0.08952	0.08966	0.08840	0.08910	0.44607
Backup filter Start, g	0.08878	0.08934	0.08804	0.08871	0.08938	0.44425
Main filter Stop, g	0.09496	0.09018	0.09656	0.09140	0.09776	0.47086
Backup filter Stop, g	0.08903	0.08946	0.08830	0.08901	0.08977	0.44557
Dry gas meter START, cu.m.	1555.53	1556.167	1556.786	1557.399	1558.733	1555.53
Dry gas meter STOP, cu.m.	1556.167	1556.786	1557.399	1558.733	1560.258	1560.258
Dilution tunnel temperature	31.64	36.30	36.59	24.10	21.61	27.60
Dry Gas Meter Average °C	15.71	17.70	18.01	18.29	17.99	17.71
Total Cycle Time (mins)	90.18	82.96	81.93	176.10	201.06	632.23
Average cycle Barometric Pressure, mB	1011	1011	1011	1011	1011	1011
Dilution Tunnel volume, cu.m.	451.69	415.28	411.72	900.39	1029.57	3208.64
Emission (g)	0.006	0.001	0.007	0.003	0.009	0.026
Emission Factor (g/kg)	0.800	0.154	1.422	0.658	1.797	**0.947**
Fuel consumption rate, kg/h	3.39	2.45	2.47	1.15	1.01	1.76
Gas Meter Sample flow rate, L/min.	7.15	7.50	7.52	7.60	7.62	7.52

NOTE: Nil

Emissions shown as a reduction or increase per stage:



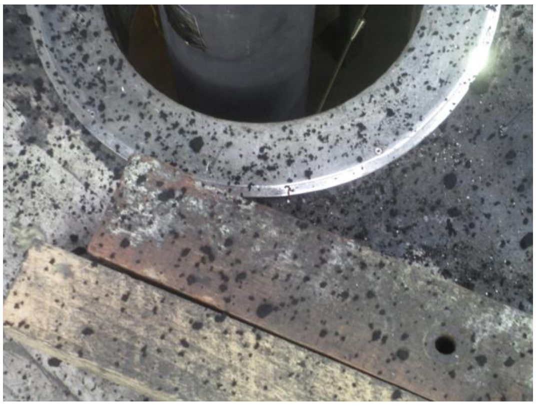




Section 4: Conclusion

Operation:

The Oeko Tube functions as Mr. Rene Haeberli had indicated previously. The creation of larger clumped particulates was generated from the smaller PM_{10} (along with other PM sizes), these particulates in an environment with no breeze present generally settled within approximately two meters of the flue outlet when tested in our laboratory.



Large particulates settling during testing near the flue

Re-entrained particulates:

The particulates shown below were the largest captured during the various tests with the Oeko Tube active, as there was no breeze these were found not far from the flue stack. These examples were exceptions to the rule as most particulates were visible but considerably smaller as seen in the photos above.

Results explained:

Emission Factor (g/kg) - Control	**1.182**	**1.708**	**2.565**
Emission Factor (g/kg) - Tube Active	**0.459**	**1.912**	**0.947**
Change	**- 61.17%**	**+ 11.94%**	**- 63.08%**

On the surface the numbers above show that the reduction of PM_{10} emissions on two of the heaters was approximately 60%, the second heater shows an increase for the reasons explained in the note shown on p8.

With a sample size so small it is unwise to assume a general reduction of 60% could be applied across all solid fuel burning heaters but it appears based on the observations made on test that by simple virtue of the particulates settling on the ground that the use of an Oeko Tube would reduced the contribution to the air sheds PM_{10} smog, it is expected that the $PM_{2.5}$ (along with all other particulate sizes) would also be reduced but testing would be needed to prove this.

Additional Considerations:

This technology and approach to the removal of PM10 particulates from the air shed does raise several points that may need to be considered. The following may be considered detrimental and need to be weighed against the potential benefits. These are not covered as part of the testing

It should be noted that the method in which the Oeko Tube works requires the electric field to be strong enough to force the particles to attach to the flue pipe but not so strong as to arc from the electrode to the flue pipe if the carbon content (level of smoke) increases (this collapses the field so it stops working). This may require a qualified installer.

After the initial setup it may be advisable for the installer to return to the site after a set period to check for error codes recoding arcing and shut down conditions.

Based on these initial observations it would appear that the type of fuel used be it the species, moisture or chemical makeup we would expect the Oeko tube to be unaffected as all carbon emissions are captured in the same manner. Only the volume of smoke appears to affect the Oeko tubes operation.

The effect the re-entrained matter may have if collected in a tank water system (drinking).
Re-entrained matter may settle on neighboring dwellings outdoor furniture, vehicles or washing etc...
The above are are only expected during specific environmental conditions, on a perfectly still night it is expected that the low temperature will force the particulates to settle quickly. During a storm or rain the effect would be unseen.

Untrained sweeps

Subsequent owners understanding of the units operation

In the event of a power failure the Oeko tube will not affect the normal operation of the solid fuel burner but the emissions would increase.

If the solid fuel burner at the dwelling is changed that would require the Oeko tube to be removed unless retuned for the new installation.

Ongoing maintenance

Notification to the operator if the system is not working

Appendix 1 – TEST METHOD APPLIED

Overview:
Testing was conducted to quantify any change in emissions through the use of the OekoTube when installed on existing approved low emissions heaters of different designs.
The testing was conducted on a small range of different heaters to establish an expected 'average reduction' in emissions and the specifics as to when the greatest reduction occurred.
The Canterbury Method (CM1.5) was used for guidance with some modification with respect to a fuel load.
All fuel was of the same composition and loaded in the same manner on both days.
Wetbacks were not considered for testing to reduce variables and complexity.

References:

AS/NZS4012:2014 - Modified
AS/NZS4013:2014 - Modified
The Canterbury Method CM1.5 – Modified

Assumptions:
The moisture content used on test was as per the CM1.5 method, care was taken to ensure that the fuel loads used on each test pair (with and without OekoTube active) are the same.

Test Method:
The test was conducted as per CM1.5 as far as practical with respect to fuel loading and reported data

Intended Deviations from CM1.5:
The efficiency was not calculated as it was not within the intended scope of testing.
The final HW and PS loads were not used as the main fuel loads established the ongoing emissions per load.
Emissions data was gathered for every main batch loaded to more accurately report the output during the test over time when compared to CM 1.5.

Test fuel:
The fuel was calculated as per CM 1.5 and was created for each pair of test days at the same time to the same effective load was used for both days to minimize any error.

Test Procedure:
The test procedure was a modified CM1.5 test.
Test phases were conducted in sequence and emissions data gathered for the startup (K, I1, I2) and each main phase separately.
Each heaters test required two days of testing.
During these tests the OekoTube was inactivated on the first day, but active on the second day.
The fuel length and weight used were as per CM1.5.

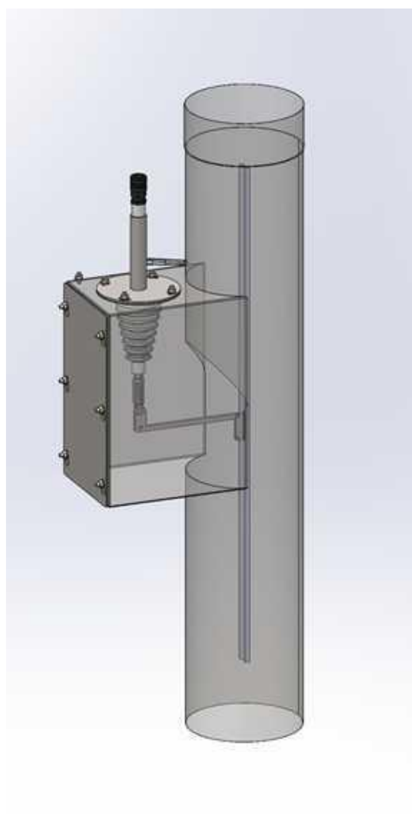
The test sequence was as follows.

Start-up phase - Kindling + Intermediate 1 + Intermediate 2	(filter swap at end - Start-up)
Hot phase - Main Load - High setting	(filter swap at end- High)
Hot phase - Main Load - High setting	(filter swap at end- High)
Hot phase - Main Load - Low setting	(filter swap at end- Low)
Hot phase - Main Load - Low setting	(filter swap at end- Low)

End of Report 0407

OekoTube Inside Testing Protocol

Wood stove type	Englander NC-13 (60,000 BTU)
Filter	OekoTube Inside 6"
Location	Washington National Mall, 2018 Wood Stove Design Challenge Washington, D.C.
Date	Friday, November 9, 2018
Tester	Norbert Senf Chair of Technical Committee Masonry Heater Association of North America



OekoTube Inside (OTi)

1 Summary

The OekoTube inside is an electrostatic precipitator (ESP) which is designed to remove fine particulates from wood burners. The device used in this experiment with a 6” flue and an 800mm (31.5”) electrode was tested with a Condar portable dilution tunnel to determine the effectiveness of its particulate reduction capacity for wood smoke.
Gravimetric tests were performed in one test, sampling 4 times at 6 minutes each with the ESP on and 4 times at 6 minutes with the ESP off. The test indicated a removal of 0.3233g or 55.6% of total particulates (PM) from a sample of 275 liters of raw flue gas, diluted 10:1 with ambient air. The removal efficiency of total PM-2.5 was not recorded separately. The test also indicated the removal of a substantial fraction of organic carbon (OC) relative to elemental carbon (EC). (Pic. 4)

2 Experimental Set-up

- Wood stove rating: 17 kW (60,000 BTU)
- Actual energy output during testing: N/A
- Year of manufacture: N/A
- Fuel type: cord wood
- Specification of filter:
  - Whatman grade 691, glass fiber, 1.5 um.
  - OTi- 180
  - D: 180 mm
  - $L_{electrode}$ 800 mm
- wood stove ignition: manual

2.1 Measuring Points

- flue diameter to OekoTube filter: 7” (180 mm)
- measuring point for unfiltered flue gas: 8 ft. (240 cm) above floor
- measuring point for filtered flue gas: 8 ft. (240 cm) above floor

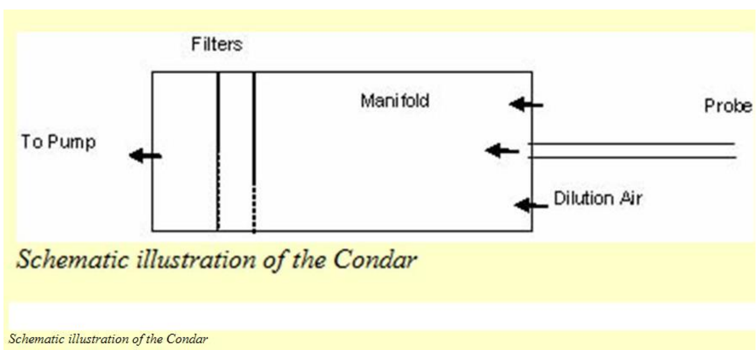
3 Measuring Devices

3.1 Gravimetric PM Measurement

The gravimetric measurements were performed by using two Condar portable dilution tunnels. The measuring device draws flue gas to be tested at the rate of 0.2 raw liters per second and dilutes them with ambient air at a 10:1 ratio before depositing them on dual glass fiber filters (primary filter plus backup).

A second probe at the same height sampled the flue gases with a Testo 330-2 gas analyzer which gives flue gas temperature, O2 and CO concentration. This normally allows calculation of a PM emissions factor in grams of PM per kg of dry fuel burned. There was a malfunction with the Testo system, and insufficient flue gas data was obtained. Therefore, the results are reported as the filter catch of particulates. The PM weights can be compared directly, due to the methodology of alternating samplers at short intervals.

Pic. 1: Condar dilution tunnel



Pic. 2 Schematic illustration of the Condar

4 Measuring Procedure

The testing was performed at the same height above the woodstove at opposing sides of the flue. To ensure equal testing conditions, the Condar filters were alternatively switched on with or without the OekoTube filter.

4.1 Gravimetric Measurement

- Condar
- Simultaneous particulate (PM), oxygen (O_2), carbon monoxide (CO) and stack temperature measurements
- No cleaning of the OekoTube Inside during the testing procedure
- Measuring intervals: alternating 4 times ESP on for 6 min and 4 times ESP off for 6 min, respectively.

Pic.3 Testing of the Englander NC-13 using 2 Codars

5 Results

The two filters were weighed before and after the tests. The difference in weight for each filter was recorded which reflected the total weight of the particulate emissions captured.

	OekoTube ESP	**net weight**:
Filter 1	OFF	0.5814g
Filter 2	ON	0.2581 g

Difference in weight	0.3233g
% PM removal	55.6%

Pic. 4 Gravimetric measurements: left without OekoTube inside (0.5814 g), right with OekoTube inside. (0.2581 g)

CTI 12212.1

Commission of **T**echnology and **I**nnovation

Interim Report - Summary

Development of new Generation Electrostatic Precipitator (ESP) for small wood fired Appliance.

Entwicklung einer neuen Generation von elektrostatischen Partikelabscheidern (ESP) für Kleinholzfeuerungen

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Michel Revaz, OekoSolve AG

Date
9-14-2012

1. Introduction

The following research has been conducted to study and observe the efficiency of the New Generation of Precipitators for small wood-fired appliances in long time trials. The project should answer the following questions:

1. How does the ESP perform new and after operating over a period of time in a particle containing flow (without cleaning)?
2. How does the ESP perform (efficiency of the electrode) during a long term period of operation?

2. Methods

2.1. ESP

Using the following electrostatic precipitator (ESP): Type 'Oeko-Tube' 2 (producer OekoSolve, Switzerland): length of electrode 1.55m; Max voltage of 27 kV; Max capacity of 16 W; Software version 2000.

2.2. Measuring system

The same design and measurement setup has been used of all three field trial installations.

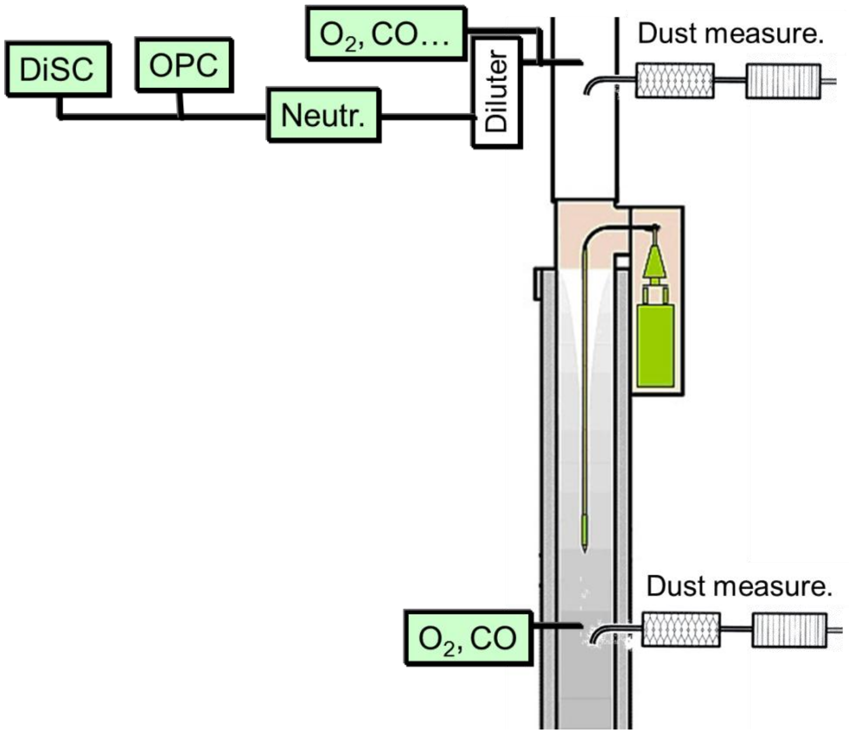


Figure 1: Measurement setup and sampling position of instruments.

The following measuring instruments have been used:
1. DiSC (Diffusion Size Classifier) measures particles between 3 – 300 nm (smallest micro dust).
2. OPC (Optical Particle Counter) - measures particles between 0.3 – 30 µm (measures 15 different particle sizes within this range).
3. Gravimetric filter method with two 'Woehler' measuring instruments (before and after ESP and with the sampling opening opposing and in line with the exhaustion flow).
4. Gas analyzer O2, CO2, CO, CXHY as CH4 (OGC) online before and after ESP.
5. Various process data (power, voltage, capacity and temperature at the end of the chimney. Temperature sensor is the standard sensor on an 'Oeko-Tube'.
6. Dust amount taken from the chimney sweeper.

2.3. Test fires

Three different fire systems (appliances) have been tested:

1. Log boiler, 40 kW, stocking by hand, combustion controlled, combustion period 6 h. $T_{fluegas}$ = 212 °C
2. Log fire 9 kW (most overloaded up to 15 kW), $T_{fluegas}$ = 320 °C
3. Pellet stove 6 kW. $T_{fluegas}$ = 90 °C


Figure 2 Pictures of tested appliances. From left to right: log boiler, log fire and pellet stove with modified storage tank.

3. Results

3.1. Phenomenon 'Re-entrainment'

The collected dust at the flue wall increases in size to form large flakes. These growing dust flakes either fall down to the fire box due to gravity or they are carried away through the flue opening into the atmosphere due to the exhaust draft. This effect is a natural cleaning process of the ESP electrode and, therefore, the precipitator does not have to be cleaned more than the annual chimney cleaning without losing its efficiency.

3.2. Comparison of the measurement principles

The precipitated efficiency for different measuring methods at the beginning and at the end of the measuring periods in appliance 1 was compared. In absence of re-entrainment the different measuring methods leads to comparable results.

Efficiency (without re-entrainment)	**Start**	**End**
Dust volume from chimney sweeper at field trial (without re-entrainment)	**79 %**	**81%**
Gravimetric measurement Woehler ($p_0 - p_1$)	**77 %**	**76%**
DiSC-measurement (ESP on/off)	**72 %**	**84%**
OPC (partly not measureable)	(0 %)	55% / 62%
Expected accordingly to Deutsch-Anderson-Formula	**73 %**	**76 %**

3.3. Chimney Sweeper

The amount of dust collected by the chimney sweeper corresponds to the expected quantity, except at appliance two, which showed the phenomenon of re-entrainment.

Appliance	logwood stocked	expected efficiency	Collected dust	in mg/m^3	resulting efficiency
Log Boiler	2‘200 kg	73%	673 g	30.6	79%
	2‘800 kg	76%	889 g	31.8	81%
Log Fire	1‘800 kg	90%	103 g	5.7	8%
	1‘080 kg	90%	126 g	11.6	16%
Pellet Stove	1‘400 kg	99%	846 g	60.6	100%

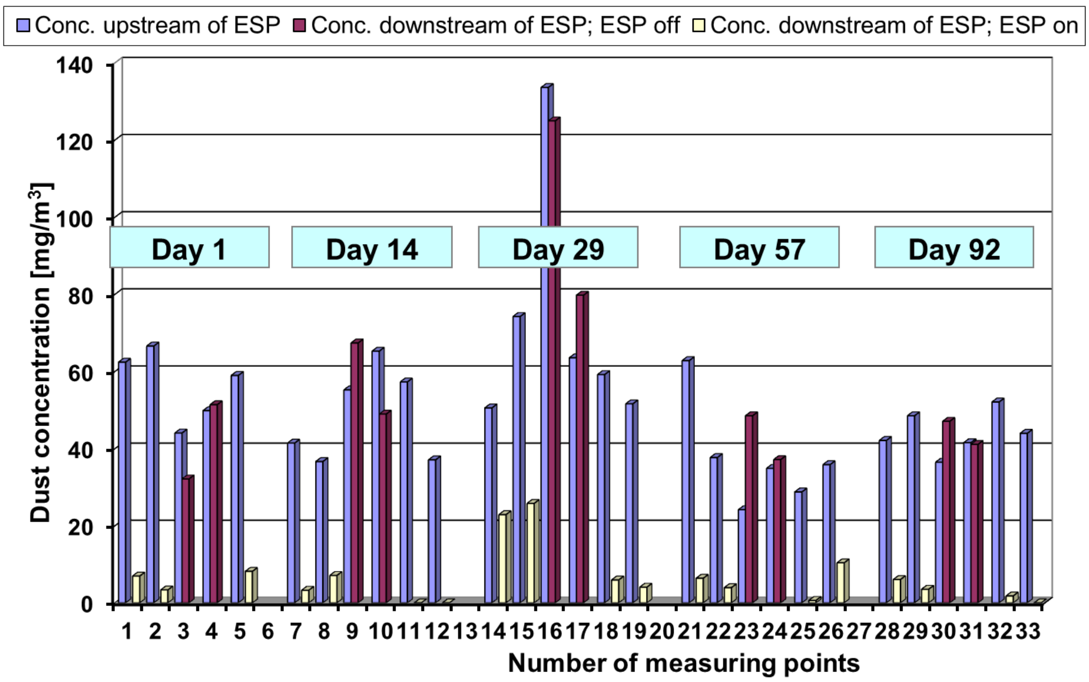
3.4. Chimney deposit

The observed deposit of dust in in the chimney corresponds to the collected dust.

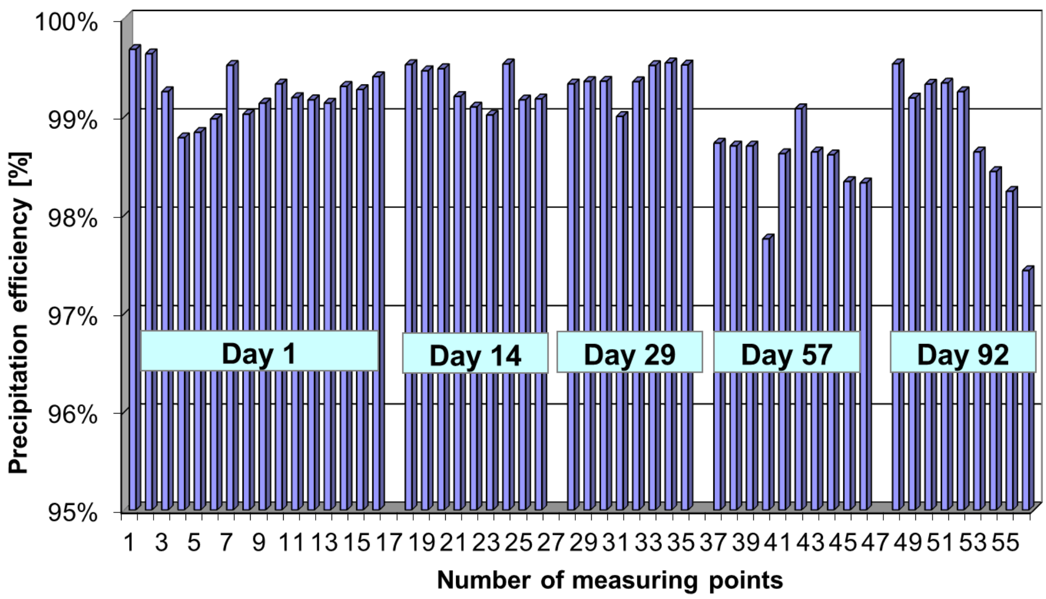
Figure 3 View to the different chimneys. From left to right: log boiler, log fire and pellet stove.

3.5. Gravimetric dust measurements

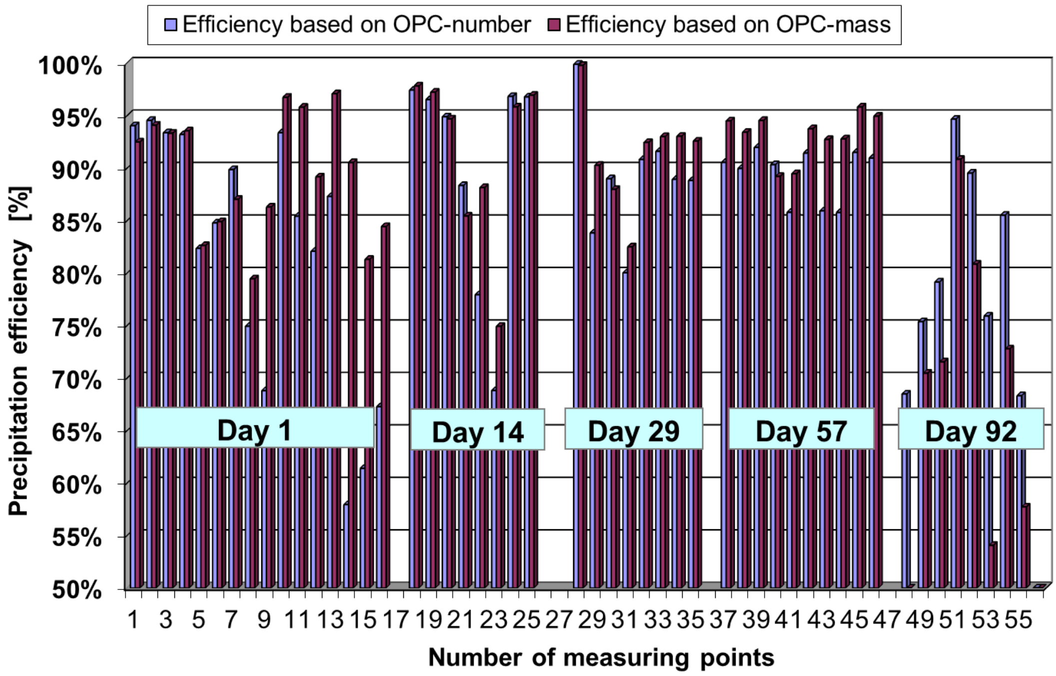
Measurements have been taken in upstream and downstream of the ESP, as well as measurements downstream of the ESP with ESP off and ESP on. There are 5 – 6 measuring points per day shown in the graph.



3.6. DiSC (Diffusion Size Classifier) Measurements



3.7. OPC (Optical Particle Counter) Measurements



3.8. Overview

The composition of the various measurement methods over the entire measurement period in appliance 3 shows no significant loss of efficiency.

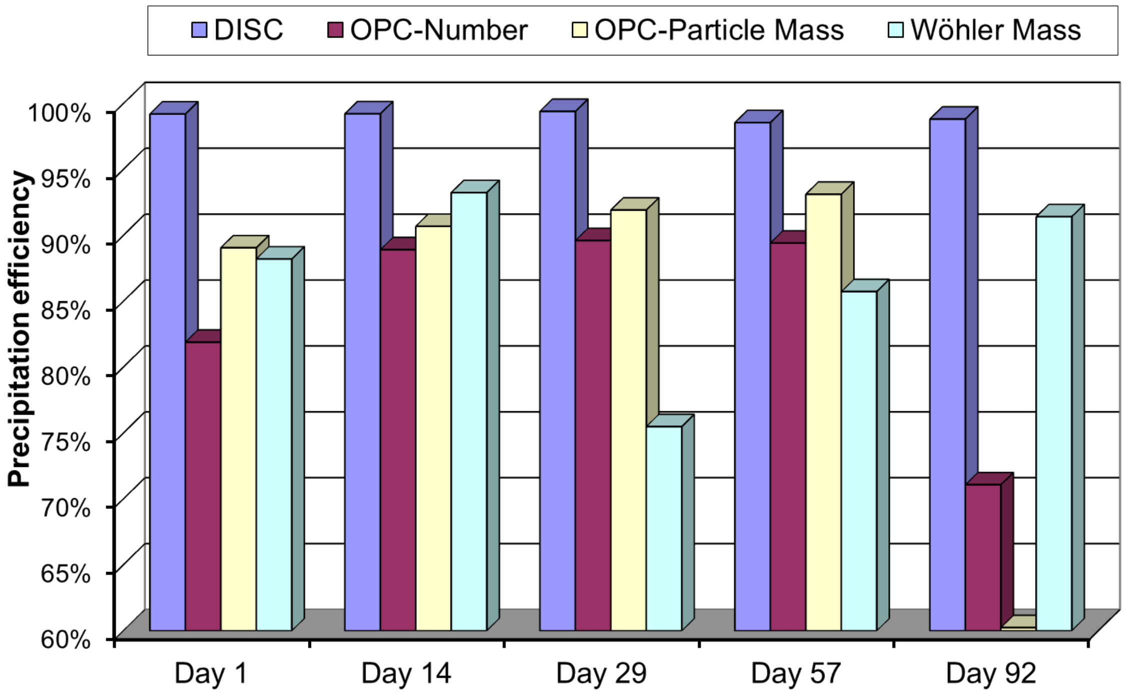


Figure 4: Composition of measurements in appliance 3.

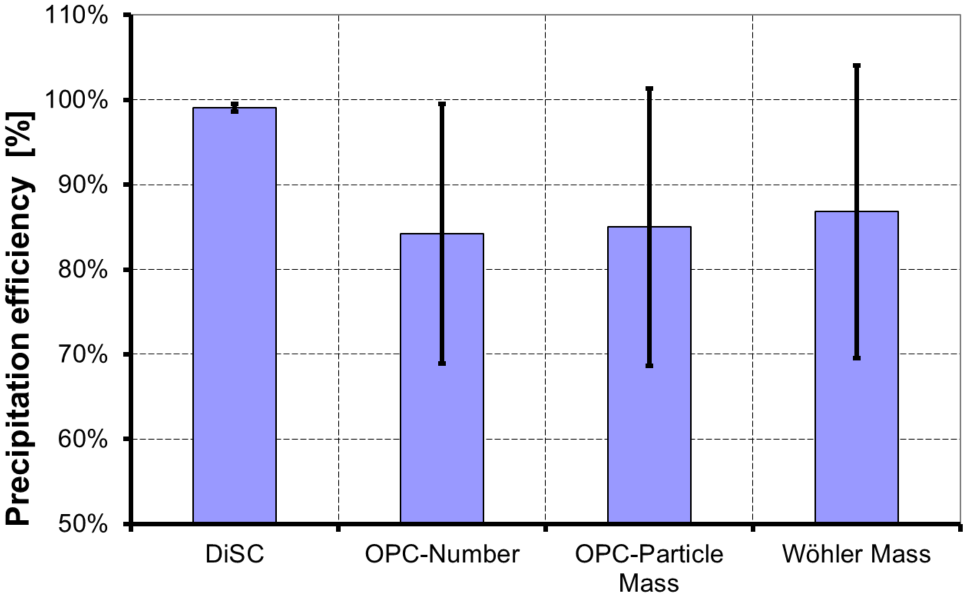


Figure 5 Average precipitation efficiency with standard deviation.

With the exception of DiSC-measurement, all other measurement methods indicate a high statistical error, due to the influence of re-entrainment. Re-entrainment phenomenon also reduces precipitation efficiency.

4. Conclusion

1. The long-term performance of the ESP (Electrostatic Precipitator) is very satisfactory. The dirtiness of the electrode does not affect the precipitation efficiency. The efficiency of the electrode is very consistent due to its self-cleaning effect ”re-entrainment”.
2. ESPs convert nano- and micro-dust to coarse dust.
3. There is no need for automatic cleaning of ESPs with small capacities.
4. The phenomenon of re-entrainment has been found in all fires tested. The ‘re-entrainment’ is especially noticeable in fires with dust that contain high levels of soot particles.
5. The re-entrainment in chimneys commences relative quickly and depends on the conductivity of the particles.
6. The re-entrainment dust will go either downwards into the fire box or upwards into the air with the upwards flue draft. The dust will settle in the near vicinity of the chimney depending on the size and weight of the particles.
7. Ageing of the electrode due to coating by particles starts occurring within 10-30 hours and can be detected by a decrease in the corona current. This can be compensated with a higher voltage.
8. The re-entrainment helps to clean of the electrode. Therefore, the ESPs work with a very high efficiency over long period of time.
9. The various measuring systems show the same precipitation efficiency under ideal conditions.
10. The precipitation efficiency measured with the gravimetric method is considerably influenced by re-entrainment.
11. The testing conditions must be defined and identical if various precipitator systems are being compared.
12. The DiSC-measuring method show the most consistent and reproducible results and these are independent of the re-entrainment.