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: NONE

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.

David C. Kelly

Signature of Representative

Date: 5 June 2019

Name: David C. Kelly

Title: President & Managing Partner

Firm: Healthy Hearth LLC

Alaska Business License No.: N/A

Email Address: cleanfireplaces@yahoo.com

Office Address for which this submittal is made:

Street: 30521 Coplasa Street

PO Box: N/A

City State Zip: Lake Elsinore, CA 92530

Phone: 951-264-8725
(with area code)

Submitted By: **Healthy Hearth LLC**
30521 Coplasa Street
Lake Elsinore, CA 92530 Contact: David Kelly Phone: 951-264-8725

Topic: **StoveCAT™ Emission Control Retro-Fit Device for Wood heaters**

ITEM 2

Meeting Minimum Requirements –
Current Production and Residential
Installation Documentation

Submitted By: **Healthy Hearth LLC**
30521 Coplasa Street
Lake Elsinore, CA 92530 Contact: David Kelly Phone: 951-264-8725

1) MEETING MINIMUM REQUIREMENTS

a) The proposed retrofit emissions control device must be in current production:

i) The **StoveCAT™** technology has been in production for about 2 years with approx. 300 units intalled across the US and Canada in retro-fit installations. The **StoveCAT™** is a very effective catalytic oxidation unit. It can remove up to 99% of particulate matter, drastically reduces Carbon Monoxide, VOC's and PAH. The **StoveCAT™** is the only passive device effective against the very small and carcinogenic 1.0 micron PM. The patented **StoveCAT™** device has been tested by OMNI Environmental (Portland, OR). **StoveCAT™** is the only passive retro-fit technology available for efficient removal of wood smoke particulates in wood burning wood heaters. The defining features of this catalytic technology are extremely low back pressure on the polluted air stream and the large surface area of the catalyst support. The **StoveCAT™** catalyst support is a reticulated ceramic structure with a surface area hundreds of times that of the conventional honeycomb materials. The **StoveCAT™** is positioned directly on the exhaust port of the wood burning appliance. The **StoveCAT™** destroys the particulates while most of the dilution air bypasses the hood and travels up the primary flue system.without restricting air flow or creating a pressure drop. The **StoveCAT™** System provides secondary ignition for the wood smoke after it leaves the firebox but before it exits the stove pipe as harmful pollution. This is the only passive retro-fit technology available for reducing harmful wood heater emissions. No gas or power is required and there are no moving parts and the **StoveCAT™** doesn't require an maintenance. The **StoveCAT™** will perform for a minimum of 10,000 hours of operation.

b) The proposed retrofit emissions control device must currently be installed in residential applications:

i) There are currently about 300 residential installations of the **StoveCAT™** across the US and Canada. The **StoveCAT™** is currently in test in Western Europe to the European Emssions Standard for CE Marking and Certification. Projected to be completed in Q1 2020.

The proposed retrofit emissions control device must be an off-the-shelf product.

The **StoveCAT™** is an "Off-the-Shelf product. We generally have 10-20 units in stock. For long term production planning, we utilize Just-in-time (JIT) inventory management as a planning and production tool. This process involves ordering and receiving component inventory for assembly and customer sales only as it is needed to produce finished goods as driven by customer orders and forecast. Our manufactured components are provided by DuraVent on a 3-4 week lead time. JIT inventory management has worked well for Healthy Hearth due primarily to our strong, fast and efficient network of suppliers. Ordering inventory on an as-needed basis means that Healthy Hearth does not hold expensive finished goods inventory. Most of our inventory consists of components requiring final assembly. Healthy Hearth relies heavily on forecast information from our customers to establish the demand for our products. Lead time is 4 weeks ARO.

2) CURRENT PRODUCTION

a) Current production of the **StoveCAT™** is peaking at about 25 units per month. However, the **StoveCAT™** and the **HearthCAT™** utilize some of the same catalytic materials. The **HearthCAT™** is the more mature product line with production projected through FY 2020 at about 2000 units. Full EPA Certification testing of the **StoveCAT™** is planned at Omni Environmental in the fall of 2020. A scaled up version of the **StoveCAT™** is also in prototype development for use on outdoor wood boilers.

3) RESIDENTIAL INSTALLATION DOCUMENTATION

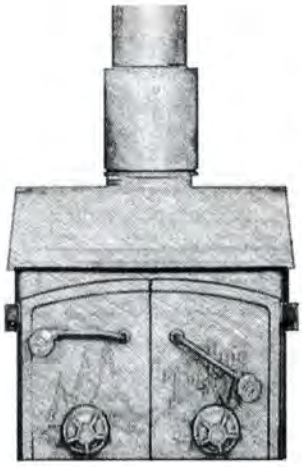
a) See attached **StoveCAT™** product information, "Installation Procedure" and details of the **StoveCAT™** Emission Control Device function and operation. (Next 3 pages).

StoveCAT™ Retro-Fit Installation Guide

Congratulations! You have purchased the GraceFire **StoveCAT™,** a revolutionary new Emission Control Device for wood burning stoves, heaters and furnaces. Follow these instructions carefully for safe and efficient operation. You will find additional information @ www.healthyhearth.net

The GraceFire StoveCAT Emission Control Device for Wood Stoves

The GraceFire **StoveCAT™** Emission Control Device from Healthy Hearth LLC is a revolutionary catalytic system designed especially for wood burning stoves. The **StoveCAT™** utilizes a patented three stage catalytic design to capture the pollutants from the wood burning fire without developing any backpressure of harmful blockage. The **StoveCAT™** Catalytic System provides secondary ignition for the wood smoke combustibles preventing them from leaving the firebox as particulate pollution. The direct flame on the catalytic surface actually cleans the catalytic unit.



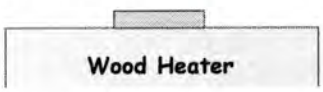
The high temperature components of the StoveCAT™ are manufactured from high quality stainless steel by DuraVent, the world's largest venting component manufacturer. The catalytic components are state-of-the-art ceramic material from Clear Skies Unlimited. The **StoveCAT™** can either be installed by a chimney sweep or as a "Do-it-Yourself" project by the homeowner.

The **StoveCAT™** is easily installed. It doesn't require any power and only has one moving part which is internal. The **StoveCAT™** catalytic device is installed on the exhaust port of the wood stove. The installation of the **StoveCAT™** converts a conventional wood burning stove into a cleaner burning heater with better heating efficiency.

These instructions allow the homeowner to easily install the emission control device on the wood heater for safe and efficient use. **Follow all Safety Instructions.**

Remove the Existing Connector Pipe from the Wood Stove

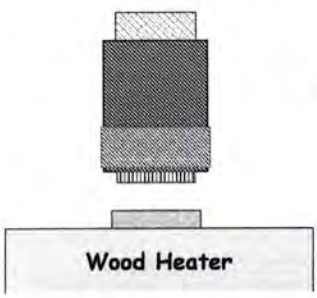
The **StoveCAT™ ECD** is 14" high. It is designed to be installed on a top mounted 6" exhaust port. You only need to remove enough connector pipe to make the installation. On the top of the **StoveCAT™ ECD** is a 6" DVL adapter from Duravent. It offers several connection options.



CAUTION

Insure mounting surface on the wood stove is clean and free of creosote.

Position the StoveCAT ECD on the Exhaust Port on the Wood Stove



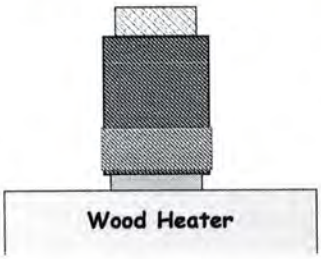
The **StoveCAT™ ECD** is easily installed on the wood heater. It simply rests on the exhaust port. There are no fasteners or mechanical connections. It is very important however that the mating surface on the bottom of the **StoveCAT™** goes inside of the exhaust port on the stove. Insure that the **StoveCAT™** is aligned properly.

CAUTION

A gasket is bonded to the bottom of the **StoveCAT™.** It will seal on the mounting surface of the wood stove. Insure that the gasket is in place prior to installation.

StoveCAT™ Retro-Fit Installation Guide

Align the StoveCAT ECD on the Exhaust Port

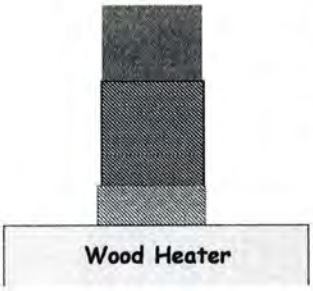


The weight of the **StoveCAT™** will properly seal the device on the wood heater. It simply rests on the exhaust port. There are no fasteners or mechanical connections.

CAUTION

It is very important that the mating surface on the bottom of the **StoveCAT™** goes inside of the exhaust port on the stove. Insure that the **StoveCAT™** is aligned properly.

Install the Connector Pipe



There are several different types of connector pipes on existing wood stoves. Generally, all of these pipes are 6" in size. The **StoveCAT™** is designed to be installed on a 6" exhaust port equipped with 6" stove pipe. Getting a proper pipe connection seal on the top of the **StoveCAT™** is an important safety consideration.

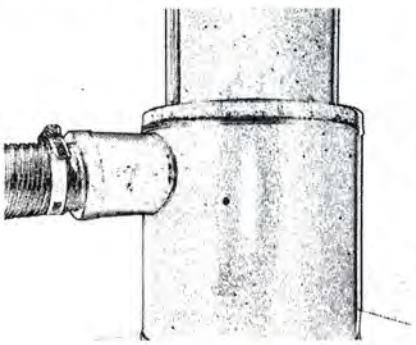
CAUTION

It is very important that the pipe connected to the StoveCAT™ is installed properly without any leaks. Wood smoke is very dangerous and cannot be allowed to enter the living area.

Flexible Air Intake Line

All catalytic technologies require oxygen or combustion air to function properly. The **StoveCAT™** ECD is equipped with a 36" long 2" ID aluminum flexible air line that provides combustion air to the catalytic components during operation. The combustion air mixes with the hydrocarbons in the wood smoke and fires the catalytic technology. The combustion air line should be the last **StoveCAT™** component to be installed.

Installing the Flexible Air Intake Line



The last step in the installation of the **StoveCAT™** is to connect the flexible air line to the air intake on the retro-fit device. The end of the air line is designed to slip over the 2" connection on the air intake. A 2" hose clamp is included with the flex hose. The hose clamp should be tightened around the end of the flex line until the connection is hand-tight. DO NOT USE ANY TOOLS OTHER THAN A SCREW DRIVER TO INSTALL THE CLAMP.

Once the flexible air line is connected, the airline should be shaped to create a bend downward around the back of the stove. The bottom of the airline should have at least 3" clearance from the floor without any objects nearby.

CAUTION

The first time that the wood stove is operated after installation of the **StoveCAT™,** the stove should be monitored for any smoke spillage. Check the mounting connection on the top of the stove and the connector pipe for any leakage.

Submitted By: **Healthy Hearth LLC**
30521 Coplasa Street
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The **StoveCAT™** is a totally passive catalytic retro-fit device. Unlike previous catalytic retro-fit devices for wood heaters, with the **StoveCAT™**, no action is required on the part of the user. During the early start-up phase of a fire or the cool-down phase (e.g., just prior to the fire going out), lower temperatures and lower exhaust flow can lead to hydrocarbon build up on the catalytic components. Other retro-fit devices must be removed from the exhaust flow path during start-up (by moving or bypassing the catalytic medium), and then replaced in the exhaust flow path by the user after the wood heater reaches a higher operating temperature. Those devices have proven to be inefficient and have no suitable mechanism to ensure that the emission reduction device is achieving efficient operation.

In contrast, the **StoveCAT™** remains stationary with no moving parts and enables the wood heater to function properly without any intervention, whether at low or high operating temperatures. In other words, the **StoveCAT™** is totally passive, and requires neither electrical power nor a mechanical or electrical control system.

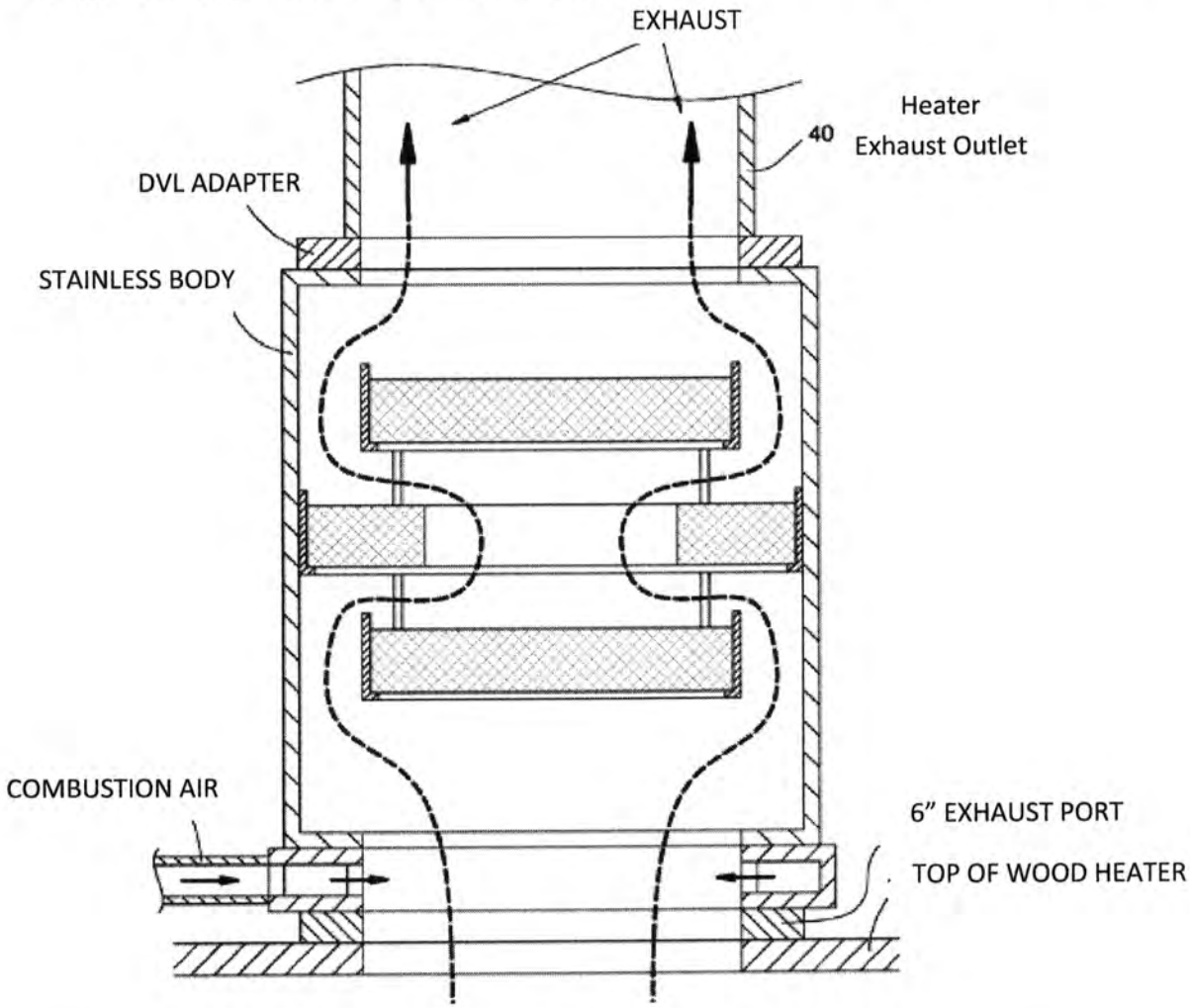

EXHIBIT (1): StoveCAT™ @ Low Temp. Operation (Non-Catalytic)

The design arrangement of the catalytic components in the **StoveCAT™** is such that, even if the catalytic component were to become temporarily blocked with retained organic particulates or products of incomplete combustion, the exhaust gas from the wood heater will continue to flow around the catalytic components and out of the exhaust flue. The **StoveCAT™** and its constituent catalyst-coated components remain in place throughout all phases of the fuel burn cycles of the wood heater without creating any back-pressure.

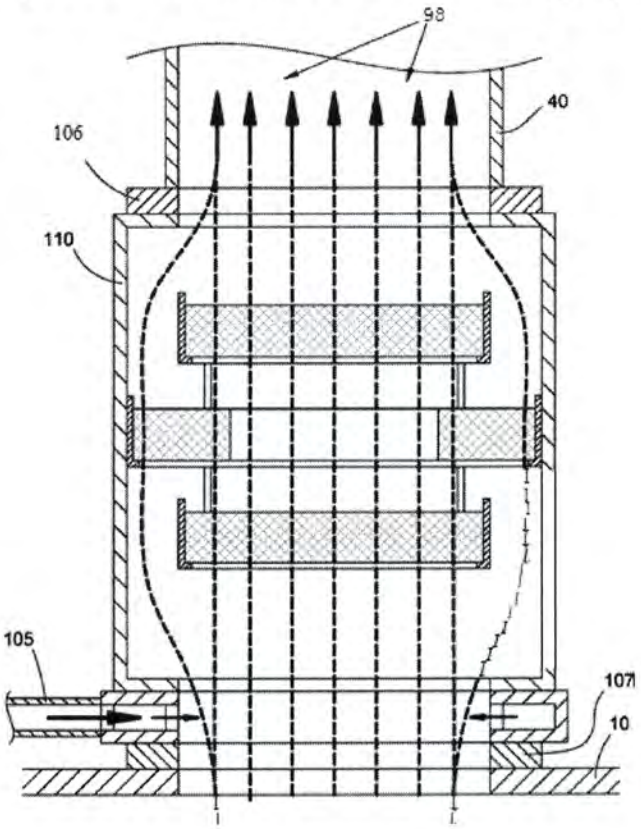

EXHIBIT (2): StoveCAT™ @ High Temp. Operation over 350F (Catalytic)

During periods of operation when exhaust gas passing through the exhaust flue exceeds the light-off temperature of 350F, the **StoveCAT™** will destroy the organic particulates and species gas pollution with sustained catalytic temperatures of 900-1000F. At exhaust gas temperatures below the catalyst light off temperature of 350F, the catalyst-coated medium acts as a particulate filter to capture and retain organic particulates or airborne solids (products of incomplete combustion). When the exhaust gas temperature later exceeds the catalyst light-off temperature, the retained organic particulates or products of incomplete combustion are eliminated at an efficiency rate approaching 99%. As with any catalytic device that enables substantially complete combustion, decomposition of organic particulates and products of incomplete combustion is exothermic, so that additional thermal energy is released by the wood heater, as radiant heat thereby increasing its efficiency.

Submitted By: **Healthy Hearth LLC**
30521 Coplasa Street
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Topic: StoveCAT Emission Control Retro-Fit Device for Wood heaters

ITEM 3
Number of Residential
Installations

Healthy Hearth LLC is submitting this information for your review and consideration per the requirements of FNSB RFP No. 19047:

Submitted By: **Healthy Hearth LLC**
30521 Coplasa Street
Lake Elsinore, CA 92530 Phone: 951-264-8725

NOTICE

Healthy Hearth will not be able to provide any specifics about our customers, their addresses and / or any of their confidential personal information.

Whenever a Healthy Hearth customer provides their private information to complete a purchase or other transaction, we guarantee the privacy and protection of their personal information. Whether they provide their credit card, write a check, provide their social security number, their mailing address, email address or phone number, they are trusting us with their confidential information and we in turn assure them that their personal information will be confidential and safeguarded by Healthy Hearth LLC.

However, we are providing some general application information about our catalytic products used for the reduction of wood smoke pollutants:

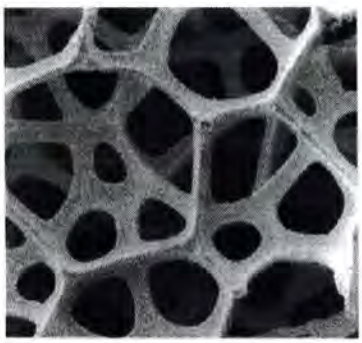
INSTALLATIONS

Healthy Hearth specializes in catalytic solutions for wood smoke after market applications. Our Stove Combustor Emission Control Technology for catalytic wood heaters is an award winning catalytic system designed especially for wood burning stoves. It has been commercially available for almost 18 years. We have sold almost 50,000 replacement wood stove combustors @ www.stovecombustors.com. Our technology is latest EPA Approved Catalytic Technology for wood stove applications.

There is a big difference between the "Old" Honeycomb Combustor technology and our Reticulated Ceramic Combustor. The Honeycomb Combustor is two or three times as thick as our catalyst support, yet our technology is more efficient in removing harmful wood smoke emissions and ensuring that your wood burning appliance operates at peak performance. The honeycomb catalyst support is also famous for thermal fatigue and erosion. For the past 40 years, honeycomb combustors have been cracking, eroding and falling out of catalytic wood stoves. Our technology doesn't suffer from any of these problems. Our proprietary catalytic system is the only emission control technology that works in the direct flame of a wood stove or fireplace. The direct flame on the catalytic surface actually cleans the catalytic unit.

Our catalytic design is protected by a technology patent as an "Engineered Reticulated Structure." The Engineered Reticulated Structure is a unique three-dimensional continuously repeating material array of nodes and ligaments with the geometrical angles between adjacent nodes and their connecting ligaments such as to create an open skeleton with an

interconnecting void phase interrupted only by the ligament-node array. The ligament-node array thus delimits interconnected void volumes of equal dimensions continuously and equally dispersed throughout the volume of the structure.



Our reticulated structure is distinguished from other low-density structures by the complete absence of material membranes closing the planes formed by the pattern of the ligaments and nodes and intersecting and closing off the voids of the reticulated structure.

Our reticulated structure has a unique open nature with extensive surface area and low resistance to the passage of fluids as seen in figure below.

Fluid flow Characteristics of Reticulated Ceramic Structure

A two-dimensional geometric analog of the reticulated structure would be the array of ligaments and nodes created with metallic wire commonly called "screen" or "wire cloth." Other so-called open structures and foams have an uncontrolled and defective structure with numerous material membranes (walls) closing the plane of the ligament-node array. The presence of the membranes and subsequent closure of the open structure restricts the passage of fluids through the structure and is for the subject application a distinct and fundamental difference. The reticulated structure can be made in an assortment of void sizes and numerical distribution of voids per unit of volume by controlling the diameter or width and thickness of the ligaments and nodes or controlling the length of the ligaments respectively.
The superior catalytic performance of this type of support structure has been verified by extensive independent testing at OMNI Environmental Test Labs in Portland, OR

This proprietary catalytic technology is also used in wood burning fireplaces. The HearthCAT™ is the only passive emission control system that is effective in the demanding operating environment of a wood burning fireplace. We have sold approx. 7000 HearthCAT's over the past 10 years.

The HearthCAT™ technology was awarded the prestigious Clean Air Excellence Award by EPA in 2010.

Our catalytic components utilize a proprietary Platinum catalyst that fires at approx. 320F and has a service life of 10000 hours under normal operating conditions.

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ATTACHMENT C
NON-COLLUSION AFFIDAVIT

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

STATE OF ALASKA)
)SS
FOURTH JUDICIAL DISTRICT)

I, David C. Kelly (printed/typed name) of Healthy Hearth LLC (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.

David C Kelly Healthy Hearth LLC
Contractor

David C. Kelly
By (signature)

5/31/2019
(date)

President / Managing Partner
Title

(SEAL)

SEE ATTACHED JURAT

SUBSCRIBED AND SWORN TO before me this _____ day of _____, 20___.

Notary Public in and for the State of ___. My commission expires:

CALIFORNIA JURAT WITH AFFIANT STATEMENT GOVERNMENT CODE § 8202

☑ See Attached Document (Notary to cross out lines 1–6 below)
☐ See Statement Below (Lines 1–6 to be completed only by document signer[s], not Notary)

Signature of Document Signer No. 1 *Signature of Document Signer No. 2 (if any)*

A notary public or other officer completing this certificate verifies only the identity of the individual who signed the document to which this certificate is attached, and not the truthfulness, accuracy, or validity of that document.

State of California
County of Riverside

GILBERT AQUINO
Notary Public - California
Riverside County
Commission # 2273202
My Comm. Expires Jan 23, 2023

Place Notary Seal and/or Stamp Above

Subscribed and sworn to (or affirmed) before me
on this 31 day of May, 20 19,
Date *Month* *Year*
by
(1) David Charles Kelly
(and (2)),
Name(s) of Signer(s)

proved to me on the basis of satisfactory evidence to be the person(s) who appeared before me.

Signature
Signature of Notary Public

OPTIONAL

Completing this information can deter alteration of the document or fraudulent reattachment of this form to an unintended document.

Description of Attached Document

Title or Type of Document: Attachment C Non Collusion Affidavit
Document Date: 5/31/19 Number of Pages: 1
Signer(s) Other Than Named Above:

©2017 National Notary Association

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.

Healthy Hearth LLC
Contractor

David C. Kelly
By: (signature)

6/5/2019
(date)

David C. Kelly / President / Managing Partner
(Name and Title)

Submitted By: **Healthy Hearth LLC**
30521 Coplasa Street
Lake Elsinore, CA 92530 Phone: 951-264-8725

Topic: **StoveCAT Emission Control Retro-Fit Device for Wood heaters**

ITEM 6

Existing Test Data

Healthy Hearth LLC is submitting this information for your review and consideration per the requirements of FNSB RFP No. 19047:

Submitted By: **Healthy Hearth LLC**
30521 Coplasa Street
Lake Elsinore, CA 92530 Phone: 951-264-8725

TESTING & PERFORMANCE

1) Projected Performance of the StoveCAT™ IAW Testing Guidelines Outlined in RFP-19048

RFP-19048 from the FNSB describes PM emissions testing of an emission control device to be installed on a pellet fueled heater. The stated goal of the proposed testing is very ambitious, to reduce the PM emissions of a pellet fueled appliance to a level comparable to an oil fired heater.

We believe that the **StoveCAT™** will perform very well in the test environment described in FNSB RFP-19048. The unique design of the **StoveCAT™** allows for for excellent exhaust flow reticulated catalyst support of the **StoveCAT™** actually scrubs the polluted airstream. Moisture content is always a key consideration in evaluating the performance of catalytic device. Pellets are heavily compressed, so they're dense and low in moisture, generally under 10% creating a hotter more intense flame. The burn pot serves as the carburetor for the stove, mixing the air and fuel to create combustion. This operation sets up perfectly for the add-on **StoveCAT™** device to be effective. The average exhaust temperature of a pellet stove is around 400F. This is a perfect temp for **StoveCAT™** operation. It is hot enough to activate the catalyst but low enough to create hydrocarbons to fuel catalytic activity. The average PM emissions from a pellet appliance are .6 g/hr. to 3.1 g/hr. averaging 1.6 g/hr. These operating variables coupled with the very low moisture content of the pellet fuel create a perfect operating scenario for the **StoveCAT™** to reduce the PM from a pellet appliance to a level never before seen.

Comments from Healthy Hearth Regarding of the StoveCAT™ ECD: In the next section, you will find a test report dated 29 Dec 2015 from OMNI-Test Laboratories, Inc. (OMNI) for emissions testing funded by Puget Sound Clean Air Agency (PSCAA) to evaluate whether provided woodstove retrofit devices were able to effectively reduce particulate matter (PM) and polycyclic aromatic hydrocarbon (PAH) emissions from residential wood burning stoves that predate EPA emissions certification.

Testing was performed on two different uncertified stoves without any retrofit device over a range of specified operating conditions in order to establish a baseline set of results. The stoves were then equipped with the provided retrofit devices to compare test results against the baseline data. This evaluation contracted is for emission evaluations only. The retrofit devices connected to the systems were not evaluated against any safety or installation requirements.

The emissions testing conducted by Omni Test of the **StoveCAT™** Emission Control Device concluded that a Non-EPA Certified wood heater retrofitted with a **StoveCAT™** ECD, would burn much cleaner with PM and PAH reductions over 80%, VOC reductions of 74% and CO emission reductions over 60%. However, even with very high percentage reductions in pollutants, the final PM emissions with the **StoveCAT™** installed were still higher than the current EPA standard of 4.5 g/hr. How can that be? The explanation is simple. There were so many exceptions taken to the standards governing the test environment that the final emission results were much higher than they would have been had the Method 28 and 5G Standards been followed without exceptions especially related to fuel moisture content and burn times. Some notable exceptions to EPA Method 28 and Method 5G are as follows:

a) Due to the nature of the stoves used in the test, which have poor heat transfer efficiency, stack gas temperatures were much higher than those typically encountered during 5G-3 testing. As a result of these high stack temperatures, the dilution tunnel flow rate needed to be increased in order to keep tunnel temperatures and filter temperatures manageable. This had a negative impact on the test results.

b) Equation 5G-4, emissions adjustment factor was not used. All emissions rates reported are the raw unadjusted values. *The adjustment factor changes emission values in a non-linear manner, which*

would have the effect of distorting the results of any emission reduction evaluations. This had a negative impact on the test results.

c) Sampling was not done isokinetically in accordance with 6.6.1. This test method is written for tests done on stacks that have flow rates which are more or less constant for the duration of the test. For a batch load process such as a wood stove, flow rates are too variable from test to test and minute to minute to maintain isokinetic flow. Instead of using a hooked nozzle, the sample was withdrawn from the stack from a probe at 90 degrees to the flow of stack gases to negate any effects of stagnation, and the sample rate was kept constant throughout the test run. This had a negative impact on the test results.

d) Fuel moisture requirements specified in section 7.1.2 were ignored as required by the standard test plan to perform the tests with much higher moisture content in the fuel:

e) Test fuel loading densities were not strictly adhered to as specified in section 8.8.4. All fuel loads were identical with respect to the number and mix of 2x4s and 4x4s, as well as test fuel length. These parameters were established using test loads in the moisture range specified in section 7.1.2. The majority of the higher moisture tests loads were well over the specified loading density, as they contained as much as an extra 3 lbs. of water compared to a fuel load in the proper moisture range. This had a negative impact on the test results.

f) After the wet fuel is loaded onto the coal-bed, the catalyst firing is delayed by the slow ignition of the wood fuel. Catalytic activation can be delayed by as much as 17-20 minutes due to the higher moisture content, unlike a fire with wood fuel @ <20% moisture content where the catalyst becomes active within 3-5 minutes.

g) A disproportional amount of particulate emissions occur during the kindling phase (or re-fueling phase) before efficient combustion and particulate mitigation (secondary combustion through catalytic activity) is underway. Because a "hot start" is used per Method 28 for the certification method, i.e., particulate sampling is started immediately after a fuel charge is added to an already hot coal bed. The highest concentrations of PM were found to be 23.35 to 47.54 mg/m3 upon initial combustion for a wood moisture content of 37.4%. After 120 minutes, the concentrations of PM were reduced to an average of 4.57 mg/m3. During normal operation, fuel wood is re-supplied to the wood heater every 120 minutes, though the average test runs here were conducted for 159 minutes. The total PM concentration depends on the wood moisture content and total wood burning cycle time. An increase of the wood moisture content exponentially enhances the particulate concentration early in the burn cycle. The smoke particles concentrations are reduced as the combustion progresses. Carbon monoxide is the first effluent gas released following steam and as the CO burns, the catalyst temperature will rise. Then the hot **StoveCAT™ ™ ™** catalyst can easily and efficiently eliminate the hydrocarbons released as the wood temperature increases and the hydrocarbon content is distilled off.

h) Based on a 2004 Hearth, Patio and Barbecue Association survey the average freestanding woodstove length of use is 5.8 hours. In colder climates where 90% of wood heaters are used, particularly in rural settings where wood combustion is more likely to be the primary source of heat, hot start-up scenarios are very common. The 2004 Hearth, Patio and Barbecue Association survey also showed that 44% of stoves are used eight or more hours per occasion (See table below).

Length of use per occasion (hours)	Percent of total freestanding stoves
Never burned	10%
1 hour or less	3%
1 to 3 hours	12%
3 to 5 hours	15%
5 to 7 hours	16%
8 or more hours	44%

i) PAH and VOC concentrations exhibit a similar influence from wood moisture content and the wood burning period. In addition, the PAH concentration exhibits a non-linear dependence on smoke particle concentration, underscoring the significance of wood moisture content and burning period with respect to both physical and chemical characteristics of smoke particles.

j) Crib Wood" dimensional lumber Douglas Fir, untreated, certified C grade or better, air-dried with a 16-20% wet basis moisture content is normally required for the Method 28 fueling protocol. The fact that the wood moisture content for most of this testing was artificially increased to the 30-40% range by soaking the dimensional lumber fuel cribs in water for 48 hours prior to testing caused the catalytic **StoveCAT™** to remain inactive for much of the critical start-up period when much of the PM is released.

k) During testing, due to the extremely high moisture content, the baseline data for g/kg of PM was over 70% higher on average than the baseline 5G standard or AP-42 value of 15.3 g/kg (5H equivalent), or the 12.3 g/kg (5G equivalent). See comparison chart below column H:

A	B	C	D	E	F	G	H
Run ID	**Stove**	**Retrofit**	**ID**	**Burn Rate (kg/hr)**	**Emissions Factor (g/kg)**	**PM Emissions Factor g/kg 5G Equivilent (Reference)**	**PM Emissions Factor Increase from Moisture Content %**
2	Schrader	Baseline	D	1.39	24.29	12.3	51%
4	Schrader	Baseline	D	2	18.11	12.3	68%
5	Schrader	Baseline	B	1.61	18.16	12.3	68%
6	Schrader	Baseline	B	1.89	21.26	12.3	58%
7	Schrader	Baseline	C	3.7	9.8	12.3	126%
8	Schrader	Baseline	C	3.45	8.93	12.3	138%
18	Schrader	Grace Fire	D	2.14	3.46	–	–
19	Schrader	Grace Fire	B	2.38	3.65	–	–
20	Schrader	Grace Fire	C	3.74	1.71	–	–
21	Princess	Baseline	B	1.7	32.63	12.3	38%
22	Princess	Baseline	C	3.44	14.22	12.3	86%
23	Princess	Baseline	B	1.55	35.42	12.3	35%
24	Princess	Baseline	D	1.49	26.76	12.3	46%
25	Princess	Baseline	D	1.46	24.48	12.3	50%
26	Princess	Baseline	C	4.81	14.28	12.3	86%
31	Princess	Grace Fire	C	2.47	4.34	–	–
32	Princess	Grace Fire	B	1.43	8.59	–	–
33	Princess	Grace Fire	D	1.18	5.46	–	–
34	Princess	Grace Fire	B	1.42	10.63	–	–

FIGURE 2: PM FACTORS DURING TESTING OF STOVECAT™ ™ ™ RETRO-FIT

l) Method 28 as revised covers the fueling and operating procedures for measuring PM emissions from wood fired room heaters and fireplace inserts. Four burn rate categories (kg/hr of wood fuel burned) are used to calculate the weighted average emission rate, based on a hot to hot (no cold start test cycle). Method 28 incorporates the provisions of ASTM E2780-10 except that the startup, burn rate categories, low burn rate requirements and weightings of Method 28 must be used.

Conclusions: There should be a direct and consistent correlation between the baseline PM emissions and the **StoveCAT™** PM emissions at the same or similar burn rates and condition of the wood fuel.

In August 2001, we conducted initial EPA Certification testing of our catalytic component at Omni Environmental. The testing was conducted per EPA Method 28 and 5H. This involved 4 test runs in the same Princess wood heater that was used in the **StoveCAT™** Retro-Fit testing as referenced in the chart shown above.

The average PM reduction during the 2001 testing was 91% when compared to the 5H Baseline Standard of 15 g/kg of PM emissions as shown in the chart below: (See Figure 3)

RUN #	BURN KG/HR	PM 2.5 G/KG	G/KG METHOD 5H BASELINE	REDUCTION %
1	1.79	1.84	15	88%
2	1.44	1.35	15	91%
3	1.18	1.54	15	90%
4	0.99	0.77	15	95%

FIGURE 3: PM FACTORS DURING TESTING IN 2001

During the **StoveCAT™** Retro-Fit evaluation testing, we were able to reduce PM emissions by an average of 82%. This should have been sufficient to achieve a PM emissions average in g/hr. that is below the current EPA standard of 4.5 g/hr. However, the higher moisture content of the wood fuel during retro-fit testing coupled with the shorter burn times (average 159.3 minutes), were too much for the **StoveCAT™** to overcome in order to achieve our goal of PM emissions < 4.5 g/hr.

We believe that the results from the 2001 EPA certification testing of our catalyst reflect more accurately the potential of the **StoveCAT™** catalytic retro-fit device. During the 2001 testing, the average burn time was 282.5 minutes or 4.7 hours with wood fuel moisture averaging 21.2%. The weighted average results from our 2001 EPA Certification Testing were 1.28 g/hr. This is well below the requirements of any current standard and easily demonstrates that we have the best performing catalytic component in the market.

We believe that the **StoveCAT™** Emission Control Device for wood heaters will provide PM emissions reduction below the current EPA standard of 4.5 g/hr. when tested to the requirements of EPA Method 28 utilizing the EPA 5G-3 Sampling Method without deviating from the established EPA requirements for moisture content or burn times.

Submitted By: **Healthy Hearth LLC**
30521 Coplasa Street
Lake Elsinore, CA 92530 Phone: 951-264-8725

Topic: **StoveCAT Emission Control Retro-Fit Device for Wood heaters**

ITEM 6

Existing Test Data
Retro-Fit Testing @ Omni-Test
Report No. 0323WS001N
29 Dec 2015
(No Page Limit)

Healthy Hearth LLC is submitting this information for your review and consideration per the requirements of FNSB RFP No. 19047:

REDACTED VERSION, 6/5/2018

Woodstove Retrofit Efficacy Testing
OMNI Report# 0323WS001N

Prepared for:

Dr. Phillip Swartzendruber
Puget Sound Clean Air Agency
1904 Third Avenue – Suite 105
Seattle, WA 98101

Prepared by:

OMNI-Test Laboratories, Inc.
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Portland, OR 97230

December 29, 2015

REDACTED VERSION, 6/5/2018

1. Introduction

OMNI-Test Laboratories, Inc. (OMNI) was contracted by Puget Sound Clean Air Agency (PSCAA) to evaluate whether provided woodstove retrofit devices were able to effectively reduce particulate matter (PM) and polycyclic aromatic hydrocarbon (PAH) emissions from residential wood burning stoves that predate EPA emissions certification.

Testing was performed on two different uncertified stoves without any retrofit device over a range of specified operating conditions in order to establish a baseline set of results. The stoves were then equipped with the provided retrofit devices to compare test results against the baseline data. This evaluation contracted is for emission evaluations only. The retrofit devices connected to the systems were not evaluated against any safety or installation requirements.

The two uncertified stoves used for testing were already in OMNI's possession for the purpose of performing studies similar in nature to this project. The stoves and their relative condition are discussed in Section 2 of this report.

A total of four retrofit devices were evaluated for this project. Each device for testing was selected by PSCAA. A representative sample of each retrofit device was submitted to OMNI from the manufacturer of each product at the beginning of the testing phase. Further descriptions of each retrofit device are discussed in Section 2 of this report.

Testing was conducted at OMNI's facilities in Portland, Oregon by Sebastian Button between June 24 and October 16, 2015.

Emissions of total particles (PM) and PAHs were measured. Additionally, carbon dioxide (CO_2), carbon monoxide (CO), temperatures (chimney, room, meter boxes, particulate filters and dilution tunnel), fuel mass, and air and sample flow were measured to support emission and efficiency calculations. Standard methods were used to the extent feasible for all testing.

A detailed description of the testing program is provided as Section 2. The results of the testing are summarized in Section 3. Complete individual test data records, calculations, laboratory notes, PAH lab analyses, calibration records, and photographic documentation can be found in appendices attached to this report.

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2. Methodology

2.1 Measurement Methods

Standard sampling methods were used to collect and monitor all parameters. Table 1 lists the methods used and the pollutants measured. PM samples were collected from a dilution tunnel. PAH samples and supporting measurements were taken from the heater chimney (stack). The pollutants measured included:

- PM measured from the dilution tunnel
- PAHs measured from the stack
- Carbon monoxide (CO) measured from the stack
- Carbon dioxide (CO_2) measured from the stack

Table 1 - Compounds, Parameters, Sampling and Monitoring Methods, Collection and Monitoring Devices, Analytical Laboratories, and Analytical Methods

Group	Analytical Compounds	Sampling Method	Collection Device	Analytical Laboratory	Analytical Method
Particles	Total PM	EPA Method 5G-3	47 mm Glass Fiber A/E Filter	OMNI	Gravimetric
Gases	Carbon Monoxide (CO)	EPA Method 10	Non-dispersive infrared analyzer (NDIR)	N/A	N/A
	Carbon Dioxide(CO_2)	EPA Method 3A	Non-dispersive infrared analyzer (NDIR)	N/A	N/A
	Polycyclic Aromatic Hydrocarbons (PAH)	EPA Compendium Method 0010	102 mm Glass Fiber A/E Filter & XAD-2 Sorbent Resin	RJ Lee Group	EPA Compendium Method TO-13 Modified*
Efficiency	Flue Gas CO, CO_2	CSA B415.1-10	Non-dispersive infrared analyzer (NDIR)	N/A	N/A

*See appropriate laboratory reports in the appendices for modifications to analytical method

In addition to the above sampling methods, the stoves were operated in accordance with EPA Method 28.

2.1.1 Method Modifications

The test methods listed in Section 2.1 were strictly adhered to with a couple of notable exceptions detailed below.

EPA Method 5G-3:

1. Section 8.5.1 specifies a dilution tunnel flow rate of 140±14 dscf/min. Due to the nature of the stoves used in this project, which have poor heat transfer efficiency, stack gas temperatures were much higher than those typically encountered during 5G-3 testing. As a result of these high stack temperatures, the dilution tunnel flow rate needed to be increased in order to keep tunnel temperatures and filter temperatures manageable.
2. Equation 5G-4, emissions adjustment factor was not used. All emissions rates reported are the raw unadjusted values. The adjustment factor changes emission values in a non-linear manner, which would have the effect of distorting the results of any emission reduction evaluations.

EPA Method 28:

1. Fuel moisture requirements specified in section 7.1.2 were ignored as required by the test plan to perform tests with higher moisture fuel.
2. Test fuel loading densities were not strictly adhered to as specified in section 8.8.4. All fuel loads were identical with respect to the number and mix of 2x4s and 4x4s, as well as test fuel length. These parameters were established using test loads in the moisture range specified in section 7.1.2. The majority of the higher moisture tests loads were well over the specified loading density, as they contained as much as an extra 3 lbs of water when compared to a fuel load in the proper moisture range.

EPA Compendium Method 0010

1. Sampling was not done isokinetically in accordance with 6.6.1. This test method is written for tests done on stacks that have flow rates which are more or less constant for the duration of the test. For a batch load process such as a wood stove, flow rates are too variable from test to test and minute to minute to maintain isokinetic flow. Instead of using a hooked nozzle, the sample was withdrawn from the stack from a probe at 90 degrees the flow of stack gases, to negate any effects of stagnation, and the sample rate was kept constant throughout the test run.
2. Upon completion of each test run the filter and XAD-2 cartridge from the PAH sampling system were sealed and stored in a refrigerator until a batch of samples were ready for shipment to the analytical laboratory, RJ Lee Group. All sample recovery and analysis were performed as described in the lab reports in Appendix 3.

2.2 Test Appliances and Retrofit Devices

Schrader Woodstove (Unknown Model)

The Schrader stove is a freestanding woodstove with a medium (1.64 ft^3) sized firebox and a 6 inch flue collar located on the top of the unit. The unit is constructed primarily of steel and the firebox is lined with firebrick.

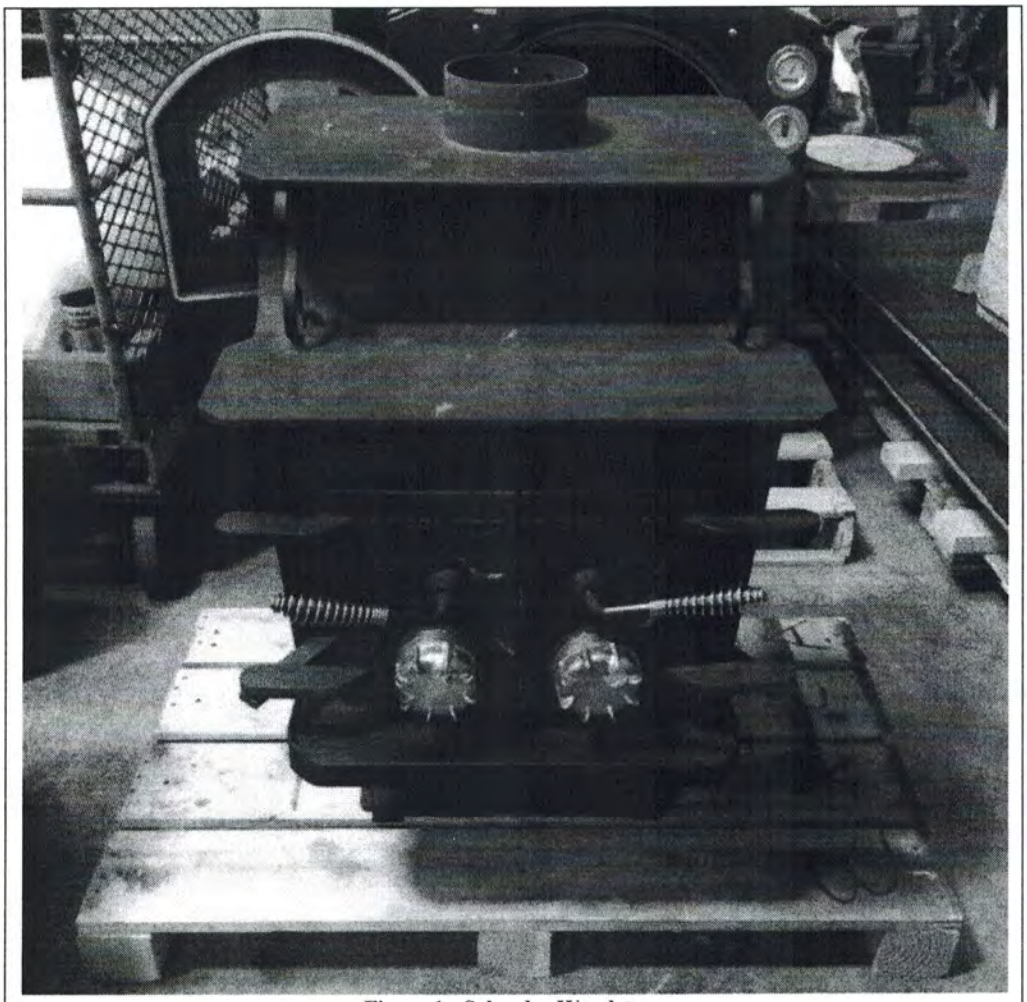

Figure 1 - Schrader Woodstove

Combustion air is controlled by dual spin draft knobs on each of the two doors. This stove does not contain any sort of baffling or secondary air combustion. Although the stove body is in good overall condition, the doors do not close tightly, causing an air leak into the stove. This air leak lead to relatively high "low burn" tests, as summarized in Section 3.

Blaze King Princess (Pre-NSPS Non-catalytic model)

The princess stove is a freestanding woodstove with a slightly larger (2.14 ft^3) sized firebox and a 6 inch flue collar located on the top of the unit. This unit is also constructed primarily of steel and the firebox is lined with firebrick.

Figure 2 - Princess Woodstove

Combustion air enters the firebox through an opening located at the bottom rear of the heater and is controlled by a flapper door connected to a bimetallic thermostat coil, which reduces airflow with increasing temperature in order to maintain a constant combustion rate. Similar to the Schrader stove, this appliance does not have any secondary air system or internal flame baffling.

Grace Fire

The Grace Fire retrofit device is a passive system that utilizes a three stage reticulated ceramic catalyst structure and a secondary air intake system to ensure adequate combustion air is present.

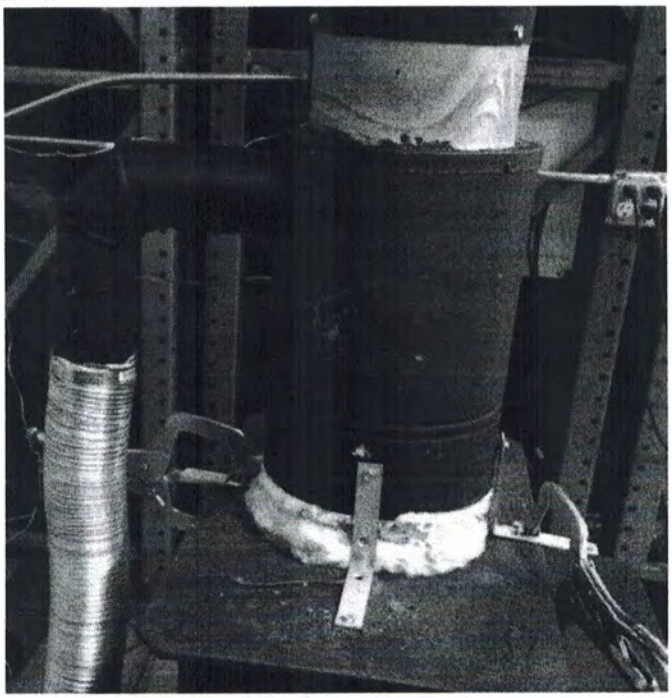

Figure 5 – Grace-Fire Device

2.3 Test Plan and Summary of Test Runs

The experimental design for this project was developed by PSCAA. For each of the two uncertified woodstoves that were used for testing, a set of baseline emissions results were established by performing a pair of tests with the stove operating within three different operational parameters pairs, as described in Table 2. This resulted in six baseline emissions tests for each woodstove.

Table 2 - Test Parameters

Parameter Pair ID	Burn Rate	Wood Moisture
B	Low	Higher (30-40% Dry Basis)
C	High	Higher (30-40% Dry Basis)
D	Low	Lower (19-25% Dry Basis)

For the tests performed on these particular woodstoves, the term "Low Burn Rate" does not strictly adhere to the Method 28 definition of a low burn (<0.80 kg/hr), but is rather in reference to the air control setting, which was adjusted the lowest possible level for each given stove during these tests. As the data summary in Section 3 shows, the low burn rates were higher than 0.80 kg/hr. Similarly, in an effort to maintain consistent results, the target burn rate for "High Burn Rate" tests was 3.0 – 4.0 kg/hr, rather than burning the appliances at the maximum air setting.

Upon completion of the baseline tests on the Schrader stove, each of the four retrofit devices was installed in accordance with instructions received from each manufacturer, and tested once at each of the three parameter pairs. The top three performing retrofit devices, as determined by PSCAA, were then subjected to further tests on the Princess stove.

Table 3 presents a summary of all tests performed, including which test parameter was used. For all tests the air controls were set at the beginning of the test, and not changed until testing was completed; see laboratory run notes in Appendix 4 for exact test settings.

Table 3 - Summary of Test Runs Performed

Run ID	Test Date	Stove	Test Parameter	Retrofit ID
1	Test run not included in dataset due to sampling equipment malfunctions			
2	6/24/2015	Schrader	D	Baseline
3	Test run not included in dataset due to platform scale issues which lead to mistiming of test start and end criteria.			
4	7/16/2015	Schrader	D	Baseline
5	7/17/2015	Schrader	B	Baseline
6	7/20/2015	Schrader	B	Baseline
7	7/21/2015	Schrader	C	Baseline
8	7/21/2015	Schrader	C	Baseline
18	8/24/2015	Schrader	D	Grace Fire
19	8/25/2015	Schrader	B	Grace Fire
20	8/26/2015	Schrader	C	Grace Fire
21	9/9/2015	Princess	B	Baseline
22	9/10/2015	Princess	C	Baseline
23	9/11/2015	Princess	B	Baseline
24	9/14/2015	Princess	D	Baseline
25	9/16/2015	Princess	D	Baseline
26	9/17/2015	Princess	C	Baseline
31	9/28/2015	Princess	C	Grace Fire
32	9/29/2015	Princess	B	Grace Fire
33	9/30/2015	Princess	D	Grace Fire
34	10/1/2015	Princess	B	Grace Fire

3. Testing Results

3.1 Particulate Sampling Results

Particulate emissions results for all test runs performed are summarized in Table 4. Complete minute by minute particulate sampling data for each run is presented in Appendix 1. Each test run presented passed all quality checks for precision and proportionality, including pre and post-test leak checks. Table 5 summarizes the calculated efficiencies and CO emissions using CSA B415.1.

As indicated in the laboratory notes in Appendix 4, during several test runs, the front filter of the sampling trains were changed out during testing. The changes were necessary due to particle and moisture loading on the filters, which caused the sample rates to drop to the point that sampling pumps could not maintain sufficient flow. This is a relatively common issue with high emissions appliances, and is one of reasons dual sampling trains are used, to validate results when one of the trains experiences a temporary loss in flow. As mentioned above, even with the filter change outs, sampling proportionality and dual train comparisons were within acceptable limits for each test run.

3.2 PAH Sampling Results

PAH emissions results are summarized in Table 6. As the lab reports in Appendix 3 explain, for the first set of samples received (Run 2), the filter and the XAD-2 extractions were analyzed separately, but for all subsequent analyses the extractions were combined into a single sample for cost effectiveness.

One issue of note regarding the Run 2 samples; there was the large concentration of phenolic compounds in the extracts, which proved disruptive to the chromatography equipment. After consultations with the analytical laboratory director, it was determined that all subsequent analyses would include a "clean-up" process on the extractions to eliminate the extraneous materials. This process was done primarily to protect the laboratory equipment from potential unwarranted damage, and also allowed for a "cleaner," targeted analysis of EPA 7-PAHs, which are classified as probable human carcinogens.

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Table 4 – Particulate Matter Emission Results

Run ID	Stove	Retrofit	Parameter ID	Burn Rate (kg/hr)	Emissions Rate (g/hr)	Emissions Factor (g/kg)	Total Emissions (g)
2	Schrader	Baseline	D	1.39	33.82	24.29	117.80
4	Schrader	Baseline	D	2.00	36.17	18.11	85.01
5	Schrader	Baseline	B	1.61	29.3	18.16	86.94
6	Schrader	Baseline	B	1.89	40.25	21.26	101.30
7	Schrader	Baseline	C	3.70	36.23	9.8	55.54
8	Schrader	Baseline	C	3.45	30.79	8.93	48.75
18	Schrader	Grace Fire	D	2.14	7.39	3.46	15.65
19	Schrader	Grace Fire	B	2.38	8.68	3.65	18.38
20	Schrader	Grace Fire	C	3.74	6.41	1.71	8.44
21	Princess	Baseline	B	1.70	55.45	32.63	189.47
22	Princess	Baseline	C	3.44	48.99	14.22	90.64
23	Princess	Baseline	B	1.55	54.84	35.42	216.60
24	Princess	Baseline	D	1.49	40.01	26.76	140.69
25	Princess	Baseline	D	1.46	35.83	24.48	144.52
26	Princess	Baseline	C	4.81	68.7	14.28	87.02
31	Princess	Grace Fire	C	2.47	10.72	4.34	24.83
32	Princess	Grace Fire	B	1.43	12.31	8.59	46.57
33	Princess	Grace Fire	D	1.18	6.43	5.46	34.08
34	Princess	Grace Fire	B	1.42	15.11	10.63	65.21

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Table 5 - Efficiency and CO Emissions Results

Run ID	Stove	Retrofit	Parameter ID	HHV efficiency (%)	LHV efficiency (%)	CO emission factor (g/kg)	CO emission rate (g/hr)
2	Schrader	Baseline	D	64.2	69.4	207.2	288.6
4	Schrader	Baseline	D	68.7	74.3	163.6	327.1
5	Schrader	Baseline	B	66.7	72.0	169.4	273.5
6	Schrader	Baseline	B	66.9	72.3	153.9	291.4
7	Schrader	Baseline	C	69.3	74.9	124.6	460.9
8	Schrader	Baseline	C	66.1	71.5	130.6	450.4
18	Schrader	Grace Fire	D	69.2	74.8	40.4	86.3
19	Schrader	Grace Fire	B	67.7	73.2	34.7	82.5
20	Schrader	Grace Fire	C	64.4	69.6	51.5	192.8
21	Princess	Baseline	B	59.7	64.5	190.3	323.5
22	Princess	Baseline	C	59.0	63.7	157.9	544.0
23	Princess	Baseline	B	50.4	54.4	218.3	319.8
24	Princess	Baseline	D	57.2	61.8	204.0	305.5
25	Princess	Baseline	D	58.9	63.6	163.6	239.5
26	Princess	Baseline	C	55.3	59.7	205.3	988.1
31	Princess	Grace Fire	C	56.4	61.0	60.6	149.7
32	Princess	Grace Fire	B	56.3	60.8	108.7	155.8
33	Princess	Grace Fire	D	55.8	60.3	94.7	111.6
34	Princess	Grace Fire	B	55.0	59.5	111.2	159.3

Test Results - EPA Method 28 & 5G

Manufacturer: Schrader
Retrofit Device Grace Fire
Project No.: 0323WS001N
Test Parameter ID: D
Run: 18
Test Date: 08/24/15

Burn Rate (Composite)	**2.14 kg/hr dry**
Average Tunnel Temperature	132 degrees Fahrenheit
Average Gas Velocity in Dilution Tunnel - vs	18.45 feet/second
Average Gas Flow Rate in Dilution Tunnel - Qsd	11422.3 dscf/hour
Average Gas Flow Rate in Chimney Flue - Qsf	1163.7 dscf/hour
Average Delta p	0.071 inches H20
Average Delta H	1.14 inches H20
Total Time of Test	127 minutes

	PAH SAMPLE TRAIN	PM SAMPLE TRAIN 1	PM SAMPLE TRAIN 2
Total Sample Volume - Vm	8.970 cubic feet	14.460 cubic feet	16.363 cubic feet
Average Orifice Temperature	84 degrees Fahrenheit	93 degrees Fahrenheit	88 degrees Fahrenheit
Total Sample Volume (Standard Conditions) - Vmstd	8.758 dscf	14.187 dscf	16.024 dscf
Total Particulates - m_n		9.6 mg	9.9 mg
Particulate Concentration (dry-standard) - C_r/C_s		0.00068 grams/dscf	0.00062 grams/dscf
Total Particulate Emissions - E_T	See PAH Analysis	16.36 grams	14.94 grams
Particulate Emission Rate		7.73 grams/hour	7.06 grams/hour
Emissisons Factor		3.62 g/kg	3.30 g/kg
Difference from Average Total Particulate Emissions		0.71 grams	0.71 grams
	Dual Train Comparison Results Are Acceptable		

FINAL AVERAGE RESULTS

Total Particulate Emissions - E_T	15.65 grams
Particulate Emission Rate	**7.39 grams/hour**
Emissisons Factor	3.46 grams/kg

OMNI-Test Laboratories, Inc.

Manufacturer:	Schrader
Model:	Grace Fire
Date:	08/24/15
Run:	18
Control #:	N/A
Test Duration:	127
Output Category:	Low

Technicians: S. Button

Test Results in Accordance with CSA B415.1-09

	HHV Basis	LHV Basis
Overall Efficiency	69.2%	74.8%
Combustion Efficiency	97.5%	97.5%
Heat Transfer Efficiency	71%	76.8%

Output Rate (kJ/h)	29,305	27,799	**(Btu/h)**
Burn Rate (kg/h)	2.14	4.71	**(lb/h)**
Input (kJ/h)	42,331	40,155	**(Btu/h)**

Test Load Weight (dry kg)	4.52	9.97	**dry lb**
MC wet (%)	18.29		
MC dry (%)	22.38		
Particulate (g)	0		
CO (g)	183		
Test Duration (h)	2.12		

Emissions	**Particulate**	**CO**
g/MJ Output	0.00	2.95
g/kg Dry Fuel	0.00	40.40
g/h	0.00	86.34
lb/MM Btu Output	0.00	6.85

Air/Fuel Ratio (A/F)	14.03

VERSION: 2.3 3/23/2010

Test Results - EPA Method 28 & 5G

Manufacturer: Schrader
Retrofit Device Grace Fire
Project No.: 0323WS001N
Test Parameter ID: B
Run: 19
Test Date: 08/25/15

Burn Rate (Composite)	**2.38 kg/hr dry**
Average Tunnel Temperature	134 degrees Fahrenheit
Average Gas Velocity in Dilution Tunnel - vs	17.16 feet/second
Average Gas Flow Rate in Dilution Tunnel - Qsd	10599.7 dscf/hour
Average Gas Flow Rate in Chimney Flue - Qsf	1177.1 dscf/hour
Average Delta p	0.063 inches H20
Average Delta H	1.14 inches H20
Total Time of Test	127 minutes

	PAH SAMPLE TRAIN	PM SAMPLE TRAIN 1	PM SAMPLE TRAIN 2
Total Sample Volume - Vm	8.970 cubic feet	14.423 cubic feet	17.022 cubic feet
Average Orifice Temperature	82 degrees Fahrenheit	90 degrees Fahrenheit	86 degrees Fahrenheit
Total Sample Volume (Standard Conditions) - Vmstd	8.793 dscf	14.226 dscf	16.769 dscf
Total Particulates - m_n		11.6 mg	13.8 mg
Particulate Concentration (dry-standard) - C_r/C_s		0.00082 grams/dscf	0.00082 grams/dscf
Total Particulate Emissions - E_T	See PAH Analysis	18.29 grams	18.46 grams
Particulate Emission Rate		8.64 grams/hour	8.72 grams/hour
Emissisons Factor		3.63 g/kg	3.67 g/kg
Difference from Average Total Particulate Emissions		0.08 grams	0.08 grams
	Dual Train Comparison Results Are Acceptable		

FINAL AVERAGE RESULTS

Total Particulate Emissions - E_T	18.38 grams
Particulate Emission Rate	**8.68 grams/hour**
Emissisons Factor	3.65 grams/kg

OMNI-Test Laboratories, Inc.

Manufacturer:	Schrader
Model:	Grace Fire
Date:	08/25/15
Run:	19
Control #:	N/A
Test Duration:	127
Output Category:	Low

Technicians: S. Button

Test Results in Accordance with CSA B415.1-09

	HHV Basis	LHV Basis
Overall Efficiency	67.7%	73.2%
Combustion Efficiency	97.9%	97.9%
Heat Transfer Efficiency	69%	74.7%

Output Rate (kJ/h)	31,908	30,268	**(Btu/h)**
Burn Rate (kg/h)	2.38	5.24	**(lb/h)**
Input (kJ/h)	47,141	44,719	**(Btu/h)**

Test Load Weight (dry kg)	5.04	11.10	**dry lb**
MC wet (%)	25.99		
MC dry (%)	35.12		
Particulate (g)	0		
CO (g)	175		
Test Duration (h)	2.12		

Emissions	**Particulate**	**CO**
g/MJ Output	0.00	2.58
g/kg Dry Fuel	0.00	34.65
g/h	0.00	82.45
lb/MM Btu Output	0.00	6.01

Air/Fuel Ratio (A/F)	13.70

VERSION: 2.3 3/23/2010

Test Results - EPA Method 28 & 5G

Manufacturer: Schrader
Retrofit Device Grace Fire
Project No.: 0323WS001N
Test Parameter ID: C
Run: 20
Test Date: 08/26/15

Burn Rate (Composite)	**3.74 kg/hr dry**
Average Tunnel Temperature	177 degrees Fahrenheit
Average Gas Velocity in Dilution Tunnel - vs	19.44 feet/second
Average Gas Flow Rate in Dilution Tunnel - Qsd	11174.6 dscf/hour
Average Gas Flow Rate in Chimney Flue - Qsf	1529.2 dscf/hour
Average Delta p	0.076 inches H20
Average Delta H	1.16 inches H20
Total Time of Test	79 minutes

	PAH SAMPLE TRAIN	PM SAMPLE TRAIN 1	PM SAMPLE TRAIN 2
Total Sample Volume - Vm	5.580 cubic feet	9.105 cubic feet	9.944 cubic feet
Average Orifice Temperature	83 degrees Fahrenheit	93 degrees Fahrenheit	87 degrees Fahrenheit
Total Sample Volume (Standard Conditions) - Vmstd	5.446 dscf	8.927 dscf	9.752 dscf
Total Particulates - m_n		5.3 mg	5.4 mg
Particulate Concentration (dry-standard) - C_r/C_s		0.00059 grams/dscf	0.00055 grams/dscf
Total Particulate Emissions - E_T	See PAH Analysis	8.74 grams	8.15 grams
Particulate Emission Rate		6.63 grams/hour	6.19 grams/hour
Emissisons Factor		1.77 g/kg	1.65 g/kg
Difference from Average Total Particulate Emissions		0.29 grams	0.29 grams
	Dual Train Comparison Results Are Acceptable		

FINAL AVERAGE RESULTS

Total Particulate Emissions - E_T	8.44 grams
Particulate Emission Rate	**6.41 grams/hour**
Emissisons Factor	1.71 grams/kg

OMNI-Test Laboratories, Inc.

Manufacturer:	Schrader
Model:	Grace Fire
Date:	08/26/15
Run:	20
Control #:	N/A
Test Duration:	79
Output Category:	High

Technicians: S. Button

Test Results in Accordance with CSA B415.1-09

	HHV Basis	LHV Basis
Overall Efficiency	64.4%	69.6%
Combustion Efficiency	96.5%	96.5%
Heat Transfer Efficiency	67%	72.2%

Output Rate (kJ/h)	47,776	45,320	**(Btu/h)**
Burn Rate (kg/h)	3.74	8.25	**(lb/h)**
Input (kJ/h)	74,148	70,337	**(Btu/h)**

Test Load Weight (dry kg)	4.93	10.86	**dry lb**
MC wet (%)	26.11		
MC dry (%)	35.34		
Particulate (g)	0		
CO (g)	254		
Test Duration (h)	1.32		

Emissions	**Particulate**	**CO**
g/MJ Output	0.00	4.04
g/kg Dry Fuel	0.00	51.51
g/h	0.00	192.79
lb/MM Btu Output	0.00	9.38

Air/Fuel Ratio (A/F)	11.87

VERSION: 2.3 3/23/2010

Test Results - EPA Method 28 & 5G

Manufacturer: Princess
Retrofit Device Grace Fire
Project No.: 0323WS001N
Test Parameter ID: C
Run: 31
Test Date: 09/28/15

Burn Rate (Composite)	**2.47 kg/hr dry**
Average Tunnel Temperature	131 degrees Fahrenheit
Average Gas Velocity in Dilution Tunnel - vs	16.70 feet/second
Average Gas Flow Rate in Dilution Tunnel - Qsd	10305.8 dscf/hour
Average Gas Flow Rate in Chimney Flue - Qsf	1562.2 dscf/hour
Average Delta p	0.067 inches H20
Average Delta H	1.11 inches H20
Total Time of Test	139 minutes

	PAH SAMPLE TRAIN	PM SAMPLE TRAIN 1	PM SAMPLE TRAIN 2
Total Sample Volume - Vm	9.817 cubic feet	15.628 cubic feet	17.123 cubic feet
Average Orifice Temperature	79 degrees Fahrenheit	88 degrees Fahrenheit	84 degrees Fahrenheit
Total Sample Volume (Standard Conditions) - Vmstd	9.625 dscf	15.274 dscf	16.726 dscf
Total Particulates - m_n		15.7 mg	17.6 mg
Particulate Concentration (dry-standard) - C_r/C_s		0.00103 grams/dscf	0.00105 grams/dscf
Total Particulate Emissions - E_T	See PAH Analysis	24.54 grams	25.12 grams
Particulate Emission Rate		10.59 grams/hour	10.84 grams/hour
Emissisons Factor		4.29 g/kg	4.39 g/kg
Difference from Average Total Particulate Emissions		0.29 grams	0.29 grams
	Dual Train Comparison Results Are Acceptable		

FINAL AVERAGE RESULTS

Total Particulate Emissions - E_T	24.83 grams
Particulate Emission Rate	**10.72 grams/hour**
Emissisons Factor	4.34 grams/kg

OMNI-Test Laboratories, Inc.

Manufacturer:	Princess
Model:	Grace Fire
Date:	09/28/15
Run:	31
Control #:	N/A
Test Duration:	139
Output Category:	High

Technicians: S. Button

Test Results in Accordance with CSA B415.1-09

	HHV Basis	LHV Basis
Overall Efficiency	56.4%	61.0%
Combustion Efficiency	96.4%	96.4%
Heat Transfer Efficiency	59%	63.3%

Output Rate (kJ/h)	27,604	26,186	**(Btu/h)**
Burn Rate (kg/h)	2.47	5.44	**(lb/h)**
Input (kJ/h)	48,925	46,410	**(Btu/h)**

Test Load Weight (dry kg)	5.72	12.61	**dry lb**
MC wet (%)	24.94		
MC dry (%)	33.23		
Particulate (g)	0		
CO (g)	347		
Test Duration (h)	2.32		

Emissions	**Particulate**	**CO**
g/MJ Output	0.00	5.42
g/kg Dry Fuel	0.00	60.63
g/h	0.00	149.73
lb/MM Btu Output	0.00	12.61

Air/Fuel Ratio (A/F)	20.35

VERSION: 2.3 3/23/2010

Test Results - EPA Method 28 & 5G

Manufacturer: Princess
Retrofit Device Grace Fire
Project No.: 0323WS001N
Test Parameter ID: B
Run: 32
Test Date: 09/29/15

Burn Rate (Composite)	**1.43 kg/hr dry**
Average Tunnel Temperature	112 degrees Fahrenheit
Average Gas Velocity in Dilution Tunnel - vs	17.44 feet/second
Average Gas Flow Rate in Dilution Tunnel - Qsd	11130.6 dscf/hour
Average Gas Flow Rate in Chimney Flue - Qsf	965.1 dscf/hour
Average Delta p	0.070 inches H20
Average Delta H	1.08 inches H20
Total Time of Test	227 minutes

	PAH SAMPLE TRAIN	PM SAMPLE TRAIN 1	PM SAMPLE TRAIN 2
Total Sample Volume - Vm	16.033 cubic feet	25.173 cubic feet	26.954 cubic feet
Average Orifice Temperature	80 degrees Fahrenheit	89 degrees Fahrenheit	86 degrees Fahrenheit
Total Sample Volume (Standard Conditions) - Vmstd	15.696 dscf	24.574 dscf	26.243 dscf
Total Particulates - m_n		27.1 mg	29.1 mg
Particulate Concentration (dry-standard) - C_r/C_s		0.00110 grams/dscf	0.00111 grams/dscf
Total Particulate Emissions - E_T	See PAH Analysis	46.44 grams	46.69 grams
Particulate Emission Rate		12.27 grams/hour	12.34 grams/hour
Emissisons Factor		8.57 g/kg	8.61 g/kg
Difference from Average Total Particulate Emissions		0.13 grams	0.13 grams
	Dual Train Comparison Results Are Acceptable		

FINAL AVERAGE RESULTS

Total Particulate Emissions - E_T	46.57 grams
Particulate Emission Rate	**12.31 grams/hour**
Emissisons Factor	8.59 grams/kg

OMNI-Test Laboratories, Inc.

Manufacturer:	Princess
Model:	Grace Fire
Date:	09/29/15
Run:	32
Control #:	N/A
Test Duration:	227
Output Category:	Low

Technicians: S. Button

Test Results in Accordance with CSA B415.1-09

	HHV Basis	LHV Basis
Overall Efficiency	56.3%	60.8%
Combustion Efficiency	93.0%	93.0%
Heat Transfer Efficiency	61%	65.4%

Output Rate (kJ/h)	15,980	15,159	**(Btu/h)**
Burn Rate (kg/h)	1.43	3.16	**(lb/h)**
Input (kJ/h)	28,389	26,930	**(Btu/h)**

Test Load Weight (dry kg)	5.42	11.95	**dry lb**
MC wet (%)	24.37		
MC dry (%)	32.22		
Particulate (g)	0		
CO (g)	590		
Test Duration (h)	3.78		

Emissions	**Particulate**	**CO**
g/MJ Output	0.00	9.75
g/kg Dry Fuel	0.00	108.74
g/h	0.00	155.84
lb/MM Btu Output	0.00	22.66

Air/Fuel Ratio (A/F)	23.32

VERSION: 2.3 3/23/2010

Test Results - EPA Method 28 & 5G

Manufacturer: Princess
Retrofit Device Grace Fire
Project No.: 0323WS001N
Test Parameter ID: D
Run: 33
Test Date: 09/30/15

Burn Rate (Composite)	**1.18 kg/hr dry**
Average Tunnel Temperature	106 degrees Fahrenheit
Average Gas Velocity in Dilution Tunnel - vs	16.10 feet/second
Average Gas Flow Rate in Dilution Tunnel - Qsd	10410.0 dscf/hour
Average Gas Flow Rate in Chimney Flue - Qsf	908.5 dscf/hour
Average Delta p	0.065 inches H20
Average Delta H	1.12 inches H20
Total Time of Test	318 minutes

	PAH SAMPLE TRAIN	PM SAMPLE TRAIN 1	PM SAMPLE TRAIN 2
Total Sample Volume - Vm	22.460 cubic feet	35.795 cubic feet	39.579 cubic feet
Average Orifice Temperature	78 degrees Fahrenheit	88 degrees Fahrenheit	85 degrees Fahrenheit
Total Sample Volume (Standard Conditions) - Vmstd	22.113 dscf	35.117 dscf	38.750 dscf
Total Particulates - m_n		22 mg	23.6 mg
Particulate Concentration (dry-standard) - C_r/C_s		0.00063 grams/dscf	0.00061 grams/dscf
Total Particulate Emissions - E_T	See PAH Analysis	34.56 grams	33.60 grams
Particulate Emission Rate		6.52 grams/hour	6.34 grams/hour
Emissisons Factor		5.53 g/kg	5.38 g/kg
Difference from Average Total Particulate Emissions		0.48 grams	0.48 grams
	Dual Train Comparison Results Are Acceptable		

FINAL AVERAGE RESULTS

Total Particulate Emissions - E_T	34.08 grams
Particulate Emission Rate	**6.43 grams/hour**
Emissisons Factor	5.46 grams/kg

OMNI-Test Laboratories, Inc.

Manufacturer:	Princess
Model:	Grace Fire
Date:	09/30/15
Run:	33
Control #:	N/A
Test Duration:	318
Output Category:	Low

Technicians: S. Button

Test Results in Accordance with CSA B415.1-09

	HHV Basis	LHV Basis
Overall Efficiency	55.8%	60.3%
Combustion Efficiency	94.1%	94.1%
Heat Transfer Efficiency	59%	64.1%

Output Rate (kJ/h)	13,030	12,360	**(Btu/h)**
Burn Rate (kg/h)	1.18	2.60	**(lb/h)**
Input (kJ/h)	23,349	22,149	**(Btu/h)**

Test Load Weight (dry kg)	6.25	13.77	**dry lb**
MC wet (%)	17.06		
MC dry (%)	20.57		
Particulate (g)	0		
CO (g)	592		
Test Duration (h)	5.30		

Emissions	**Particulate**	**CO**
g/MJ Output	0.00	8.57
g/kg Dry Fuel	0.00	94.71
g/h	0.00	111.63
lb/MM Btu Output	0.00	19.91

Air/Fuel Ratio (A/F)	24.55

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Test Results - EPA Method 28 & 5G

Manufacturer: Princess
Retrofit Device Grace Fire
Project No.: 0323WS001N
Test Parameter ID: B
Run: 34
Test Date: 10/01/15

Burn Rate (Composite)	**1.42 kg/hr dry**
Average Tunnel Temperature	105 degrees Fahrenheit
Average Gas Velocity in Dilution Tunnel - vs	16.75 feet/second
Average Gas Flow Rate in Dilution Tunnel - Qsd	10867.8 dscf/hour
Average Gas Flow Rate in Chimney Flue - Qsf	1193.6 dscf/hour
Average Delta p	0.067 inches H20
Average Delta H	1.09 inches H20
Total Time of Test	259 minutes

	PAH SAMPLE TRAIN	PM SAMPLE TRAIN 1	PM SAMPLE TRAIN 2
Total Sample Volume - Vm	18.293 cubic feet	28.614 cubic feet	31.385 cubic feet
Average Orifice Temperature	75 degrees Fahrenheit	84 degrees Fahrenheit	81 degrees Fahrenheit
Total Sample Volume (Standard Conditions) - Vmstd	18.136 dscf	28.294 dscf	30.961 dscf
Total Particulates - m_n		41.1 mg	41.1 mg
Particulate Concentration (dry-standard) - C_r/C_s		0.00145 grams/dscf	0.00133 grams/dscf
Total Particulate Emissions - E_T	See PAH Analysis	68.15 grams	62.28 grams
Particulate Emission Rate		15.79 grams/hour	14.43 grams/hour
Emissisons Factor		11.10 g/kg	10.15 g/kg
Difference from Average Total Particulate Emissions		2.93 grams	2.93 grams
	Dual Train Comparison Results Are Acceptable		

FINAL AVERAGE RESULTS

Total Particulate Emissions - E_T	65.21 grams
Particulate Emission Rate	**15.11 grams/hour**
Emissisons Factor	10.63 grams/kg

OMNI-Test Laboratories, Inc.

Manufacturer:	Princess
Model:	Grace Fire
Date:	10/01/15
Run:	34
Control #:	N/A
Test Duration:	257
Output Category:	Low

Technicians: S. Button

Test Results in Accordance with CSA B415.1-09

	HHV Basis	LHV Basis
Overall Efficiency	55.0%	59.5%
Combustion Efficiency	93.2%	93.2%
Heat Transfer Efficiency	59%	63.8%

Output Rate (kJ/h)	15,619	14,816	**(Btu/h)**
Burn Rate (kg/h)	1.43	3.16	**(lb/h)**
Input (kJ/h)	28,391	26,932	**(Btu/h)**

Test Load Weight (dry kg)	6.14	13.53	**dry lb**
MC wet (%)	23.99		
MC dry (%)	31.56		
Particulate (g)	0		
CO (g)	682		
Test Duration (h)	4.28		

Emissions	**Particulate**	**CO**
g/MJ Output	0.00	10.20
g/kg Dry Fuel	0.00	111.15
g/h	0.00	159.30
lb/MM Btu Output	0.00	23.70

Air/Fuel Ratio (A/F)	25.24

VERSION: 2.3 3/23/2010

StoveCAT™ Wood Stove Retrofit Device

- *Eliminate Smoke and Particulate Emissions*
- *Increase the Stove Heating Efficiency*

StoveCAT™ Retro-Fit for Wood Heaters

Where there is Smoke
There is no
GRACE FIRE

I ♥ CLEAN AIR

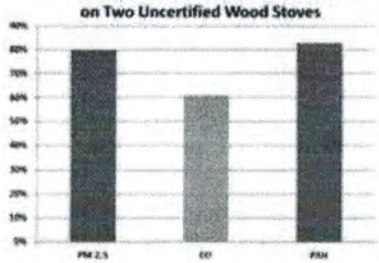
The **StoveCAT™** ECD is a product of GraceFire LLC using the proprietary Clear Skies Unlimited catalyst coated reticulated ceramic foam as the critical design component.

The **StoveCAT™** Wood Stove Retro-Fit is the only passive solution for reducing harmful emissions from wood burning stoves and heaters. The **StoveCAT™** offers the following features:

- *Unique Three-Stage Catalytic Array*
- *No Power Required*
- *No Risk of Flow Blockage*
- *No Moving Parts Inside the Unit*
- *Projected Catalytic Life of 10 Years*
- *Easily Removed for Cleaning the Flue*
- *Affordable Technology*
- *Increases the Heating Efficiency of the Stove*

The **StoveCAT™** will also increase the heating efficiency. More energy and less pollution with the **StoveCAT™** from GraceFire.

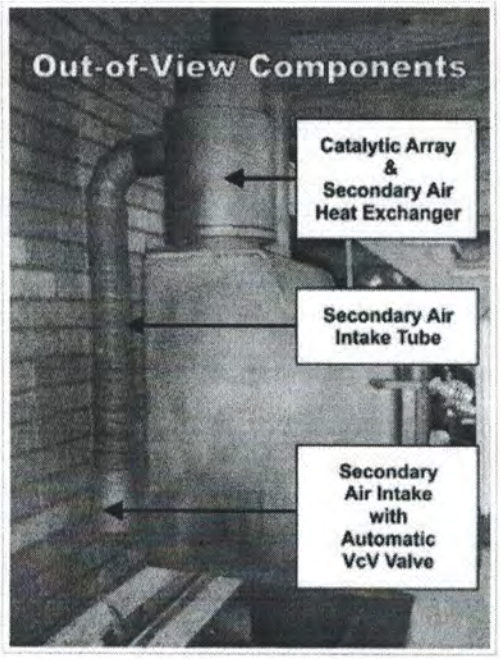
Mean Reduction in Emissions for StoveCAT Wood Heater Retro-Fit Compared to Baseline on Two Uncertified Wood Stoves



Performance Testing

*The Gracefire **StoveCAT** Emission Control Device was recently Emissions Tested at Omni Environmental Testing Laboratories in Portland, OR. The testing was performed on two Uncertified Wood Stoves. Harmful wood smoke particulate emissions and PAH emissions were reduced by 80%. Carbon Monoxide Emissions were reduced by over 60%.*

Manufactured by
DuraVent
Member of M&G Group



Puget Sound Clean Air Agency
Mean Reduction in Emissions for StoveCAT Wood Heater Retro-Fit Compared to Baseline on Two Uncertified Wood Stoves