

# TEST REPORT

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**PRODUCT EVALUATED:**

**MODEL VAPOR FIRE 100 WOOD FORCED-AIR FURNACE**

**Report of Testing Model Vapor Fire Wood Forced-Air Furnace for compliance as an "Affected Wood Heater" with the applicable requirements of the following criteria: CAN/CSA B415.1-2010 Performance Testing of Solid-Fuel-Burning Heating Appliances, ASTM E2515-11 Determination of Particulate Matter Emissions Collected by a Dilution Tunnel, EPA 40 CFR Part 60 "Standards of Performance for New Residential Wood Heaters, New Residential Hydronic Heaters and Forced-Air Furnaces", March 16, 2015, and U.S EPA Alternate Test Method for the model Vapor Fire 100.**

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REVISION SUMMARY

DATE	SUMMARY
August 7, 2017	Revised Table 1 – Data Summary Part A, Actual Load. The percentage of maximum output was corrected to indicate what the actual output percentage was for each category based on the maximum output.
August 11, 2017	Revised Section II.C – Summary of Test Results, CO Emissions. Changed CO emission result from a weighted average of 101.59 g/hr to a weighted average of 0.82 g/min per the 2015 NSPS. Revised Table 3 – Weighted Average, CO Emissions. Changed the column for CO emissions from g/hr to g/min and added the corrected results in g/min. Revised Section VII – Conclusion. Conclusion was changed from compliance with Step 1 limits to compliance with Step 2 limits and added rational based on the EPA alternate test method.
September 6, 2017	Revised cover page to include reference to the EPA Alternate Test Method. Updated Section I.A to include reference to the EPA Alternate Test Method. Updated Section II.B(2) to explain the use of the EPA Alternate Test Method.

## **I. INTRODUCTION**

Intertek Testing Services NA (Intertek) has conducted testing for Lamppa Manufacturing, on model Vapor Fire 100 Wood Air Furnace to evaluate all applicable performance requirements included in “Determination of particulate matter emissions from wood forced-air furnaces.”

### ***I.A* PURPOSE OF TEST**

The test was conducted to determine if the unit is in accordance with U.S EPA requirements under EPA 40 CFR Part 60 “Standards of Performance for New Residential Wood Heaters, New Residential Hydronic Heaters and Forced-Air Furnaces”. This evaluation began on 9/19/16 and was completed on 10/04/16. The following test methods were applicable:

ASTM E2515-11- Standard Test Method for Determination of Particulate Matter Emissions Collected by a Dilution Tunnel

CSA B415.1-10 - Performance Testing of Solid-Fuel-Burning Heating Appliances

U.S. EPA Alternate Test Method issued to Lamppa Manufacturing for the Vapor Fire 100.

### ***I.B* LABORATORY**

The tests on the model Vapor Fire 100 Wood Forced-Air Furnace were conducted at the Intertek testing Services Laboratory located at 8431 Murphy Drive, Middleton, WI, 53562. The laboratory is accredited by the U.S. EPA, Certificate Number 3. The test was conducted by Ken Slater and observed by Daryl Lamppa of Lamppa Manufacturing.

### ***I.C* DESCRIPTION OF UNIT**

The model Vapor Fire 100 Wood Forced-Air Furnace is constructed of sheet steel. The outer dimensions are 53-inches deep, 52-inches high, and 27-inches wide. The unit has a door located on the front of the unit.

(See product drawings.)

Proprietary drawings and manufacturing methods are on file at Intertek in  
(Intertek location)

## ***I.D REPORT ORGANIZATION***

This report includes summaries of all data necessary to determine compliance with the regulations. Raw data, calibration records, intermediate calculations, drawings, specifications and other supporting information are contained in appendices to this report.

## **II. SUMMARY**

### ***II.A PRETEST INFORMATION***

A sample was submitted to Intertek directly from the client. The sample was not independently selected for testing. The test unit was received at Intertek in Middleton, WI on July 28, 2016 and was shipped via the client. The unit was inspected upon receipt and found to be in good condition. The unit was set up following the manufacturer's instructions without difficulty.

Following assembly, the unit was placed on the test stand. Prior to beginning the emissions tests, the manufacturer operated the unit for a minimum of 50 hours at high-to-medium burn rates to break in the heater. This break-in period was witnessed by Lamppa Manufacturing's staff and a signed document is included in the final report. The unit was found to be operating satisfactory during this break-in. The 50 plus hours of pre-burning were conducted from July 22, 2016 to July 24, 2016. The fuel used for the break-in process was wood.

Following the pre-burn break-in process the unit was allowed to cool and ash and residue was removed from the firebox. The unit's chimney system and laboratory dilution tunnels were cleaned using standard wire brush chimney cleaning equipment. On September 19, 2016 the unit was set-up for testing.

## ***II.B INFORMATION LOG***

### **II.B(1) TEST STANDARD**

From 9/19/16 to 10/04/16, the unit was tested for EPA emissions. For Wood Forced-Air Furnaces, the test was conducted in accordance with CSA B415.1-2010. The fuel used for the test run was Oak cordwood.

The applicable EPA regulatory limits are:

Step 1 – 2016 – 0.93 lbs/MMBtu Output (0.4 g/MJ) – For furnaces rated less than 65,000 Btu/hr

Step 1 – 2017 – 0.93 lbs/MMBtu Output (0.4 g/MJ) – For furnaces rated more than 65,000 Btu/hr

Step 2 – 2020 – 0.15 lbs/MMBtu Output (0.026 g/MJ)

### **II.B(2) Deviation from Standard Method**

The Step 2 requirements for EPA 40 CFR Part 60 “Standards of Performance for New Residential Wood Heaters, New Residential Hydronic Heaters and Forced-Air Furnaces” specifies that a wood forced-air furnace must be operated at the output rates as noted for wood burning hydronic heaters. The Step 2 output rates indicate <15% of maximum output for Category 1, 16-24% of maximum output for Category 2, 25-50% of maximum output for Category 3, and 100% of output for Category 4. Lamppa Manufacturing submitted a request to the U.S. EPA to allow the Vapor Fire 100 to operate at the output rates specified in CSA B415.1-2010 and still comply with the Step 2 requirements of EPA 40 CFR Part 60. The U.S. EPA issued an Alternate Test Method, written by Steffan Johnson, to Lamppa Manufacturing permitting the use of the output rates as outlined in CSA B415.1-2010. The approved output rates are <35% of maximum output for Category 1, 35-53% of maximum output for Category 2, 53-76% of maximum output for Category 3, and 100% of output for Category 4.

The set-up, operation procedures, and the output rates for the model Vapor Fire 100 was performed in accordance with applicable clauses from CSA B415.1-2010.

## ***II.C SUMMARY OF TEST RESULTS***

The appliance tests resulted in the following performance:

Particulate Emissions: 0.093 lbs/MMBtu Output (0.040 g/MJ)

Carbon Monoxide Emissions: 0.82 g/min

Heating Efficiency: 54.3% (Higher Heating Value Basis)

## ***II.D DESCRIPTION OF TEST RUNS***

RUN #1 (9/19/16) Air control set at full open position. Due to an unexpected power failure the test was discontinued.

RUN #2 (9/20/16) Air control set at full open position, burn time was 356 minutes with a category 4 burn rate of 2.558 kg/hr. The test was loaded and the door closed. Final Btu rate was 34,567 with a 0.0429 lb/MMbtu.

RUN #3 (9/21/16) Air control set to level 2 position with the thermostat set at 125°F, burn time was 550 minutes with a category 2 burn rate of 1.748 kg/hr. The door was closed. Final Btu reading was 13,517 with a 0.244 lb/MMbtu.

RUN #4 (9/22/16) Air control set to level 2 position with the thermostat set at 125°F, burn time was 490 minutes with a category 2 burn rate of 1.918 kg/hr. The door was closed. Final Btu reading was 14,414 with a 0.145 lb/MMbtu.

RUN #5 (9/23/16) Air Control set to level 2 position with the thermostat set at 125°F, burn time was 549 minutes with a category 2 burn rate of 1.635 kg/hr, The door was closed. Final Btu reading was 17,372 with a 0.033 lb/MMbtu.

RUN # 6 (9/29/16) Air control set to low setting with the thermostat set at 135°F, burn time was 421 minutes with a category 1 burn rate of 2.114 kg/hr, The door was closed, Final Btu reading was 18,906 with a 0.172 lb/MMbtu. Btu is higher than category 1 burn rate therefore this test is a category 2.

RUN # 7 (9/30/16) Air Control set to level 2 setting with the thermostat set at 145°F, client removed hi-limit switch, burn time was 611 minutes with a category 1 burn rate of 1.463 kg/hr, The door was closed, Final Btu reading was 9,332 with a 0.147 lb/MMbtu.

RUN #8 (10/03/16) Air control set at medium position with the thermostat set at 105°F. Due to an unexpected power failure the test was discontinued.

RUN #9 (10/04/16) Air control set at medium position with the thermostat set at 105°F. Burn time was 465 minutes with a category 3 burn rate of 1.999 kg/hr. The door was closed. Final Btu reading was 25,236 with a 0.092 lb/MMbtu.

Standard specifies that tests can be averaged, therefore test run #3 and #6 will not be used, Test runs 4 and 5 will be averaged for a category 2 burn.

## II.D SUMMARY OF OTHER DATA

TABLE 1. - DATA SUMMARY PART A

Category	Run No.	Load % Capacity	Target Load	Actual Load	Actual Load	⊖	W <sub>fuel</sub>	MC <sub>ave</sub>	Q <sub>in</sub>	Q <sub>out</sub>
						Test Duration	Wood Weight as-fired	Wood Moisture	Heat Input	Heat Output
			Btu/hr	Btu/hr	% of Max	hrs	lb	% DB	Btu	Btu
I	7	<35% of max	12,622	9,332	26%	10.18	40.96	24.72	279,146	95,032
II	4,5	35-53% of max	15,867	15,521	43%	8.66	41.85	23.97	286,931	135,300
III	9	53-76% of max	27,407	25,236	70%	7.75	42.49	24.42	290,273	195,581
IV	2	Max capacity	36063	36063	100%	5.93	41.59	24.48	284,455	194,522

TABLE 2. - DATA SUMMARY PART B

Category	Run No.	Load % Capacity	E <sub>T</sub>	E	E	E <sub>g/hr</sub>	η <sub>del</sub>	η <sub>SLM</sub>
			Total PM Emissions	PM Output Based	PM Output Based	PM Rate	Delivered Efficiency	Stack Loss Efficiency
			g	lb/mmBtu Out	g/MJ	g/hr	%	%
I	7	<35% of max	6.35	0.147	0.06	0.62	34.0%	77.7%
II	4,5	35-53% of max	4.87	0.089	0.04	0.58	47.4%	79.9%
III	9	53-76% of max	8.21	0.093	0.04	1.06	67.4%	79.1%
IV	2	Max capacity	3.79	0.043	0.02	0.64	68.4%	79.0%



**TABLE 3. - WEIGHTED AVERAGE**

Category	Run No.	Weighting Factor	$\eta \times F_i$	$E_{g/MJ,i} \times F_i$	$CO_{g/min} \times F_i$	Input $E_{lb/mmbtu,i} \times F_i$	Output $E_{lb/mmbtu,i} \times F_i$	$E_{g/hr,i} \times F_i$
I	7	0.250	0.085	0.016	0.295	0.013	0.037	0.156
II	4,5	0.250	0.118	0.010	0.214	0.009	0.022	0.145
III	9	0.250	0.168	0.010	0.016	0.016	0.023	0.265
IV	2	0.250	0.171	0.005	0.007	0.007	0.011	0.160
<b>Totals</b>		<b>1.000</b>	<b>54.3%</b>	<b>0.040</b>	<b>0.822</b>	<b>0.045</b>	<b>0.093</b>	<b>0.726</b>

**TABLE 4. - GENERAL SUMMARY OF RESULTS**

Run No.	Burn Rate (kg/hr)(Dry)	1 <sup>st</sup> Hour Emissions (g/hr)	Run Time (min)
<b>7</b>	<b>1.463</b>	<b>1.9</b>	<b>611</b>
<b>4,5</b>	<b>1.776</b>	<b>1.05</b>	<b>519</b>
<b>9</b>	<b>1.999</b>	<b>2.6</b>	<b>465</b>
<b>2</b>	<b>2.558</b>	<b>1.3</b>	<b>356</b>

**TABLE 5. - CSA B415.1 RESULTS**

Run No.	CO Emissions (g/hr)	Heating Efficiency (% HHV)	Heat Output (Btu/hr)
<b>7</b>	<b>70.75</b>	<b>77.7%</b>	<b>21,281</b>
<b>4,5</b>	<b>51.38</b>	<b>79.9%</b>	<b>26,557</b>
<b>9</b>	<b>74.70</b>	<b>79.1%</b>	<b>29,659</b>
<b>2</b>	<b>0.47</b>	<b>79.0%</b>	<b>37,914</b>

### III. PROCESS DESCRIPTION

#### III.A TEST SET-UP DESCRIPTON

A standard 6" diameter vertical single wall pipe and insulated chimney system was installed to 15' above floor level. The single wall pipe extended to 8 feet above the floor and insulated chimney extended the remaining height.

#### III.B AIR SUPPLY SYSTEM

Combustion air enters a 2" x 6" inlet located on the side of the heater, which is directed to the firebox. All gases exit through the 6" flue also located at the top of the heater. The heater is natural draft.

### ***III.C TEST FUEL PROPERTIES***

Wood used for the testing is split and seasoned oak cordwood. Oak has a default heating value of 8550 Btu/hr (19887 kJ/kg) and a moisture content between 19% and 25% on a dry basis.

## **IV. SAMPLING SYSTEMS**

### ***IV.A. SAMPLING LOCATIONS***

Particulate samples are collected from the dilution tunnel at a point 20 feet from the tunnel entrance. The tunnel has two elbows and two mixing baffles in the system ahead of the sampling section. (See Figure 3.) The sampling section is a continuous 13 foot section of 6 inch diameter pipe straight over its entire length. Tunnel velocity pressure is determined by a standard Pitot tube located 60 inches from the beginning of the sampling section. The dry bulb thermocouple is located six inches downstream from the Pitot tube. Tunnel samplers are located 60 inches downstream of the Pitot tube and 36 inches upstream from the end of this section. (See Figure 1.)

Stack gas samples are collected from the steel chimney section 8 feet  $\pm$  6 inches above the scale platform. (See Figure 2.)

**IV.A.(1) DILUTION TUNNEL**

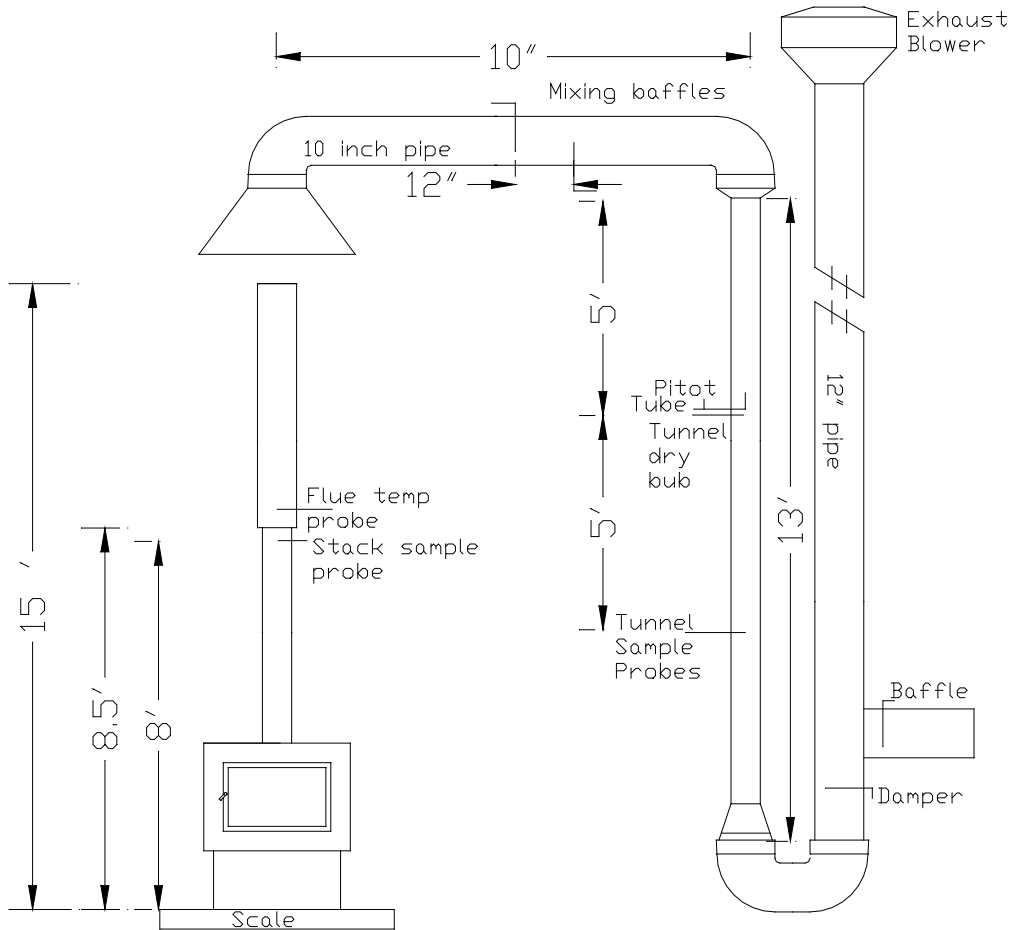
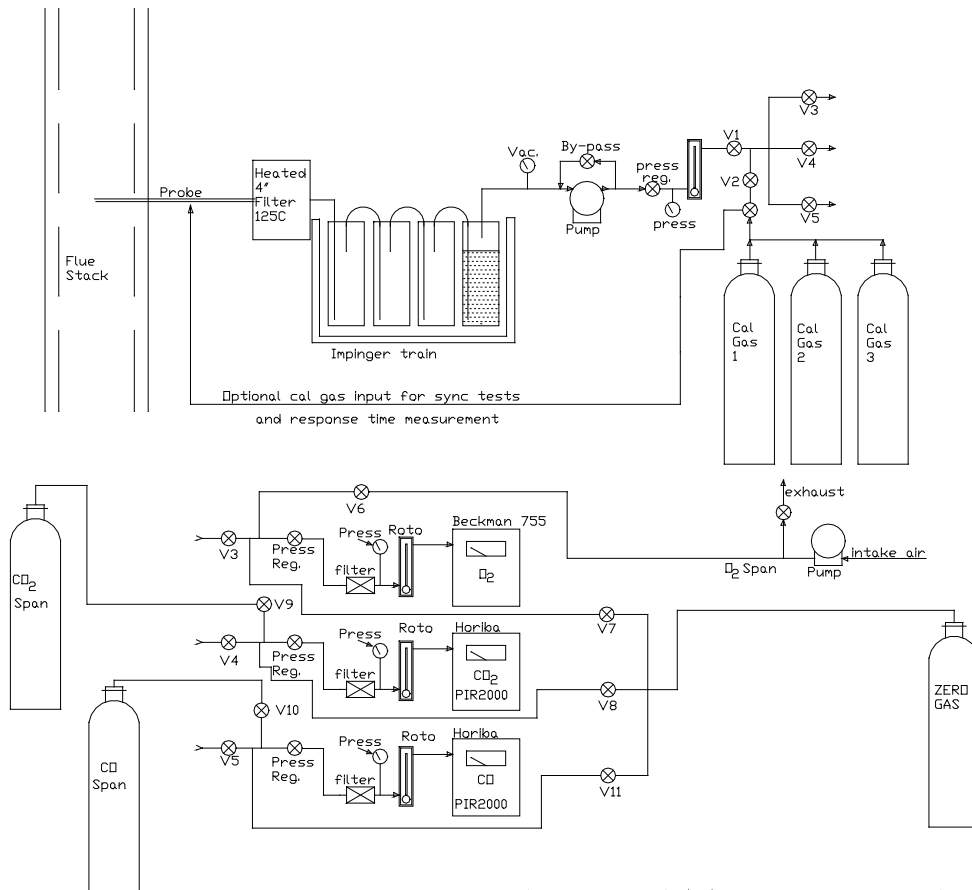


FIGURE 1

**IV.B. OPERATIONAL DRAWINGS**

**IV.B.(1) STACK GAS SAMPLE TRAIN**



ITS FLUE GAS SAMPLE TRAIN

FIGURE 2

**IV.B.(2). DILUTION TUNNEL SAMPLE SYSTEMS**

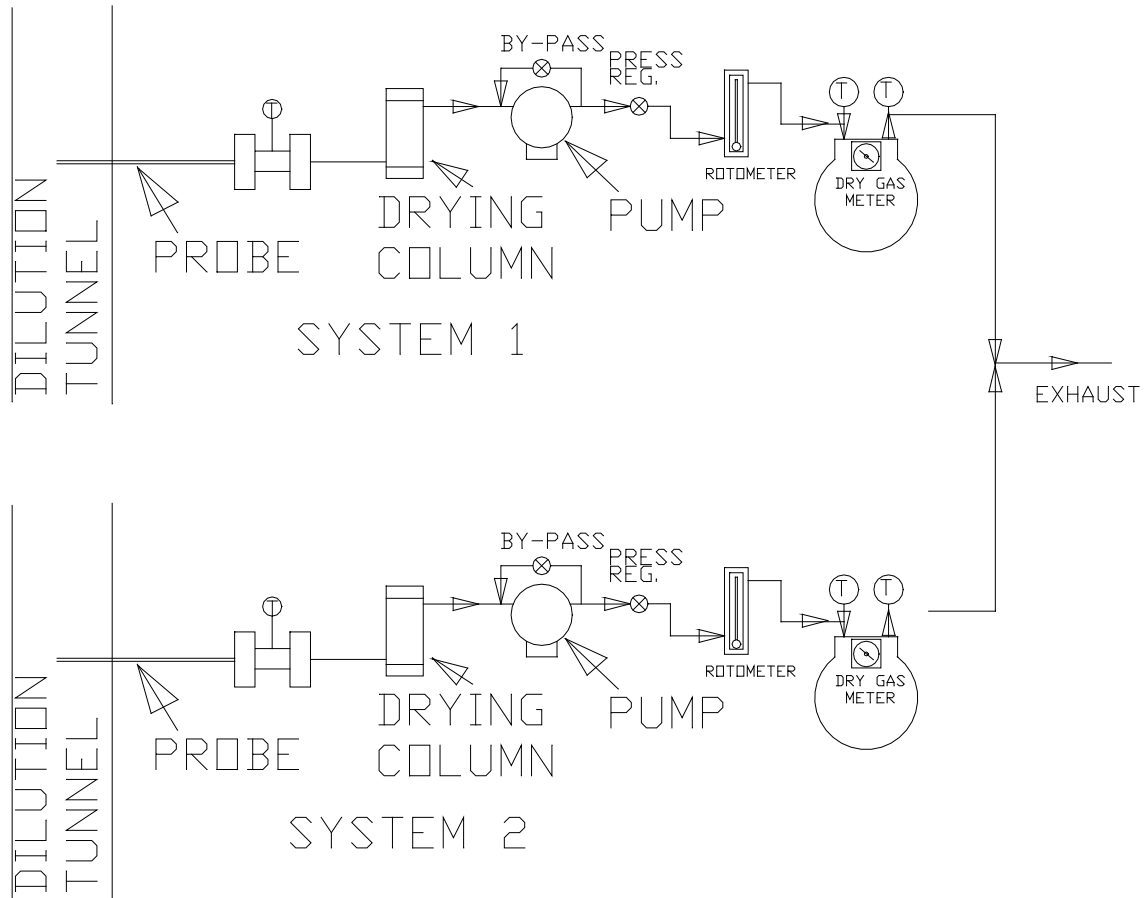


Figure 3

## V. SAMPLING METHODS

### V.A. PARTICULATE SAMPLING

Particulates were sampled in strict accordance with ASTM E2515-2011. This method uses two identical sampling systems with Gelman A/E 61631 binder free, 47-mm diameter filters. The dryers used in the sample systems are filled with "Drierite" before each test run. In order to measure first-hour emissions rates the a third filter set is prepared at one hour into the test run, the filter sets are changed in one of the two sample trains. The two filter sets used for this train are analyzed individually to determine the first hour and total emissions rate.

## VI. QUALITY ASSURANCE

### VI.A. INSTRUMENT CALIBRATION

#### VI.A. (1). *DRY GAS METERS*

At the conclusion of each test program the dry gas meters are checked against our standard dry gas meter. Three runs are made on each dry gas meter used during the test program. The average calibration factors obtained are then compared with the six-month calibration factor and, if within 5%, the six-month factor is used to calculate standard volumes. Results of this calibration are contained in Appendix D.

An integral part of the post test calibration procedure is a leak check of the pressure side by plugging the system exhaust and pressurizing the system to 10" W.C. The system is judged to be leak free if it retains the pressure for at least 10 minutes.

The standard dry gas meter is calibrated every 6 months using a Spirometer designed by the EPA Emissions Measurement Branch. The process involves sampling the train operation for 1 cubic foot of volume. With readings made to .001 ft<sup>3</sup>, the resolution is .1%, giving an accuracy higher than the  $\pm 2\%$  required by the standard.

***VI.A.(2). STACK SAMPLE ROTAMETER***

The stack sample rotometer is checked by running three tests at each flow rate used during the test program. The flow rate is checked by running the rotometer in series with one of the dry gas meters for 10 minutes with the rotometer at a constant setting. The dry gas meter volume measured is then corrected to standard temperature and pressure conditions. The flow rate determined is then used to calculate actual sampled volumes.

***VI.A.(3). GAS ANALYZERS***

The continuous analyzers are zeroed and spanned before each test with appropriate gases. A mid-scale multi-component calibration gas is then analyzed (values are recorded). At the conclusion of a test, the instruments are checked again with zero, span and calibration gases (values are recorded only). The drift in each meter is then calculated and must not exceed 5% of the scale used for the test.

At the conclusion of each unit test program, a three-point calibration check is made. This calibration check must meet accuracy requirements of the applicable standards. Consistent deviations between analyzer readings and calibration gas concentrations are used to correct data before computer processing. Data is also corrected for interferences as prescribed by the instrument manufacturer's instructions.

***VI.B. TEST METHOD PROCEDURES******VI.B.(1). LEAK CHECK PROCEDURES***

Before and after each test, each sample train is tested for leaks. Leakage rates are measured and must not exceed 0.02 CFM or 4% of the sampling rate. Leak checks are performed checking the entire sampling train, not just the dry gas meters. Pre-test and post-test leak checks are conducted with a vacuum of 10 inches of mercury. Vacuum is monitored during each test and the highest vacuum reached is then used for the post test vacuum value. If leakage limits are not met, the test run is rejected. During, these tests the vacuum was typically less than 2 inches of mercury. Thus, leakage rates reported are expected to be much higher than actual leakage during the tests.

**VI.B.(2). TUNNEL VELOCITY/FLOW MEASUREMENT**

The tunnel velocity is calculated from a center point Pitot tube signal multiplied by an adjustment factor. This factor is determined by a traverse of the tunnel as prescribed in EPA Method 1. Final tunnel velocities and flow rates are calculated from EPA Method 2, Equation 6.9 and 6.10. (Tunnel cross sectional area is the average from both lines of traverse.)

Pitot tubes are cleaned before each test and leak checks are conducted after each test.


**VI.B.(3). PM SAMPLING PROPORTIONALITY**

Proportionality was calculated in accordance with ASTM E2515-11. The data and results are included in Appendix C.

**VII. CONCLUSION**

This test demonstrates that this unit is an affected facility under the definition given in the regulation. The emission rate of 0.093 lb/MMBtu meets the EPA requirements for the Step 2 limits based on the alternate test method created and approved by the U.S. EPA. The alternate test method allows the Lamppa Manufacturing model VF100 to be operated at output rates as specified in Clause 7.2 of CSA B415.1-2010 in order to comply with the Step 2 requirements of EPA 40 CFR Part 60 "Standards of Performance for New Residential Wood Heaters, New Residential Hydronic Heaters and Forced-Air Furnaces", March 16, 2015.

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