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LAMPPA MANUFACTURING TEST REPORT

SCOPE OF WORK
EPA EMISSIONS TESTING FOR MODEL VF100

REPORT NUMBER
105224549MID-003R2

TEST DATE(S)
10/10/22 - 12/08/22

ISSUE DATE **REVISED DATE**
10/24/22 12/13/22

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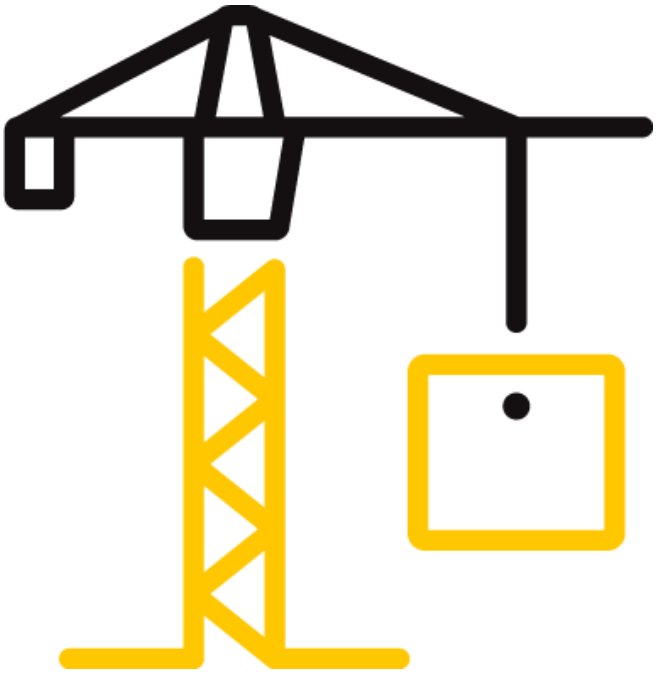

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TEST REPORT FOR LAMPPA MANUFACTURING

Report No.: 105224549MID-003R2
Date: 11/18/22

REPORT ISSUED TO

LAMPPA MANUFACTURING
9501 Hwy 135 North
Tower, MN 55790

SECTION 1

SCOPE

Intertek Building & Construction (B&C) was contracted by Lamppa Manufacturing to perform Research & Development (R&D) testing in accordance with EPA 40 CFR Part 60, “Standards of Performance for New Residential Wood Heaters, New Residential Hydronic Heaters and Forced-Air Furnaces,” ASTM E2515-17, "Standard Test Method for Determination of Particulate Matter Emissions Collected by a Dilution Tunnel," and CSA B415.1-10 (R2020), "Performance Testing of Solid-Fuel-Burning Heating Appliances" on their model VF100 Solid Fuel Air Furnace. Results obtained are tested values and were secured by using the designated test method(s). Testing was conducted at Intertek test facility in Middleton, WI.

Unless differently required, Intertek reports apply the "Simple Acceptance" rule also called “Shared Risk approach,” of ILAC-G8:09/2019, Guidelines on Decision Rules and Statements of Conformity.

Intertek B&C will service this report for the entire test record retention period. The test record retention period ends four years after the test date. Test records, such as detailed drawings, datasheets, representative samples of test specimens (where required by Certification or Accreditation bodies), or other pertinent project documentation, will be retained for the entire test record retention period.

For INTERTEK B&C:

COMPLETED BY:	Ken Slater	**REVIEWED BY:**	Brian Ziegler
TITLE:	Associate Engineer - Hearth	**TITLE:**	Technical Team Leader - Hearth
SIGNATURE:	Ken Slater	**SIGNATURE:**	
DATE:	12/13/22	**DATE:**	12/15/22

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SECTION 2
SUMMARY OF TEST RESULTS

The appliance tests resulted in the following performance:
Run #2 - Particulate Emissions: 0.74 g/hr and 0.054 lb/MMBtu Output for Category 4
Run #3 - Particulate Emissions: 0.38 g/hr and 0.116 lb/MMBtu Output for Category 1
Run #2 - Carbon Monoxide Emissions: 1.08 g/min for Category 4
Run #3 - Carbon Monoxide Emissions: 0.82 g/min for Category 1
Run #2 - Heating Efficiency: 68.6% (Higher Heating Value Basis) for Category 4
Run #3 - Heating Efficiency: 18.7% (Higher Heating Value Basis) for Category 1
Run #6 - Particulate Emissions: 1.44 g/hr and 0.216 lb/MMBtu Output for Category 2
Run #7 - Particulate Emissions: 1.18 g/hr and 0.135 lb/MMBtu Output for Category 3
Run #6 - Carbon Monoxide Emissions: 2.49 g/min for Category 2
Run #7 - Carbon Monoxide Emissions: 2.59 g/min for Category 3
Run #6 - Heating Efficiency: 37.5% (Higher Heating Value Basis) for Category 2
Run #7 - Heating Efficiency: 44.3% (Higher Heating Value Basis) for Category 3
Run #9 – Particulate Emissions: 0.67 g/hr and 0.097 lb/MMBtu
Run #11 – Particulate Emissions: 0.38 gr/hr and 0.055 lb/MMBtu
Run #9 – Carbon Monoxide Emissions: 1.60 g/min for Category 2
Run #11 – Carbon Monoxide Emissions: 1.11 g/min for Category 2
Run #9 – Heating Efficiency: 43.3% (Higher Heating Value Basis) for Category 2
Run #11 – Heating Efficiency: 54.1% (Higher Heating Value Basis) for Category 2

SECTION 3
TEST METHOD(S)

The specimen was evaluated in accordance with the following:

EPA 40 CFR Part 60-2015, *Standards of Performance for New Residential Wood Heaters, New Residential Hydronic Heaters and Forced-Air Furnaces*

ASTM E2515-17, *Standard Test Method for Determination of Particulate Matter Emissions Collected by a Dilution Tunnel*

CSA B415.1-10 (R2020), *Performance Testing of Solid-Fuel-Burning Heating Appliances*

SECTION 4
MATERIAL SOURCE

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 October 6, 2022 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.

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TEST REPORT FOR LAMPPA MANUFACTURING
Report No.: 105224549MID-003R2
Date: 11/18/22

SECTION 5
EQUIPMENT

EQUIPMENT	INV NUMBER	CALIBRATION DUE	MU
Platform Scale	008	4/4/23	0.035 lbs
Balance	713	4/4/23	0.00006 g
Data Logger	986	4/7/23	0.06°F
Scale	1134	4/20/23	0.12 lbs
Timer	1213	4/5/23	0.06sec
Timer	1212	4/5/23	0.06 sec
Flow Meter	1413	3/20/23	7.5E-03 slpm
Flow Meter	1414	3/20/23	7.5E-03 slpm
Flow Meter	1519	3/20/23	7.4E-03 slpm
Barometer (Mecurial)	437	NA	0.05 in Hg
Anemometer	1457	5/24/23	5.0 fpm
Pressure Transducer	1406	1/13/23	0.0006 in/wc
Pressure Transducer	1407	1/13/23	0.0006 in/wc

SECTION 6
LIST OF OFFICIAL OBSERVERS

NAME	COMPANY
Dale Horihan	Lamppa Manufacturing
Ken Slater	Intertek B&C

SECTION 7
TEST PROCEDURE

From October 10, 2022 to December 8, 2022, the unit was tested for EPA emissions. For air furnaces, the test was conducted in accordance with CSA B415.1-2010 (R2020). The fuel used for the test run was oak cordwood.

The applicable EPA regulatory limits are:

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

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Step 1 – 2017 – 0.93 lbs/MMBtu Output (0.4g/MJ) – For furnaces rated more than 65,000 Btu/hr
Step 2 – 2020 – 0.15 lbs/MMBtu Output (0.026 g/MJ)

TEST SET-UP DESCRIPTION

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

AIR SUPPLY SYSTEM

Combustion air enters an inlet pipe 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 exhaust gases are assisted by a combustion blower.

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 18% and 28% on a dry basis.

SAMPLING LOCATIONS

Particulate samples are collected from the dilution tunnel at a point 20 feet from the tunnel entrance. The tunnel has two elbows 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 ± 6 inches above the scale platform. (See Figure 2.)

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Report No.: 105224549MID-003R2
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FIGURE 1 – DILUTION TUNNEL

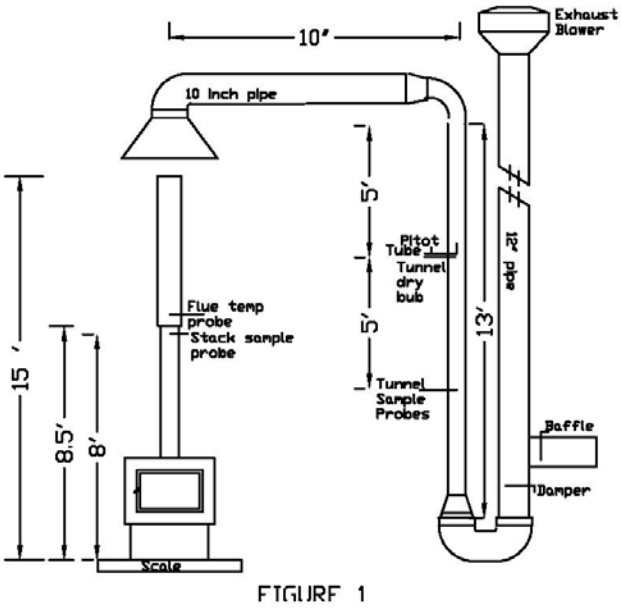
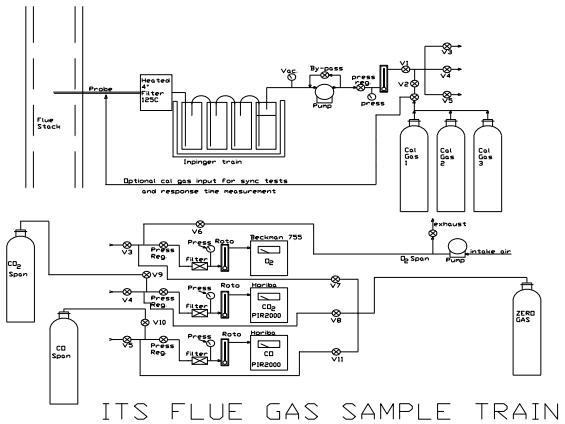


FIGURE 1

FIGURE 2 – STACK GAS SAMPLE TRAIN



ITS FLUE GAS SAMPLE TRAIN
FIGURE 2

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FIGURE 3 – DILUTION TUNNEL SAMPLE SYSTEMS

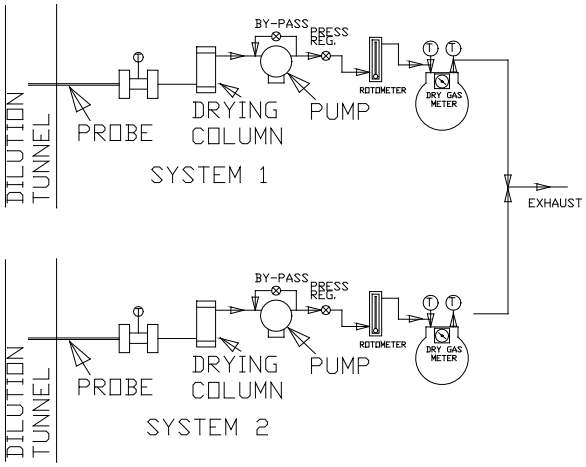

Figure 3

SAMPLING METHODS

PARTICULATE SAMPLING

Particulates were sampled in strict accordance with ASTM E2515. This method uses two identical sampling systems with Pall PTFE coated glass fiber filters #7221, 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 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.

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.

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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.

TEST METHOD PROCEDURES

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.

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.

PM SAMPLING PROPORTIONALITY

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

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TEST REPORT FOR LAMPPA MANUFACTURING
Report No.: 105224549MID-003R2
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DEVIATIONS FROM STANDARD METHOD:

Alternative Test Method Dated 10/07/22 from US EPA

SECTION 8
TEST CALCULATIONS

NOMENCLATURE FOR ASTM E2515:

A = Cross-sectional area of tunnel m2 (ft2).

B_{ws} = Water vapor in the gas stream, proportion by volume (assumed to be 0.02 (2.0 %)).

C_p = Pitot tube coefficient, dimensionless (assigned a value of 0.99).

c_r = Concentration of particulate matter room air, dry basis, corrected to standard conditions, g/dscm (gr/ dscf) (mg/dscf).

c_s = Concentration of particulate matter in tunnel gas, dry basis, corrected to standard conditions, g/dscm (gr/dscf) (mg/dscf).

E_T = Total particulate emissions, g.

F_p = Adjustment factor for center of tunnel pitot tube placement.
$F_p = V_{strav}/V_{scent}$

K_P = Pitot Tube Constant, $34.97 \frac{m}{\sec} \left[\frac{\left(\frac{g}{g}\blacksquare mole\right)(mm\ Hg)}{(K)(mm\ water)}\right]^{\frac{1}{2}}$

or

= Pitot Tube Constant, $85.49 \frac{ft}{\sec} \left[\frac{\left(\frac{lb}{lb}-mole\right)(in\ Hg)}{(R)(in\ water)}\right]^{\frac{1}{2}}$

L_a = Maximum acceptable leakage rate for either a pretest or post-test leak- check, equal to 0.0003 m3/min (0.010 cfm) or 4 % of the average sampling rate, whichever is less.

L_p = Leakage rate observed during the post-test leak-check, m3/min (cfm).

m_p = mass of particulate from probe, mg.

m_f = mass of particulate from filters, mg.

m_g = mass of particulate from filter gaskets, mg.

m_r = mass of particulate from the filter, filter gasket, and probe assembly from the room air blank filter holder assembly, mg.

m_n = Total amount of particulate matter collected, mg.

M_s = the dilution tunnel dry gas molecular weight (may be assumed to be 29 g/g mole (lb/lb mole).

P_{bar} = Barometric pressure at the sampling site, mm Hg (in. Hg).

P_g = Static Pressure in the tunnel (in. water).

P_R = Percent of proportional sampling rate.

P_s = Absolute average gas static pressure in dilution tunnel, mm Hg (in. Hg).

P_{std} = Standard absolute pressure, 760 mm Hg (29.92 in. Hg).

Q_{std} = Average gas flow rate in dilution tunnel.
$Q_{std} = 60\ (1 - B_{ws})\ V_s\ A\ [T_{std}\ P_s/T_s\ P_{std}]$

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dscm/min (dscf/min).

T_m = Absolute average dry gas meter temperature, K (R).

T_{mi} = Absolute average dry gas meter temperature during each 10-min interval, *i*, of the test run.

$$T_{mi} = (T_{mi(b)} + T_{mi(e)})/2$$

where:

$T_{mi(b)}$ = Absolute dry gas meter temperature at the beginning of each 10-min test interval, i, of the test run, K (R), and

$T_{mi(e)}$ = Absolute dry gas meter temperature at the end of each 10-min test interval, i, of the test run, K (R).

Ts = Absolute average gas temperature in the dilution tunnel, K (R).

Tsi = Absolute average gas temperature in the dilution tunnel during each 10-min interval, i, of the test run, K (R).

$$T_{si} = (T_{si(b)} + T_{m=si(e)})/2$$

where:

$T_{si(b)}$ = Absolute gas temperature in the dilution tunnel at the beginning of each 10-min test interval, i, of the test run, K (R), and

$T_{si(e)}$ = Absolute gas temperature in the dilution tunnel at the end of each 10-min test interval, i, of the test run, K (R).

V_m = Volume of gas sample as measured by dry gas meter, dcm (dcf).

V_{mc} = Volume of gas sampled corrected for the post test leak rate, dcm (dcf).

V_{mi} = Volume of gas sample as measured by dry gas meter during each 10-min interval, i, of the test run, dcm.

$V_{m(std)}$ = Volume of gas sample measured by the dry gas meter, corrected to standard conditions.

$$V_{m(std)} = K_1 V_m Y [(P_{bar} + (\Delta H/13.6))/T_m]$$

where:

K_1 = 0.3855 K/mm Hg for SI units and = 17.64 R/in. Hg for inch-pound units.

$$V_{m(std)} = K_1 V_{mc} Y [(P_{bar} + (\Delta H/13.6))/T_m]$$

where:

V_{mc} = Vm– (Lp– La)u

V_{mr} = Volume of room air sample as measured by dry gas meter, dcm (dcf), and

$V_{mr(std)}$ = Volume of room air sample measured by the dry gas meter, corrected to standard conditions.

$$V_{m(std)} = K_1 V_{mr} Y [(P_{bar} + (\Delta H/13.6))/T_m]$$

Where:

K_1 = 0.3855 K/mm Hg for SI units and = 17.64 R/in. Hg for inch-pound units, and

V_s = Average gas velocity in the dilution tunnel.

$$V_s = F_p K_p C_p (\sqrt{\Delta P_{avg}})(\sqrt{(T_s/P_s M_s)})$$

V_{si} = Average gas velocity in dilution tunnel during each 10-min interval, i, of the test run.

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$$V_{si} = F_p K_p C_p (\sqrt{\Delta P_i})(\sqrt{(T_{si}/P_s M_s)})$$

V_{scent} = Average gas velocity at the center of the dilution tunnel calculated after the Pitot tube traverse.
V_{strav} = Average gas velocity calculated after the multipoint Pitot traverse.
Y = Dry gas meter calibration factor.
ΔH = Average pressure at the outlet of the dry gas meter or the average differential pressure across the orifice meter, if used, mm water (in. water).
ΔP_{avg} = Average velocity pressure in the dilution tunnel, mm water (in. water).
ΔP_i = Velocity pressure in the dilution tunnel as measured with the Pitot tube during each 10-min interval, i, of the test run.

$$\Delta P_i = (\Delta P_{i(b)} + \Delta P_{i(e)})/2$$

where:
$\Delta P_{i(b)}$ = Velocity pressure in the dilution tunnel as measured with the Pitot tube at the beginning of each 10-min interval, i, of the test run, mm water (in. water), and
$\Delta P_{i(e)}$ = Velocity pressure in the dilution tunnel as measured with the Pitot tube at the end of each 10-min interval, i, of the test run, mm water (in. water).
θ = Total sampling time, min.
10 = ten min, length of first sampling period.
13.6 = Specific gravity of mercury.
100 = Conversion to percent.

TOTAL PARTICULATE WEIGHT – ASTM E2515

$$M_n = m_p + m_f + m_g$$

PARTICULATE CONCENTRATION – ASTM E2515

$$C_s = K_2(m_n/V_{m(std)}) \text{ g/dscm (g/dscf)}$$

where:
K_2 = 0.001 g/mg

TOTAL PARTICULATE EMISSIONS (g) – ASTM E2515

$$E_T = (C_s - C_r)Q_{std}\theta$$

PROPORTIONAL RATE VARIATION (%) – ASTM E2515

$$PR = [\theta(V_{mi} V_s T_m T_{si})/(10(V_m V_{si} T_s T_{mi})] \times 100$$

MEASUREMENT OF UNCERTAINTY – ASTM E2515

$$MU_{weighing} = \sqrt{0.1^2} \bullet X$$

GENERAL FORMULA – ASTM E2515

$$uY = \sqrt{((\delta Y/\delta x_1) \times u_1)^2 + \ldots + ((\delta Y/\delta x_n) \times u_n)^2}$$

Where:
$\delta Y/\delta x_i$ = Partial derivative of the combining formula with respect to individual measurement xi,
u_i = is the uncertainty associated with that measurement.

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TOTAL PARTICULATE EMISSIONS – ASTM E2515

$$E_T = (c_s - c_r)\, Q_{std}\, \theta$$

where:

c_s = sample filter catch/(sample flow rate x test duration), g/dscf,
c_r = room background filter catch/(sample flow x sampling time), g/dscf,
Q_{std} = average dilution tunnel flow rate, dscf/min, and
θ = sampling time, minutes.

MU OF c_s

$c_s = F_c/(Q_{sample} \times \theta) = 0.025/(0.25 \times 180) = 0.0005555$
$\delta c_s/\delta F_c = 1/Q_{sample} \bullet \Theta = 1/0.25 \bullet 180 = 0.0222$
$\delta c_s/\delta Q_{sample} = -F_c/Q^2_{sample} \bullet \Theta = -0.025/0.25^2 \bullet 180 = -0.00222$
$\delta c_s/\delta \Theta = -F_c/Q_{sample} \bullet \Theta^2 = -0.025/0.25 \bullet 180^2 = -0.000003$
$MUc_s = \sqrt{(0.00027 \bullet 0.0222)^2 + (0.0025 \bullet -0.00222)^2}$
$\sqrt{+ (0.1 \bullet -0.000003)^2} = 0.0000091g$
Thus, c_s would be 0.555 mg/dscf ± 0.0081 mg/dscf at 95% confidence level.

MU OF c_r

$c_r = BG_c/(QBG \times \theta) = 0.002/(0.15 \times 180) = 0.000074$
$\delta c_r/\delta BG_c = 1/Q_{BG} \bullet \Theta = 1/0.15 \bullet 180 = 0.03704$
$\delta c_r/\delta Q_{BG} = -BG_c/Q^2_{BG} \bullet \Theta = -0.002/0.15^2 \bullet 180 = -0.0004938$
$\delta c_r/\delta \Theta = -BG_c/Q_{BG} \bullet \Theta^2 = -0.002/0.15 \bullet 180^2 = -0.0000004$
$MUc_r = \sqrt{(0.00027 \bullet 0.03704)^2 + (0.0015 \bullet -0.0004938)^2}$
$\sqrt{+ (0.1 \bullet -0.0000004)^2} = 0.00001g$
Thus, c_r would be 0.074 mg/dscf ± 0.01 mg/dscf at 95% confidence level.

E_T AND MU_{ET}

$E_T = (c_s - c_r)\, Q_{sd}\, \theta = (0.000555 - 0.000074) \times 150 \times 180 = 13.00g$
$\delta E_T/\delta c_s = Q_{std} \bullet \Theta = 150 \bullet 180 = 27{,}000$
$\delta E_T/\delta c_r = Q_{std} \bullet \Theta = 150 \bullet 180 = 27{,}000$
$\delta E_T/\delta Q_{std} = c_s \bullet \Theta - c_r \bullet \Theta = 0.000555 \bullet 180 - 0.000074 \bullet 180 = 0.08667$
$\delta E_T/\delta \Theta = c_s \bullet Q_{std} - c_r \bullet Q_{std} = 0.000555 \bullet 180 - 0.000074 \bullet 180 = 0.07222$
$MU_{ET} = \sqrt{(27{,}000 \bullet 0.0000081)^2 + (27{,}000 \bullet 0.00001)^2\, (0.08667 \bullet 3)^2}$
$\sqrt{+ (0.07222 \bullet 0.1)^2} = 0.436$
Thus the result in this example would be:
ET = 13.00g ± 0.44 g at a 95% confidence level.

EFFICIENCY – CSA B415.1

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The change in enthalpy of the circulating air shall be calculated using the moisture content and temperature rise of the circulating air, as follows:

$$\Delta h = \Delta t\ (1.006 + 1.84x)$$

Where:
Δh = change in enthalpy, kJ/kg
Δt = temperature rise, °C
1.006 = specific heat of air, kJ/kg °C
1.84 = specific heat of water vapor, kJ/kg °C
x = humidity ratio, kg/kg

The equivalent duct diameter shall be calculated as follows:

$$ED = 2HW/H+W$$

Where:
ED = equivalent duct diameter
H = duct height, m
W = duct width, m

The air flow velocity shall be calculated as follows:

$$V = F_p \times C_p \times 34.97 \times \sqrt{T/28.56(P_{baro} + P_s)}$$

where
V = velocity, m/s
F_P = Pitot tube calibration factor determined from vane anemometer measurements
C_P = Pitot factor
= 0.99 for a standard Pitot tube or as determined by calibration for a Type S Pitot tube
34.97 = Pitot tube constant
Note: The Pitot tube constant is determined on the basis of the following units: $m/s[g/g\ mole\ (mm\ Hg)/(K)(mm\ H_2O)]^{0.5}$
ΔP = velocity pressure, mm H2O
T = temperature, K
28.56 = molecular weight of air
P_{Baro} = barometric pressure, mm Hg
P_s = duct static pressure, mm Hg

The mass flow rate shall be calculated as follows:

$$m = 3600VAp$$

where:

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m = mass flow rate, kg/h
V = air flow velocity, m/s
3600 = number of seconds per hour
A = duct cross-sectional area, m2
p = density of air at standard temperature and pressure (use 1.204 kg/m3)

The rate of heat release into the circulating air shall be calculated using the air flow and change in enthalpy, as follows:

$$\Delta e = \Delta h \times m$$

Where:
Δe = rate of heat release into the circulating air, kJ/h
Δh = change in enthalpy of the circulating air, kJ/kg
m = mass air flow rate, kg/h

The heat output over any time interval shall be calculated as the sum of the heat released over each measurement time interval, as follows:

$$E_t = \sum(\Delta e \times i) \text{ for } i = t_1 \text{ to } t_2$$

Where:
Et = delivered heat output over any time interval t_2–t_1, kJ
i = time interval for each measurement, h

The average heat output rate over any time interval shall be calculated as follows:

$$e_t = E_t / t$$

where
e_t = average heat output, kJ/h
t = time interval over which the average output is desired, h

The total heat output during the burn shall be calculated as the sum of all the heat outputs over each time interval, as follows:

$$E_d = \sum(E_t) \text{ for } t = t_0 \text{ to } t_{final}$$

Where:
E_d = heat output over a burn, kJ/h (Btu/h)
E_t = heat output during each time interval, kJ/h (Btu/h)

The efficiency shall be calculated as the total heat output divided by the total energy input, expressed as a percentage as follows:

$$\text{Efficiency, \%} = 100 \times E_d / I$$

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Where:
E_d = total heat output of the appliance over the test period, kJ/kg
I = input energy (fuel calorific value as-fired times weight of fuel charge), kJ/kg (Btu/lb)

SECTION 9
TEST SPECIMEN DESCRIPTION

The model VF100 Solid Fuel 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 fueling door located on the front.

SECTION 10
TEST RESULTS

DESCRIPTION OF TEST RUNS:

RUN #1 (10/10/22): The furnace was set to draw a category 4 output rate. The computer control was turned on. The Test load weighed 42.29 lbs. and utilized a 4.3 lb. coal bed. The average Btu/hr. output was 34,295. Burn time was 13 minutes. Test was aborted at 13 minutes into the test due to filters pugging and the proportional rate between the two trains could not be maintained.

RUN #2 (10/10/22): The furnace was set to draw a category 4 output rate. The computer controller was turned on. The test load weighed 41.20 lbs. and utilized a 4.3 lb. coal bed. The average Btu/hr. output was 30,002. Burn time was 400 minutes. The kg/hr. burn rate was 2.31.

RUN #3 (10/11/22): The furnace was set to draw a category 1 draw rate. The computer controller was turned on. The Test load weighed 36.78 lbs. and utilized a 3.7 lb. coal bed. The average Btu/hr. output was 7,291. Burn time was 396 minutes. The kg/hr. burn rate was 2.06.

RUN #4 (10/12/22): The furnace was set to draw a category 2 output rate. The computer control was turned on. The Test load weighed 42.82 lbs. and utilized a 4.3 lb. coal bed. The average Btu/hr. output was 15,519. Burn time was 284 minutes. Test was aborted at 284 minutes into the test due to filters pugging and the proportional rate between the two trains could not be maintained.

RUN #5 (10/13/22): The furnace was set to draw a category 2 output rate. The computer control was turned on. The Test load weighed 35.89 lbs. and utilized a 3.6 lb. coal bed. The average Btu/hr. output was 15,633. Burn time was 123 minutes. Test was aborted at 123 minutes into the test due to filters pugging and the proportional rate between the two trains could not be maintained.

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Telephone: 608-836-4400
Facsimile: 608-831-9279
www.intertek.com/building

TEST REPORT FOR LAMPPA MANUFACTURING
Report No.: 105224549MID-003R2
Date: 11/18/22

RUN #6 (11/1/22): The furnace was set to draw a category 2 output rate. The computer control was turned on. The Test load weighed 35.66 lbs. and utilized a 3.6 lb. coal bed. The average Btu/hr. output was 14,727. Burn time was 386 minutes. The kg/hr. burn rate was 2.07.

RUN #7 (11/2/22): The furnace was set to draw a category 3 output rate. The computer control was turned on. The Test load weighed 35.58 lbs. and utilized a 3.6 lb. coal bed. The average Btu/hr. output was 19,243. Burn time was 346 minutes. The kg/hr. burn rate was 2.29.

RUN #8 (11/3/22): The furnace was set to draw a category 2 output rate. At about the middle of the test, the manufacturer went to look at the limit switch setting on the heater and touched a wire leading to the limit switch, which was removed. When the wire was being reattached, the wire touched the junction box, shorted out, and tripped the electrical breaker for the lab. This shutdown the test equipment, including the computer and data logger and all data for this test was lost.

RUN #9 (12/6/22): The furnace was set to draw a category 2 output rate. The computer control was turned on. The Test load weighed 36.48 lbs. and utilized a 3.8 lb. coal bed. The average Btu/hr. output was 15,245. Burn time was 446 minutes. The kg/hr. burn rate was 1.86.

RUN #10 (12/7/22): The furnace was set to draw a category 2 output rate. The computer control was turned on. The Test load weighed 35.92 lbs. and utilized a 3.8 lb. coal bed. Test was aborted at 238 minutes into the test due to faulty component, limit switch not activating blower motor.

RUN #11 (12/8/22): The furnace was set to draw a category 2 output rate. The computer control was turned on. The Test load weighed 35.56 lbs. and utilized a 3.6 lb. coal bed. The average Btu/hr. output was 15,182. Burn time was 540 minutes. The kg/hr. burn rate was 1.48.

The test runs has been found to be appropriate, with no anomalies, and the test runs have been validated and is deemed compliant. No negative weight was found on the filters, as the filters and gaskets are weighed together to eliminate filter material transfer to gaskets. All weightings were handled property, with no negative weight on gaskets or probes.

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TEST REPORT FOR LAMPPA MANUFACTURING
Report No.: 105224549MID-003R2
Date: 11/18/22

TABLE 1 – DATA SUMMARY PART A

						Θ	W_{fuel}	MC_{ave}	Q_{in}	Q_{out}
Cat	**Run No.**	**Load % Capacity**	**Target Load**	**Actual Load**	**Actual Load**	**Test Duration**	**Wood Weight as-fired**	**Wood Moisture**	**Heat Input**	**Heat Output**
			Btu/hr	Btu/hr	% of Max	hrs	lb	% DB	Btu	Btu
1	**3**	<35% of Max	**<10,500**	**7,291**	**24.3**	**6.6**	**36.78**	**22.53**	**257,994**	**48,123**
2	**4**	35%-53% of Max	**10,500-15,901**	**15,519**	**51.7**	**4.7**	**42.82**	**22.22**	**301,113**	**73,456**
2	**5**	35%-53% of Max	**10,500-15,901**	**15,633**	**52.1**	**2.1**	**35.89**	**23.19**	**250,398**	**32,048**
2	**6**	35%-53% of Max	**10,500-15,901**	**14,727**	**49.1**	**6.4**	**35.66**	**21.37**	**252,540**	**94,744**
2	**9**	35%-53% of Max	**10,500-15,901**	**15,245**	**50.8**	**7.4**	**36.48**	**19.85**	**261610**	**113324**
2	**10**	35%-53% of Max	**10,500-15,901**	**9,718**	**32.3**	**3.9**	**35.92**	**19.62**	**258,099**	**38,550**
2	**11**	35%-53% of Max	**10,500-15,901**	**15,182**	**50.6**	**9**	**35.56**	**21.08**	**252,426**	**136,634**
3	**7**	53%-76% of Max	**15,901-22,802**	**19,243**	**64.1**	**5.8**	**35.58**	**21.99**	**250,690**	**110,971**
4	**1**	100%	**30,002**	**34,295**	**114.3**	**0.22**	**42.29**	**24.51**	**291,924**	**7,431**
4	**2**	100%	**30,002**	**30,002**	**100**	**6.7**	**41.20**	**21.41**	**291,666**	**200,013**

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TEST REPORT FOR LAMPPA MANUFACTURING
Report No.: 105224549MID-003R2
Date: 11/18/22

TABLE 2. – DATA SUMMARY PART B

			E_T	E	E	E	E	$E_{g/hr}$	η_{del}	η_{SLM}
Category	**Run No.**	**Load % Capacity**	**Total PM Emissions**	**PM Output Based**	**1st Hour Emissions**	**1st Hour Emissions**	**PM Output Based**	**PM Rate**	**Delivered Efficiency**	**Stack Loss Efficiency**
			g	lb/mmBtu Out	g/hr	Lb/mmBtu Out	g/MJ	g/hr	%	%
1	**3**	<35% of Max	**2.53**	**0.116**	**1.6**	**0.427**	**0.050**	**0.38**	**18.7**	**77.0**
2	**4**	35%-53% of Max	**17.33**	**0.520**	**NA**	**NA**	**0.224**	**3.66**	**24.4**	**NA**
2	**5**	35%-53% of Max	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
2	**6**	35%-53% of Max	**9.29**	**0.216**	**2.5**	**0.428**	**0.093**	**1.44**	**37.5**	**72.9**
2	**9**	35%-53% of Max	**4.96**	**0.097**	**0.8**	**0.145**	**0.042**	**0.67**	**43.3**	**75.0**
2	**10**	35%-53% of Max	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
2	**11**	35%-53% of Max	**3.43**	**0.055**	**0.8**	**0.105**	**0.024**	**0.38**	**54.1**	**76.9**
3	**7**	53%-76% of Max	**6.82**	**0.135**	**3.7**	**0.332**	**0.058**	**1.18**	**44.3**	**74.0**
4	**1**	100%	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**
4	**2**	100%	**4.96**	**0.054**	**1.4**	**0.093**	**0.024**	**0.74**	**68.6**	**77.3**

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TABLE 3 - CSA B415.1 RESULTS

RUN NO.	CO EMISSIONS (g/min)	HEATING EFFICIENCY (% HHV)	HEAT OUTPUT (Btu/hr)
2	1.08	77.3	33,691
3	0.82	77.0	29,690
6	2.49	72.9	28,518
7	2.59	74.0	32,018
9	1.60	75.0	26,302
11	1.11	76.9	21,465

TABLE 4 – AVERAGED RESULTS

CATEGORY	AVERAGE VALUE	CO EMISSIONS (g/min)	HEATING EFFICIENCY (% HHV) (DIRECT OUTPUT)
1	0.25	0.82	18.7
2*	0.25	1.36	48.7
3	0.25	2.59	44.3
4	0.25	1.08	68.6
	Average	1.46	45.1

*Note – Results for Category 2 are a straight average of test runs 9 and 11.

Runs 1, 4, and 5 were aborted due to filters plugging during the test, run 8 was aborted due to tripped electrical breaker, no data saved, run 10 was aborted due to faulty limit switch, so CSA B415.1 results were not calculated.

SECTION 11
CONCLUSION

This test demonstrates that this unit an affected facility under the definition given in the regulation. The emission rates meet the EPA requirements for the Step 2 limits.
Run #2 - 0.055 lb/MMBtu Output for Category 4
Run #7 - 0.135 lb/MMBtu Output for Category 3
Run #3 - 0.116 lb/MMBtu Output for Category 1
Run #9 – 0.097 and Run #11- 0.055 averaged to 0.076 lb/MMBtu Output for Category 2

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TEST REPORT FOR LAMPPA MANUFACTURING
Report No.: 105224549MID-003R2
Date: 11/18/22

SECTION 12
PHOTOGRAPHS

Test #1

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TEST REPORT FOR LAMPPA MANUFACTURING
Report No.: 105224549MID-003R2
Date: 11/18/22

Test #2

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TEST REPORT FOR LAMPPA MANUFACTURING
Report No.: 105224549MID-003R2
Date: 11/18/22

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TEST REPORT FOR LAMPPA MANUFACTURING
Report No.: 105224549MID-003R2
Date: 11/18/22

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TEST REPORT FOR LAMPPA MANUFACTURING
Report No.: 105224549MID-003R2
Date: 11/18/22

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TEST REPORT FOR LAMPPA MANUFACTURING
Report No.: 105224549MID-003R2
Date: 11/18/22

Test #6

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Test #7 Pic

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TEST REPORT FOR LAMPPA MANUFACTURING
Report No.: 105224549MID-003R2
Date: 11/18/22

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TEST REPORT FOR LAMPPA MANUFACTURING
Report No.: 105224549MID-003R2
Date: 11/18/22

Test #9

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TEST REPORT FOR LAMPPA MANUFACTURING
Report No.: 105224549MID-003R2
Date: 11/18/22

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TEST REPORT FOR LAMPPA MANUFACTURING
Report No.: 105224549MID-003R2
Date: 11/18/22

Test #11

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SECTION 13
REVISION LOG

REVISION #	DATE	PAGES	REVISION
0	10/24/22	N/A	Original Report Issue
1	11/18/22	3, 15, 16, 17, 24, 25	Added test information for tests 6, 7, and 8.
2	12/13/22	3, 4, 7, 9, 16, 17, 18, 19, 28, 29, 30	Added test information for test 9, 10, 11. Added Teflon Filter info in sampling section. Added ATM to Deviation from Standard. Added Table 4 for averaged results.