TEST REPORT

REPORT NUMBER: G101258894MID-002
REPORT DATE: September 24, 2013

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RENDERED TO

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CANADA

PRODUCT EVALUATED:

Model G200

Report of Testing Model G200 Wood-fueled hydronic heater for compliance with the applicable requirements of the following criteria: EPA Test Method 28 WHH for Measurement of Particulate Emissions and Heating Efficiency of Outdoor Wood-Fired Hydronic Heating Appliances.

TABLE OF CONTENTS

I. INTRODUCTION 4
I.A. GENERAL 4
I.B. TEST UNIT DESCRIPTION 4
I.C. RESULTS 4
I.D. PRETEST INFORMATION 4

II. SUMMARY OF TEST RESULTS 5
II.A EPA RESULTS 5
II.B 8-HOUR HEAT OUTPUT & EFF RATINGS 6
II.C SUMMARY OF OTHER DATA 7

III. PROCESS DESCRIPTION 8
III.A DISCUSSION 8
III.B UNIT DIMENSIONS 9
III.C AIR SUPPLY SYSTEM 9
III.D OPERATION DURING TEST 9
III.E TEST FUEL PROPERTIES 9
III.F START UP OPERATION 9

IV. SAMPLING SYSTEM 10
IV.A SAMPLING LOCATIONS 10
IV.A.1 DILUTION TUNNEL 11
IV.B. OPERATIONAL DRAWINGS 12
IV.B.1 STACK GAS SAMPLE TRAIN 12
IV.B.2 DILUTION TUNNEL SAMPLE SYSTEM 13

V. SAMPLING METHODS 14
V.A. PARTICULATE SAMPLING 14

VI. QUALITY ASSURANCE 14
VI.A. INSTRUMENT CALIBRATION 14
VI.A.1 DRY GAS METERS 14
VI.A.2 STACK SAMPLE ROTAMETER 14
VI.A.3 GAS ANALYZERS 15
VI.B. TEST METHOD PROCEDURES 15
VI.B.1 LEAK CHECK PROCEDURES 15
VI.B.2 TUNNEL VELOCITY/FLOW MEASUREMENT 15
VI.B.3 PM SAMPLING PROPORTIONALITY 15

VII. RESULTS & OBSERVATIONS 16

APPENDICES

Laboratory Operating Procedure .... A
Data and Calculation Forms .... B
Calibration Documents C
Unit Drawings and Installation Manual .... D
Dry Gas Meter Calibration Data.. E
Unit Preburn Documentation .... F

I. INTRODUCTION

I.A. GENERAL

From September 9-12, 2013 Intertek Testing Services NA Inc. (Intertek) conducted tests on the model G200 wood-fired outdoor hydronic heater to determine emission and efficiency results for SteelTech, Inc.

Tests were conducted by Brian Ziegler and Ken Slater at the Intertek Testing Services NA Inc. laboratory located at 8431 Murphy Drive, Middleton, Wisconsin. The laboratory elevation is 860 feet above sea level. Tests were evaluated to EPA Test Method 28 WHH Measurement of Particulate Emissions and Heating Efficiency of Outdoor Wood-Fired Hydronic Heating Appliances as a reference standard.

I.B. TEST UNIT DESCRIPTION

The model G200 is constructed of steel with a steel and fire brick firebox. The unit weighs 2372 lbs. dry. The water vessel is located around and above the firebox and holds 1600 lbs. of water.

I.C. RESULTS

The unit as tested produced a weighted average emission rate of 0.066 lbs/million Btu output for year round.

I.D. PRETEST INFORMATION

The test unit was received at Intertek Testing Services NA Inc. in Middleton, Wisconsin on September 9, 2013. 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 and instrumented with thermocouples in the specified locations.

The chimney system and laboratory dilution tunnel was cleaned using standard wire brush chimney cleaning equipment.

On September 9, 2013, the unit was ready for testing.

II. SUMMARY OF TEST RESULTS

II.A EPA Results

Table 1A. Data Summary Part A

Category	Run No.	Load % Capacity	Target Load	Actual Load	Actual Load	Θ Test Duration	W_{fuel} Wood Weight as-fired	MC_{ave} Wood Moisture	Q_{in} Heat Input	Q_{out} Heat Output
			Btu/hr	Btu/hr	% of Max	hrs	lb	% DB	Btu	Btu
I	2	<15% of Max	34,800	31,984	13.8%	26.13	161.11	23.33	1,123,420	835,839
II	3	16-24% of Max	55,680	52,530	22.6%	15.57	152.94	23.25	1,067,186	817,721
III	4	25-50% of max	116,000	113,878	49.1%	7.67	156.08	21.58	1,104,048	873,061
IV	1	Max capacity	232,000	214,636	92.5%	3.78	156.26	23.11	1,091,556	812,040

Table 1B. Data Summary Part B

Category	Run No.	Load % Capacity	T2 Min Min Return Water Temp.	E_T Total PM Emissions	E PM Output Based	E PM Output Based	$E_{g/hr}$ PM Rate	$E_{g/kg}$ PM Factor	η_{del} Delivered Efficiency	η_{SLM} Stack Loss Efficiency
			ºF	g	lb/mmBtu Out	g/MJ	g/hr	g/kg	%	%
I	2	<15% of Max	149.61	31.35	0.083	0.036	1.20	0.529	74.4%	77.7%*
II	3	16-24% of Max	149.09	24.32	0.066	0.028	1.56	0.432	76.6%	78.9%
III	4	25-50% of max	142.8	16.29	0.041	0.018	2.12	0.280	79.1%	79.4%
IV	1	Max capacity	122.91	19.33	0.052	0.023	5.11	0.336	74.4%	82.4%

* NOTE: The Stack Loss Efficiency for the category 1 did result in two anomalies. 1) During the long off cycles, the CO and CO2 was reading zero; therefore giving high excess air numbers. The off cycle numbers were removed from the data. 2) During the on cycles, the CO2 numbers were reading as high as 27%. This concluded that there was some electrical interference and these numbers were removed from the data.

II.B 8-Hour Heat Output and Efficiency Ratings

Table 1C: Hang Tag Information

MANUFACTURER:	**SteelTech, Inc.**		
MODEL NUMBER:	**G200**		
MAXIMUM OUTPUT RATING:	**232,000**		Btu/hr
8-HOUR OUTPUT RATING:	$Q_{out\text{-}8hr}$	111,315	Btu/hr
8-HOUR AVERAGE EFFICIENCY:	$\eta_{avg\text{-}8hr}$	**79.0%**	**(Using higher heating value)**
		85.0%	(using lower heating value)
ANNUAL EFFICIENCY RATING:	η_{avg}	**76.2%**	**(Using higher heating value)**
		82.1%	(using lower heating value)
PARTICULATE EMISSIONS:	E_{avg}	1.74	GRAMS/HR (average)
		0.066	**LBS/MILLION Btu OUTPUT**

II.C Summary of other Data

Table 2. Year Round Use Weighting

Run No.	Category	Weighting Factor	$\eta_{del,i} \times F_i$- HHV	$\eta_{del,i} \times F_i$- LHV	$E_{g/MJ,i} \times F_i$	$E_{g/kg,i} \times F_i$	$E_{lb/mmbtu,i} \times F_i$	$E_{g/hr,i} \times F_i$
II	1	0.437	0.325	0.350	0.016	0.231	0.036	0.524
III	2	0.238	0.182	0.196	0.007	0.103	0.016	0.372
IV	3	0.275	0.217	0.234	0.005	0.077	0.011	0.584
I	4	0.050	0.037	0.040	0.001	0.017	0.003	0.256
	Totals	**1.000**	**76.2%**	**82.1%**	**0.028**	**0.428**	**0.066**	**1.736**

EPA Method 28 OWHH

Category	**1**	**2**	**3**	**4**
Run Number	2	3	4	1
Test Date	9/10/2013	9/11/2013	9/12/2013	9/9/2013
Total Test Fuel Weight (lb)	161.11	152.94	156.08	156.26
Avg. Test Fuel Moisture (% dry)	23.33	23.25	21.58	23.11
Avg. Temp. of Water in load side (^oF)	118.53	119.15	107.99	88.03
Temp. Diff. in/out of Heat Exchanger (^oF)	95.77	99.23	94.54	51.93
Liquid Flow Rate (gal/min)	0.68	1.10	2.46	8.93
Test Duration (min)	1568.00	934.00	460.00	227.00
Burn Rate (kg/hr)	2.27	3.62	7.60	15.22
Average Barometric Pressure (“Hg)	29.11	29.13	29.10	28.83
Average Delta p (inches of water)	0.07	0.07	0.07	0.07
Average Gas Velocity in Tunnel (feet/sec)	16.22	16.34	16.39	15.66
Average Gas Flow Rate in Dilution Tunnel (Qsd),(dscf/m)	764.34	770.19	772.39	737.94
Target Load High	34800	55680	116000	255200
Target Load Low	<34800	37120	58000	208.800
Actual Load	31984	52530	113878	214636
Quercus Ruba L. Fuel Heating Value	8600		Btu/lb Higher Heating Value	

III. PROCESS DESCRIPTION

III.A. DISCUSSION

RUN #1 (September 9, 2013). The cooling water for the heat exchanger was set to draw a category 4 burn rate. Minor adjustments were made to maintain the heat exchange rate. The Test Load weighed 156.26 lbs. and utilized a 31 lb. coal bed. The average Btu/hr output was 214,636. Burn time was 3.78 hours. The kg/hr burn rate was 15.22. The deviation between the two sample collections did result in an 11.69% deviation, which is greater than the allowed 7.5%. The g/Kg deviation was then used. This resulted in a difference of 0.065 g/Kg, which is less than the limit of 0.5 g/Kg.

RUN #2 (September 10, 2013). The cooling water for the heat exchanger was set to draw a category 1 burn rate. Minor adjustments were made to maintain the heat exchange rate. The Test Load weighed 161.11 lbs. and utilized a 32 lb. coal bed. The average Btu/hr output was 31,984. Burn time was 26.13 hours. The kg/hr burn rate was 2.27. The deviation between the two sample collections did result in a 9.13% deviation, which is greater than the allowed 7.5%. The g/Kg deviation was then used. This resulted in a difference of 0.079 g/Kg, which is less than the limit of 0.5 g/Kg.

RUN #3 (September 11, 2013). The cooling water for the heat exchanger was set to draw a category 2 burn rate. Minor adjustments were made to maintain the heat exchange rate. The Test Load weighed 152.94 lbs. and utilized a 31 lb. coal bed. The average Btu/hr output was 52,530. Burn time was 15.57 hours. The kg/hr burn rate was 3.62. The deviation between the two sample collections did result in a 9.03% deviation, which is greater than the allowed 7.5%. The g/Kg deviation was then used. This resulted in a difference of 0.096 g/Kg, which is less than the limit of 0.5 g/Kg.

RUN #4 (September 12, 2013). The cooling water for the heat exchanger was set to draw a category 3 burn rate. Minor adjustments were made to maintain the heat exchange rate. The Test Load weighed 156.08 lbs. and utilized a 31 lb. coal bed. The average Btu/hr output was 113,878. Burn time was 7.67 hours. The kg/hr burn rate was 7.60.

III.B. UNIT DIMENSIONS

Overall dimensions are 48-in wide, 79-in deep, 72-in high.

III.C. AIR SUPPLY SYSTEM

Combustion air enters the unit in the front of the unit aided by a combustion air blower. Combustion air is controlled electronically with modulating dampers. This air is directed to the Firebox. Combustion products flow through a heat exchanger system. Combustion products exit through a 8-in flue collar located on the top of the outer enclosure.

III.D. OPERATION DURING TEST

The water-to-water heat exchanger was adjusted for each of the heat loads by increasing or decreasing the water flow through the cooling side of the heat exchanger. The inlet and outlet water temperatures on the boiler were monitored to determine the Delta-T.

III.E TEST FUEL PROPERTIES

The fuel used was Quercus Ruba L. (Oak, Red). The fuel was dimensionally cut to 4 in. by 4 in. by 24 inches in length. The fuel was dried to average moisture content between 20% and 23% on a dry basis. Spacers of Quercus Ruba L. (Oak, Red) measuring ¾ x 1½ x 4 inches were attached 1 inch from each end of each load component and on two sides. Fuel Load components were arranged in a 3 component, 2 component, 2 component, 2 component and 1 component fashion.

III.F. START-UP OPERATION

Each test was started with a clean firebox and the scale zeroed. A fire was started. During the pretest loads, the water flow was adjusted to establish target heat draw. After verification the heat draw could be consistently stable, the sampling system was started and was operated for the duration of the test run.

IV. SAMPLING SYSTEMS

The ASTM E2515-2007 sampling procedure was used.

IV.A. SAMPLING LOCATIONS

Particulate samples are collected from the dilution tunnel at a point 16 feet from the tunnel entrance. The tunnel has two elbows ahead of the sampling section. (See Figure 3.) The sampling section is a continuous 14-foot section of 12-inch diameter pipe straight over its entire length. Tunnel velocity pressure is determined by a standard Pitot tube located 96 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 36 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.)

IV.A.(1) DILUTION TUNNEL

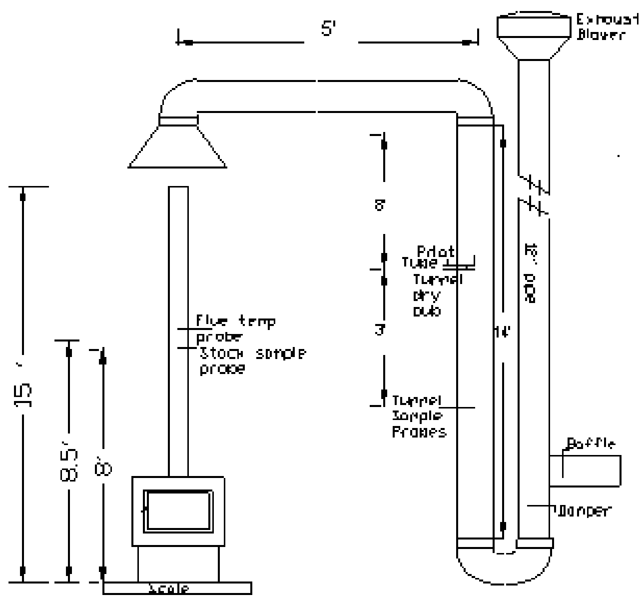
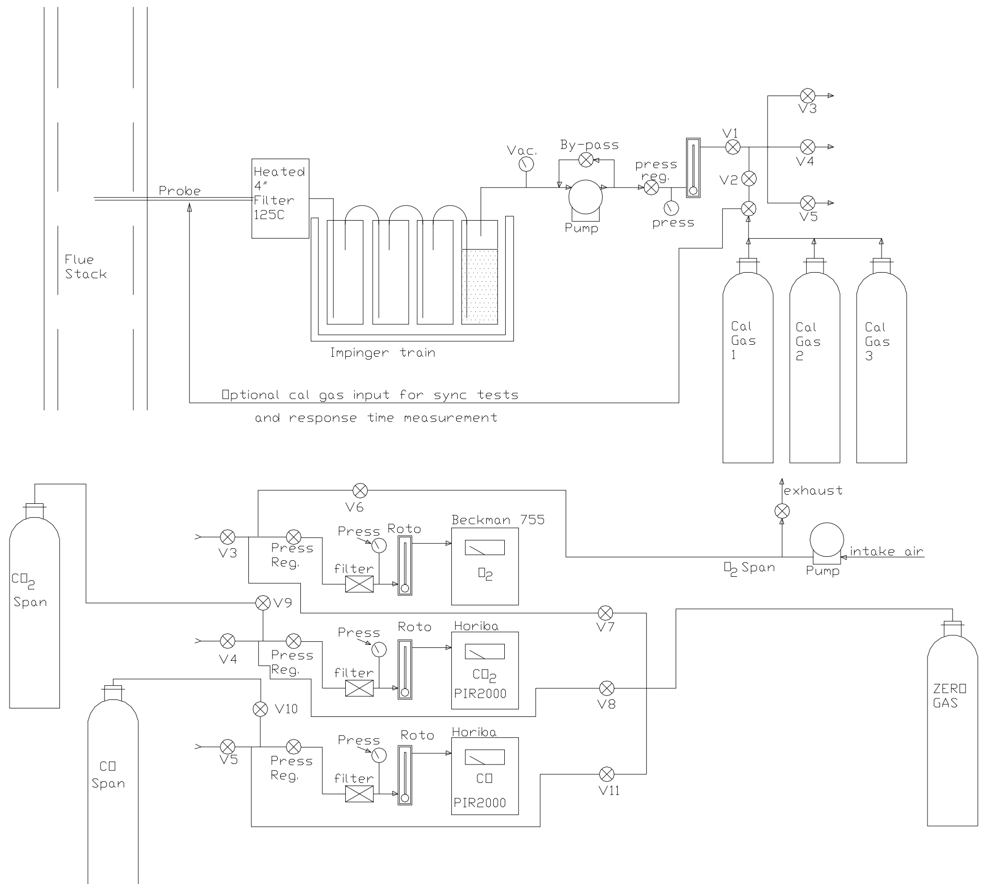


FIGURE 1

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

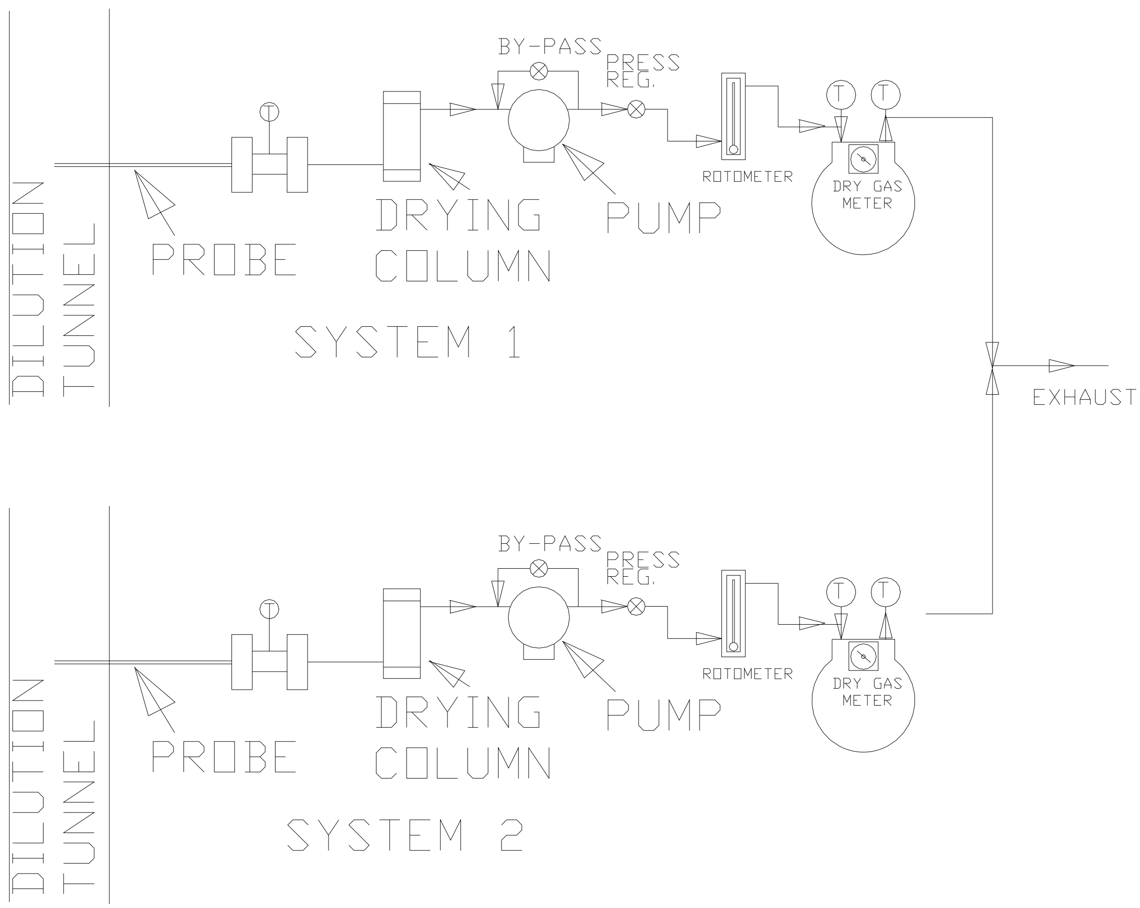


Figure 3

V. SAMPLING METHODS

V.A. PARTICULATE SAMPLING

Particulates were sampled in strict accordance with ASTM E2515-07. 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.

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^3, the resolution is .1%, giving an accuracy higher than the ±2% required by the standard.

VI.A.(2). STACK SAMPLE ROTOMETER

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 five-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 (5G-3)

Proportionality was calculated in accordance with EPA Method 5G-3. The data and results are included in Appendix C.

VII RESULTS AND OBSERVATIONS

The Model G200 has been found to be in compliance with the applicable performance and construction requirements of the following criteria for Phase 2 of the EPA WHH Partnership:
"**EPA Test Method 28 WHH Measurement of Particulate Emissions and Heating Efficiency of Outdoor Wood-Fired Hydronic Heating Appliances**"

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