TEST REPORT

REPORT NUMBER: G101074993MID-002.2
REPORT DATE: April 26, 2013

EVALUATION CENTER
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Middleton, WI 53562

RENDERED TO

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CANADA

PRODUCT EVALUATED:

Model G100

Report of Testing Model G100 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.

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I. INTRODUCTION

I.A. GENERAL

From March 18-21, 2013 Intertek Testing Services NA Inc. (Intertek) conducted tests on the model G100 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 G100 is constructed of steel with a steel and fire brick firebox. The unit weighs 1390 lbs. dry. The water vessel is located around and above the firebox and holds 731 lbs. of water.

I.C. RESULTS

The unit as tested produced a weighted average emission rate of 0.074 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 March 12, 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 March 18, 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	18,000	17,829	14.9%	15.17	66.18	22.79	463,503	270,406
II	3	16-24% of Max	28,800	27,956	23.3%	11.73	67.77	23.81	470,723	328,013
III	4	25-50% of max	60,000	57,334	47.8%	6.20	64.8	23.37	451,706	355,470
IV	1	Max capacity	120,000	110,963	92.5%	3.32	68.31	21.61	483,089	368,028

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	156.16	12.98	0.106	0.045	0.86	0.925	58.3%	74.0%
II	3	16-24% of Max	155.52	6.99	0.047	0.020	0.60	0.404	69.7%	57.3%*
III	4	25-50% of max	152.05	6.98	0.043	0.019	1.13	0.385	78.7%	75.3%*
IV	1	Max capacity	137.98	14.12	0.085	0.036	4.26	0.554	76.2%	79.7%

*NOTE: Stack Loss Method efficiency – In the category 2 and 3 tests the stack loss efficiency calculated per CSA B415.1-2010 is lower than the delivered efficiency. An analysis of the data shows that during idle periods the flue gas oxygen concentration approached ambient levels while the CO_2 levels were typically less than 1%. During these periods the weight loss and stack gas data essentially indicate that there is near zero actual flow in chimney and thus there is no significant stack loss occurring. Oxygen levels approach ambient concentrations due to room air diffusion into the chimney when no flow through the appliance is occurring. However, the stack loss algorithm is calculating a significant loss during these periods. This situation can be accounted for by simply deleting the data for the idle periods. Weight change data shows no actual weight loss during these periods as well although the scale has some noise and thus shows changes of +/- a few tenths of a pound which also create errors in the energy loss calculation.

An indication of this problem can be seen in the two calculations of A/F in the B415.1 test method. A/F is calculated for each data increment and the results are averaged (cell M16 of the spread sheet). In addition, the average O_2, CO and CO_2 concentrations are used to calculate an A/F ratio (cell P5 of spreadsheet). A large difference between these determinations of A/F is an indicator that the results are likely to be inaccurate. The following shows these A/F values for this test series.

				w/ Idle Period Data Removed	
Run Number	**Category**	**A/F (Cell M16)**	**A/F (Cell P5)**	**A/F (M16)**	**SLM Eff.**
2	1	488	36.8	23.99	74.84
3	2	364	22.9	22.01	73.98
4	3	76.3	14.55	16.59	79.88
1	4	8.78	8.72	NA	NA

Only the category 4 test produced good agreement in the A/F determinations. When the data for the category 1 through 3 runs is adjusted to remove data from periods where no stack flow is occurring, the stack loss efficiencies calculated are considerably more accurate and show good agreement with the delivered efficiency results.

II.B 8-Hour Heat Output and Efficiency Ratings

Table 1C: Hang Tag Information

MANUFACTURER:	**SteelTech, Inc.**		
MODEL NUMBER:	**G100**		
8-HOUR OUTPUT RATING:	$Q_{out-8hr}$	47,772	Btu/hr
8-HOUR AVERAGE EFFICIENCY:	$\eta_{avg-8hr}$	**75.8%**	**(Using higher heating value)**
		81.5%	(using lower heating value)
ANNUAL EFFICIENCY RATING:	η_{avg}	**67.5%**	**(Using higher heating value)**
		72.7%	(using lower heating value)
PARTICULATE EMISSIONS:	E_{avg}	1.04	GRAMS/HR (average)
		0.074	**LBS/MILLION Btu OUTPUT**

II.C Summary of other Data

Table 2. Year Round Use Weighting

Run No.	Category	Weighting Factor	$\eta_{del,i}$ x F_i- HHV	$\eta_{del,i}$ x F_i- LHV	$E_{g/MJ,i}$ x F_i	$E_{g/kg,i}$ x F_i	$E_{lb/mmbtu,i}$ x F_i	$E_{g/hr,i}$ x F_i
I	2	0.437	0.255	0.274	0.020	0.404	0.046	0.374
II	3	0.238	0.166	0.179	0.005	0.096	0.011	0.142
III	4	0.275	0.216	0.233	0.005	0.106	0.012	0.310
IV	1	0.050	0.038	0.041	0.002	0.028	0.004	0.213
	Totals	**1.000**	**67.5%**	**72.7%**	**0.032**	**0.634**	**0.074**	**1.038**

EPA Method 28 OWHH

Category	**1**	**2**	**3**	**4**
Run Number	2	3	4	1
Test Date	3/20/2013	3/20/2013	3/21/2013	3/18/2013
Total Test Fuel Weight (lb)	66.18	67.77	64.80	68.31
Avg. Test Fuel Moisture (% dry)	22.79	23.81	23.37	21.61
Avg. Temp. of Water in load side (^oF)	120.07	120.10	115.09	98.56
Temp. Diff. in/out of Heat Exchanger (^oF)	109.62	111.16	118.23	102.08
Liquid Flow Rate (gal/min)	0.33	0.51	0.97	2.15
Test Duration (min)	910.00	704.00	372.00	199.00
Burn Rate (kg/hr)	1.61	2.12	3.84	7.68
Average Barometric Pressure (“Hg)	29.00	29.05	29.04	28.71
Average Delta p (inches of water)	0.12	0.12	0.12	0.11
Average Gas Velocity in Tunnel (feet/sec)	20.91	21.07	20.85	20.21
Average Gas Flow Rate in Dilution Tunnel (Qsd),(dscf/m)	985.53	993.12	982.67	952.43
Target Load High	18000	28800	60000	120000
Target Load Low	<18000	19200	30000	108000
Actual Load	17829	27956	57334	110963
Quercus Ruba L. Fuel Heating Value	8600		Btu/lb Higher Heating Value	

III. PROCESS DESCRIPTION

III.A. DISCUSSION

RUN #1 (March 18, 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 68.31 lbs. and utilized a 13 lb. coal bed. The average Btu/hr output was 110,963. Burn time was 3.32 hours. The kg/hr burn rate was 7.68.

RUN #2 (March 20, 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 66.18 lbs. and utilized a 13 lb. coal bed. The average Btu/hr output was 17,829. Burn time was 15.17 hours. The kg/hr burn rate was 1.61.

RUN #3 (March 20, 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 67.77 lbs. and utilized a 13 lb. coal bed. The average Btu/hr output was 27,956. Burn time was 11.73 hours. The kg/hr burn rate was 2.12.

RUN #4 (September 15, 2011). 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 64.80 lbs. and utilized a 13 lb. coal bed. The average Btu/hr output was 57,334. Burn time was 6.20 hours. The kg/hr burn rate was 3.84.

III.B. UNIT DIMENSIONS

Overall dimensions are 33-in wide, 50.5-in deep, 64.5-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 6-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 14 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, 3 component, 3 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

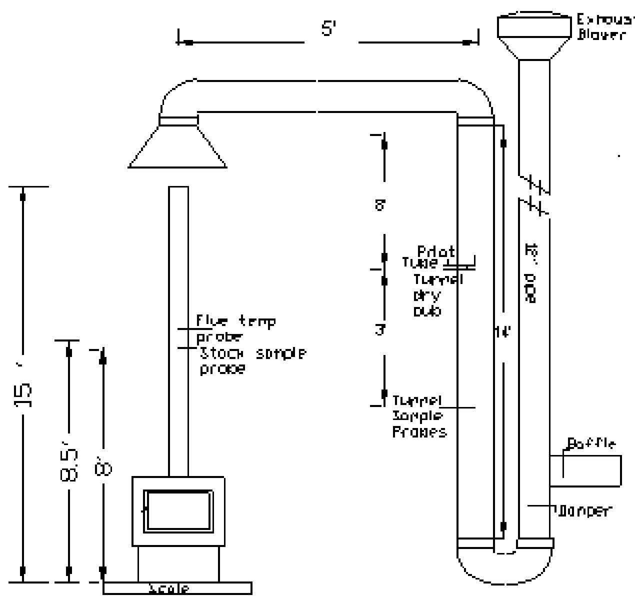
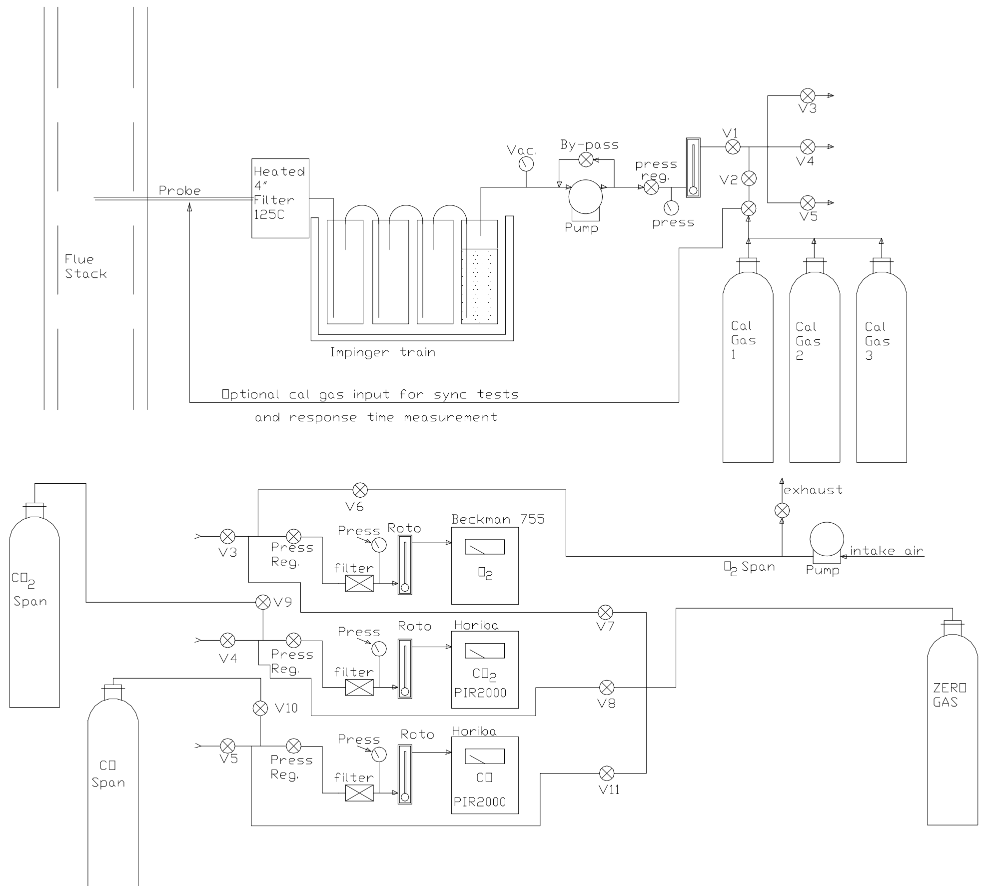


FIGURE 1

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

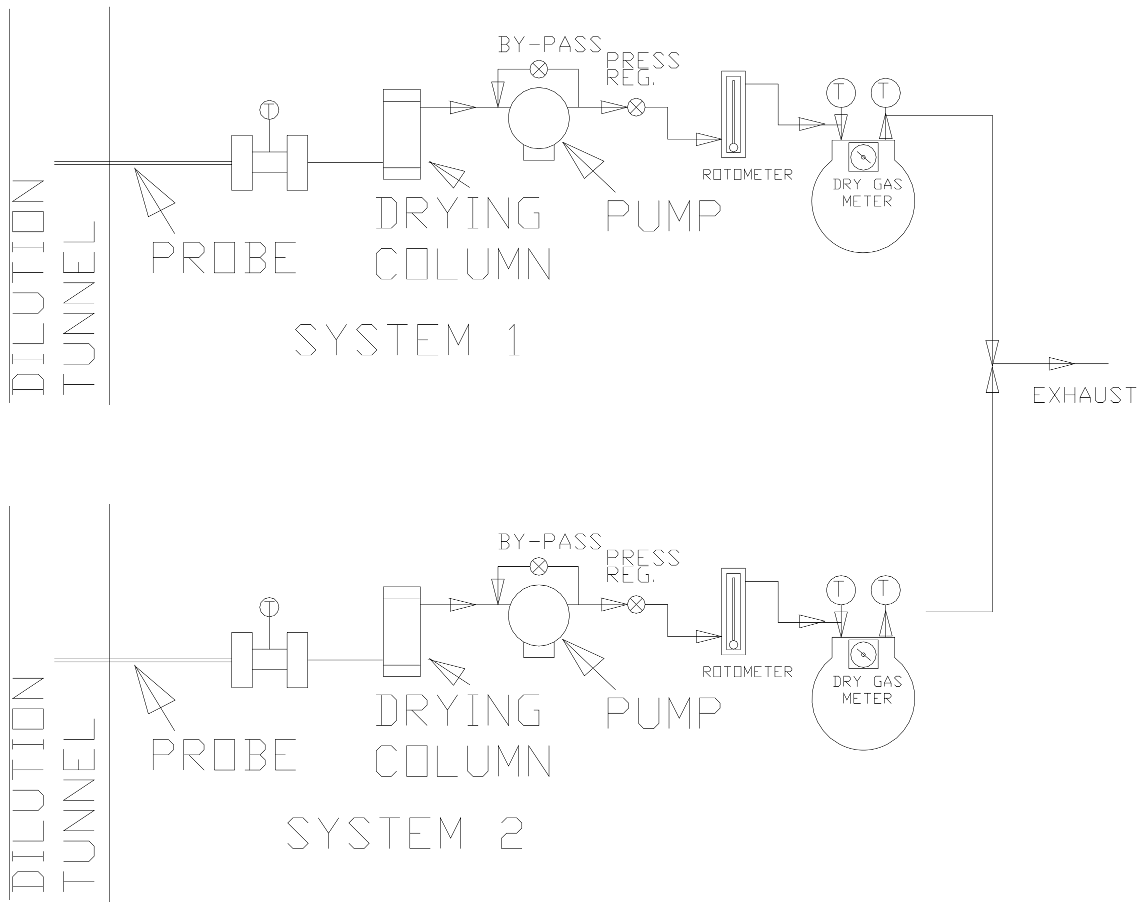


Figure 3

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 inter-ferences 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 G100 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**"

INTERTEK TESTING SERVICES NA

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