TEST REPORT

REPORT NUMBER: G100463637MID-005R2
REPORT DATE: October 26, 2011
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REVISED REPORT DATE: January 26, 2015

EVALUATION CENTER
Intertek Testing Services NA Inc.
8431 Murphy Drive
Middleton, WI 53562

RENDERED TO

Dectra Corporation
3425 33rd Avenue, NE
Saint Anthony, MN 55418

PRODUCT EVALUATED:

Model WHS2000 Solid Fuel Hydronic Furnace

Report of Testing Model WHS2000 Solid Fuel Hydronic Heater for compliance with the applicable requirements of the following criteria: Annex A1 Modified test method for wood-fired hydronic appliances that utilize thermal storage of ASTM E2618-13 Measurement of particulate emissions and heating efficiency of outdoor solid fuel-fired hydronic heating appliances.

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APPENDICES

REVISION SUMMARY

DATE	SUMMARY
November 8, 2011	Added explanation for models WHS2000H and WHS2000V to section VII.
November 14, 2011	Added corrected data to tables in section II.
January 26, 2015	Corrections due to error in standby loss formula. Report revised to update to the 2013 edition of ASTM E2618 including more accurate values for fuel higher and lower heating values.

I. INTRODUCTION

I.A. GENERAL

From October 3, 2011 to October 6, 2011 Intertek Testing Services NA Inc. (Intertek) conducted tests on the WHS2000 Solid Fuel Hydronic Heater to determine emission and efficiency results for Dectra Corporation.

Tests were conducted by Ken Slater at the Dectra Corporation facility located at 1162 Red Fox Road, Arden Hills, Minnesota. Tests were originally evaluated to the Appendix X1 Modified test method for wood-fired hydronic appliances that utilize thermal storage for ASTM E2618-09 Standard Test Method for Measurement of Particulate Emissions and Heating Efficiency of Outdoor Solid Fuel-Fired Hydronic Heating Appliances. This report has been revised to reflect calculated values as specified in the 2013 edition of ASTM E2618 Annex A1. No changes have been made in the test procedure or measurement process from the 2009 edition. The only change of significance is the use of more accurate higher and lower heating values for the fuel. This revision also corrects an error in the stand-by loss calculation formula.

I.B. TEST UNIT DESCRIPTION

The model WHS2000 is a solid fueled unit with a 14.15 cubic foot firebox constructed of carbon sheet steel, and weighs 3574 lbs. dry. The heat exchanger extends through the water vessel, which holds 15588 lbs. of water. This corresponds to a total water capacity of 1870 gallons. This appliance is designed as a full heat storage system which has the capacity to safely store 100% of the output produced by burning a single full fuel load of seasoned cordwood.

The appliance consists of a large horizontal cylindrical steel tank with a firebox installed in a vertical head which connects to a ceramic fiber refractory lined secondary combustion chamber and then to steel piping which makes several passes through the water in the tank and exits through the rear head where it connects to a chimney collar. Combustion air is supplied through a pipe that routes air to a front and delivers some air through openings above and below the firebox door that aim at the front of the firebox and over the fuel to supply secondary air to the secondary combustion chamber. The firebox is lined on the bottom with firebrick. The blower is operated by a controller that turns it off when the flue gas temperature approaches the water temperature.

I.C. RESULTS

The unit as tested produced an average emissions rate of:
0.070 lbs/million Btu of output (0.030 g/MJ) for the heating season.
0.071 lbs/million Btu of output (0.030) for year round use.

I.D. PRETEST INFORMATION

The unit was inspected upon arrival at the Dectra Corporation facility and found to be in good condition. The unit was set up per the manufacturer's instructions. 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 October 3, 2011 the unit was ready for testing.

II. SUMMARY OF TEST RESULTS

II.A EPA Results

Table 1A. Data Summary Part A

					Θ	W_{fuel}	MC_{ave}	Q_{in}	Q_{out}
Category	**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
I	15% of Max	30,000	30,000	15%	26.5	158.51	23.60	1,098,058	795,589
II	20% of Max	40,000	40,000	20%	20.3	158.51	23.60	1,098,058	810,695
III	37.5% of Max	75,000	75,000	37.5%	11.1	158.51	23.60	1,098,058	832,835
IV	Max Capacity	200,000	200,000	100%	4.2	158.51	23.60	1,098,058	849,404

Table 1B. Data Summary Part B

			E	E	$E_{g/hr}$	$E_{g/kg}$	$\eta_{del\text{-}HHV}$	$\eta_{del\text{-}LHV}$
Category	**Load % Capacity**	**Total PM Emissions**	**PM Output Based**	**PM Output Based**	**PM Rate**	**PM Factor**	**Delivered Efficiency HHV**	**Delivered Efficiency LHV**
		g	lb/mmBtu Out	g/MJ	g/hr	g/kg	%	%
I	15% of Max	26.0	0.072	0.031	0.98	0.447	72.03%	77.6%
II	16-24% of Max	26.0	0.071	0.030	1.28	0.447	73.40%	79.0%
III	25-50% of max	26.0	0.069	0.030	2.34	0.447	75.41%	81.2%
IV	Max capacity	26.0	0.067	0.029	6.13	0.447	76.91%	82.8%

II.B 8-Hour Heat Output and Efficiency Ratings

Table 1C: Hang Tag Information

MANUFACTURER:	**Dectra**		
MODEL NUMBER:	**WHS2000**		
MAXIMUM OUTPUT RATING	$Q_{out\text{-}Max}$	200,000	Btu/hr
8-HOUR OUTPUT RATING:	$Q_{out\text{-}8hr}$	105,050	Btu/hr
8-HOUR AVERAGE EFFICIENCY:	$\eta_{avg\text{-}8hr}$	**76.1%**	**(Using higher heating value)**
		81.9%	(using lower heating value)
ANNUAL EFFICIENCY RATING:	η_{avg}	**73.5%**	**(Using higher heating value)**
		79.2%	(using lower heating value)
PARTICULATE EMISSIONS:	E_{avg}	1.69	GRAMS/HR (average)
		0.071	**LBS/MILLION Btu OUTPUT**

II.C Summary of Emissions Data

Table 2A. Year Round Use Weighting

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	$E_{lb/mmbtu\ Output,\ i}$ x F_i	$E_{g/hr,i}$ x F_i
I	0.437	0.315	0.339	0.014	0.195	0.031	0.429
II	0.238	0.175	0.188	0.007	0.106	0.017	0.306
III	0.275	0.207	0.223	0.008	0.123	0.019	0.645
IV	0.050	0.038	0.041	0.001	0.022	0.007	0.307
Totals	**1.000**	**73.5%**	**79.2%**	**0.030**	**0.447**	**0.070**	**1.69**

Table 2B. Heating Season Use Weighting

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	$E_{lb/mmbtu\ Output,i}$ x F_i	$E_{g/hr,i}$ x F_i
I	0.175	0.126	0.136	0.005	0.078	0.013	0.172
II	0.275	0.202	0.217	0.008	0.123	0.019	0.353
III	0.450	0.339	0.365	0.013	0.201	0.031	1.055
IV	0.100	0.077	0.083	0.003	0.045	0.003	0.613
Totals	**1.000**	**74.4%**	**80.1%**	**0.030**	**0.447**	**0.071**	**2.19**

II.D Summary of Other Data

	Run 1	Run 2	Run 3	Standby	Units
Steel Mass	3574	3574	3574	3574	lbs
Water Mass	15588	15588	15588	15588	lbs
Fuel Load Weight	156.69	153.37	159.79		lbs
Fuel MC (dry basis)	24.56	23.02	23.24		%
Kindling Mass	1.85	1.95	1.87		lbs
Kindling MC (dry basis)	10	10	10		%
Starting system temp.	120.28	125.64	124.70	172.20	F
Ending System Temp.	172.20	179.6	180.50	169.20	F
Average Room Temp.	75.94	79.06	78.53	77.21	
Burn Time	162	166	171		Minutes
Burn Time	2.70	2.77	2.85		Hours
Standby Test Duration				18	Hours
HHV	8600	8600	8600		BTU/lb
Dry Fuel Weight	58	57	60		Kg
Burn Rate	21.42	20.74	20.91		Kg/hr
Input	1,096,339	1,087,444	1,129,655		BTU
Heat Stored	828,952	860,486	889,753		BTU
Average			859,730		BTU
Standby Loss Rate				28.4	BTU/hr-F
Total Emissions	25.291	20.147	32.674		Grams
Total Emissions	0.056	0.044	0.072		lbs
Category I Output Rate	30000	30000	30000	2416	BTU/hr
Category II Output Rate	40000	40000	40000	2416	BTU/hr
Category III Output Rate	75000	75000	75000	2416	BTU/hr
Category IV Output Rate	200000	200000	200000	2416	BTU/hr
				Average	
Output Time Cat I	25.6	26.5	27.4	26.5	Hours
Output Time Cat II	19.5	20.3	21.0	20.3	Hours
Output Time Cat III	10.7	11.1	11.5	11.1	Hours
Output Time Cat IV	4.1	4.3	4.2	4.2	Hours
				Average	
Category I Efficiency	70.0%	73.2%	72.9%	72.0%	
Category II Efficiency	71.3%	74.6%	74.3%	73.4%	
Category III Efficiency	73.3%	76.7%	76.3%	75.4%	
Category IV Efficiency	74.7%	78.2%	77.8%	76.9%	
Category I Emissions	0.073	0.056	0.087	0.072	**lb/mmBTU output**
Category II Emissions	0.071	0.055	0.086	0.071	**lb/mmBTU output**
Category III Emissions	0.069	0.053	0.084	0.069	**lb/mmBTU output**
Category IV Emissions	0.068	0.052	0.082	0.067	**lb/mmBTU output**

III. PROCESS DESCRIPTION

III.A. DISCUSSION

RUN #1 (October 3, 2011). The starting temperature in the heat storage vessel was 120.28°F. Burn time was 2.70 hours and ended with a heat storage vessel temperature of 172.2°F.

RUN #2 (October 4, 2011). The starting temperature in the heat storage vessel was 125.6°F. Burn time was 2.77 hours and ended with a heat storage vessel temperature of 179.1°F.

RUN #3 (October 5, 2011). The starting temperature in the heat storage vessel was 124.7°F. Burn time was 2.85 hours and ended with a heat storage vessel temperature of 180.5°F.

III.B. UNIT DIMENSIONS

Overall dimensions are 71.75-in wide, 122.5-in deep, 76.75-in high.

III.C. AIR SUPPLY SYSTEM

Combustion air enters from a fresh air intake located on the rear of the unit. The air travels to a collar in the front of the unit where it enters the firebox via primary and secondary combustion air nozzles. The movement of combustion air is aided by a constant 3600 RPM induced-draft combustion air blower. Combustion products flow through a heat exchanger system before exiting through a 6-in flue collar located at the top back of the outer enclosure. Combustion air is terminated by an electronic digital controller. The controller compares the flue and water temperatures until they fall to within 5 °F of each other. The blower is then turned off and combustion air is terminated.

III.D. OPERATION DURING TEST

The boiler is operated until the entire fuel load is consumed and there is no further combustion in the firebox. The end of the test is determined when the water storage temperature is no longer increasing.

III.E TEST FUEL PROPERTIES

The fuel used was Quercus Ruba L. (Oak, Red). The fuel was split cordwood with cross sectional dimensions approximately 3 to 7 inches x 24 inches in length. The fuel was dried to average moisture content between 19% and 25% on a dry basis. Individual pieces weighed between 6 and 13.5 pounds with an average weight of 8.7 pounds.

III.F. START-UP OPERATION

The cordwood fuel started with newspaper and a measured kindling load. As the test load was being lit, the sampling system was started simultaneously. The unit was allowed to operate until all combustion in the firebox had ceased.

IV. SAMPLING SYSTEMS

The ASTM E2515-09 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 10-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.)

IV.A.(1) DILUTION TUNNEL

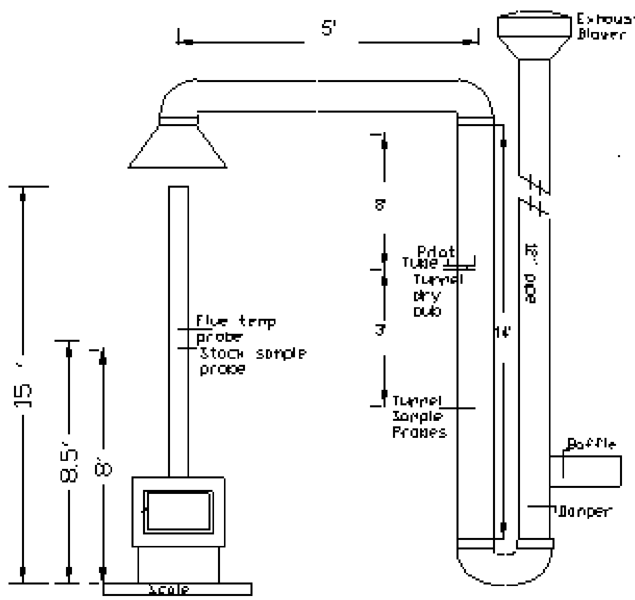

FIGURE 1

IV.B.OPERATIONAL DRAWINGS

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

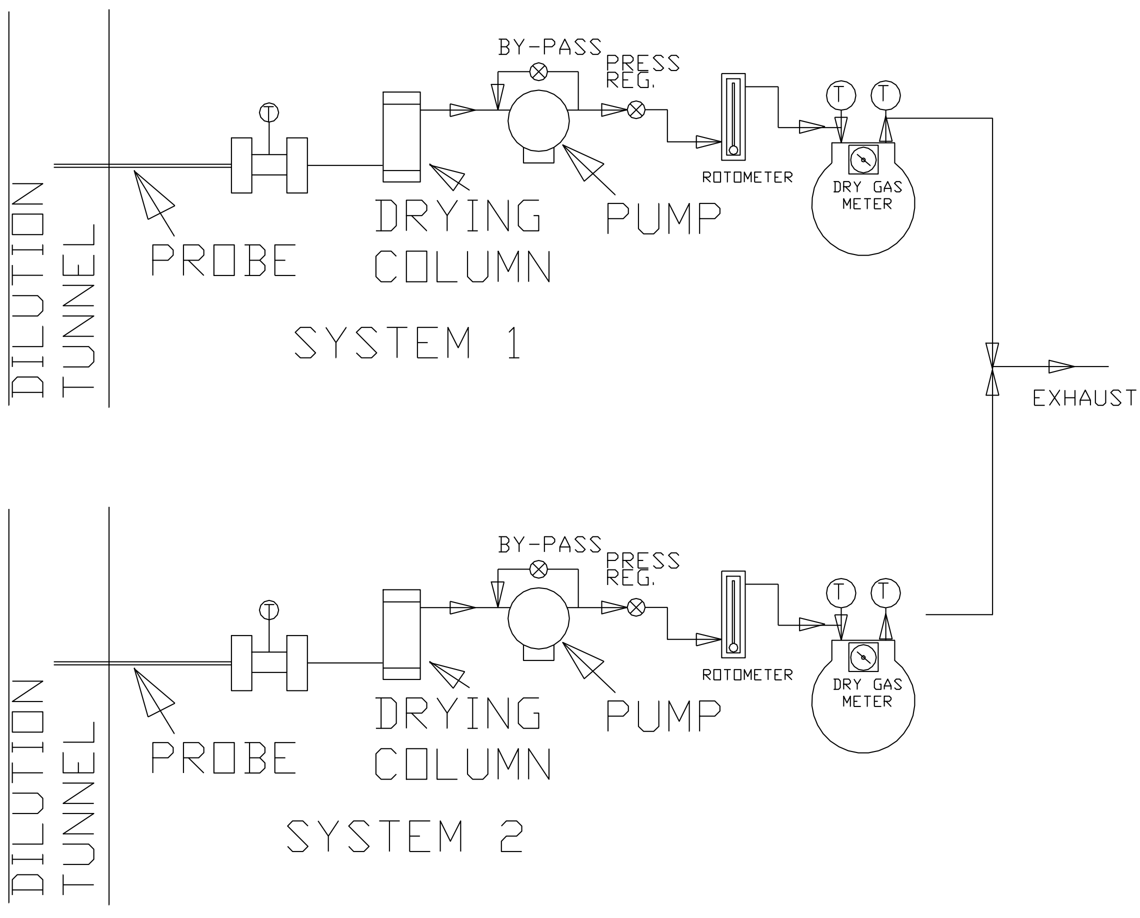

Figure 2

V. SAMPLING METHODS

V.A. PARTICULATE SAMPLING

Particulates were sampled in strict accordance with ASTM E2515-09. 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.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 ASTM E2515. Final tunnel velocities and flow rates are calculated from E2515, Equations 3 and 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. The data and results are included in Appendix C.

VII. RESULTS AND OBSERVATIONS

The Model WHS2000 has been found to be in compliance with the applicable performance and construction requirements of the following criteria:
"**Annex A1 Modified test method for wood-fired hydronic appliances that utilize thermal storage of ASTM E2618-13 Measurement of particulate emissions and heating efficiency of outdoor solid fuel-fired hydronic heating appliances**"

The model WHS2000V was the model tested, which is configured with a vertical flue located at the top back of the unit. Model WHS2000H is an identical model with the only difference being that the flue exits horizontally out the back of the unit. The model WHS2000H does contain slightly more water in the vessel due to the flue area is not notched out for the vertical flue exit.

INTERTEK TESTING SERVICES NA

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