TEST REPORT

REPORT NUMBER: G100248857MID-006R
REPORT DATE: April 22, 2011
REVISED DATE: June 23, 2011
REVISED DATE: January 27, 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 WHS1500V Solid Fuel Hydronic Furnace

Report of Testing Model WHS1500 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
April 27, 2011	Revised model designation to indicate that model WHS1500V was tested. Also added model WHS1500H as a similar model.
June 23, 2011	Revised to correct category IV Output to Reflect 4 hour output capacity based on total stored energy and correct table headings.
November 3, 2014	Revised Section II to update summary of results to match current reports and data recordings.
January 27, 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 March 28, 2011 to April 1, 2011 Intertek Testing Services NA Inc. (Intertek) conducted tests on the WHS1500V 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 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 WHS1500 is a solid fueled unit with a 14.15 cubic foot firebox is constructed of carbon sheet steel, and weighs 3140 lbs. dry. The heat exchanger extends through the water vessel, which holds 11574 lbs. of water. This corresponds to a total water capacity of 1447 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:
0.135 lbs/million Btu of output (0.058 g/MJ) for the heating season
0.138 lbs/million Btu of output (0.059 g/MJ) for year round

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 March 29, 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	26,550	26,550	15.0%	24.1	145.7	22.40	1,025,295	640,524
II	20% of Max	35,400	35,400	20.0%	18.6	145.7	22.40	1,025,295	659,848
III	37.5% of Max	66,375	66,375	37.5%	10.4	145.7	22.40	1,025,295	688,947
IV	Max Capacity	177,000	177,000	100.0%	4.02	145.7	22.40	1,025,295	711,355

Table 1B. Data Summary Part B

		E_T	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	41.283	0.142	0.061	1.71	0.763	62.3%	67.1%
II	16-24% of Max	41.283	0.138	0.059	2.21	0.763	64.2%	69.1%
III	25-50% of Max	41.283	0.132	0.057	3.98	0.763	66.9%	72.1%
IV	Max Capacity	41.283	0.128	0.055	10.27	0.763	69.1%	74.4%

II.B 8-Hour Heat Output and Efficiency Ratings

Table 1C: Hang Tag Information

MANUFACTURER:	**Dectra**		
MODEL NUMBER:	**WHS1500**		
MAXIMUM OUTPUT RATING	$Q_{out\text{-}Max}$	177,000	Btu/hr
8-HOUR OUTPUT RATING:	$Q_{out\text{-}8hr}$	87,179	Btu/hr
8-HOUR AVERAGE EFFICIENCY:	$\eta_{avg\text{-}8hr}$	**68.0%**	**(Using higher heating value)**
		73.2%	(using lower heating value)
ANNUAL EFFICIENCY RATING:	η_{avg}	**64.6%**	**(Using higher heating value)**
		69.5%	(using lower heating value)
PARTICULATE EMISSIONS:	E_{avg}	2.88	GRAMS/HR (average)
		0.138	**LBS/MILLION Btu OUTPUT**

II.C Summary of other 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	$E_{lb/mmbtu\text{-}Output,i}$ x F_i	$E_{g/hr,i}$ x F_i
I	0.437	0.273	0.294	0.027	0.334	0.062	0.748
II	0.238	0.153	0.165	0.014	0.182	0.033	0.527
III	0.275	0.185	0.199	0.016	0.210	0.036	1.094
IV	0.050	0.035	0.037	0.003	0.038	0.006	0.514
Totals	**1.000**	**64.6%**	**69.5%**	**0.059**	**0.763**	**0.138**	**2.88**

Note:1 LHV Efficiency based on 7988 Btu/dry lb specified in ASTM E2618-13.

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	0.109	0.118	0.011	0.134	0.025	0.299
II	0.275	0.177	0.191	0.016	0.210	0.038	0.609
III	0.45	0.302	0.326	0.026	0.343	0.060	1.790
IV	0.1	0.069	0.075	0.006	0.076	0.013	1.027
Totals	1	**65.8%**	**70.8%**	**0.058**	**0.76**	**0.135**	**3.73**

II.D Summary of other Data

	Run 2	Run 3	Run 4	Standby	Units
Steel Mass	3140	3140	3140	3140	lbs
Water Mass	11574	11574	11574	11574	lbs
Fuel Load Weight	144.13	142.52	143.75		lbs
Fuel MC (dry basis)	22.3	23.5	21.4		%
Kindling Mass	2.14	2.24	2.2		lbs
Kindling MC (dry basis)	10	10	10		%
Starting system temp.	126.6	128.3	126.2	172.0	F
Ending System Temp.	188.1	187.4	188.8	165.4	F
Average Room Temp.	65.9	66.4	65.6	66.4	
Burn Time	164	170	168		Minutes
Burn Time	2.73	2.83	2.80		Hours
Standby Test Duration				19	Hours
HHV	8600	8600	8600		BTU/lb
Dry Fuel Weight	54.4	53.3	54.6		Kg
Burn Rate	19.89	18.81	19.51		Kg/hr
Input	1,030,216	1,010,091	1,035,557		BTU
Heat Stored	730,528	702,263	744,056		BTU
Average	725,616				BTU
Standby Loss Rate				41.4	BTU/hr-F
Total Emissions	39.81	44.29	39.75		Grams
Total Emissions	0.088	0.098	0.088		lbs
Category I Output Rate	26,550	26,550	26,550	3523	BTU/hr
Category II Output Rate	35,400	35,400	35,400	3523	BTU/hr
Category III Output Rate	66,375	66,375	66,375	3523	BTU/hr
Category IV Output Rate	177,000	177,000	177,000	3523	BTU/hr
				Average	
Output Time Cat I	24.3	23.4	24.7	24.1	Hours
Output Time Cat II	18.8	18.0	19.1	18.6	Hours
Output Time Cat III	10.5	10.0	10.6	10.4	Hours
Output Time Cat IV	4.0	3.9	4.0	4.02	Hours
				Average	
Category I Efficiency	62.6%	61.4%	63.4%	62.5%	
Category II Efficiency	64.5%	63.2%	65.3%	64.4%	
Category III Efficiency	67.3%	66.0%	68.2%	67.2%	
Category IV Efficiency	69.6%	68.2%	70.4%	69.4%	
Category I Emissions	0.136	0.157	0.133	0.142	lbm/mmBTU output
Category II Emissions	0.132	0.153	0.129	0.138	lbm/mmBTU output
Category III Emissions	0.126	0.146	0.124	0.132	lbm/mmBTU output
Category IV Emissions	0.123	0.142	0.120	0.128	lbm/mmBTU output

III. PROCESS DESCRIPTION

III.A. DISCUSSION

RUN #1 (March 29, 2011). RUN #1 was considered a outlier and the data was not used in the determination of the average emissions and efficiency performance.

RUN #2 (March 30, 2011). The starting temperature in the heat storage vessel was 127^{o}F. Burn time was 2.73 hours and ended with a heat storage vessel temperature of 188^{o}F.

RUN #3 (March 31, 2011). The starting temperature in the heat storage vessel was 128^{o}F. Burn time was 2.83 hours and ended with a heat storage vessel temperature of 187^{o}F.

RUN #4 (April 1, 2011). The starting temperature in the heat storage vessel was 126^{o}F. Burn time was 2.80 hours and ended with a heat storage vessel temperature of 189^{o}F.

III.B. UNIT DIMENSIONS

Overall dimensions are 71.75-in wide, 96-in deep, 71.5-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 of 3 to 8 inches by 16 inches in length. The fuel was dried to average moisture content between 19% and 25% on a dry basis. The average piece weight was 5 to 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

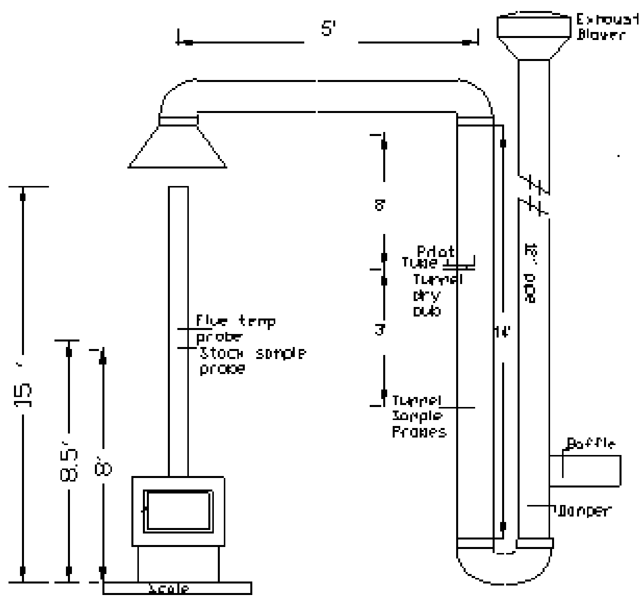

FIGURE 1

IV.B.OPERATIONAL DRAWINGS

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

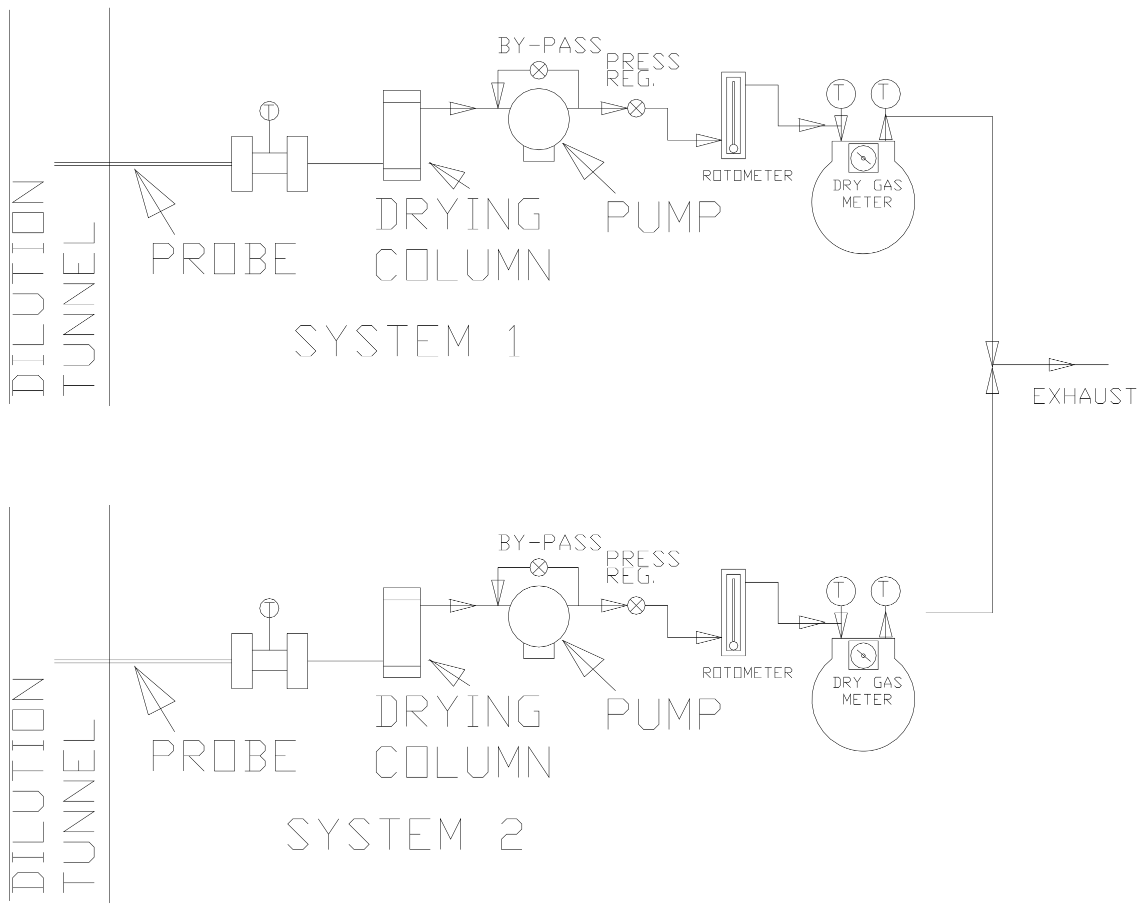

Figure 2

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 EPA Method 1. Final tunnel velocities and flow rates are calculated from ASTM E2515, Equation 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 (5G-3)

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

VII RESULTS AND OBSERVATIONS

The Model WHS1500V 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 WHS1500V was the model tested, which is configured with a vertical flue located at the top back of the unit. Model WHS1500H is an identical model with the only difference being that the flue exits horizontally out the back of the unit. The model WHS1500H 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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