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Ratings of Popular Pellet Stoves: Background

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By John Ackerly and Gabriella McConnel

This paper provides background and testing details for the report "Ratings of Popular Pellet Stoves." After some introductory comments, this paper has sections on the 5 criteria that we tested the stoves for: Cleanliness, efficiency, maintenance, heat output and visibility of glass. At the end we include background material on how we tested hopper size.

It is important to remember that our testing was done under certain conditions and the performance of these stoves could be quite different if, for example, they were cleaned well every day or if a much higher quality pellet was used. Also, we tested the stoves only for one month, so we have no data on longer-term reliability. It is important for consumers to research on sites like hearth.com to assess reliability and repair costs.

For the rest of this document, the stoves will be referred to just by their manufacturer's name: the England Stove Works 25-PDCVC will be referred to as the Englander, the Enviro M55 insert as the Enviro, the Harman Accentra 52i insert as the Harman, the Piazzetta Sabrina as the Piazzetta, the Quadra-Fire Mt. Vernon AE as the Quadra-Fire, and the Ravelli RV80 as the Ravelli.

Figure 1. Pictured from left to right: Harman, Enviro, Quadra-Fire, Englander, Piazzetta and Ravelli.

Scoring System

For each of the five criteria, we had numerical data from the testing and the lowest scoring stove always got a "1" and the highest got a "5." We then set ranges, such as 1-20, 21-40, 41-60, 61-80 and 81-100. If several of the stoves fell into the 61-80, for example, they both got a "4." In one of the scoring areas, no stove got a "2", and three stoves got a "5." We decided to use this system, even though there are likely to be many stoves that perform better and worse than these on the market. A rating of "5" does not mean its five times better than a "1" and it may not even mean its twice as good, depending on the scoring criteria.

Test Description

We tested the six stoves side-by-side at the Alliance for Green Heat in a simulated "real-world" test lab located in Takoma Park, MD. The six stoves were anonymously purchased from several retailers in the United States in Maryland, New York, and New Jersey. The stoves were chosen based on interviews with scores of retailers about which were their best selling North American and European stoves. The stoves were first tested at Brookhaven National Laboratory, which will produce an academic report on their testing, which included emissions in grams per hour (PM 2.5) and the efficiency, based on CSA B415.

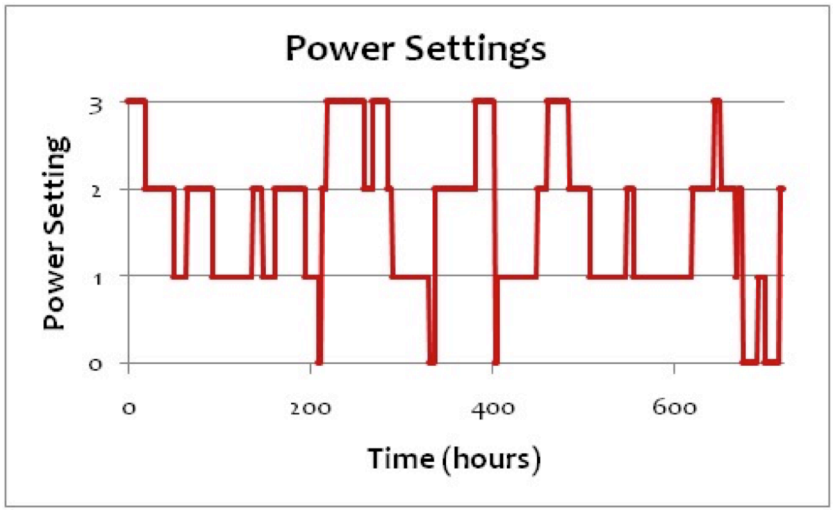

Figure 2. Power setting distribution during 30-day testing period (0=off, 1=low, 2=medium, 3=high) and most testing was done at the medium setting.

The stoves were tested in a screened-in porch that was open to outside air. The stoves were all installed with DuraVent brand PelletVent Pro venting systems, double walled piping with an inner wall of stainless steel and a galvalume outer wall that is sealed by metal-to-metal connection. In addition to venting pipe, the freestanding stoves were installed with a PelletVent Pro Tee for easy cleanout. The hole for the Testo 320 probe was drilled at 6 feet above the floor. (Eight feet, specified by ASTM, was not possible because the venting needed to exit the side of the structure below 8 feet on several stoves)

Figure 3. After several hours of use, the filter in the Testo gets dirty and needs to be switched out with a new one.

The six stoves were loaded with pellets, turned on and operated nearly 24 hours a day, 7 days a week, for 30 days. The 30-day period began at 2:30 on September 2, 2015 and ended at 2:30 on October 2, 2015. Testing of the six stoves began on September 5, 2015. Some stoves periodically burned only 20 – 22 hours if they ran out of pellets in the middle of the night, particularly at high burn rates. The stoves burned at high for 127 hours and 45 minutes, at medium for 262 hours and 33 minutes, at low for 281 hours and 50 minutes, and were off for 46 hours and 22 minutes (due to cleaning and more specific testing goals).

All six stoves were tested in the same way to the maximum extent possible. Stoves were set to override room temperature settings in order to stay burning at a set heat output level throughout the experiment. Stoves were powered on and set at low, medium or high power setting, and operated for 1 hour at that setting before the start of testing. After burning for an hour to reach steady state, the stoves were tested for 15 minutes each using a Testo 320

Combustion Analyzer. The specific parameters were set on the Testo 320 (Flue gas analysis; 10% moisture wood), and it was zeroed in open air before each test. Zeroing of the Testo 320 ranges from a 30 second rinse to a 3-minute rinse and indicates on the screen when the instrument has finished zeroing. During each 15-minute test, the Testo 320 took readings each second, recorded on a computer using Testo EasyHeat software and averaged to obtain daily values.

The Testo 320 was purchased specifically for this experiment, came with pre-calibrated sensors, and not used before the start of the 30-day burn period. Filters on the Testo 320 were visually inspected for soot build-up and changed frequently, and dates for filter changes were recorded. During filter changes, compressed air was used to clear the probe shaft. The condensate container was emptied every week before the start of testing but frequently had little to no condensate accumulation.

Figure 4. Comparing numbers from the Wohler 550 and Testo 320.

At the beginning of the 30 days of testing, we hired Biomass Controls, Connecticut, to simultaneously test with a Wohler 550 flue gas analyzer to verify readings on the Testo.

Cleanliness

The EPA measures cleanliness of stoves by measuring the emission rate of particulate matter (PM) and stoves as of 2015 have to emit no more than 4.5 grams per hour. PM is expensive and complicated to measure accurately. We used carbon monoxide (CO), which is a reasonable good proxy for PM[1].

Figure 5. A sample of soot wiped off the glass of each stove shows a variety of consistencies and black and brown colors and build-up collected during glass cleaning.

We chose to present CO numbers as the Testo recorded them, instead of correcting them to the same oxygen level since we were using CO as an indicator of cleanliness, and not as a modified combustion efficiency indicator.

Most of the stoves operated consistently in the 300 – 600 part per million (ppm) of CO, which is quite good for residential biomass combustion and far better than non-catalytic wood stoves. One notable achievement of the Quadra-Fire is that it burned exceptionally clean at its highest heat setting in our tests. It averaged only 114 ppm CO on its highest heat setting, when other stoves were between 350 ppm (Ravelli) and 1,290 ppm (Piazzetta). The Harman was far higher than the other stoves, and even higher than the Piazzetta. For consumers who care most about putting as few pollutants into the air and expect to be burning their stove mostly at medium or high, the Quadra-Fire is a clear winner.

In all the graphs produced in this report, we did not include the straight trend lines indicating the general course of tendency of combustion values for the Piazzetta because it missed the last week of testing, which would lead to unrepresentative trend lines compared to the other stoves. We did include the trend lines for the Harman even though the Harman could not be tested on its high heat setting. Our Testo combustion meter would go into shut down mode when the CO readings went above 4,000 parts per million. The stove completed the full four weeks but the CO and probably the efficiency trend line would have been even higher if we had been able to test the stove at its high burn.

[1] This NIH study found that "CO is a good proxy for PM 2.5" with solid fuels. http://www.ncbi.nlm.nih.gov/pubmed/11351731.
Other studies have also found CO to be a good proxy for PM, http://journals.lww.com/epidem/Fulltext/2011/01001/Biomass_Smoke_and_Cooking__Can_Carbon_Monoxide_Be.810.aspx.

30-DAY CO (PPM) AVERAGES				
STOVES	POWER SETTING			
	LOW	MEDIUM	HIGH	OVERALL
England Stove Works 25-PDVC	598 ±129	465±277	841±930	**542±405**
Enviro M55 insert	653±199	493±84	651±139	**534±141**
Harman Accentra 52i insert	407±213	907±311	N/A	**821±375**
Piazzetta Sabrina	307*	517±357	1291*	**684±544**
Quadra-Fire Mt. Vernon AE	382±174	347±112	114 ±45	**318±141**
Ravelli RV80	607±99	432±71	350±46	**428 ±105**
Stove Average	**492±163**	**527±202**	**650±290**	**554±285**

*Piazzetta Sabrina only had one run on low and one run on high (not an average)

Our database of CO readings over a month period provides an excellent opportunity to see how stoves performed compared to one another. When EPA accredited labs test pellet stoves, manufacturers are allowed to bring their own fuel (which is not allowed with wood stove testing), resulting in test data based on fuels with very different moisture and ash contents. The Quadra-Fire, for example was tested by OMNI Lab with 4.5% moisture pellets and received a 2.7-gram per hour certification. A month later, it was retested at a different lab, Intertek, with 2.3% moisture pellets and achieved a 0.5-gram an hour certification. It is unclear if there is a 2.3% moisture pellet on the commercial market and it is clearly not representative of the moisture content of commercially available pellets. These typically fall in the 3.5% to 7.0% range. This is one of the causes leading to variability in EPA testing of pellet stoves that we were able to drastically reduce in our testing.

EPA CERTIFICATION DATA (G/HR.)									
MANUFACTURER	MODEL	G/HR. (AVG.)	LOW	MEDIUM LOW	MEDIUM HIGH	HIGH	LAB	MOISTURE % (DRY)	ASH
England Stove Works	25-PDVC	3.1	5.65	2.19	2.36, 2.62	N/A*	Intertek	7.38	N/A*
Grouppo Piazzetta	Sabrina	2.3	1.57	2.19	2.77	3.2	Intertek	3.60	N/A*
Quadra-Fire (HHT)	Mt. Vernon AE	1.1	1.06	0.89	1.13	1.97	Intertek	5.44	N/A*
Harman (HHT)	Accentra 52i Insert	1.5	1.02	0.8	1.21	5.61	OMNI	5.63	0.50%
Ravelli	RV 80	3	N/A*	3.00, 3.53	2.40, 2.81	N/A*	PolyTest	6.53	N/A*
Enviro	M55	1	1.12	1.14	0.92	0.91	OMNI	2.98	N/A*
Averages		**2**	**2.1**	**2**	**2.7**	**2.9**		**5.26**	

Data from EPA accredited labs doing certification testing shows most of these stoves have highest grams per hour at their high burn rate. It also shows very large differences in the moisture content of the test fuel. Ash content was only reported by one lab.

Another important issue is that the method of testing pellet stoves has changed. As of 2015, the EPA endorsed the ASTM 2779 method, which is a shorter and simpler test that the previous Method 28 protocol. The ASTM method is likely to provide lower gram per hour readings, allowing more pellet stoves to pass the 2020 emission standards without redesign. The ASTM method is a continuous sampling method, where pulling filters in between burn rates is not required. This reduces the cost of testing, but data regarding the

relationship between emissions and burn rate will no longer be obtained.

We took periodic photos of the vent pipe where the smoke exits, and found a noticeable difference in PM deposits, consistent with tested CO levels (Figure 7). Several had very little noticeable soot build up, whereas the higher emitting stoves had build up of dark soot nodules after several weeks. We burned up to 1 ton of pellets in each stove, and the build up on the pipe clearly showed a need for a T-cleanout, annual chimney cleaning, and inspection. While our tests only lasted 30 days, conceivably if a home used 5 or 6 tons, cleaning the chimney twice a year would be advisable for dirtier burning stoves. Some manufacturers recommend cleaning the stove every 2 or 3 tons of pellets.

Figure 7. Exhaust pipes after one week of testing

Efficiency

The Testo relies on measuring oxygen in the stack and also uses stack temperature, ambient temperature and other factors for its efficiency calculation. When oxygen in the stack climbs above 15%, or stays in the 16% to 18% range, it is a clear sign that the stove is not running very efficiently. On medium burn the most efficient of the 6 stoves, the Harman and Piazzetta, had 10% to 12% oxygen in the stack on their best days, and an overall average of 13% and 14% oxygen (Figure 8). The Enviro with the worst efficiency overall, averaging 18% at medium burn, 20% at high 17% at low (Figure 8).

By "efficiency," we are referring to thermal efficiency, which is the ratio of heat delivered to the heated space to the heat content of the fuel burned, expressed as a percentage[2]. Efficiency is measured by what is known as the "stack loss" method, that tracks how much heat and chemical energy is lost through the chimney compared to what remains in the house.

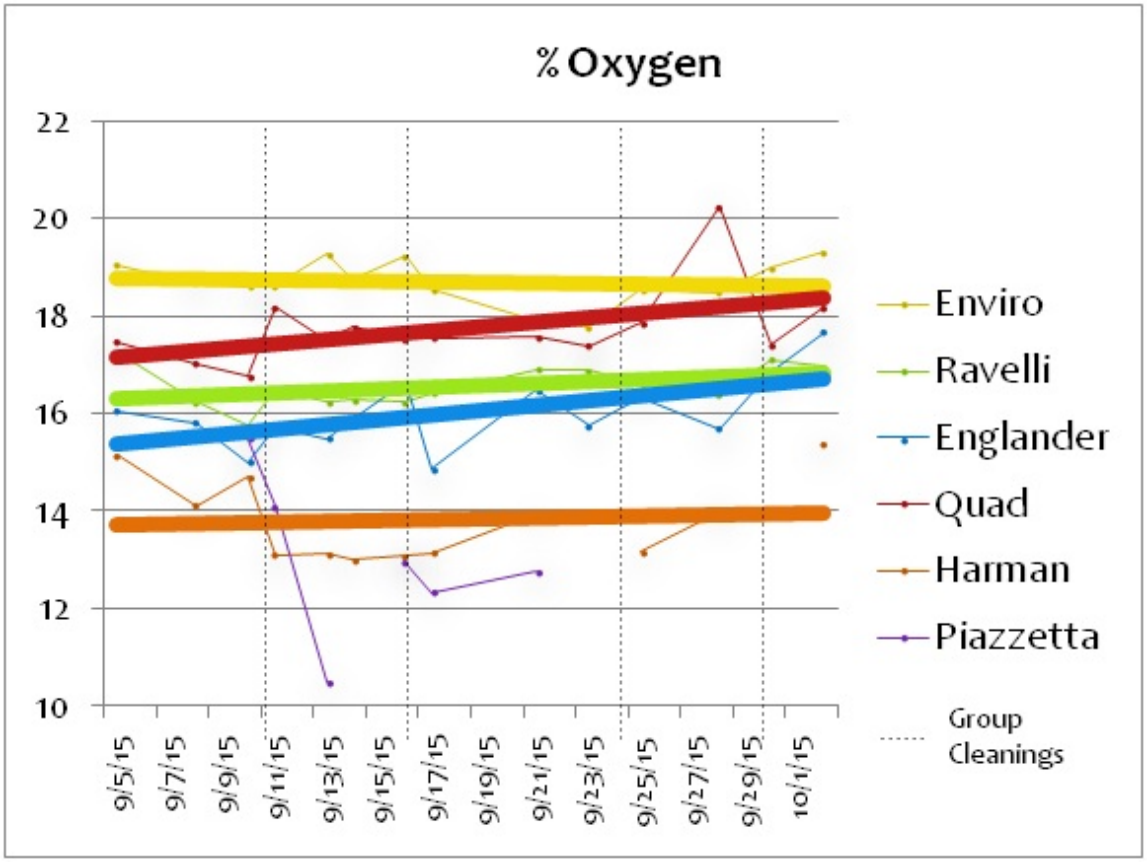

Figure 8. Percent oxygen averages during the 30-day testing period measured by the Testo 320 gas analyzer on medium burn rates.

The Testo provided a European (LHV) calculation and does not conform to the EPA approved CSA B415 efficiency calculation method. Moreover, the Testo efficiency is a much rougher estimate since you cannot input exact moisture content and other parameters required by the EPA accepted B-415 calculation.

[2] The Engineer's Guide to Efficiency Requirements in Wood Burning Stoves, Intertek Lab, 2013, p. 3

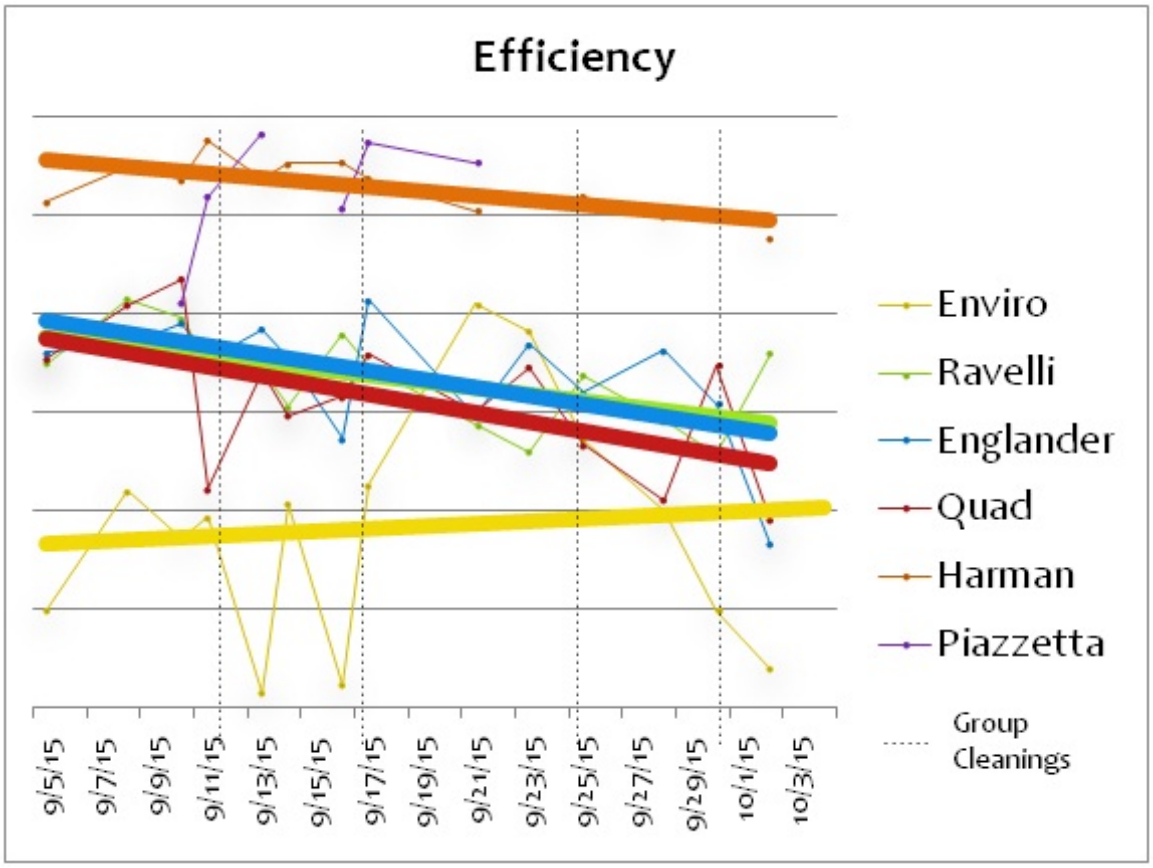

Figure 9. Efficiency averages and trends for 30-day testing period of six popular pellet stoves

30-DAY OXYGEN CONTENT (%) AVERAGES				
STOVES	POWER SETTING			
	LOW	MEDIUM	HIGH	OVERALL
England Stove Works 25-PDVC	17.1±1.25	16.0±0.70	14.5±0.77	16.0±1.06
Enviro M55 insert	20.1±0.35	18.6±0.54	17.0±2.52	18.7±1.27
Harman Accentra 52i insert	18.5±0.32	14.0±0.91	N/A	15.0±2.22
Piazzetta Sabrina	15.9*	13.1±1.54	13.6±0.31	13.5±1.63
Quadra-Fire Mt. Vernon AE	18.2±0.26	17.8±0.81	15.2±0.30	17.4±1.18
Ravelli RV80	19.1±1.28	16.6±0.53	15.8±0.43	16.8±1.15
Stoves Combined	18.1±0.70	16.0±0.84	15.2±0.86	16.2±1.42

*Piazzetta Sabrina only had one run on low (not an average)

The Testo efficiency and oxygen numbers do provide a reliable basis for ranking the stoves against each other over a month-long period[3].

[3] For a discussion of the measurement ranges and resolution/Accuracy and response times, see page 13 of the Testo manual: https://www.testo.com/resources/media/global_media/produkte/testo_320/320_IM_0970_3200_en.pdf.

30-DAY STACK TEMPERATURE AVERAGES			
STOVES	POWER SETTING		
	LOW	MEDIUM	HIGH
England Stove Works 25-PDVC	382±59	433±26	464±31
Enviro M55 insert	198±31	298±20	327±43
Harman Accentra 52i insert	280±15	399±29	N/A
Piazzetta Sabrina	342*	397±46	386±25
Quadra-Fire Mt. Vernon AE	275±18	323±20	425±14
Ravelli RV80	225±54	386±29	446±13

*Piazzetta Sabrina only had one run on low and one run on high (not an average)

The trend lines in the efficiency graph show that 5 of the stoves lost an average of 5% in efficiency over the month trial. Each stove burned about 1 ton of pellets during the month. We are not aware of long-term aging studies on pellet stoves, and they are clearly needed. The most important take-away for consumers: regularly clean your stove, especially the burn pot. In addition, have a comprehensive professional cleaning done once a year or as recommended in the owner's manual.

The other important take-away is that once manufacturers start disclosing verified efficiencies on the list of EPA certified stoves, choosing a higher efficiency model from a local dealer who can service it is likely to save you in fuel costs over the long term.

"Most manufacturers will not have to disclose their actual efficiencies until 2019 or 2020. Leading wood stove companies are starting to voluntarily disclose them, but pellet stove manufacturers are not. The EPA has some of the actual efficiencies, but manufacturers provided that data to the EPA as "Confidential Business Information." The Alliance for Green Heat filed a Freedom of Information Act request with the EPA, but to date the EPA is upholding the confidentiality of the efficiencies.

Figure 11. Testo 320 Gas Analyzer in "sensor protection" mode after attempting a high power test on the Harman.

Stack temperature is a measurement of the gas temperatures in the middle of the flue, six feet above the floor. On a medium power setting, the Englander had the highest average stack temperature (433°F), while the Enviro had the lowest (298°F). On a low power setting, this pattern continued, with the Englander having the highest (382°F) and the Enviro insert the lowest (198°F) by more than 25°F.

During the 3 tests on the high power setting, this pattern continued, with the England Stove having the highest average temperature (464°F) and the Enviro the lowest (327°F). Unfortunately, we were unable to complete 15-minute tests on the Harman at its high setting because when CO rose above 3,000 ppm, the Testo would go into shutdown mode, to protect its sensors (Figure 11). We believe the Harman would have had one of the higher average temperatures as it was the second highest temperature average (399°F) during the medium power burns and seemed to be radiating a great amount of heat in the screened in porch.

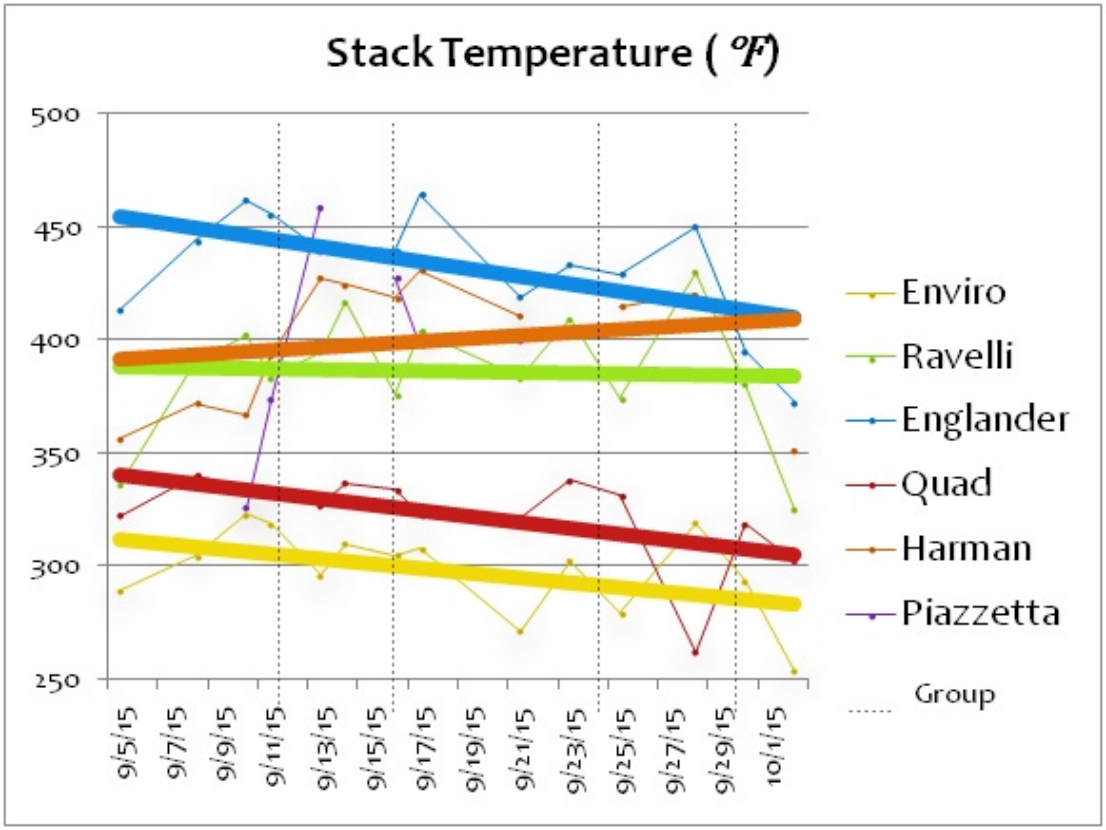

Figure 10. Stack temperature averages during 30-day testing period, measured by the Testo 320 Gas Analyzer.

Maintenance

We graded stoves by how often they needed their burn pot cleaned in order to ignite or keep running. Some of the stoves needed more frequent burn pot scraping and some did not need any, during our tests. The stoves were cleaned four times as a group during the 30-day testing, at least once every eight days. The group cleaning included scraping the burn pot, emptying the ash pan, vacuuming the ash pan area and cleaning the glass. This takes about 10 minutes per stove.

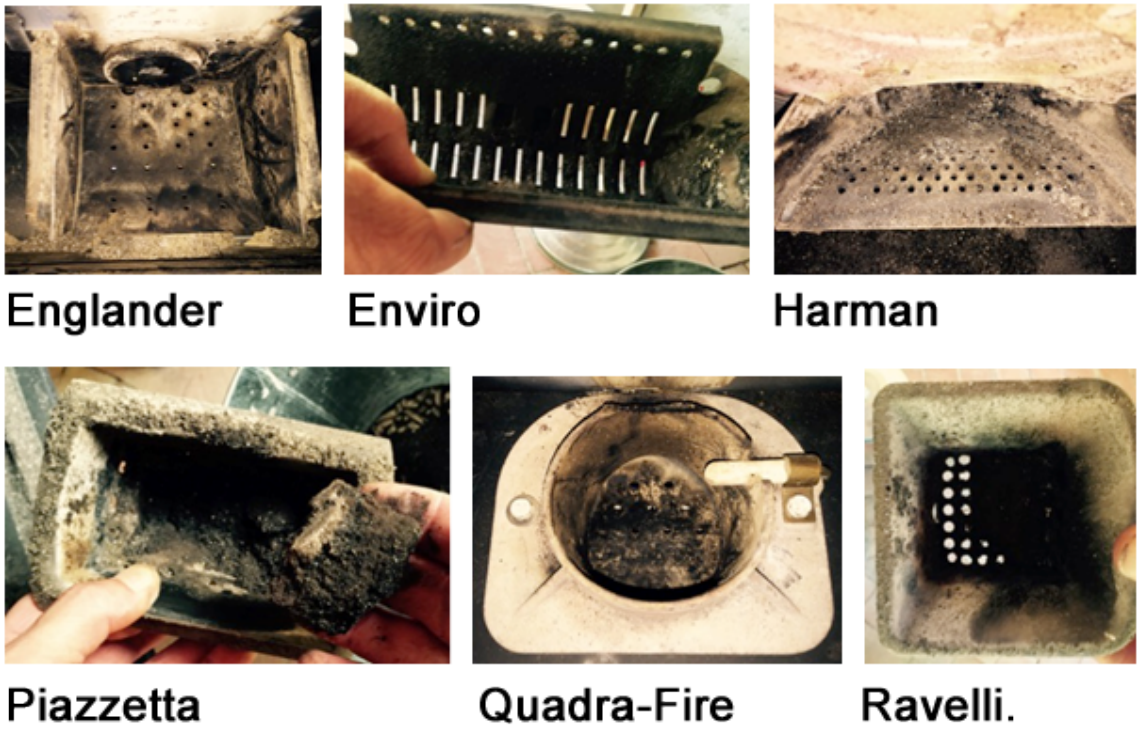

Figure 12. Burn pot design is one of the most important elements of a stove. Some are removable and some have automated cleaning mechanisms.

In between the four group cleanings, individual stoves got mini cleaning consisting of a simple burn pot scrape only if the stove would not relight and could not be tested. Individual cleanings were recorded and totaled for each stove. We observed that the stoves with the smaller sized burn pots (Ravelli, Englander, Piazzetta) required much more frequent cleaning than the larger stoves, 2 of which that had automatic cleaning systems (Enviro, Quadra-Fire). The ones with automatic cleaning systems, the Enviro and Quadra-Fire did not need or receive any individual cleanings, and may not have even needed the routine group cleanings that we provided. The Piazzetta received the most individual cleanings followed by the Englander. Since the Piazzetta could not be tested the fourth week, an average of each week's number of individual cleanings (approximately 1.5) was used for the fourth week to provide a cleaning score that was equivalent to the other stoves.

Our testing resulted in the need to clean some of the stoves much more than others, partially a result of the type of pellet we used. An expensive, 100% softwood pellet may have shown that none of the stoves we tested needed much cleaning. We used a pellet that is relatively typical of medium quality pellets that are widely available in the eastern US, with 0.5 to 0.6 ash content. Had we used a lower quality pellet, cleaning would likely have been required even more often.

Heat Output

For this rating, we combined maximum heat put and the heat turndown ratio for each stove. Maximum heat output was measured using the high power setting. We calculated the burn rate by measuring the time it took to burn a full hopper of pellets and also to burn a 10-pound test load. A combination of the data from these two methods allowed us to calculate a pounds per hour average for each stove. Once a pound per hour for the highest power setting was calculated, we multiplied by the BTU/pound output of the fuel (8,261) and an average efficiency (67%).

Burn rate x BTU/lb. x (efficiency/100) = BTU per hour

Calculated BTU output at high burn was almost 22,000 BTU/hr. for three of the stoves. This would be a slightly conservative if the stoves were higher than 67% efficiency. Or, BTU output would be higher with a high quality 100% softwood pellet that can have 9,000 BTUs per pound, but are not common in the marketplace. Our BTU outputs are based on pellets independently tested at 8,261 BTUs per pound, which is a bit higher than the average BTU content of most pellets.

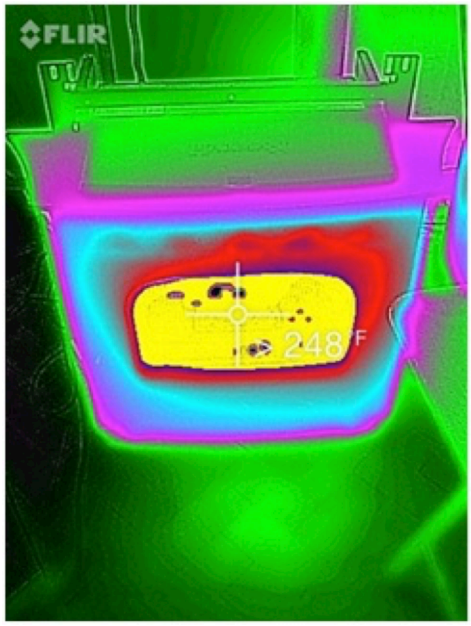

Figure 13. Infrared picture of Harman Accentra 52i insert.

The Piazzetta had the highest maximum heat output (21,973 BTU/hr.) and the Englander had the lowest (14,778 BTU/hr.). Three of the stoves had an output above 21,000 BTU/hr. (Enviro, Harman, Piazzetta), while 3 stoves were less than 18,000 BTU/hr. (Ravelli, Englander, Quadra-Fire).

The BTU numbers provided on the EPA list of certified stoves are provided by the test labs and do not have to use the actual efficiency of the stove. Labs can use the old 78% EPA default number, which is often 5 – 15 points higher than the actual efficiency, and they may be able to use very high estimated BTU output, rather than the BTUs of the pellets that the lab tested with.

The turndown ratio indicates the functional range of heat output of a combustion device. It is the ratio of maximum level of heat output to minimal level of heat output. A greater turndown ratio allows for more control of the stove heat range. For example, a stove with a maximum output of 4 pounds per hour and a minimum output of 2 pound per hour would have a turndown ratio of 2. The turndown ratio was measured 2 ways. First, each stove was filled to capacity (specified in hopper size section) and let burn completely at least two times on the highest power setting. High power burn times were recorded, and the hopper size was divided by the average of these times to reach a pounds per hour measurement. This method was repeated for low power setting burns. The high average was divided by the low average to calculate the turndown ratio. Next, each stove was given 10 pounds of pellets on the high setting and allowed to burn out completely. This 10-pound test was repeated on the lowest power setting. Burn times were recorded and divided from 10 pounds to calculate each pound per hour average. The turndown ratios were calculated using a combination of the full-hopper burn averages and the 10-pound test averages. The Harman had the largest turndown ratio (2.65), while the Englander had the smallest turndown ratio (1.41). The majority of the stoves had turndown ratios greater than 2, with the exception of the Englander (1.41) and the Piazzetta (1.74).

Alliance for Green Heat
6906 Laurel Ave.
#5461
Takoma Park, MD 20912
Phone: 301-204-9562 or 214-662-0357

(The online version of this report includes photos, many links to external sources and to additional background material about how we conducted the testing and determined the ratings. See: http://www.forgreenheat.org/decathlon/details.html)

The Alliance for Green Heat promotes modern wood and pellet heat as a low-carbon, sustainable and affordable residential energy solution. The Alliance works to advance cleaner and more efficient wood heating appliances and focuses on low and middle-income families. Founded in 2009, the Alliance is a 510(c)(3) non-profit organization based in Maryland.