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Laboratory Assessment of Stiebel-Eltron Accelera 220 E Heat Pump Water Heater

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Executive Summary

The Northwest Energy Efficiency Alliance (NEEA) contracted with Ecotope, Inc. and Cascade Engineering Services, Inc. to conduct a laboratory assessment of the Stiebel-Eltron Accelera 220 E heat pump water heater (HPWH) for northern climate installations. Cascade Engineering evaluated the Accelera 220 E using a testing plan developed by Ecotope to assess HPWH performance.

The goal of the work is to evaluate the product using the Northern Climate Heat Pump Water Heater Specification. The test matrix, specified fully in Appendix A, includes the standard US Department of Energy (DOE) 24- and 1-hour tests for both the previous DOE test procedure and the new test procedure released in 2014, as well as low-ambient-temperature tests and noise output level measurements.

Overall, the results suggest that the Stiebel-Eltron Accelera 220 E is a highly-efficient water heater. Specific findings include:

- Measured Northern Climate Specification Metrics:
  - Northern Climate Energy Factor: 2.58
  - Percent of tank drained before resistance elements engage in 1-hour test: 82% (Note: element does not engage; the test runs until water is cold)
  - Compressor low-ambient temperature operating cutoff: 32°F
  - Number of consecutive, sixteen-gallon, efficient showers: 3
  - Sound level: 55 dBA
- Individual Test Results:
  - Energy Factor from 24-hour test at 67°F: 2.81
  - Energy Factor from 24-hour test at 50°F: 2.47
  - Uniform Energy Factor from 24-hour test at 67°F: 3.03
  - Uniform Energy Factor from 24-hour test at 50°F: 2.53
  - 1-hour test: 46.0 gallons
  - 2014 1-hour test: 43.5 gallons
- The Accelera 220 E exhibits high energy factors in all of the tests, due in large part to the fact that it does not use its resistance element. Indeed, in order to use the resistance element, a user must manually engage the resistance mode, which only heats the top of the tank, and will turn off after a delay, reverting to compressor-only heating as a default. The refrigeration cycle, using R-134a, is efficient, offering a Coefficient of Performance near 3 at 67°F ambient air temperature. With a compressor input power of 500-600W, the tank has a nominal heating capacity of 1.5+ kW from the refrigeration cycle. This ranks among the highest of the currently-available integrated HPWHs.
- The first hour rating is relatively small for a 58-gallon tank, but this is traded off against higher efficiency levels. With no resistance element use in normal operation, the first hour rating drops but the number of efficient, hot showers delivered comparatively increases. Overall, with an operating range as low as 32°F, the Accelera 220 E will likely yield low energy use in all installations across the Pacific Northwest.

1. Introduction

The Northwest Energy Efficiency Alliance (NEEA) contracted with Ecotope, Inc. and Cascade Engineering Services, Inc. to conduct a laboratory assessment of the Stiebel-Eltron Accelera 220 E heat pump water heater (HPWH) for northern climate installations. Cascade Engineering evaluated the Accelera 220 E using a testing plan developed by Ecotope to assess HPWH performance.

The tests included measurement of basic characteristics and performance, including first hour rating and Department of Energy (DOE) Energy Factor (EF); description of operating modes; measuring heat pump efficiency at lower ambient temperatures; and conducting a number-of-showers test at 50°F ambient. Appendix A includes a table describing all tests performed for this report.

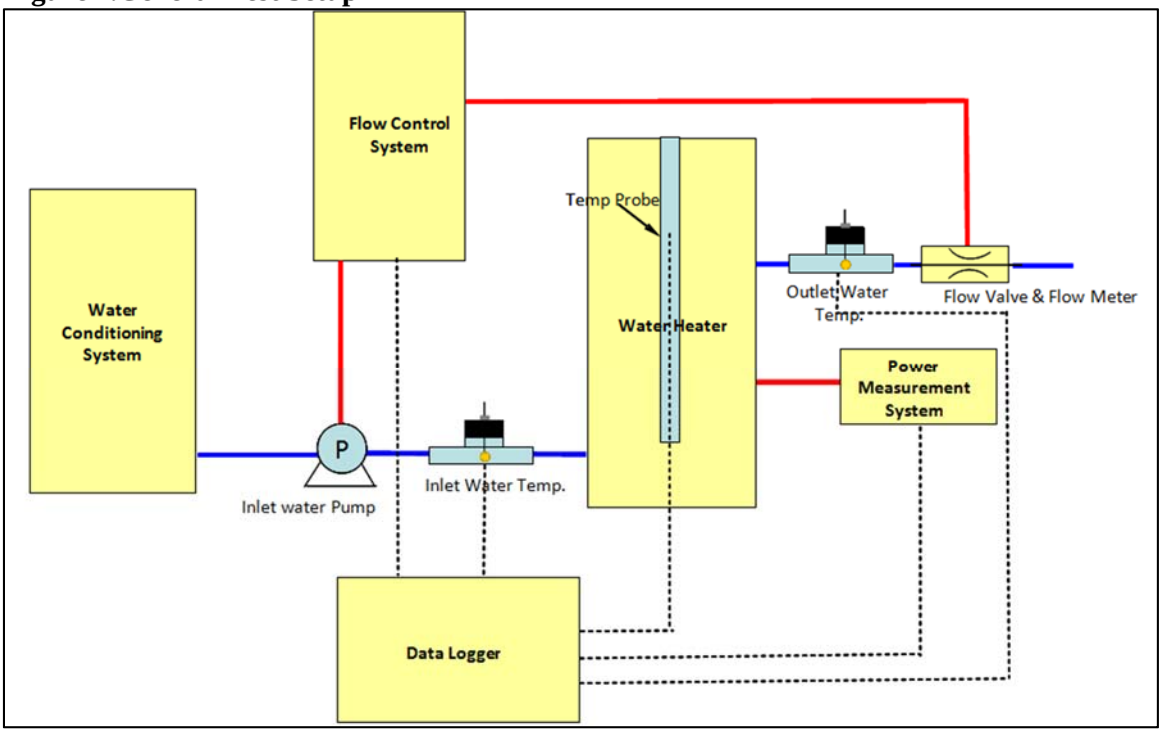
2. Methodology

Cascade Engineering collaborated with Ecotope and NEEA to devise methods and protocols suitable for carrying out the testing plan. Cascade Engineering incorporated the following documents into its procedures:

- The heat pump water heater measurement and verification protocol developed by Ecotope http://www.bpa.gov/energy/n/emerging_technology/pdf/HPWH_MV_Plan_Final_012610.pdf
- Northern Climate Specification for Heat Pump Water Heaters http://neea.org/northernclimatespec
- Department of Energy testing standards from Appendix E to Subpart B of 10 CFR 430
- American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Standard 118.2-2006 for the Method of Testing for Rating Residential Water Heaters

Figure 1 shows a schematic representation of the test setup.

Figure 1.General Test Setup

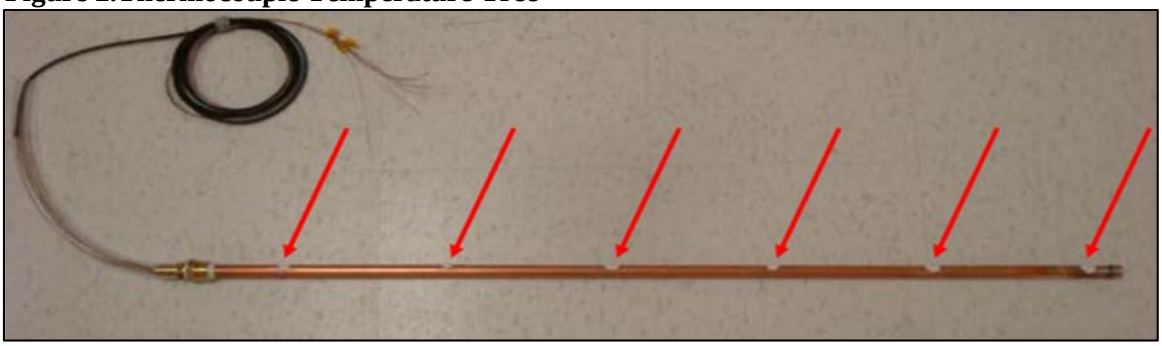


Ambient temperature control is provided by an ESPEC Model # EWSX499-30CA walk-in thermal chamber. The chamber is capable of regulating both temperature and humidity over a wide range, and independently monitors and records temperature and humidity conditions at one-minute intervals.

Conditioned water is stored in a large tank to be supplied to the water heater at the desired inlet temperature. A pump and a series of flow control valves in the inlet and outlet water piping control the water flow rate and maintain water pressure. A flow meter measures and reports the actual water flow.

Cascade Engineering installed an instrumentation package to measure the required points specified by the DOE test standard as well as additional points to gain further insight into HPWH operation. A tree of six thermocouples positioned at equal water volume segments measured tank water temperature (Figure 2). Cascade Engineering measured inlet and outlet water temperatures with thermocouples immersed in the supply and outlet lines. Three thermocouples mounted to the surface of the evaporator coil at the refrigerant inlet, outlet and midpoint monitored the coil temperature to indicate the potential for frosting conditions.

Figure 2.Thermocouple Temperature Tree



Note: Arrows indicate measurement points.

A data acquisition (DAQ) system collects all the measurements at three-second intervals and logs them to a file. In a post processing step, Ecotope merges the temperature log of the thermal chamber with the DAQ log file to create a complete dataset for analysis.

3. Findings: Equipment Characteristics

3.1. Basic Equipment Characteristics

The Accelera 220 E (shown in Figure 3) is an integrated heat pump water heater with a nominally 220-liter, or 58-gallon, tank. It is one of two recent equipment offerings from Stiebel-Eltron. The other is the Accelera 300 E, which has a 300-liter tank size (not available in the US market at the time of this writing). The most notable feature of this equipment compared to other integrated, hybrid HPWHs on the market is its resistance element usage: unless specifically initiated by the user (or ambient temperatures drop below operating specifications), the unit will not use any resistance heat. Even when engaged, the resistance mode will turn off after the tank has fully heated. The 220 E has only a single, small resistance element located in the top of the tank.

Figure 3. The Accelera 220 E

Tank temperature sensing is accomplished by a combination of sensors. The 220 E has a point sensor at the top of the tank and an “integral” sensor that spans the entire height of the tank. The “integral” sensor measures the average temperature of the tank.

The size of the heat exchanger constitutes a unique feature of the Accelera 220 E. The heat exchanger wraps around more than two-thirds the height of the tank. The relatively high location of a part of the heat exchanger has an unusual effect on the temperature of the tank during heating. Although water will be heated to the setpoint in most of the tank, a significant portion of the bottom of the tank remains cold. By design, the bottom remains cold for increased refrigerant sub-cooling, which improves heat pump efficiency. Measurements showed at least ten gallons of water remaining approximately 40°F below setpoint at the end of a typical recovery cycle. Although the tank has a measured capacity of 56 gallons of water (see Table 1), the effective

stored hot water volume is approximately 46 gallons. The remaining water is warmer than the inlet water temperature, but generally well below a usable temperature of 105°F.

Table 1. Properties of the Stiebel-Eltron Accelera 220 E

	Laboratory Measurement
Tank Volume (gallons)	58 nominal, 56 measured
Refrigerant	R-134a
Airflow Path	Side to Side
Upper Element (W)	1,500
Lower Element (W)	NA
Compressor (W)	480 – 600
Standby (W)	1.75
Fan (W)	24 nominal
Low-Temperature Cutoff (°F)	32
Tank Heat Loss Rate (Btu/hr°F)	7.12

3.2. Operating Modes

Standard Mode: Only the heat pump is allowed to operate. It provides the highest level of efficiency and heats only with the refrigeration cycle. If the ambient temperature drops below that specified in Table 1 as the "Low-Temperature Cutoff," the compressor will not operate. Standby heating will generally keep the average temperature within 8-10°F of the setpoint.

Comfort Heating Mode: When user-activated via a button on the equipment control panel, comfort heating mode will start heating using both the compressor and resistance element in parallel. The resistance element disengages when the top of the tank reaches 149°F, and the compressor will heat until the rest of the tank reaches 149°F. At that time, the operating parameters automatically switch back to the previously-used values.

4. Findings: Testing Results

4.1. First Hour Rating and Energy Factor

As described in the Methodology section, Cascade Engineering carried out tests using both the older (pre-2014) and new (2014) DOE test procedures. Notably, the pre-2014 test procedure requires the average tank temperature at the start of a test to be 135°F ±5°F. Due to the colder temperatures in the lower portion of the tank, the researchers set the water heater to a temperature of 149°F to attain an average tank temperature of 135°F. This somewhat-unusual move is necessary to comply with the testing specification. In contrast, the 2014 test procedure specifies the outlet water temperature at 125°F, which allowed the lab to use a 125°F setpoint for those tests because the water at the top of the tank met the testing conditions.

The remainder of this section shows graphs of all the tests depicting the water heater's responses to various draw patterns. The graphs show the results for both the previous and the current DOE test procedures. The notation of "EF" for Energy Factor, or no specific modifiers, indicates a test under the previous procedure. The notation of "UEF," for Uniform Energy Factor, or a specific mention of "2014" indicates a test under the current (published in 2014) test procedure.

4.1.1. 1-Hour Test

Figure 4 and Figure 5 illustrate the results of the 1-hour tests for the pre-2014 and 2014 DOE test procedures, respectively.

Figure 4. DOE 1-Hour Test

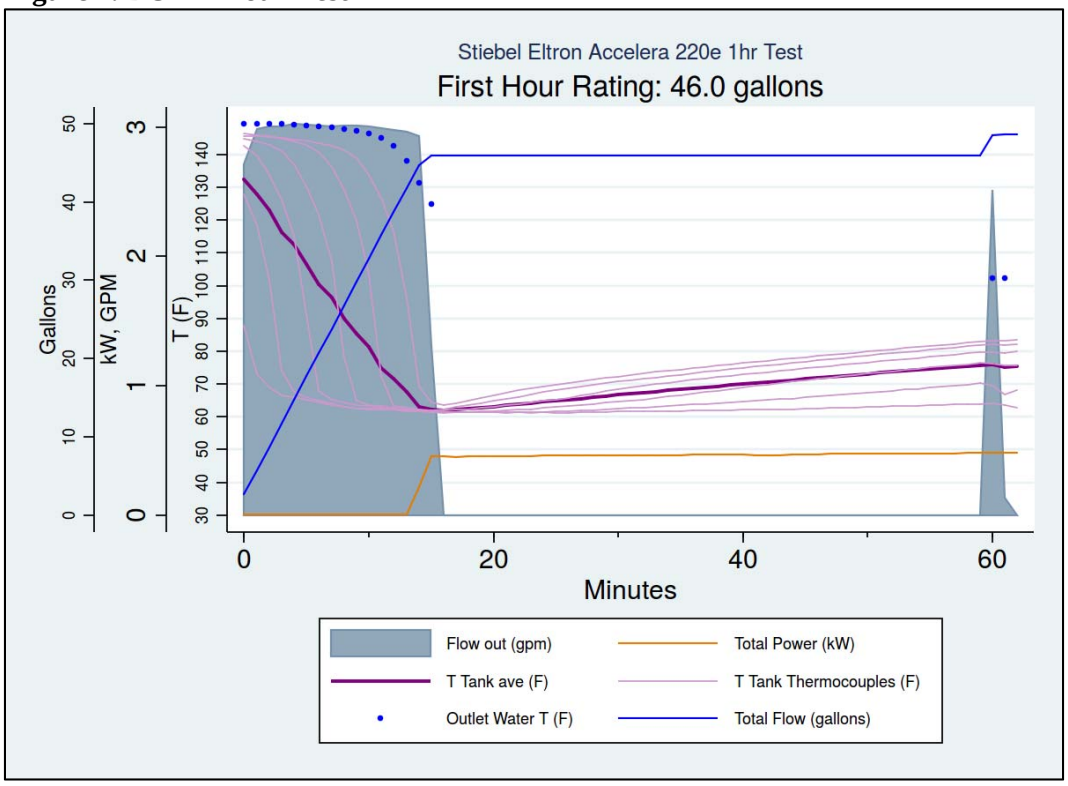
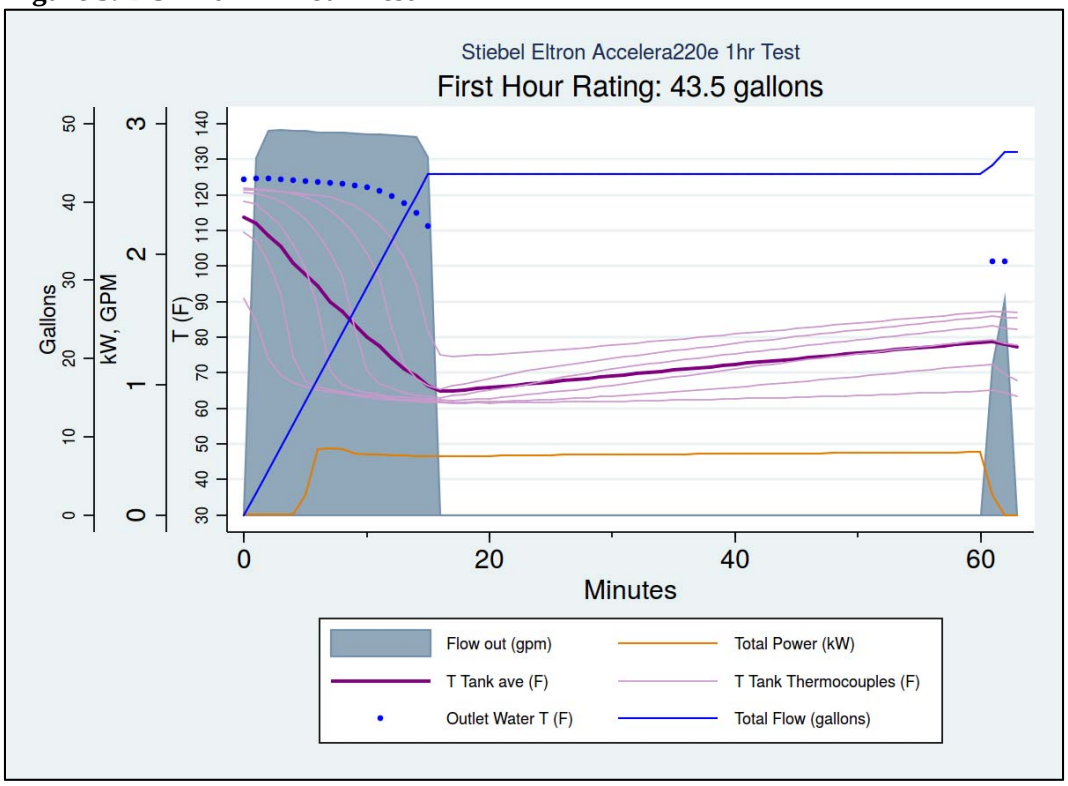


Figure 5. DOE 2014 1-Hour Test



4.1.2. Energy Factor and Uniform Energy Factor Tests

Figure 6 through Figure 11 illustrate the results of Energy Factor and Uniform Energy Factor tests conducted for the Accelera 220 E.

Figure 6. DOE 24-Hour EF Test, First Eight Hours

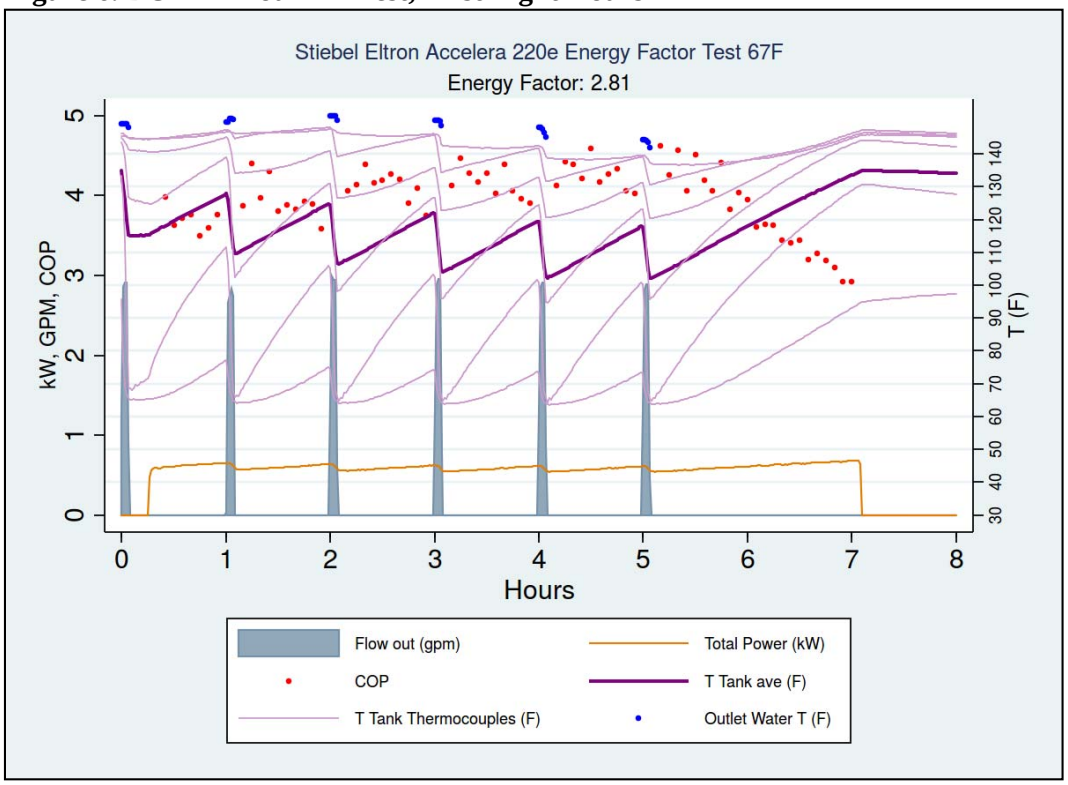


Figure 7. DOE 24-Hour EF Test, Full 24 Hours

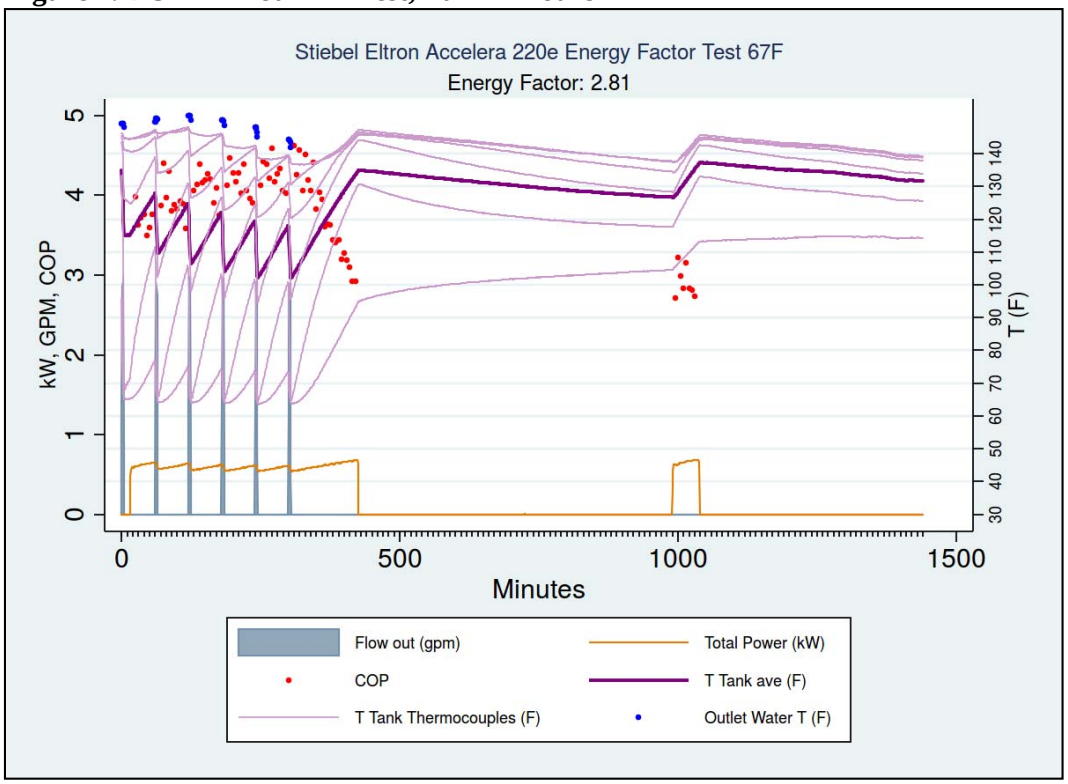


Figure 8. DOE 24-Hour, 50°F Ambient Air 50°F Inlet Water, First Eight Hours

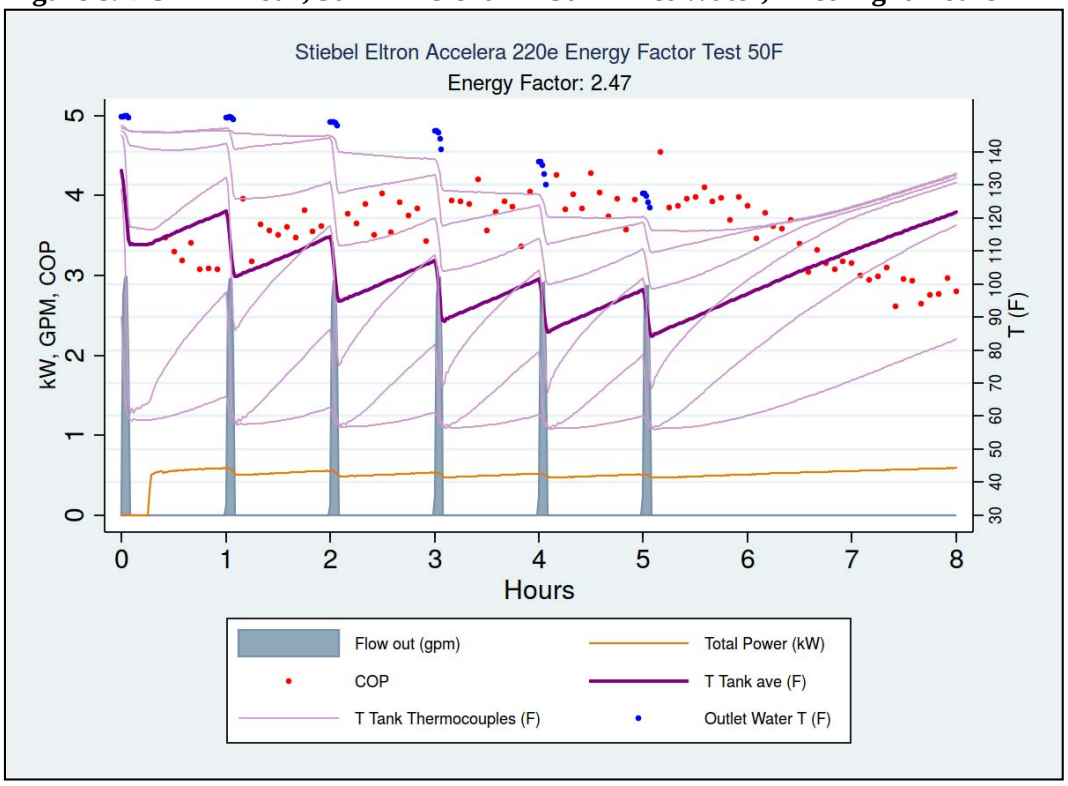


Figure 9. DOE 24-Hour, 50°F Ambient Air 50°F Inlet Water, Full 24 Hours

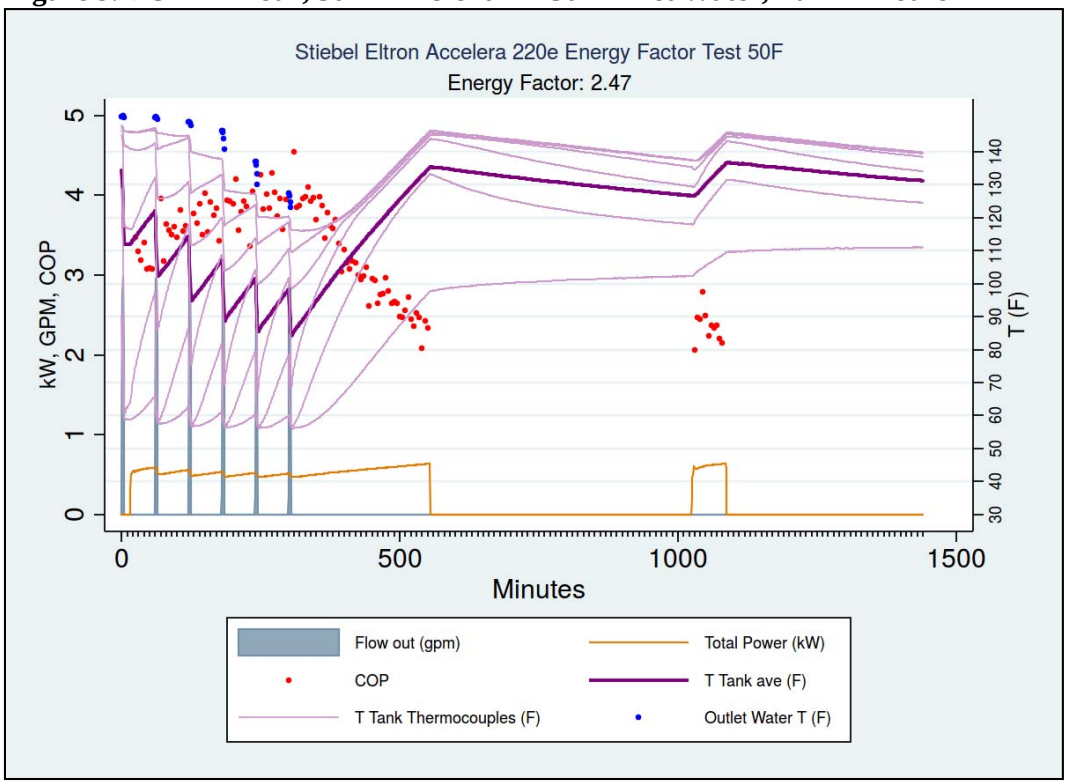


Figure 10. DOE 24-Hour UEF Test 67°F

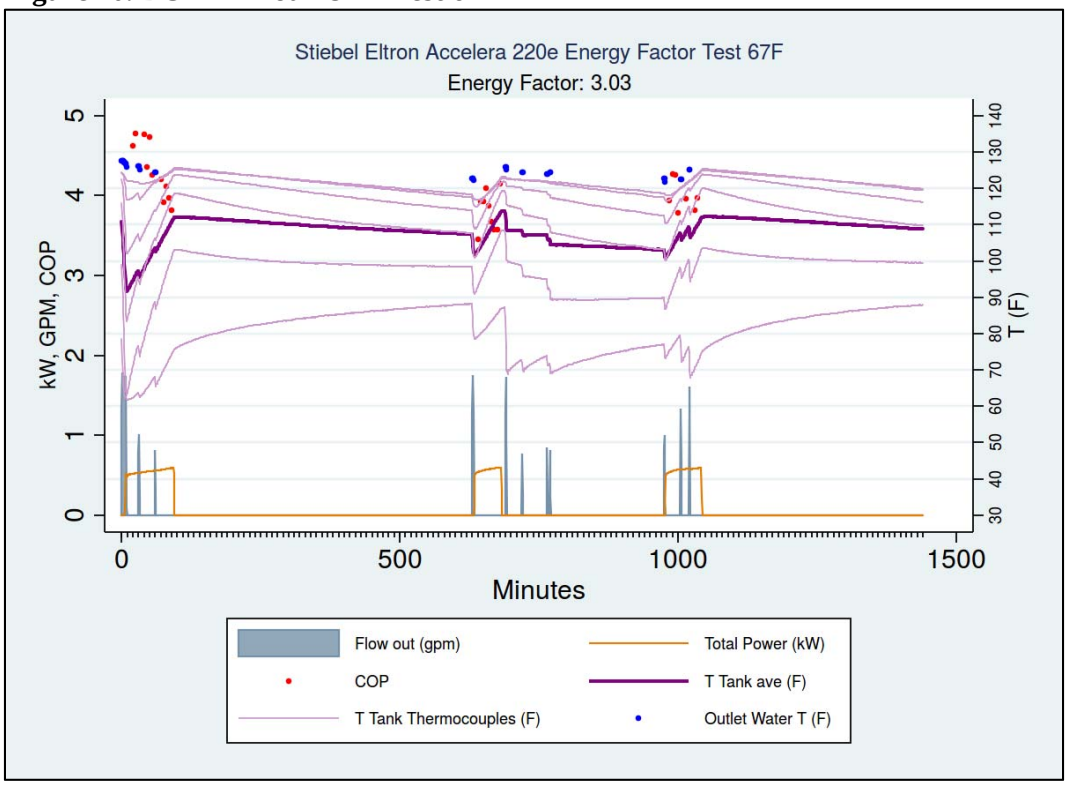
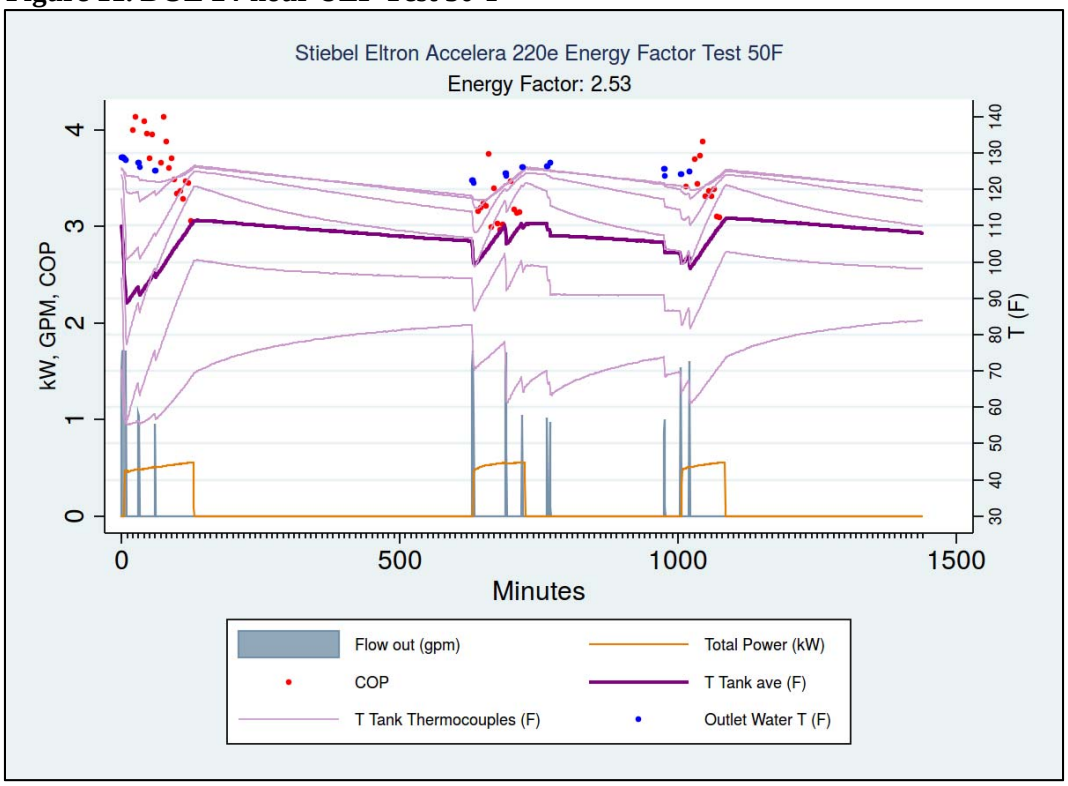


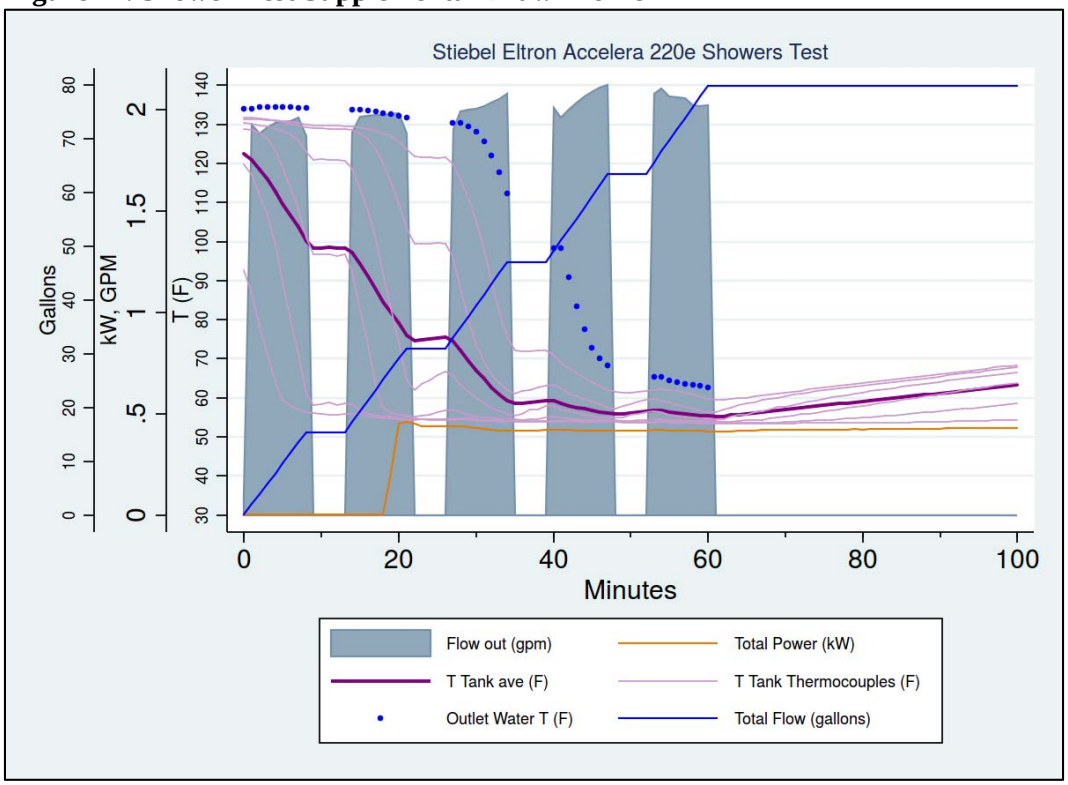
Figure 11. DOE 24-hour UEF Test 50°F



4.2. Efficient Showers Test

Figure 12 illustrates the supplemental draw profile for the efficient showers test. This test demonstrates the performance of the unit with three consecutive 16 gallon draws in 35 minutes.

Figure 12. Shower Test Supplemental Draw Profile



4.3. Low Temperature Limit

The unit will not operate the compressor at an ambient temperature below 32°F. It uses resistance elements exclusively below this temperature.

4.4. Noise Measurements and Additional Observations

The lab also measured the sound level of the equipment. Researchers placed the unit in a room near a wall and then measured the sound level at five different points on a circumference three feet distant and five feet high. The ambient temperature for the test was ~72°F. The decibel level when the unit is running is 55 dBA.

5. Conclusions

Overall, the results suggest that the Stiebel-Eltron Accelera 220 E is a highly-efficient water heater. Specific findings include:

- Measured Northern Climate Specification Metrics:
  - Northern Climate Energy Factor: 2.58
  - Percent of tank drained before resistance elements engage in 1-hour test: 82% (Note: element does not engage; the test runs until water is cold)
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References

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Appendix A -- Testing Matrix

Test Name	Ambient Air Conditions					Inlet Water		Tank Set Point		Airflow inch. static pressure	Operating Mode	Notes
	Dry-Bulb		Wet-Bulb									
	F	C	F	C	RH	F	C	F	C			
DOE Standard Rating Point Tests												
DOE-1-hour_old	67.5	20	57	14	50%	58	14	149	65	0.0"	Standard	Follow test sequence in Federal Register 10 CFR Part 430 Section **5.1.4, using old test standard**
DOE-24-hour_old	67.5	20	57	14	50%	58	14	149	65	0.0"	Standard	Follow test sequence in Federal Register 10 CFR Part 430 Section **5.1.5, using old test standard**
DOE-24-hour-50_old	50	10	44	7	58%	50	10	149	65	0.0"	Standard	Follow test sequence in Federal Register 10 CFR Part 430 Section **5.1.5, using old test standard,** but replace ambient conditions with those given in this table.
DOE-1-hour	67.5	20	57	14	50%	58	14	125	52	0.0"	Standard	Follow test sequence in Federal Register 10 CFR Part 430 Section **5.1.4**
DOE-24-hour	67.5	20	57	14	50%	58	14	125	52	0.0"	Standard	Follow test sequence in Federal Register 10 CFR Part 430 Section **5.1.5**
DOE-24-hour-50	50	10	44	7	58%	50	10	125	52	0.0"	Standard	Follow test sequence in Federal Register 10 CFR Part 430 Section **5.1.5,** but replace ambient conditions with those given in this table.
Draw Profiles												
DP-SHW-50	50	10	44	7	58%	50	10	135	52	0.0"	Standard	Draw Profile: DP-SHW. Conduct identical, repeated draws until ending conditions observed.
Additional Observations												
AO-VOL	Measure tank water volume											
AO-PWR	One-time measurements of component power										Standard	Make measurement of fan, pump, and circuit board power draw if possible.
Noise Measurement												
NOI	Measure combined fan and compressor noise									0.0"	Standard	Install equipment in relatively quiet room. Measure sound at 1 meter away, 1.8 meters high at several points around circumference of tank using a hand-held meter.

Appendix B – Measurement Instrumentation List

Equipment	Make and Model	Function	Accuracy	Calibration Expires on
Walk-in Chamber	Make : ESPEC, Model No.: EWSX499-30CA	Test environment temperature and relative humidity control	±1 °C	8/11/2015
Data Acquisition System	Make : Agilent Technologies, Model No : Agilent 34970A	Log temperature, power and flow rate data	Voltage: 0.005% of reading + 0.004% of range Temperature: (Type T):1.5°C	9/9/2015
Thermocouple	OMEGA, T type	Temperature measurement	0.8 °C	Note 1
Power Meter	Yokogawa WT500 Power Analyzer	Continuous power measurement (System and Heat Pump)	Main Unit: Current range: *0.5 to 40A* Voltage range: *15 to 1000V* Basic Power Accuracy: *0.1%* frequency range: *DC 0.5 Hz to 100 kHz*	5/23/2015
Power Source	Fluke 5520	Power meter comparison/calibration	AC Current ±0.15%	4/14/2015
Current Transformer (25:5)	Make: Midwest Model: 3CT625SP	Use with Acuvim Power meter for Total UUT power and Heater power measurement	0.4% at 5VA	Note 1
Flow Meter	Make: Seametrics Model: SPX-050 and FT420 Indicator	Water flow measurement	±1 % of full scale	Oct 2014 (Factory calibrated)
Flow Controller	Make: Watlow Model: F4P	Control timing of flow pattern	NA	NA
Hand-held temperature and Humidity meter	Omega RH820W	Lab environment temperature and humidity measurement	± 0.5° C	6/11/2015
Electronic Scale	Dogain Model: TS300K Range 300 Kg	Measurement of water mass	300 x 0.05Kg 660 x 0.1 lb	3/9/2015