TÜV Rheinland PTL, LLC
2210 South Roosevelt Street
Tempe, AZ 85282

Test Report

Solar Thermal System Testing according to a Customized Test Program

TÜV Report No. R1-SNV120827-011

Tempe, AZ
June 2013

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on

Solar Thermal System Testing
according to
Customized Test Program

Client:	Sunnovations, Inc.
TÜV PTL Quotation No:	SNV120827
Order of:	SNV120827
Test Engineer:	S. Driskill, (tel: 480-966-1700)
Authorizing Engineer:	M. Witt, (tel: 480-295-8167)
Department:	Solar Thermal Testing
Date:	**6/4/2013**
No . of pages:	13

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Summary of test results

Qualification of a Solar Thermal System in accordance with
Customized Test Program

Manufacturer : Sunnovations, Inc.

Manufacturing Address : 1616 Anderson Road
McLean, Virginia 22102, USA

Model Number : Ohm

Collector Type : Heat Meter

Basis of testing : Customized Test Program

Test	Date		Comments
	Start	End	
Accuracy validation testing	4/5/13	5/20/13	

Test engineer

Samantha Driskill

Authorizing engineer

Mark Witt

1 Setting of tasks

Sunnovations, Inc. has tasked TÜV-PTL to conduct validation testing on the **Ohm** system according to a test plan developed on the basis of the initial verification tests described EN 1434-5: 2007.

2 Sampling

Provided by manufacturer	✓

3 Description of system components and test setup

Manufacturer	Sunnovations, Inc.
Model number	**Ohm**
Type	Heat Meter

3.1 Heat Meter

Manufacturer	Sunnovations, Inc.
Calculator	Ohm (aka “Emily”)
Calculator Software Version	5/10/13
Sensor	Ohm

Figure 3-1 Photo of Sunnovations, Inc. **Ohm** Heat Meter computer with modification for serial communication output

Figure 3-2 Photo of Sunnovations, Inc. Ohm sensor

3.2 Storage Tank

Tank make	Bradford White
Tank model	SDW275R6DS-1NCWW
Tank volume [L]	284

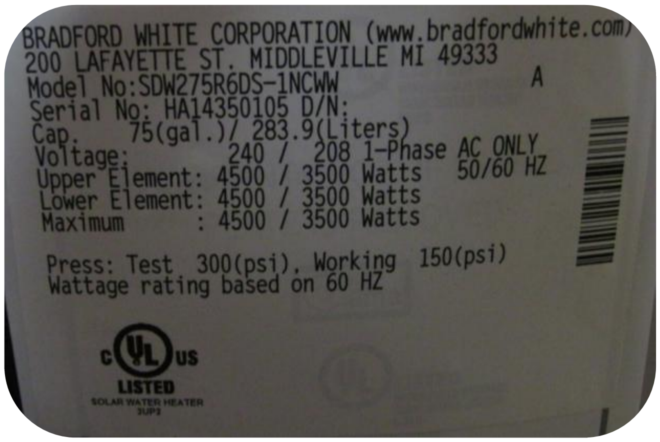

Figure 3-3 Tank label plate for **Bradford White** SDW275R6DS-1NCWW

3.3 Test setup

Figure 3-3 Photo of test setup for evaluation Sunnovations, Inc. **Ohm** heat meter

3.4 Reference Equipment

Equipment	Manufacturer	Model Number	Asset Number
Flow meter	Omega	FTB 1312	S012
Temperature Sensors	Omega	P-M-1/10-1/8-6-1/8-T-25	S045, S046
Data Acquisition	Campbell Scientific	CR1000	A404

3.5 Reference Equipment Uncertainty

Expanded uncertainty	0.749%

The reported uncertainty is based on a combined Type B standard uncertainty determined on the basis of the reference equipment specifications and calibrations multiplied by a coverage factor k≈2, providing a level of confidence of approximately 95%. Given the limited number of test runs, Type A uncertainty for standard deviation has not been included.

4 Test procedure

The Sunnovations Ohm sensor was installed according to manufacturer instructions in a 75 gallon Bradford White storage tank with electrical auxiliary heaters. A photograph of the test setup can be found in Figure 3-3. Three test runs were conducted in order to reduce uncertainty.

The relevant standard for heat meters, EN 1434, was developed for heat meter constructions limited to two temperature sensors and a flow meter. However, the Sunnovations Ohm heat meter utilizes neither in order to measure energy changes in the storage volume. Instead, the Ohm employs an enthalpy sensor and a processing algorithm which assigns energy changes to certain sources. Therefore, a strict application of the evaluation procedures in EN 1434-5 is not possible. The most applicable language is contained in Section 5.7, excerpted below, where $\Delta\theta$ indicates temperature difference and q is flow rate. While the ranges of temperature difference and flow rate are not applicable to the Sunnovations Ohm heat meter due to the heat meter having near temperature sensors or a flow meter, they do apply to the reference equipment. Therefore, some attempt could be made to follow these guidelines once the manufacturer establishes limits for flow rate and temperature.

5.7 Complete meter

The verification of the complete meter shall be carried out, at least within each of the following ranges

For heating applications:

a)	$\Delta\Theta_{min}$	$\leq \Delta\Theta \leq$	$1{,}2\ \Delta\Theta_{min}$	and	$0{,}9\ q_p$	$\leq q \leq$	q_p
b)	10 K	$\leq \Delta\Theta \leq$	20 K	and	$0{,}1\ q_p$	$\leq q \leq$	$0{,}11\ q_p$
c)	$\Delta\Theta_{max}$ - 5 K	$\leq \Delta\Theta \leq$	$\Delta\Theta_{max}$	and	q_i	$\leq q \leq$	$1{,}1\ q_i$

Figure 4-1 Excerpt of section 5.7 of EN 1434-5: Initial verification tests

In lieu of a direct application of the procedures outlined in EN 1434-5, a procedure for the evaluation of tank energy based on SRCC TM-1 was developed as follows:

Before the first test run after launching the Ohm, both upper and lower thermostats were set to “high”and the electrical heaters were plugged in. Several hours were allowed to pass so that the Ohm algorithm could ‘calibrate’ the tank losses.

For each test run the following procedure was conducted:

1. Plug in the electrical heaters to the power source.
2. Allow the tank to heat up for at least 1.5 hours.
3. Unplug the heaters from the power source.
4. Conduct a line purge in order to clear the piping of all stagnated water so that the draw fluid enters the tank at uniform temperature throughout draw.
5. Conduct purge/draw of part of the tank volume at 7 LPM for approximately 15-20 minutes.

Per manufacturer instruction, the duration of each tank draw was limited such that the exit temperature of the tank remained above 40°C at minimum. This is due to the processing algorithm which is based on “normal use” and the assumption that tank draws will typically be stopped once the tank temperature falls below the threshold of being useful for warmth.

5 Test results

For each test run, the reference equipment was sampled on a 10 second interval and totalized over the course of the run. This running total is used to generate the curves found in below and to provide a total energy use figure for comparison to the Sunnovations, Inc. Ohm heat meter.

It should be noted that a bug in the Ohm processing algorithm was discovered during testing. The results contained in this report are indicative only of the sensor and calculator with the algorithm updated over-the-air on 5/10/13. Thus, the run numbering starts at 10, when the change was made. All previous test runs are not included in this test report.

Table 5-1 represents a summary of the final three test runs. All error percentages are within one standard deviation of the mean value, indicating acceptable agreement between test runs.

Table 5-1 Summary of test results

	Ohm Purge Energy [Wh]	Reference Purge Energy [Wh]	Absolute Error
Run 10	4874	4851	0.60%
Run 11	4609	4564	0.99%
Run 12	6557	6596	0.47%
Average			0.69%

The following three figures (5-1, 5-2, and 5-3) show a graphical representation of the purge energy totalized over time for each test run. The Ohm data does not include a timestamp. Therefore, the correlated time for the Ohm has set by using the Ohm timecode pegged to the reference equipment timestamp. Furthermore, due to the fact that the Ohm was sampling on 5 minute interval during test, the actual time at start of purge was finely adjusted based on the reference equipment timestamp.

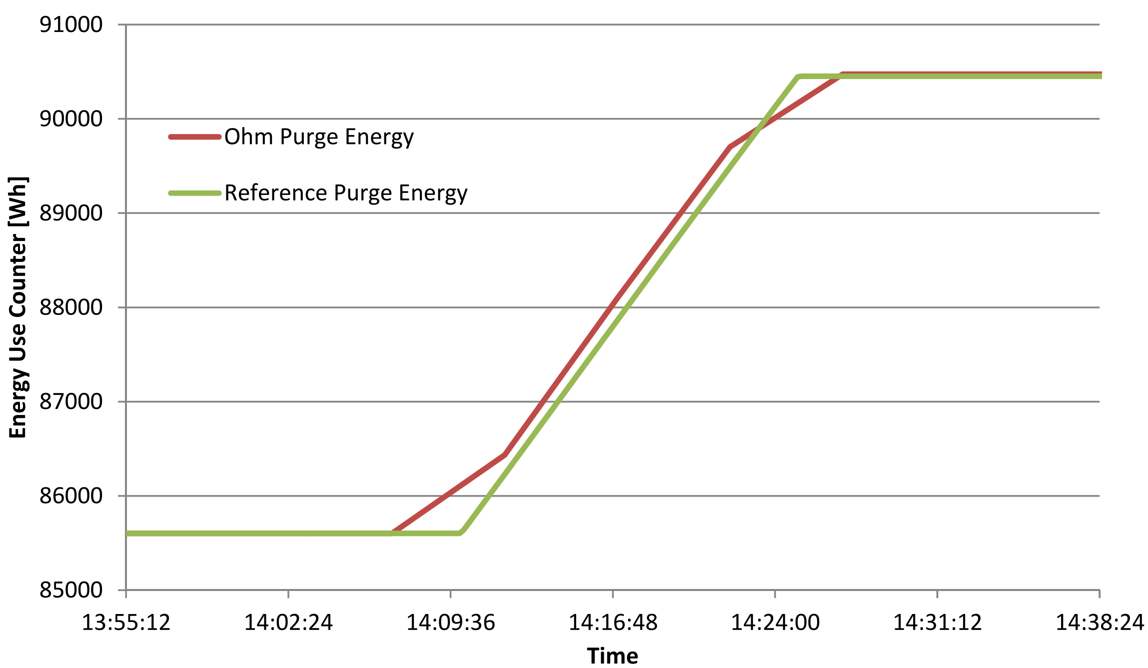

Figure 5-1 Energy Drawn from Tank, Run 10

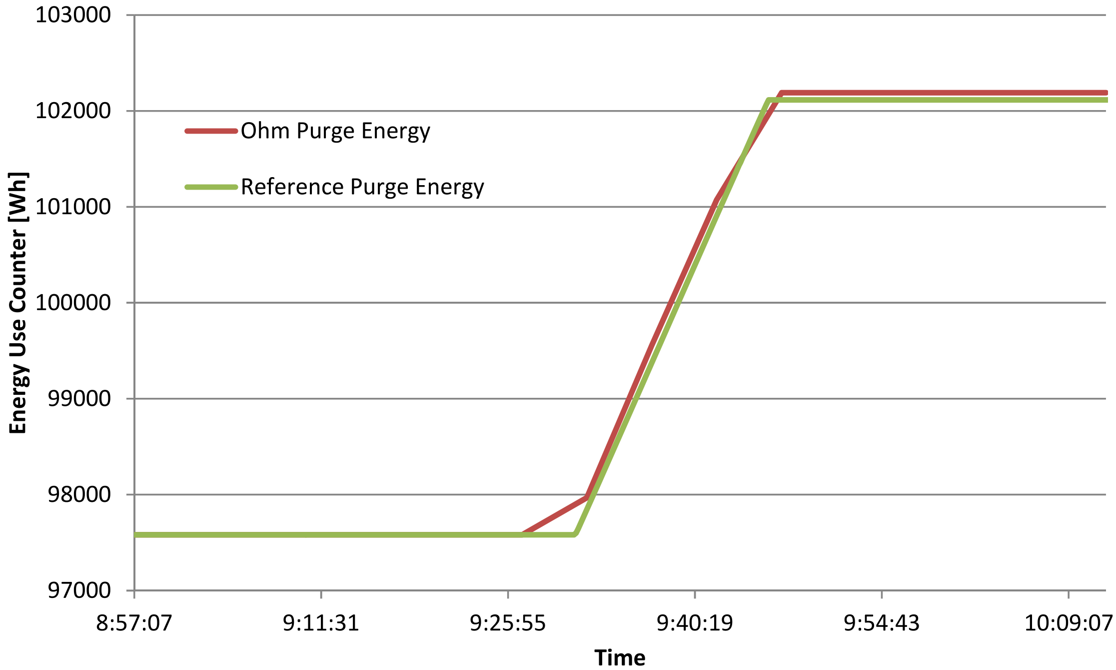

Figure 5-2 Energy Drawn from Tank, Run 11

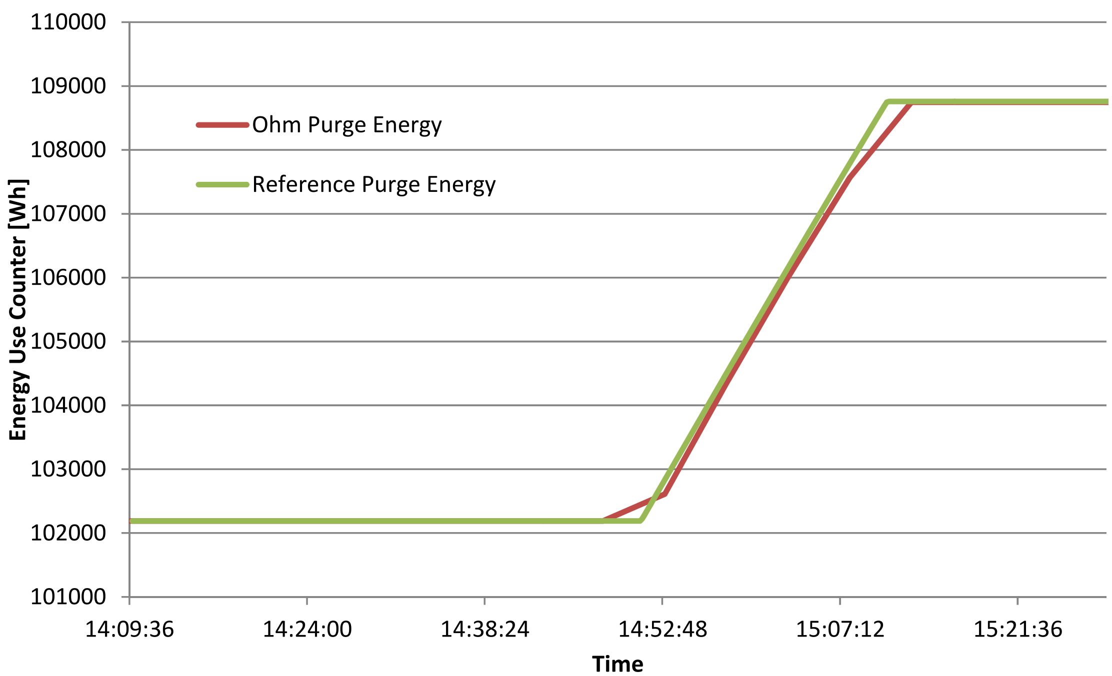

Figure 5-3 Energy Drawn from Tank, Run 12

6 Comparison to conventional flow rate-based heat meter

In addition to the baseline accuracy determination, comparison to a conventional heat meter intended for use in a solar domestic hot water system was also executed empirically under the same flow, temperature, and procedural conditions as the evaluation of the Ohm. A flow meter and pair of temperature sensors from a market-available heat meter were plumbed hydraulically in series with the tank draw lines.

Figure 6-4 shows a comparison of errors for all test runs on both the Ohm and conventional meters. In addition, the mean of all errors for each meter along with lines showing one standard deviation (σ=1) are shown. It can be seen that, under the specified conditions of operation, the Ohm performs favorably when compared to a conventional heat meter with mean absolute errors on totalized energy drawn of 0.69% and 1.36%, respectively.

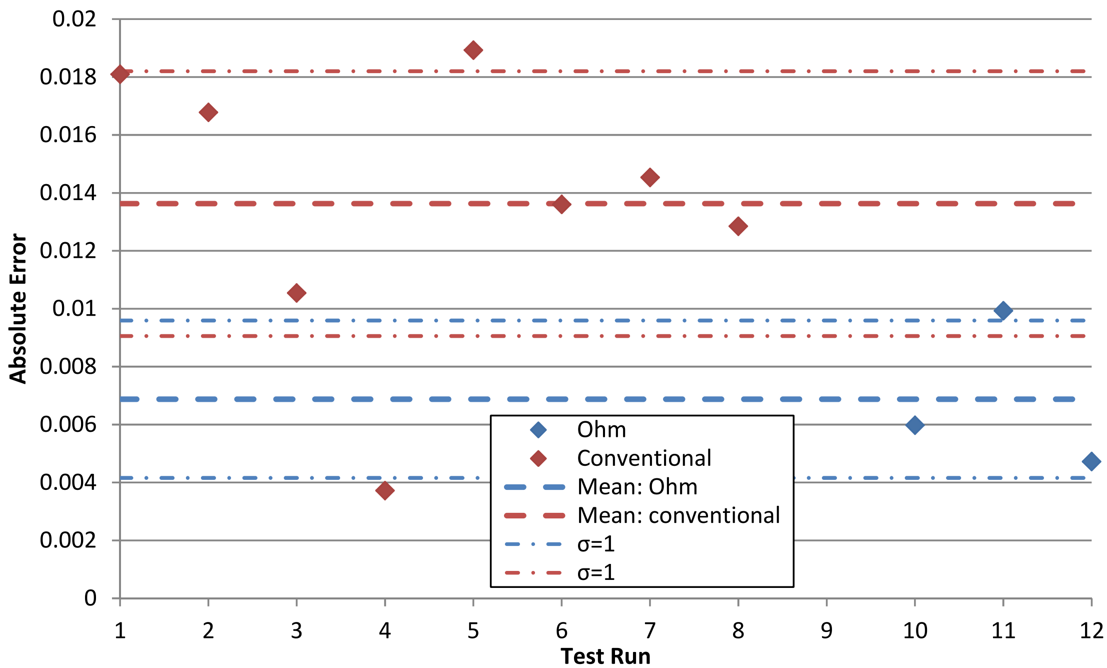

Figure 6-1 Comparison of errors for all test runs on both Ohm and conventional meter with standard deviation of σ=1

7 Conclusions

The scope of this test program was to determine the baseline accuracy of the Sunnovations Ohm heat meter versus both reference equipment and a conventional heat meter. However, this heat meter is designed to measure enthalpy changes in a storage volume and via algorithm assign those energy changes to representative sources; for example, energy changes due to solar input, auxiliary input from electrical elements, energy used by the consumer, or energy lost from the storage volume. The testing methodology was developed in order to facilitate both a means to measure the Ohm in a technically sound manner and to compare like-to-like to a conventional heat meter. Thus, in this test program only the measurement of energy used by the consumer was evaluated. While some limited data for the other sources was collected, these were not strictly part of the test design and therefore not analysed in any detail. In short, the accuracy figures included herein are not indicative of the total accuracy of the Sunnovations Ohm for all operating conditions and energy sources, but are limited to the conditions of operation within the test program design and goals.

Thus, the error of the Sunnovations Ohm heat meter can be reported as 0.7% with an equipment uncertainty of 0.75% for measurement of Energy Used under the tank draw conditions described in this test report.