Development and Evaluation of New Testing Protocols for Measuring the Performance of Showerheads in the United States and Canada

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ABSTRACT

Consumer satisfaction survey and laboratory test results are provided for 43 efficient and 30 standard showerheads to indicate the effectiveness of new test specifications developed by the American Society of Mechanical Engineers (ASME) and Canadian Standards Association (CSA) Joint Harmonization Task Force (JHTF) for flow rate, force, and coverage over a range of flowing pressures from 20 to 80 pounds per square inch gauge (psig). The current showerhead standard is 2.5 gallons per minute (gpm) at 80 psig flowing pressure (A112.18.1/CSA-B125.1-1992/2005). The United States Environmental Protection Agency (US EPA) WaterSense® and their consultant, Eastern Research Group (ERG), collaborated with ASME/CSA JHTF on new showerhead test protocols to develop a WaterSense® showerhead specification of 2 gpm at 80 psig flowing pressure. Approximately 64 to 77 percent of tested showerheads do not meet the WaterSense® specification for flow rate, force, or coverage. Based on these findings, this study recommends that California not adopt a flow rate standard lower than 2.5 gallons per minute at 80 psig flowing pressure as specified in the California Green Building standards. Instead, the study supports the voluntary WaterSense® showerhead specification of 2.0 gpm at 80 psig to give manufacturers time to design more efficient showerheads. Showering in the US consumes 15 to 20% of total residential indoor water use or 1.4 trillion gallons per year. Annual savings from new showerhead standards and labels are estimated at 64,605 million gallons of water, 188 million therms, and 3,066 GWh, and $600 million.

Introduction

Showering in the United States (US) consumes 15 to 20% of total residential indoor water use or approximately 1.4 trillion gallons of water per year (Biermayer 2005). The benchmark for showerheads, as specified in the Energy Policy Act of 1992, is a maximum of 2.5 gallons per minute (gpm) when measured at a flowing pressure of 80 pounds per square inch gauge (psig), as determined through testing per the American Society of Mechanical Engineers (ASME) and Canadian Standards Association (CSA) A112.18.1/CSA-B125.1-1996. The California Green Building Standards include a mandatory prescriptive approach for showerheads of 2.0 gpm at a flowing pressure of 80 psig (CGBSC. 2010). However, due to poor showerhead performance and user dissatisfaction, residential and non-residential consumers have replaced single showerheads with multiple showerheads that may use more than the maximum water flow regulations intended. Consumers replace single showerheads with multiple showerheads to increase flow, coverage, force or other attributes that result in a better shower experience. Another reason is to obtain a therapeutic experience similar to a whirlpool tub or spa.

Consumer preferences have been analyzed in studies by manufacturers, hotel chains, and utility companies (Plumbing & Mechanical Magazine, 2002). One study found 66% of respondents wanted more water flow and 60% wanted more force. One large US hotel company tested more than 150 showerheads before deciding to install custom-designed showers having

two heads. Another US hotel company installed single showerheads in each room after testing showerheads with more than 7,000 guests who rated them on water pressure, coverage, and flexibility of spray settings (HHM 2004).

The water and energy savings associated with development of new testing protocols to improve showerhead performance can be inferred from a report entitled, *Trends in Shower Design and Their Effect on Energy and Water Use*, published in the Proceedings of 2006 ACEEE Summer Study on Energy Efficiency in Buildings (Biermayer 2005). The potential water savings from improved showerhead performance to counteract the trend to multiple showerheads is estimated at 177 million gallons per day or 64,605 million gallons per year. The potential annual energy savings from improved showerhead performance are 188 million therms, 3,066 GWh, and $600 million. The savings in California would be roughly 10% of these savings or 6,405 million gallons per year, 18.8 million therms per year, and 307 GWh per year. The net annual benefits to California are estimated at approximately $60 million.

This report provides market research, technical information, laboratory measurement data, and consumer satisfaction survey results from a three-year Public Interest Energy Research (PIER) study funded by the California Energy Commission (CEC) to collaborate with the American Society of Mechanical Engineers (ASME) and the Canadian Standards Association (CSA) Joint Harmonization Task Force to evaluate showerhead efficiency and performance, with the intent of developing new test protocols and the WaterSense® showerhead specification.

Joint Harmonization Task Force

The ASME and the CSA established a Joint Harmonization Task Force (JHTF) in 2007 with the intent of developing new showerhead test protocols and performance standards. The JHTF included showerhead manufacturers, water and energy utilities, testing laboratories, and consultants. The US Environmental Protection Agency (EPA) WaterSense® and their consultant, Eastern Research Group (ERG), worked with the JHTF to collaborate on new showerhead test protocols and the WaterSense® Specification for Showerheads (Tanner 2009). EPA published its WaterSense® Notice of Intent (NOI) to develop a specification for high-efficiency showerheads in August 2007. In its notice, WaterSense® identified its goal to label products that are 20% more water-efficient than average products.

JHTF members identified a health and safety concern regarding the potential risk of thermal shock or scalding caused when a device using hot or cold water is activated while a shower is operating. Water can be diverted away from the shower fitting, causing a pressure drop in either the hot or cold water supply to the shower. A sudden temperature change can cause either an abrupt physical reaction resulting in a fall or scalding if the temperature increase is severe. To reduce temperature-related shower injuries, most U.S. plumbing codes require automatic-compensating valves that comply with ASSE 10162 or ASME A112.18.1/CSA B125.1.[1] The JHTF evaluated temperature profiles associated with a drop in hot and cold water pressure for standard and efficient showerheads installed with and without auto-compensating valves designed for a flow rate of 2.5 gpm. The JHTF evaluated the data before it recommended a flow rate designation for high-efficiency showerheads.

[1] An automatic-compensating mixing valve (thermostatic, pressure balancing or combination) helps regulate water temperature through balancing hot and cold water supply pressures or through controlling mixed outlet temperature with a thermostatic element to maintain outlet water temperature within ± 3.6°F.

The JHTF developed new showerhead test protocols to verify performance attributes in the laboratory. The JHTF conducted round-robin tests to evaluate the new test protocols with the same set of showerheads at multiple test laboratories including Robert Mowris & Associates (RMA). The set of 22 showerheads included in the round-robin tests are referred to as the "WaterSense®/ERG" models. ERG conducted consumer satisfaction testing on the same 22 showerhead models to determine whether there is a uniform preference or dislike of certain showerhead attributes and to determine whether the performance attributes adequately define user satisfaction (Wagoner 2008). RMA conducted consumer satisfaction testing to verify the ERG consumer satisfaction results for the "WaterSense®/ERG" models. RMA performed additional laboratory and consumer satisfaction testing on 51 other showerheads referred to as the "CEC PIER" models to evaluate how the new test protocols performed on a larger sample of showerheads. If the consumer testing provided conclusive results, the JHTF correlated these attributes against the laboratory test protocols and used the results to establish performance criteria for the new showerhead test protocols.

Project Advisory Committee

The project advisory committee (PAC) was organized in July 2007 and consisted of JHTF members including showerhead manufacturers, utility representatives, consultants, and industry experts. The PAC met during JHTF meetings from July 2007 through January 2010. The PAC members participated in market research surveys, provided suggestions and specifications for the showerhead test protocols, designed showerhead test fixtures, provided showerhead models for testing, and performed round-robin testing of the test protocols. Round-robin testing of the showerhead test protocols provided feedback to improve the protocols. PAC members also provided review comments of the PIER study work products and reports.

Showerhead Market Survey

The showerhead market survey interviewed twenty five showerhead manufacturers, showerhead industry experts, water and energy utility representatives, testing laboratories, consultants, hardware and home improvement retail store representatives, and other water-efficiency and conservation specialists. The objective was to understand the showerhead market and obtain standard and water-efficient showerheads for laboratory testing and consumer satisfaction surveys. Some manufacturers provided free samples for testing. Some products were purchased directly from manufacturers or through internet and retail stores. More than 100 showerheads were evaluated and considered and 73 showerheads were included in the study. The WaterSense®/ERG sample included 22 fixed showerheads and the CEC PIER sample included 41 fixed showerheads and 10 hand held showerheads.[2] The WaterSense®/ERG showerheads were included in the round-robin laboratory testing by CSA, Alsons, IAPMO, and RMA and the WaterSense®/ERG and RMA consumer satisfaction survey. The CEC PIER sample of 41 fixed and 10 handheld showerheads were included in the RMA laboratory testing and RMA consumer satisfaction survey.

[2] The WaterSense®/ERG sample included 16 unique models and 6 duplicates.

WaterSense®/ERG and CEC PIER Showerhead Samples

WaterSense®/ERG showerhead sample includes 22 showerhead models with 12 "poor performing" showerheads from several manufacturers, 5 showerheads of unknown performance, and 5 "control" showerheads selected based on success in several utility rebate programs and units frequently installed in hotel rooms. The WaterSense®/ERG models were selected to determine if users could uniformly differentiate qualitative performance and provide recommendations for showerheads to test quantitatively against the proposed ASME/CSA showerhead testing protocols in a laboratory setting. The WaterSense®/ERG consumer satisfaction survey study included a variety of showerheads with rated flow rates ranging from 0.7 gpm to 2.5 gpm at 80 psig flowing pressure.

The CEC PIER showerhead sample includes 22 showerhead models from the WaterSense®/ERG sample plus 51 additional showerhead models including 41 fixed showerheads and 10 handheld showerheads with rated flow rates ranging from 0.55 to 2.5 gpm at 80 psig flowing pressure. The CEC PIER sample included 43 efficient and 30 standard showerheads, and the WaterSense®/ERG sample included 13 efficient and 9 standard showerheads. The CEC PIER model samples were selected to compare and qualitatively and quantitatively test the EPA WaterSense® flow rate, force, and coverage criteria.

Retail Cost Survey

The retail cost survey for WaterSense®/ERG and CEC PIER model samples found an average retail price of $49.68 ± $3.04 per unit for standard 2.5 gpm showerheads with a sample size of 79 units. The average price for water saving showerheads is $36.72 ± $0.89 per unit and average rated flow rate of 1.5 ± 0.02 gpm at 80 psig with a sample size of 196 units. The average retail cost of water saving showerheads are 26 percent less than the average retail cost of conventional showerheads even from the same manufacturer. The market appears to value standard flow units at a premium price compared to water saving products, indicating a perception of inferior performance associated with water saving showerheads.

Description of the WaterSense® Showerhead Specification

WaterSense® Water Efficiency Flow Rate Criteria

The WaterSense® Specification for Showerheads requires measuring showerhead flow rates at flowing pressures of 20, 45, and 80 ± 1 psig (140, 310, and 550 ± 7 kilopascal [kPa]) with water temperature at 100 ± 10 °F (38 ± 6 °C) maintained for at least one minute (USEPA 2010). WaterSense® requires manufacturers to specify the maximum rated flow rate to be equal to or less than 2.0 gpm (7.6 liters per minute [L/min]) per the testing and verification protocols described in 10 CFR 430 Subpart F (DOE 1998), at flowing pressures of 20, 45 and 80 ± 1 psig (140, 310 and 550 ± 7 kPa). The minimum flow rate value, determined through testing, at a flowing pressure of 20 ± 1 psig (140 ± 7 kPa), shall not be less than 60 percent of the maximum flow rate value. The minimum flow rate value, determined through testing, at flowing pressures of 45 ± 1 psig (310 ±7 kPa) and 80 ± 1 psig (550 ±7 kPa), shall not be less than 75 percent of the maximum flow rate value.

WaterSense® Spray Force Criteria

The WaterSense® showerhead spray force is measured at a flowing pressure of 20 ± 1 psig (138 Pa ± 7 kPa). The minimum spray force shall not be less than 2.0 ounces (0.56N) at a pressure of 20 ± psig (140 ± kPa) at the inlet, when water is flowing.

WaterSense® Spray Coverage Criteria

The WaterSense® showerhead spray coverage is measured at a water temperature of 100 ± 10 °F (38 ± 6 °C) maintained for at least one minute with water pressure at 45 ± 1 psig (310 ± 7 kPa) at the inlet when water is flowing per the new showerhead test protocol.[3] The total combined maximum volume of water collected in the 2 and 4 inch (50, 101 mm) annular rings shall not exceed 75 percent of the total volume of water collected, and total combined minimum volume of water collected in the 2, 4, and 6 inch (50, 101, 152 mm) annular rings shall not be less than 25 percent of the total volume of water collected.

Manufacturer Survey Results

RMA conducted surveys with 25 manufacturers representing 80 to 90 percent of all showerheads sold in the US. Seventy one percent of manufacturers are members of the ASME/CSA A112.18.1 Joint Harmonization Task Force. Fifty percent of manufacturers are EPA WaterSense® partners. Twenty one percent of manufacturers are members of the US Green Building Council Water Efficiency Technology Advisory Group. The market share of the 24 manufacturers ranges from less than 1 percent to 12 percent and the average market share is 4 percent ± 1 percent. All manufacturers promote water conservation. Only one company reported receiving complaints (for another manufacturer valve) about thermal shock with their showerhead rated at less than 2.5 gpm at 80 psig. Eighty eight percent of manufacturers have conducted showerhead quality tests using showerheads rated at less than 2.5 gpm at 80 psig. Fifty percent of manufacturers give special guidance to consumers about retrofitting showerheads rated at less than 2.5 gpm at 80 psig. Fifty eight percent of manufacturers reported 47% of total sales are water saving showerheads. Seventeen percent of manufacturers report that water saving showerheads cost more than conventional showerheads rated at 2.5 gpm at 80 psig. However, the average retail cost for water saving showerheads is 26 percent less than conventional showerheads based on all showerheads in the survey. Eighty three percent of manufacturers sell water saving showerheads in California. Six manufacturers sell multi-shower units with average total sales of 3%. Forty six percent of manufacturers support a mandatory standard to reduce the maximum showerhead flow rate below 2.5 gpm to conserve energy and water. The manufacturers who support a mandatory standard for new construction represent a small market segment of less than 10 percent of the overall showerhead market share. Ninety six percent of manufacturers support the voluntary WaterSense® showerhead specification. Eighty three percent of manufacturers sell efficient showerheads with rated flow rates less than 2.5 gpm at 80 psig and the average manufacturer offers 5 models. Fifty eight percent of manufacturers donated showerheads for testing in the CEC PIER study.

[3] Drawings of the force balance test apparatus are available at www.epa.gov/watersense/pp/showerheads.htm.

Water Efficiency Flow Rate Data

Laboratory and consumer test results for the WaterSense® flow rate criteria are shown in **Table 1**. Sixty four percent of WaterSense®/ERG models tested by CSA, IAPMO, and Alsons failed to meet required tolerance of the WaterSense® flow rate criteria (14 out of 22 models).[4] Seventy seven percent of the WaterSense®/ERG models tested by RMA failed to meet required tolerance of the WaterSense® flow rate criteria (17 out of 22 models). Only 5 WaterSense®/ERG models tested by RMA pass the WaterSense® criteria while 17 fail due to the maximum measured flow rate at 80 psig being greater than manufacturer specified flow rate, or minimum flow rate at 20 psig being less than 60 percent of the maximum manufacturer specified flow rate, or measured flow rate at 45 psig being less than 75 percent of the maximum manufacturer specified flow rate or not meeting the force or coverage criteria. Sixty six percent of CEC PIER fixed showerhead models tested by RMA failed to meet required tolerance of the WaterSense® flow rate criteria (19 out of 41 models). Eighty percent of CEC PIER hand held models tested by RMA failed to meet required tolerance of the WaterSense® flow rate criteria (8 out of 10 models). Only 26 CEC PIER models pass the WaterSense® specification while 25 fail due to the maximum measured flow rate at 80 psig being greater than manufacturer specified flow rate, or minimum flow rate at 20 psig being less than 60 percent of the maximum manufacturer specified flow rate, or measured flow rate at 45 psig being less than 75 percent of the maximum manufacturer specified flow rate or not meeting the force or coverage criteria. Consumer satisfaction results are similar for the WaterSense®/ERG models with 64% and 59% "no buy." Consumer satisfaction results are lower for the CEC PIER fixed sample with 54% "no buy" and 10% "no buy" for the hand held models.

Table 1. Laboratory Test and Consumer Results for WaterSense® Flow Rate Criteria

Laboratory Test Sample	Sample Size	Failed Maximum Flow Exceeds Rated Flow	Failed Flow @ 20 psig Less than Minimum	Failed Flow @ 45 and 80 psig Less than Minimum	Percent Failed WaterSense Flow Rate Criteria	Percent Failed Consumer Satisfaction (No Buy)
CSA WaterSense® ERG Sample	22	7	9	6	64%	64%
IAPMO WaterSense® ERG Sample	22	6	12	7	64%	64%
Alsons WaterSense® ERG Sample	22	7	9	7	64%	64%
RMA WaterSense® ERG Sample	22	11	9	6	77%	59%
RMA CEC PIER Fixed Sample	41	19	8	6	66%	54%
RMA CEC PIER Hand Held Sample	10	6	2	2	80%	10%

Source: Mowris 2010

The most common showerhead failure was due to the maximum flow rate determined through testing at a flowing pressure of 80 ± 1 psig being greater than manufacturer specified flow rate at 80 psig as required in the WaterSense® Specification for Showerheads. One reason why so many showerheads fail the flow rate criteria could be the lack of government required third-party verification testing of maximum allowable flow rates. Other showerheads failed due to the minimum flow rate determined through testing at a flowing pressure of 20 ± 1 psig being less than 60 percent of the maximum flow rate specified by the manufacture per the WaterSense® Specification for Showerheads. Other showerheads failed due to the minimum flow rate required

[4] Tested showerheads are not required to meet the WaterSense® maximum rated flow rate of ≤ 2.0 gpm @ 80 psig.

in the WaterSense® Specification for Showerheads, determined through testing, at flowing pressures of 45 ± 1 psig and 80 ± 1 psi, being less than 75 percent of the maximum flow rate specified by the manufacturer per the WaterSense® Specification for Showerheads.

Spray Force Data

Laboratory test results for the WaterSense® water efficiency force criteria are shown in **Table 2**. Five percent of WaterSense®/ERG models tested by CSA (1 out of 22 models), 9 percent of the models tested by IAPMO (2 out of 22 models), and 23 percent of the models tested by Alsons and RMA (5 out of 22 models) failed to meet the required minimum WaterSense® spray force.[5] Ten percent of CEC PIER fixed showerhead models tested by RMA failed to meet required minimum WaterSense® spray force criteria (4 out of 41 models). Ten percent of CEC PIER hand held models tested by RMA failed to meet required minimum WaterSense® spray force criteria (1 out of 10 models). The spray force test was difficult to perform consistently during the round robin testing due to problems with the calibration procedures which were improved in the final version of the test protocol. Alsons and RMA performed multiple laboratory tests using the final test protocol. Consumer satisfaction force results are higher for the WaterSense®/ERG models with 36% "failed." Consumer satisfaction force results are lower for the CEC PIER sample with 32% "failed" for fixed models and zero "failed" for hand held models.

Table 2. Laboratory Test Results for WaterSense® Water Force Criteria

Laboratory Test Sample	Sample Size	Failed 2.0 Force @ 20 psig	Failed 2.3 Force @ 20 psig	Failed 2.6 Force @ 20 psig	Percent Failed WaterSense® Force Criteria	Failed Consumer Satisfaction Force Criteria
CSA WaterSense® ERG Sample	22	1	2	5	4.5%	36%
IAPMO WaterSense® ERG Sample	22	2	4	5	9.1%	36%
Alsons WaterSense® ERG Sample	22	5	9	15	22.7%	36%
RMA WaterSense® ERG Sample	22	5	10	12	22.7%	36%
RMA CEC PIER Fixed Sample	41	4	7	11	9.8%	32%
RMA CEC PIER Hand Held Sample	10	1	2	4	10.0%	0%

Source: Mowris 2010

Spray Coverage Data

Laboratory test results for the WaterSense® water efficiency force criteria are shown in **Table 3**. Eighteen percent of WaterSense®/ERG models tested by CSA, IAPMO, and Alsons (4 out of 22 models) failed to meet the required minimum WaterSense® spray coverage.[6] Nine percent of the WaterSense®/ERG models tested by RMA failed to meet the required minimum WaterSense® spray coverage criteria. RMA performed multiple coverage tests of each showerhead, and this explains the difference between RMA and other laboratory results. Ten

[5] The WaterSense® force criteria minimum shall not be less than 2.0 ounces (0.56N) at a pressure of 20 ± psig (140 ± kPa) at the inlet, when water is flowing.

[6] The WaterSense® coverage criteria combined maximum volume of water collected in the 2 and 4 inch (50, 101 mm) annular rings shall not exceed 75% of the total volume of water collected and; total combined minimum volume of water collected in the 2, 4, and 6 inch (50, 101, 152 mm) annular rings shall not be less than 25% of the total volume of water collected.

percent of CEC PIER fixed showerheads tested by RMA failed to meet required minimum WaterSense® spray coverage criteria (4 out of 41 models). Ten percent of CEC PIER hand held models failed to meet required minimum WaterSense® spray coverage criteria (1 out of 10 models). Consumer satisfaction coverage results are higher for the WaterSense®/ERG models with 41% "failed" and 27% "failed." Consumer satisfaction coverage results are higher for the CEC PIER fixed sample with 22% "failed" and zero "failed" for hand held models.

Table 3. Laboratory Test Results for WaterSense® Water Spray Coverage Criteria

Laboratory Test Sample	Sample Size	Failed WaterSense Coverage Criteria	Failed Consumer Satisfaction Coverage Criteria
CSA WaterSense® ERG Sample	22	18%	41%
IAPMO WaterSense® ERG Sample	22	18%	41%
Alsons WaterSense® ERG Sample	22	18%	41%
RMA WaterSense® ERG Sample	22	9%	27%
RMA CEC PIER Fixed Sample	41	10%	22%
RMA CEC PIER Hand Held Sample	10	10%	0%

Source: Mowris 2010

Consumer Satisfaction Survey

The WaterSense®/ERG and CEC PIER studies asked five survey questions using the same scoring criteria (see **Table 4**, Q1 through Q5). The CEC PIER study also asked participants to rate each showerhead on noise (Q6), overall satisfaction (Q7), and time required (seconds) to rinse a small amount of conditioner from their hair (Q8). The amount of conditioner is approximately 25 millimeters diameter in the palm of the hand (the size of one US Quarter). After applying the measured amount of conditioner to their hair, CEC PIER consumer survey participants entered the shower to rinse conditioner from their hair and press the "start" button on a waterproof wristwatch or stopwatch. When all conditioner is rinsed from the hair, the participant pressed the "stop" button and recorded "rinsing time" in the survey response form.

Table 4. Consumer Satisfaction Survey Questions

Q1 - Temperature (1=Excellent, 3=Poor) ___ (1 to 3)
Q2 - Force (1=excellent, 3=too soft or too hard)? ___ (1 to 3)
Q3 - Coverage (1=Excellent, 3=Poor)? ___ (1 to 3)
Q4 - Rinsing Action (1=Excellent, 3=Poor) ___ (1 to 3)
Q5 - Purchase showerhead (No Buy, Buy)? ___ (0 or 1)
Q6 - Noise (1=Quiet, 3=too loud)? ___ (1 to 3) CEC PIER Study Only
Q7 - Overall Satisfaction (1=Excellent, 3=Poor)? ___ (1 to 3) CEC PIER Study Only
Q8 - Rinsing Time to remove conditioner (seconds)? ___ CEC PIER Study Only

WaterSense®/ERG Consumer Satisfaction Survey Participants

The WaterSense®/ERG consumer satisfaction study included 38 participants from 22 households who were either employees of ERG or relatives of ERG employees. None of the participants work on the WaterSense® specification development. The 38 participants included 17 females and 21 males ranging in age from 22 to 78, with a majority falling in the 20 to 40 range. Participants were asked to measure the flow rate of their existing showerhead before installing the test showerheads to provide a baseline. Participants were asked demographic

questions to understand user characteristics. Participants were informed that they would be testing a variety of showerheads with varying flow rates and performance characteristics and that their feedback was going to be used to help WaterSense® develop showerhead specifications. Participants were unaware they were intentionally testing some poor performing showerheads. Each household tested 4 showerheads for one week assigned at random. Participants rated each showerhead on force, coverage, temperature, noise, and overall quality by answering the first five survey questions described in **Table 1**. Nearly every household also tested a control showerhead. At the end of each weekly evaluation, participants were asked to provide feedback on the performance of the showerheads. Participants were also instructed to measure and record the flow rate of each showerhead at the end of the weekly evaluation period.

CEC PIER Consumer Satisfaction Survey Participants

The RMA CEC PIER consumer satisfaction survey included 34 females and 38 males ranging in age from 17 to 55. Surveys were conducted at a hotel located in Truckee, California. Participants were asked demographic questions before testing showerheads to understand user characteristics. Showerhead testing was conducted with participants who were given the choice of performing tests in one or more days. Participants tested and rated each showerhead based on temperature, force, coverage, rinsing action, purchase, noise, overall quality, and rinsing time by answering the consumer satisfaction survey questions described in **Table 4**. Consumer satisfaction testing was conducted in two phases. Phase I required 13 days with one 5-hour shift per day. Four participants tested 48 showerheads per shift during Phase I. Phase II required 7 days with two 3-hour shifts per day. Four participants each tested 25 showerheads per shift during Phase II. Each showerhead survey took approximately five minutes. Upon completion of a day of testing, participants returned the wristwatch or stopwatches and robes and were paid $20.00 for every hour of testing. Each CEC PIER participant tested 73 showerheads.

Consumer Satisfaction Survey Results for WaterSense®/ERG Models

WaterSense®/ERG and CEC PIER participants agreed on 80 percent of the models. Six models received a “buy” rating (including 3 efficient models) and 11 models received a “no-buy” rating from both participant groups. Participants disagreed on 2 standard models (A and E) and 2 efficient models (G and K). WaterSense®/ERG participants rated 64% “no buy,” while CEC PIER participants rated 59% “no buy.” Thirty-six percent of all models failed the consumer force rating, while only 4.5 to 23% failed the force test. Twenty-seven to 41% of all models failed the consumer coverage rating, while only 9 to 18% failed the coverage test. This shows an inconsistency between rated and measured input. The “no buy” rating for efficient models is 69% for both participant groups. The “no buy” rating for standard models is 56% for ERG participants and 44% for CEC PIER participants. Seventy-eight percent of standard models and 54% of efficient models failed the flow rate test.

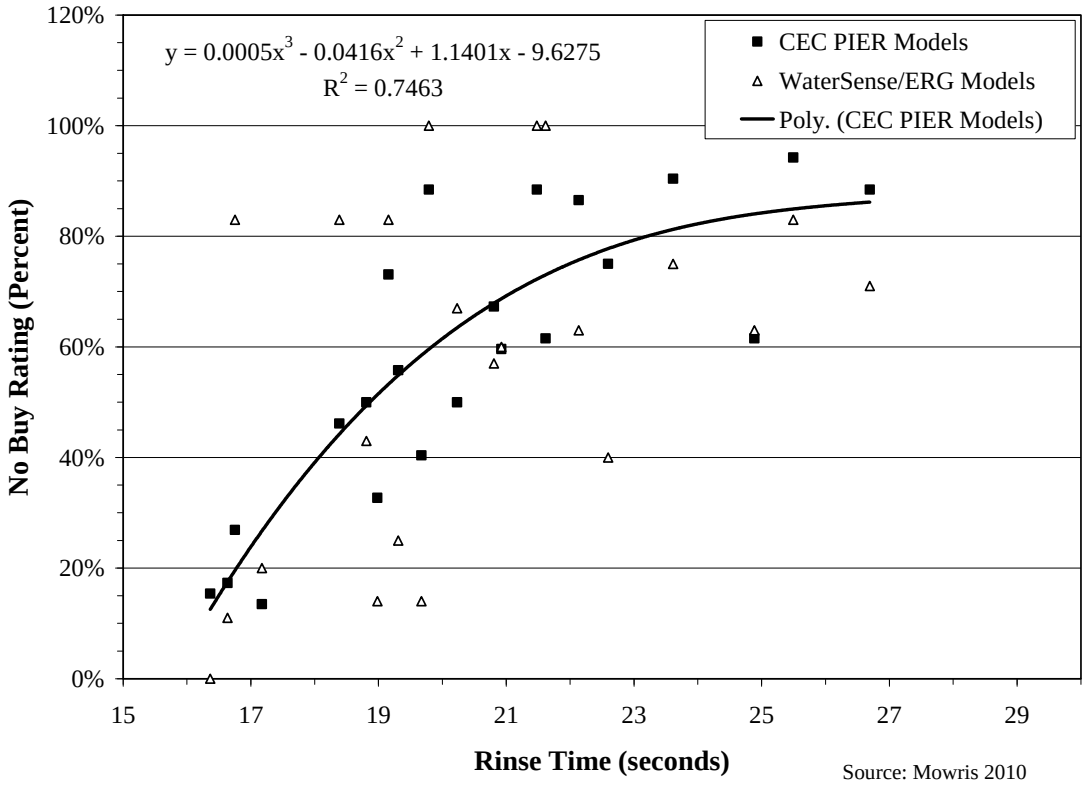
The CEC PIER “no buy” rating is correlated to rinse time to remove hair conditioner in **Figure 1**. The polynomial curve fit has a 0.746 R-squared coefficient indicating 74.6 percent of the variation in “no buy” response is correlated to rinse time. The remaining 23.4 percent is due to variability in consumer preference.

Table 5. Flow Rates and Consumer Survey Results for WaterSense®/ERG Models

Showerhead Model	Rated Flow @ 80 psig GPM	Tested Flow @ 80 psig GPM	Pass Flow Rate Test Criteria	ERG Consumer Satisfaction	ERG Consumer Rating	CEC PIER Consumer Satisfaction	CEC PIER Consumer Rating
A	2.5	2.33	Fail	33%	No Buy	50%	Buy
B	2.0	2.03	Fail	0%	No Buy	12%	No Buy
C	0.5	1.17	Fail	17%	No Buy	6%	No Buy
D	2.5	1.15	Fail	0%	No Buy	38%	No Buy
E	2.5	2.46	Fail	75%	Buy	44%	No Buy
F	1.0	0.78	Fail	29%	No Buy	12%	No Buy
G	1.5	1.64	Fail	17%	No Buy	54%	Buy
H	2.5	2.31	Fail	37%	No Buy	13%	No Buy
I	2.5	2.13	Fail	25%	No Buy	10%	No Buy
J	2.5	2.07	Fail	17%	No Buy	73%	Buy
K	1.6	1.57	Pass	60%	Buy	25%	No Buy
L	2.0	1.82	Pass	86%	Buy	60%	Buy
M	2.0	1.82	Pass	86%	Buy	67%	Buy
N	1.5	1.29	Pass	40%	No Buy	40%	No Buy
O	1.5	1.26	Pass	37%	No Buy	38%	No Buy
P	1.5	1.91	Fail	17%	No Buy	27%	No Buy
Q	1.5	1.91	Fail	57%	Buy	50%	Buy
R	2.5	2.4	Pass	89%	Buy	83%	Buy
S	2.5	2.23	Pass	100%	Buy	85%	Buy
T	1.5	1.8	Fail	0%	No Buy	12%	No Buy
U	1.5	1.82	Fail	43%	No Buy	33%	No Buy
V	2.5	2.42	Pass	80%	Buy	87%	Buy

Source: Mowris 2010

Figure 1. No Buy Rating versus Rinse Time for CEC PIER and WaterSense®/ERG



Source: Mowris 2010

Consumer Satisfaction Survey Results for CEC PIER Models

Flow rates and consumer survey results for CEC PIER fixed models are shown in **Table 6**. Fifty four percent of models received a "no-buy" rating from participants, and 66 percent (19 models) failed the minimum or maximum flow rate test. Ten out of 31 efficient models received a "buy" rating. Thirty two percent failed the consumer force rating, while 10% failed the force test. Twenty two percent failed the consumer coverage rating, and 10% failed the coverage test. The "no buy" rating is 68% for efficient models and 10% for standard models.

Table 6. Flow Rates and Consumer Survey Results for CEC PIER Fixed Models

Showerhead Model	Rated Flow @ 80 psig GPM	Tested Flow @ 80 psig GPM	Pass Minimum or Maximum Flow Rate Test Criteria	CEC PIER Consumer Satisfaction	CEC PIER Consumer Rating
AA	0.6	0.9	Fail	0%	No Buy
AB	1.3	1.6	Fail	37%	No Buy
AD	1.9	2.4	Fail	27%	No Buy
AE	1.5	1.65	Fail	6%	No Buy
AF	1.5	1.8	Fail	19%	No Buy
AG	1.8	2.4	Fail	37%	No Buy
AH	2.0	3	Fail	27%	No Buy
AI	2.0	2.65	Fail	60%	Buy
AJ	1.5	1.65	Fail	19%	No Buy
AK	1.5	1.7	Fail	39%	No Buy
AL	2.5	3.3	Fail	90%	Buy
AM	1.5	1.8	Fail	10%	No Buy
AN	2.0	2.5	Fail	67%	Buy
AO	1.8	1.7	Pass	50%	Buy
AP	2.5	2.4	Pass	79%	Buy
AQ	2.5	1.6	Fail	54%	Buy
AR	1.5	1.7	Fail	63%	Buy
AS	2.5	1.6	Fail	56%	Buy
AT	2.5	2.3	Fail	62%	Buy
AU	1.5	1.5	Pass	65%	Buy
AV	1.6	1.6	Pass	17%	No Buy
AW	1.5	1.25	Fail	25%	No Buy
AX	2.0	2.4	Fail	73%	Buy
AY	2.5	2.4	Pass	69%	Buy
AZ	2.5	2.4	Pass	65%	Buy
BA	2.5	2.1	Pass	52%	Buy
BB	2.5	2.6	Fail	71%	Buy
BC	2.5	2.55	Fail	24%	No Buy
BD	1.8	1.65	Pass	65%	Buy
BE	1.6	0.5	Fail	19%	No Buy
BF	1.8	1.6	Fail	2%	No Buy
BG	1.6	1.4	Pass	33%	No Buy
BH	1.8	1.45	Pass	50%	Buy
BI	1.5	1	Fail	35%	No Buy
BJ	1.3	1.2	Pass	35%	No Buy
BK	1.5	1.25	Pass	45%	No Buy
BL	1.5	1.6	Fail	71%	Buy
BM	1.8	1.1	Fail	37%	No Buy
BN	1.8	1.5	Pass	15%	No Buy
BO	2.0	2.2	Fail	81%	Buy
BP	1.5	1.4	Pass	17%	No Buy

Source: Mowris 2010

Flow rates and consumer survey results for CEC PIER hand held models are shown in **Table 7**. Ten percent of models received a "no-buy" rating, and 20 percent passed the flow rate test. Fifty percent of efficient models (2 out of 4) passed the flow rate test. All efficient models received a "buy" rating, and only 1 out of 6 standard models received a "buy" rating. All models passed consumer force and coverage ratings, while 90 percent passed force and coverage tests.

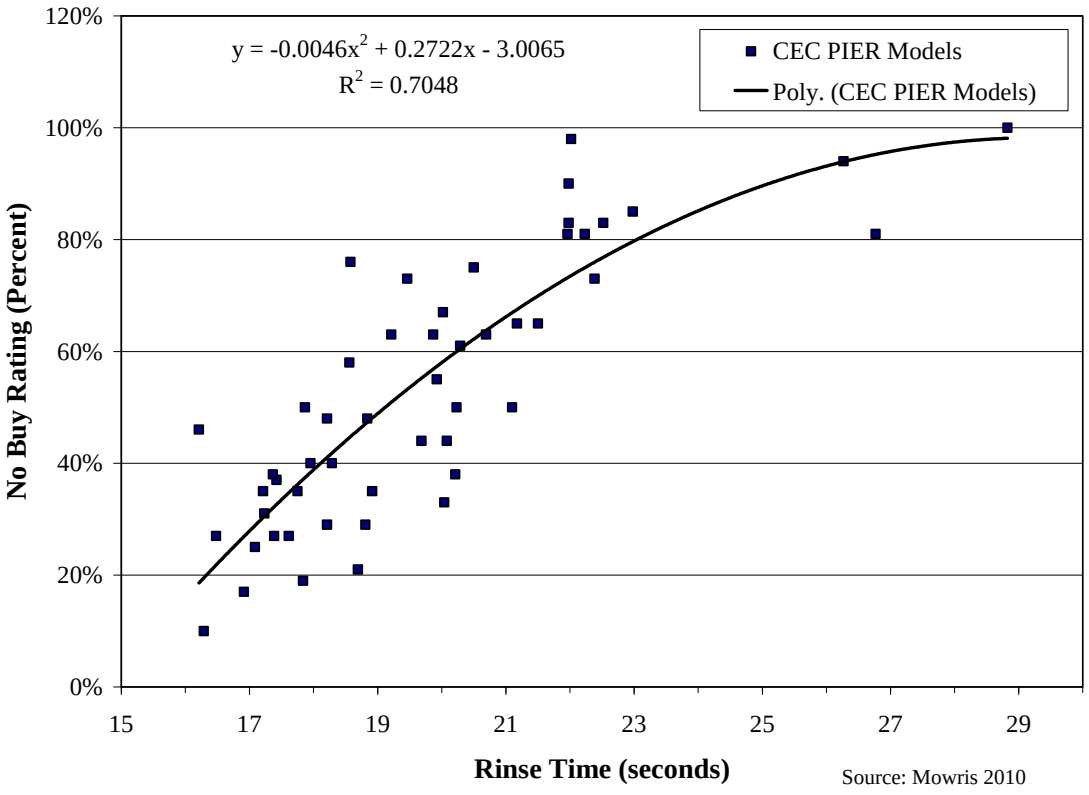
Table 7. Flow Rates and Consumer Survey Results for CEC PIER Hand Held Models

Showerhead Model	Rated Flow @ 80 psig GPM	Tested Flow @ 80 psig GPM	Pass Minimum or Maximum Flow Rate Test Criteria	CEC PIER Consumer Satisfaction	CEC PIER Consumer "Buy" or "No Buy" Rating
HHA	1.5	0.65	Fail	62%	Buy
HHB	1.5	1.2	Pass	73%	Buy
HHC	2.0	2.25	Fail	83%	Buy
HHD	2.5	2.35	Fail	42%	No Buy
HHE	1.5	1.5	Pass	52%	Buy
HHF	2.5	3.35	Fail	50%	Buy
HHG	2.5	3.05	Fail	60%	Buy
HHH	2.5	3.05	Fail	56%	Buy
HHI	2.5	3.3	Fail	75%	Buy
HHJ	2.5	2.8	Fail	73%	Buy

Source: Mowris 2010

The CEC PIER model "no buy" rating is correlated to rinse time to remove hair conditioner in **Figure 2**. The polynomial curve fit has a 0.705 R-squared coefficient indicating 70.5% of the variation in the "no-buy" response variable is correlated to the rinse time variable.

Figure 2. No Buy Rating versus Rinse Time for RMA CEC PIER Models



Source: Mowris 2010

Discussion

This study found a strong correlation between laboratory tests and consumer satisfaction survey results for the flow rate criteria where 64 to 77 percent of the WaterSense® showerheads failed the flow rate criteria and 59 to 64 percent of the same showerheads received a "no-buy" rating from the consumer satisfaction survey. There is less correlation between the laboratory tests and consumer satisfaction survey results for the WaterSense® force and coverage criteria. For the force criteria 4.5 to 22.7 percent of the 22 showerheads failed the laboratory tests while 36 percent of the same showerheads failed the consumer satisfaction force criteria. For the coverage criteria 9 to 18 percent of the 22 showerheads failed the laboratory tests while 27 to 41 percent of the showerheads failed the consumer satisfaction coverage criteria. Laboratory test results of 41 fixed showerheads correlate to consumer satisfaction survey results for flow rate but not for force or coverage. Laboratory test results of 10 hand-held showerheads do not correlate to consumer satisfaction survey results with respect to flow rate, force, or coverage primarily due to 60 percent of hand held models being non-compliant and providing higher maximum flow rates than the manufacturer specified at 80 psig.

Conclusions

Based on a survey of 25 manufacturers representing 80 to 90 percent of showerheads sold in the US, 96 percent support the voluntary WaterSense® showerhead specification. Eighty three percent of manufacturers sell efficient showerheads with rated flow rates less than 2.5 gpm at 80 psig and the average manufacturer offers 5 efficient models. The average retail cost for water saving showerheads is 26 percent less than conventional showerheads. Only one manufacturer reported receiving complaints (for another manufacturer valve) about thermal shock with their showerhead rated at less than 2.5 gpm at 80 psig.

This study found a strong correlation between laboratory tests and consumer satisfaction survey results for the flow rate criteria where 64 to 77 percent of the WaterSense® showerheads failed the flow rate criteria and 59 to 64 percent of the same showerheads received a "no-buy" rating from the consumer satisfaction survey. There is less correlation between laboratory tests and consumer satisfaction survey results for the WaterSense® force and coverage criteria. Laboratory test results of 41 fixed showerheads correlate to consumer satisfaction survey results for flow rate but not for force or coverage. Laboratory test results of 10 hand-held showerheads do not correlate to consumer satisfaction survey results with respect to flow rate, force, or coverage primarily due to 80 percent of hand held models being non-compliant providing higher flow rates than the manufacturer specified at 80 psig.

Approximately 64 to 77 percent of the showerheads tested in this study do not meet the WaterSense® specification for flow rate, force, or coverage. Based on this finding, this study does not recommend that California adopt a flow rate standard lower than 2.5 gallons per minute at 80 psig flowing pressure as specified in the California Green Building Standards. Instead the study findings support the voluntary EPA WaterSense® showerhead specification of 2.0 gpm at 80 psig flowing pressure to give manufacturers time to design more efficient showerheads.

References

American Society of Mechanical Engineers (ASME) A112.18.1/CSA-B125.1-1992/2005. New York, NY: Available online: http://files.asme.org/Catalog/Codes/PrintBook/14122.pdf.

American Society of Sanitary Engineers (ASSE) 10162 or ASME A112.18.1/CSA B125.1.

Biermayer, P. 2005. **Trends in Shower Design and Their Effect on Energy and Water Use**. Lawrence Berkeley National Laboratory. In Proceedings of 2006 ACEEE Summer Study on Energy Efficiency in Buildings, Washington, D.C..

California Green Building Standards Code (CGBSC). 2010. **Chapter 4, Section 4.303 Indoor Water Use**, Table 4.303.2 Fixture Flow Rates, Maximum flow rate at 20% reduction or 2 gpm @ 80 psi. Water conservation (plumbing) provisions will take effect in the California Building/Residential Codes on July 7, 2011. http://www.bsc.ca.gov/default.htm.

DOE 1998, Office of Energy Efficiency and Renewable Energy, 10 CFR Part 430, **Energy Conservation Program for Consumer Products: Test Procedures and Certification and Enforcement Requirements for Plumbing Products; and Certification and Enforcement Requirements for Residential Appliances; Final Rule**., March 18, 1998, section 430.32, p. 13317 of the Federal Register.

Hotel and Motel Management (HMM). 2004**. Holiday Inn Express Hits the Showers**. http://www.hotelmotel.com/hotelmotel/article/articleDetail.jsp?id=126192, Oct. 1, 2004.

Mowris, R., Woody, B. 2010. **Development of New Testing Protocols for Measuring the Performance of Showerheads.** Prepared for California Energy Commission Public Interest Energy Research Program. Sacramento, Calif.: California Energy Commission.

Plumbing & Mechanical Magazine. 2002. Available online: www.pmmag.com. June 6, 2002.

Tanner, S., Remedios, S. 2009. WaterSense®: **A Consensus-Based, Common Sense Approach for High-Efficiency Showerheads**, February 2009. Northbrook, IL.: Plumbing Engineer.

United States Environmental Protection Agency (USEPA). 2010. **WaterSense® Specification for Showerheads.** Washington, DC.: US Environmental Protection Agency. Available online: http://www.epa.gov/watersense/docs/showerheads_finalspec508.pdf

Wagoner, K. 2008. **Showerhead User Satisfaction Study**. Prepared for USEPA and ASME/CSA Joint Harmonization Task Force. Chantilly, VA.: Eastern Research Group (ERG).