Trends in Shower Design and Their Effect on Energy and Water Use

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ABSTRACT

Recent trends in shower design include the use of multi-head showerheads, body spas and shower panel systems that can use much more water and energy than typical showers. The intent of these shower systems is not necessarily to provide a cleaning function but rather a therapeutic function. This brings up a host of issues as to how these fit into the regulation of showerheads which are intended to save water and energy. The impact of energy and water savings in households is explored.

Introduction

The terminology in this report defines a *shower* as an activity, a *showerhead* as a plumbing fixture through which water flows and a *shower stall* as an enclosure in which someone takes a shower.

Recent trends in shower design include showers with multiple showerheads or showerheads in various configurations that may use more than the maximum water flow regulations allow. In some cases, the manufacturer of multiple head shower systems may believe they are technically within the letter of the law because each individual showerhead meets the maximum flow allowed. Others may interpret the regulations as defining a showerhead as the flow controlled by a single valve. In other instances, large single-head showerheads are clearly in violation of the law.

Motivations for purchasing a high flow shower system include dissatisfaction with the current single head showerhead. A consumer may want to replace a single head shower in order to get more flow, coverage, or other attributes that result in a better shower experience. The second reason is the desire to use a shower not for just a cleaning function but to provide an experience similar to a whirlpool tub or spa.

Consumer preferences have been analyzed in proprietary studies by manufacturers such as Moen, by hotels such as Westin and Holiday Inn Express; and utility companies (Plumbing & Mechanical Magazine, 2002). Moen found that 66% of respondents wanted more water flow, and 60% wanted more force. Westin tested more than 150 showerheads before deciding to install custom-designed showers having two heads. Holiday Inn Express tested showerheads with more than 7,000 guests, who rated them based on water pressure, spray coverage, and flexibility of spray settings (Hotel and Motel Management, 2004). They chose a single head showerhead.

A review of manufacturer and industry Web sites reveals that some showerhead systems are advertised as supplying as much as 10 gpm (gallons per minute) of flow. Other shower systems produce a waterfall or rain-type of effect, or have a series of water jets mounted on a vertical wall. Some “body spa” type showers recirculate large amounts of water.

Current Regulations

The U.S. Department of Energy (DOE) regulations specify showerhead test procedures that reference ASME/ANSI Standard A112.18.1M-1996. As of January 1, 1994, the maximum water use allowed for any showerhead is 2.5 gallons per minute when measured at a flowing pressure of 80 pounds per square inch gauge.

Types of Showerheads and Shower Systems

The different types of multi-head showerheads and shower systems are illustrated below.

Multiple-Head Shower

These fixtures may have two or more spray nozzles connected to one pipe. They can easily replace a single head fixture.

Source: http://www.neatitems.com/triple_showers.htm

Cascading Showerhead

These are also referred to as "rainshower" and "downpour" type fixtures. They often are mounted overhead such that the water drops straight down. They typically give a softer spray and have diameters of 6 to 8 inches. They are less likely to have more than one spray setting. The model shown below has 80 spray nozzles. This type has recently become more popular and may now account for up to 15% of sales in the United States (Homeworldbusiness.com, 2004).

Source: Consumer Reports, Hansgrohe Raindance

Shower Panel or Shower Tower

These are designed to spray water from more than one location using more than one showerhead. They may operate sequentially or as the photo shows below with all showerheads on at the same time. Some are designed for the homeowner to replace an existing single pipe fixture and some are designed to be professionally installed with all piping behind the walls.

Source: https://my.estorenw.com

Rain Systems

As shown in the photograph below, rain systems simulate rain by allowing water to fall from an overhead fixture.

Source: John Koeller

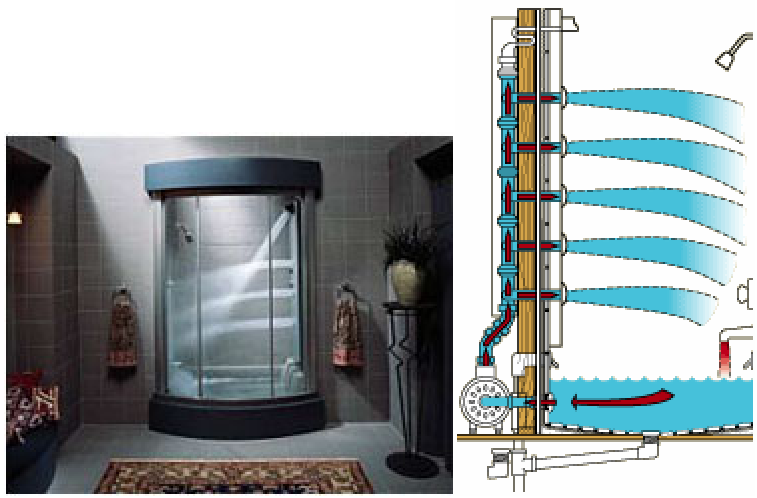
Body Spas

Body spas consist of multiple showerheads and are described by some as the vertical equivalent of a whirlpool tub. The showerheads may be activated sequentially or intermittently. The number of showerheads that are active can sometimes be controlled by the user via controls or may be set to automatically vary the spray pressure and temperature.

Sources: Kohler Body Spa Systems & Santa Cruz Sentinel, March 21, 2005

Recirculating System

In some cases, the water in a body spa is recirculated and the shower system has its own heater and pump system. In this mode, with the drain closed, the purpose of this type of shower is to provide a therapeutic function rather than a washing function. The recirclulating feature can typically be disabled to allow use as a shower.



Source: Kohler Body Spa Systems web site http://www.us.kohler.com/tech/products/

Analysis

The analysis below quantifies the additional amount of water and energy used due to a trend toward multi-head and high water use shower systems.

Uncertainty and Variables

Many of the variables that determine showerhead water use in the field are not known with certainty. In some instances data are not available, in others survey or measurement data may not be nationally representative or may be many years old. An attempt is made to estimate showerhead water use under various scenarios using a range of input parameters. These inputs are characterized as either uniform or triangular probability distributions, using estimates of the most likely value and the estimated minimum and maximum values. For example, the minimum and maximum average shower duration is the estimated range of average shower durations for the entire population. It represents the uncertainty of the average value for the country and is not intended to show the variability across all showers taken, which has a much wider range. The "most likely" value is a best guess of the average duration within the range. A triangular distribution can now be constructed by using the "most likely" value as the peak of a triangle and the probability decreasing to zero at the minimum and maximum values. These input distributions of individual parameters are entered into a program that uses the Monte Carlo method to generate a frequency distribution for each output parameter such as water and energy use. In some cases, single values are used as inputs (e.g., electricity rate, and fuel use of water heaters) because the national averages for these values have much less uncertainty than other variables.

Output frequency distributions for energy and water use are generated using, an *Excel* © spreadsheet add-in program called *Crystal Ball* ©.[1] Based on the frequency distribution values for the mean, minimum and maximum are also generated.

[1] *Crystal Ball*© is a software program that uses the Monte Carlo method of generating probability distributions.

In order to quantify water and energy use, the parameters shown in Table 1 below needed to be determined. In some cases, the *most likely* value and in all cases the *type of distribution* are based on the judgment of the author.

Data and Assumptions

Table 1. Data and Assumptions

Parameter	Value				
	Mean	**Most likely**	**Min.**	**Max.**	**Type of Distribution**
General Inputs					
U.S. population (million)	290	n/a	n/a	n/a	n/a
Persons per household	2.59	n/a	n/a	n/a	n/a
Showers per day	0.7	0.7	0.65	0.75	Uniform
Average shower duration (minutes)	8.2	8.2	8	8.4	Triangular
Flow Rates of Showerheads (gpm)					
Flow of average showerhead (1999 baseline)	2.2 gpm	2.2	2.0	2.4	Triangular
Flow of multiple-head showerheads	5.5	4	2.5	10	Triangular
Percentages of Different Showerheads					
Percent multiple-head showerheads	4.3%	4%	3%	6%	Triangular
% of time multiple-head SH is used	75%	75%	50%	100%	Uniform
Energy and Water Prices					
Electricity Rate (per kWh)	$.0906				
Natural Gas Rate (per Therm)	$ 1.092				
Water & Wastewater Rate (per 1000 gallons)	$3.19				
Energy use per gallon of shower water					
Cold water inlet temperature	60ºF				
Shower temperature	105ºF				
Electric water heater recovery efficiency	98%				
Gas water heater recovery efficiency	75%				
Percent of water heaters using electricity	42%				
Percent of water heaters using gas	58%				

Discussion of Key Input Parameters and Assumptions

Showers per day. The *REUW* study based on data from twelve cities in the United States, gives 0.75 showers & baths per day per capita (combined bath and showers). In the *REUW* study the number of showers and baths per capita per day ranges from 0.63 to 0.90. It is important to note that these values are for showers and baths. For this reason we lowered the estimate to 0.70 showers per day because we do not want to include baths.

Average shower duration. The *REUW* study using measured data provided an average shower length of 8.2 minutes and 11.6 gallons per capita per day. This *REUW* study also provides a distribution of shower durations. However, since this report is interested only in national aggregate effect on water use only the variability of the average values is used as an input uncertainty and not the entire distribution.

The length of shower is probably somewhat correlated with the flow rate and performance of the showerhead. In addition, the length of showers using new showerheads that provide a spa or whirlpool tub-like relaxation benefit may differ from showers taken only for cleanliness purposes.

Table 2. Source of Input Parameters

Parameter	Comment	Source
General Inputs		
U.S. population (million)	Census 2000 (estimate for 2002)	U.S. Census
Persons per household	Census year 2000	U.S. Census
Showers per day per person	Combined baths and showers	Mayer, DeOreo 1999, p. xxvii (*REUW*)
Average shower duration (minutes)		Mayer, DeOreo 1999, p. 99
Flow Rates of Showerheads		
Flow rate of average showerhead (1999 baseline)	Baseline (pre-retrofit) value from Seattle study in 2000	Mayer, DeOreo & Lewis, 2000
Flow of multiple-head showerheads	PMI (Plumbing Manufacturer's Institute) sponsored a survey of its members – Jan. 2006	W&W Services
Percentages of Different Showerheads		
Percent multiple-head showerheads	Survey sponsored by PMI	W&W Services
Energy and Water Prices		
Electricity Rate (per kWh)	Representative average unit costs of residential energy (2005)	DOE 2005
Natural Gas Rate (per Therm)	Representative average unit costs of residential energy (2005)	DOE 2005
Water & Wastewater Rate (per 1000 gallons) (Average marginal rate in1998 adjusted to 2004)	Based on marginal rates using 1998 Raftelis data & updated to year 2004	DOE 2000
Energy use per gallon of shower water		
Cold water inlet temperature	Author's Estimate	
Shower temperature	Author's Estimate	
Electric water heater recovery efficiency	Assumptions per DOE test procedures	
Gas water heater recovery efficiency		
Percent of water heaters using electricity	Assuming all water heaters are either gas or electric	DOE 2000
Percent of water heaters using gas		

Flow rate of average showerhead (1999 baseline). The *Seattle* study, based on a pre-retrofit study in Seattle, in the year 2000, found an actual flow rate of 2.2 gpm. The *REUW* study in 1999 also showed an average measured shower flow of 2.2 gpm. The *REUW -1999* study provided a distribution of actual flow rates. The 2.2 gpm is used as the baseline water use value.

Flow rate of multiple-head and high flow showerheads. We assumed that the most likely flow rate for this type of showerhead would be 4 gpm, but may also be as low at 2.5 gpm and as high as 10 gpm based on recent tests by the California Energy Commission confirming web site advertising that claim flow rates as high as 10 gpm. This heavily skewed triangular distribution results in a mean estimate of 5.5 gpm.

Percent of households with multiple-head showerheads. Recognizing a need for data on the sales of multiple-head showerheads, the Plumbing Manufacturers Institute (PMI) sponsored a survey by W&W Services Incorporated. The survey asked PMI members to estimate the percentage of showers that are currently being installed with any combination of two or more showerheads, body sprays or other outlets conveying water for showering. The results are shown in Table 3 below.

Table 3. Survey Results for Multi-head Showers

Percent of two or more showerheads, body spas or other outlets conveying water for showering in -	Average	Median
New construction	4.8%	5.0%
Existing that are retrofitted	5.7%	4.0%
Existing shower compartments	3.7%	3.5%

Based on the table above, this report based calculations on a "most likely" 4% of houses in the future would be fitted with two or more showerheads. It was then estimated that the minimum would be 3% and the maximum 6%, with a triangular distribution. Using the input distribution above representing the uncertainty of the number of showerheads with more than one showerhead, gives an estimate that 4.3% of all showerheads sold are of the multi-head type. In other words, without efforts to counteract the trend toward multiple-showerhead systems, over time it is reasonable to assume at least of 4.3% of shower stalls will have a multi-head showerhead, body spa type shower or other type of high flow showerhead.

Percent time multi-heads are used at the same time or used instead of a single head shower in the house. Some multi-head shower systems are designed to provide a luxury shower experience and not for a quick shower before leaving for work. Sales of these systems may increase into the future, especially when they are sold as Do-It-Yourself projects (homeowners can install showers without much technical expertise) at large merchandisers. It is recognized that many residences have more than one shower. This report assumes those households having a multi-head showerhead use it 75% of the time (i.e., of all shower events). The rest of the time they use another shower stall without a high flow showerhead.

Baseline Water and Energy Consumption

The baseline water use for showers in the United States can be used to put the water and energy savings potential into perspective. The calculations below show that showers consume 3.7 billion gallons, or approximately 9,000 acre-feet, of water every day in the United States.

[1] $GPD = P \cdot SPD \cdot f \cdot t$

Where:

GPD = gallons per day used for showers

P = Population = 290 million

SPD = Showers per person per day = 0.70

f = Shower flow rate = 2.2 gpm

t = Shower duration = 8.2 minutes

Water Savings If the Multiple or High Use Showerheads and Body Spas Are Limited

Equation 2 estimates the potential water savings if the trend toward high water use shower systems is mitigated (i.e., the additional amount of water and energy use above the current baseline, if current sales of multi-head showerheads continue at the current percentage.)

The water savings calculated below represent yearly savings after sales equilibrium has been reached, i.e., after currently installed showerheads are replaced. The energy savings are directly proportional to the water savings. Using average values, the potential water savings are 177 million gallons per day.

[2] $PWS = P \cdot SPD \cdot fr \cdot R \cdot t \cdot fu$

Where:

PWS = Potential Water Savings

P = Population = 290 million

SPD = Showers per person per day = 0.70

fr = Flow reduction = (5.5-2.2) = 3.3 gpm

R =Percent replaced by high flow showerheads = 4.3%

t = Shower duration = 8.2 minutes

fu = Fraction of time shower stall is used = 0.75

Although average values are used in the sample calculations above for clarity, the values reported in the Results section of this report are based on a distribution of inputs and a Monte Carlo simulation.

Results

Tables 4 and 5 below show the potential water and energy savings for each of the analyzed scenarios. Sources of uncertainty include differences in results from various field studies and from a lack of data. Because of the parameter uncertainties affecting the savings, ranges were used for inputs to the calculations.[1] Water savings are reported as a percentage of baseline showerhead water use. The minimum and maximum values show the uncertainty of the possible national savings and are not intended to show individual variability of saving at the household level. Table 6 shows the monetary savings due to a reduction in water and energy use. Figure 1 shows the mean value for water savings and a probability distribution of the uncertainty in this value.

Table 4. Potential Water Savings

Scenario	Percent (1) savings of water			Average Million gallons per		
	Average	Range Min.	Range Max.	Average	Range Min.	Range Max.
Counteract trend toward multiple showerheads & body spas	4.8%	0.2%	19.5%	177	11	631

(1) Percentage of baseline showerhead water use

Table 5. Potential Energy Savings Scenario(1)

Scenario	Electric Water Heater Gigawatt hours per day			Gas Water Heater Therms x 1000 per day		
	Average	Range Min.	Range Max.	Average	Range Min.	Range Max.
Counteract trend toward multiple showerheads & body spas	8.4	0.5	29.9	516	31.0	1837

(1) Assumes 42% electric water heaters, 58% gas water heaters

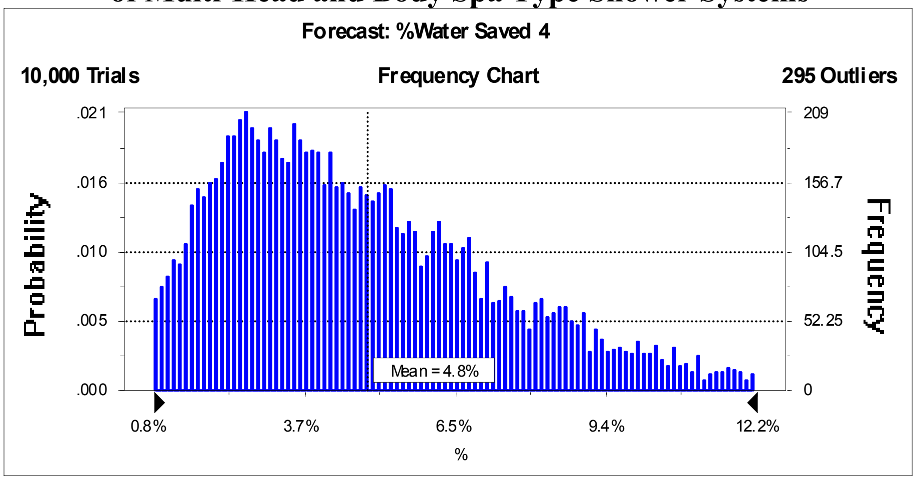
[1] Inputs were either uniform or triangular probability distributions based on estimated values for minimum, maximum, and most likely values for input parameters.

Table 6. Potential Annual Dollar Savings

Scenario	Millions of Dollar in Water and Energy Savings (1)		
	Average	Range Minimum	Range Maximum
Counteract trend toward multiple showerheads & body spas.	693	32	2,653

(1) Assumes 42% electric water heaters, 58% gas water heaters and includes the cost of water.

Figure 1. Probability Distribution of Expected Water Savings Due to Elimination of Multi-Head and Body Spa Type Shower Systems



Discussion

Issues

Will multi-head showerheads and "body spas" increase water consumption? How much multi-head showers and body spas increase water consumption depends on whether they are replacing an energy conserving showerhead or replacing a whirlpool or soaking tub. If the "body spa" replaces a whirlpool tub, and the frequency of use is similar, then maybe the water consumption is not significantly impacted. If multiple showerheads using more than the maximum allowed by regulations replace conforming showerheads, the water usage will increase. How existing regulations are interpreted and enforced will have an impact on future water usage. Once products are available for the do-it-yourselfer, without much plumbing or construction work, it is possible that more consumers will install high flow shower systems.

Effect on water heater size and plumbing. If showers use a large amount of hot water, the capacity of the water heater to provide it may need to be increased, if it is at the limits of its current capacity. Alternately, the installation of high flow shower systems may drive the conversion to demand or tankless type water heaters. Either case has implications on water heating energy consumption for the entire house.

Some high flow showers reportedly also require a larger ¾ inch pipe rather than the standard ½ inch pipe. This also has implications on the distribution heat loss for hot water piping.

What have others done regarding this issue? In 2004, anecdotal information from plumbing inspectors in Calgary, Canada indicated that 5% to 10% of new construction involved multi-head showers. Calgary considered limiting showerhead flow to 2.5 gpm per control valve (Stalker, Nancy, 2006). However, contractors responded that they would simply add more control valves to meet the requirement and this would only increase the cost of showers. Calgary also considered limiting the size of the drain but decided not to move forward on this due to liability and safety issues. To move forward on showerhead issues, the city needed more concrete (rather than anecdotal) information.

What can be done to mitigate conversions to high water consuming showerheads? The U.S. Department of Energy relies on manufacturers and other stakeholders to report non-compliance with DOE standards. Water utilities and other stakeholders have begun testing showerhead for conformance with the intent to enforce existing showerhead regulations.

A program that rates the performance of showerheads in addition to meeting existing maximum flow requirements could provide consumers with information needed to select a showerhead with the performance criteria they desire and still conserve water.

Data Needs

There are still many unknowns regarding multiple showerhead or body spa systems. Much of the unknown data relates to behavioral factors related to showering. Key data needs are listed below.

1. Behavioral Information

- Percentage of time a shower with multiple heads is used if the household also has conventional showers.
- Duration of shower with multiple showerheads as compared to a single showerhead. It is unknown whether these shower systems encourage a longer shower time or if the capacity of the water heater to provide hot water limits the duration of the shower.
- There is uncertainty on whether or not all showerheads in a shower are typically on at the same time if they are on separate valves

2. Product Information

- Flow rate of multiple showerhead (we should not necessarily assume that two showerheads use twice as much water as one showerhead). Although we know from very limited testing and advertising that some high flow showerheads use more than 2.5 gpm at rated conditions – we do not know the sales distribution of showerheads by flow rate.
- How many “body spa” type showers have an option of using recirculated water, how often this option is used and how much energy/water is saved by using these systems.
- Future trends of multiple showerhead use. Is this a current building fad or a design feature with long term popularity?

Conclusions

A trend toward multi-head showerheads and body spas can have a significant impact on residential energy and water use. While there is considerable uncertainty in predicting future trends, calculations of average increases in water and energy use show increases of 177 million gallons of water a day, 8.4 gigawatt hours per day and 516 kilo-therms per day.

The potential increase in energy and water use is also the amount that could potentially be saved by mitigation measures, including the enforcement of existing showerhead maximum flow standards. Further research can fully explore ramifications of these trends and effective policies to deal with them.

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