Research on the effect of showerhead characteristics on usage time and hot water volume

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Abstract

The CO_2 emissions of residential plumbing systems make up about 5% of Japan's emissions, and those from bathtubs and showers make up more than half. From the viewpoint of environmental impact reduction, the expansion of water-saving showers have made progress in recent years by reducing hot water use. In Japan, the optimum flow rate is displayed for each showerhead. This is calculated according to monitoring tests. However, there is no explanation of how the difference in optimal flow rate affects showering time. Therefore in this research, we calculated shower usage time in both a testing laboratory and households, to verify whether or not a time difference existed depending on showerhead characteristics. As a result, when used at the optimum flow, even if the flow was different, shower time did not change.

Keywords

Monitoring Tests, Plumbing Equipment, Shower Head, Shower Usage Time, Water-Saving Shower

1 Introduction

The shift to a low carbon society underpinned by sustainable development is increasingly critical. In Japan, progress has been made across all fields towards the reduction of greenhouse gases. However, the CO_2 emissions coefficient has worsened in the aftermath of the 2011 Tohoku earthquake. Emissions for 2011 rose 3.7% on 1990 levels. The reduction of emissions in the household sector also became increasingly important, as emissions rose 41.8%. Approximately 5% of Japan's CO_2 emissions are produced by the use of residential plumbing equipments, with over half of that being from the supply of hot water for things like bathing. [1)]

Hence, there is a strong push to develop water saving showers for bathing. The Japan Valve Manufacturers' Association decides on which types and characteristics constitute hot water saving. The percentage of reduction for hot water saving, is outlined in "The standard for determining building owner and specific building owner for streamlining with energy usage."[2)] Showers for bathing, which are classified as "hot water saving B", have an optimum flow rate that is a greater than 15% reduction on past models. The optimum flow rate is determined by a monitoring test （**Fig. 1**） designed by the Japan Valve Manufacturers' Association. The participants determine what flow rate they feel is "optimum." It is thus possible to save hot water while maintaining an effective wash and showering comfort for the user.

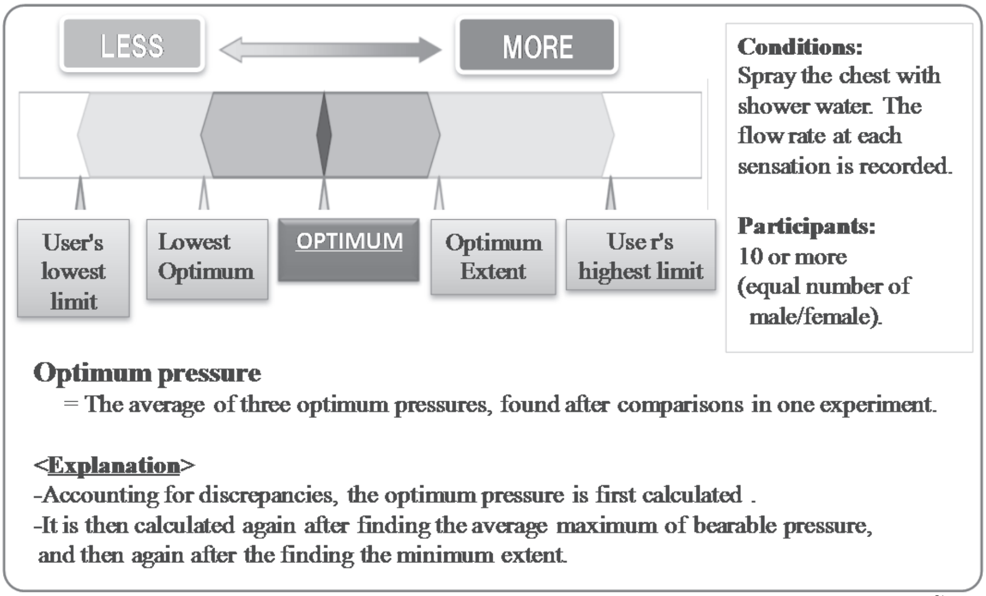


Fig. 1 Monitoring test method of showers for bathing（hot water saving B） [2)]

The shower water use (L/a time) for a single shower, is calculated by multiplying flow rate (L/min) × use time (min/a time). The reduction rate for showerheads that fulfill requirements of the "Hot water saving B" type, is based on the assumption that at the optimum flow, the showering time remains the same. However, it is difficult to find any publications that clearly address showering time according to showerhead characteristics. Consequently, in our research we calculated showering time and investigated the differences according to the showerhead characteristics, in a laboratory and homes.

2 Experiment method

2.1 Measuring showering time in a laboratory

In order to investigate changes in showering time according to showerhead characteristics, two kinds of showerheads were used and evaluated. The tested showers are outlined in **Table-1**, and the flow rate is shown in **Fig. 2**. We adopted, from T Company, the most popular shower with optimum flow rate 8.5L/min（Type I）and the most efficient water saving shower with a flow rate of 6.5 L/min（Type II）. Type II mixes air in with the water to enlarges each droplet and maintain an effective wash and showering comfort, while saving water. It is the latest water saving shower on the market.

Table-1 Test showerhead outline（T company product）

	Optimum flow rate（L/min）	Momentary stop water function
Type I	8.5	None
Type II	6.5	None

The flow rate of a composite-thermostat faucet

Conditions:
Set handle at full power
Cold water temp. 15℃
Hot water temp. 60℃

Water (hot) full power (solid line)
Test (A) (dash-dot line)
Test (B) (dashed line)

(A) For each pressure test the water was made to 40℃. Further, water pressure was tested within a range of 0.05~0.4MPa with a hot water pressure of 0.05MPa.
(B) For each pressure test the water was made to 40℃. Further, cold water and hot water were tested under the same pressure conditions.

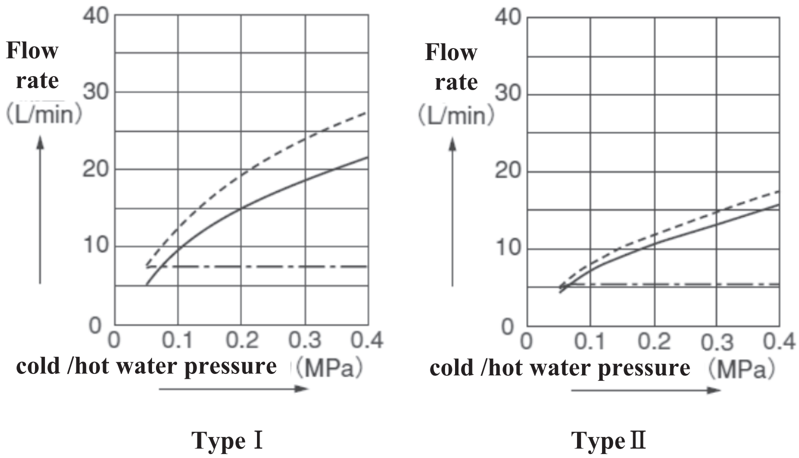


Fig. 2 Test shower flow rate graph（T company data）

The survey is outlined in **Table-2**. The survey was carried out twice, and the sample numbers for each time is outlined in Monitoring Method **Fig.1**, with equal numbers of males and females. The participants decided on their usual quantity usage of shampoo and body soap and recreated a normal shower using the same conditions for Type I and Type II. Each participant used Type I, II on different days, and calculated the time of washing required from start to finish. For each test, the correlation between the time required for hair and body washing and showerhead characteristics was analyzed. Also, the total water usage was calculated and compared based on the optimum flow rate and shower usage time.

Table-2 Outline of showering time measurement in a laboratory

Test period	First：September, 2010. Second：September, 2011.
Site	T Company laboratory of Fukuoka Prefecture
Sample	40 Fukuoka Prefecture residents, T Company staff First：5 F, 5 M. Second：15 F 15 M.
Measurement Method	The following measurements were carried out once each for Type Ⅰ, Type Ⅱ and the time it took for soap to be washed away was compared. （Ⅰ, Ⅱ were measured on different days） ①Shower flow rate was aligned with optimum flow. （Type Ⅰ：8.5L/min、Type Ⅱ：6.5 L/min） ②Each participant washed their hair and body using a consistent 'usual' amount of shampoo, and body soap. ③It finished when the participant decided "I have finished washing the soap/shampoo from my hair and body". ④The time required from start to finish was recorded using a stop watch（the timekeeper was outside of the booth）.

2.2 Measuring showering time in homes

In order to recreate actual shower usage, the participants calculated the shower usage time according to showerhead characteristics in their homes. An outline of the survey is

Table-3 Outline of showering time measurement in homes

Test Period	April 2012
Site	Participant's homes（Fukuoka Prefecture）
Sample	52 Fukuoka Prefecture residents: T Company staff and family
Measurement Method	The showerhead in participants homes was tested, and then each was tested for a week. The time that hot water was actually being emitted from the showerhead was calculated and compared. ① The shower was adjusted to the optimum flow rate and using a bucket and stopwatch the optimum flow rate was calculated. ② Rather than the quantity of shampoo and body wash being set, each participant used the amount usual for them. After a week the shower head was changed to Type II and tested for a further week. In total two weeks worth of showering time (the time water/hot water was actually emitted) was calculated using a stop watch. This is combined with the bathing patterns survey（Table-4）.

Table-4 Bathing patterns

	Bathing pattern
A	Bath with hair washing
B	Bath without hair washing
C	Shower with hair washing
D	Shower without hair washing

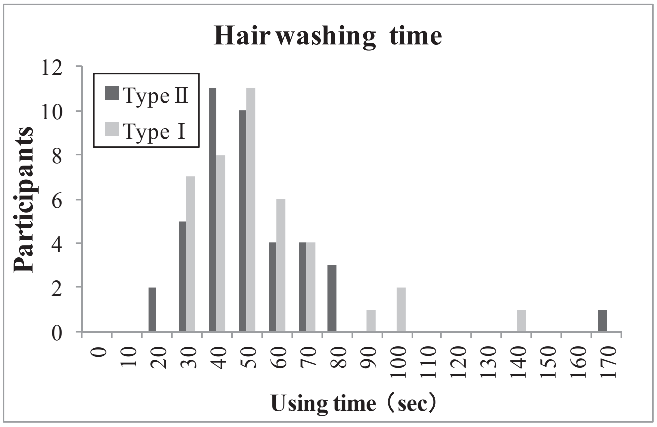
Note） bath ：The case when the person fills the bath and uses the shower.
shower ：The case when the person does not fill the bath and just uses the shower

displayed in **Table-3**. After measuring the shower already fitted in their home for a week, they changed to Type II, described in **Table-1**, and measured a further week. To recreate their actual showering circumstances, we did not impose a set amount for shampoo and body soap use. The total hot water use and showering time for the showerhead type was analyzed in the same way as conducted in the laboratory.

3 Results and discussion

3.1 Results of showering time measurement in a laboratory

The results for the required time for hair and body washing are shown in **Fig. 3** and **Fig. 4**. The average time for hair washing taken for Type I was approximately 49 seconds/ a time, with body washing averaging 58 seconds/ a time. For Type II, the required usage time for hair and body washing was relatively shorter. Regarding the time required, there is considerable unevenness according to individual participants, and as such the two variables for Type I, Type II were investigated. Hence it was found, as shown in **Fig. 5**, that the two variables are related.



【Type Ⅱ】
Average = 46.4±6.64 sec
（90%）
Standard Deviation =24.9

【Type Ⅰ】
Average = 49.25±6.00 sec
（90%）
Standard Deviation =22.5

Fig. 3 Required time distribution for hair washing in the laboratory

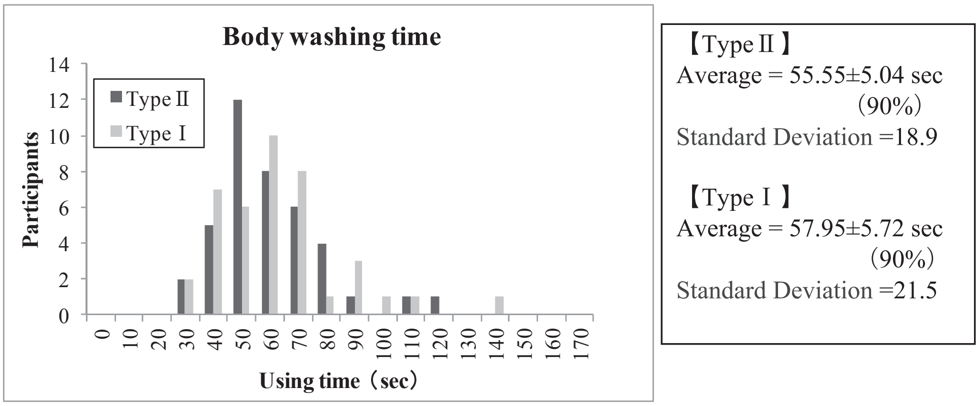


Fig. 4 Required time distribution for body washing in the laboratory

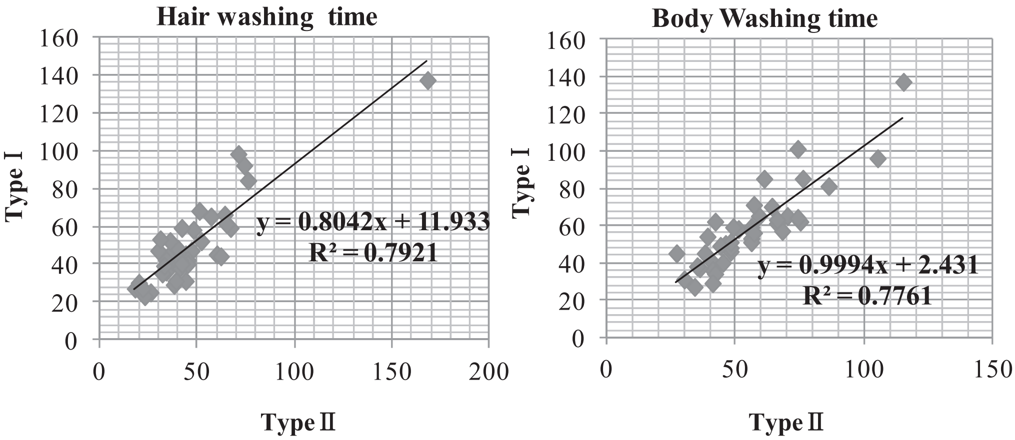


Fig. 5 Correlation of showerhead characteristic with time required for hair/body washing

Accordingly, the test for Type I, Type II, was carried out using the t-test, which is based on the significant difference in the two variables. As shown in **Table-5** there is no significant difference in hair/body washing time according to showerhead characteristic （Type I／Type II）. Thus, from the laboratory results, it is indicated that the usage time does not change with showerheads that have a different optimum flow rate.

Further, the change in the average hot water volume use according to showerhead characteristic is shown in **Table-6**. The change from Type I to Type II led to a 27% reduction in the volume of hot water used.

Table-5 Testing for significant difference in correlation of showerhead characteristic with time required for hair/body washing (t-test)

Significance level：0.05

	Hair washing time		Body washing time	
	Type II	Type I	Type II	Type I
Average (seconds/a time)	46.4	49.25	55.55	57.95
Dispersion	620.554	506.705	358.356	461.228
Number of observations	40	40	40	40
Pearson Correlation	0.890		0.881	
Hypothetical average and difference	0		0	
Latitude	39		39	
t	-1.586		-1.494	
P(T<=t) unilateral	0.060		0.072	
t limit value unilateral	1.685		1.685	
P(T<=t) bilateral	0.121		0.143	
t limit value bilateral	2.023		2.023	

t limit value_bilateral>|t|{or P（T<=t）_bilateral>0.05}

Table-6 Change in hot water use according to showerhead characteristic(average)

	Washing hair	Washing body	Total
Type I	6.5 L/a time	8.0 L/ a time	14.5 L/ a time
Type II	4.6 L/ a time	5.9 L/ a time	10.6 L/ a time
Reduction rate	28.7 %	26.1 %	27.3 %

3.2 Results of showering time measurement in homes

The attributes of participants are outlined in **Fig. 6**. The numbers of men and women are approximately even, and answers are by students and homemakers, as well as company employees. The showers already installed in homes (hereafter ‘existing shower’), were

a unit ：%

Fig. 6 The attributes of participants

Type I 46%, with 53% having an optimum flow rate of 10L/min（**Fig. 7**）. This is due to 10L/min showers being sold widely 20 years earlier. In regards to bathing patterns（**Table-4**）**,** approximately 70% of people filled up a bath（**Fig. 8**）. This survey was carried out in April, however past research results show that the percentage using just the shower increases during the summer months.

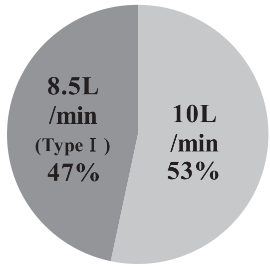


Fig. 7 Shower type in homes （optimum flow rate）

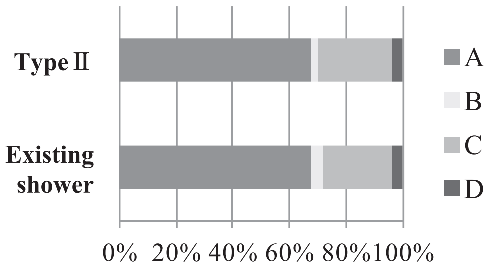


Fig. 8 Participants' bathing patterns

The difference in showering time and water usage according to bathing patterns is outlined in **Fig. 9**. The average showering time with their existing shower was 200 seconds/a time, while with TypeⅡ it changed to 202 seconds/a time. The average hot water use with their usual shower was 35.5L/a time, while TypeⅡ was 29.9L/a time. Consequently, the reduction rate by changing to the Type II shower was 16%.

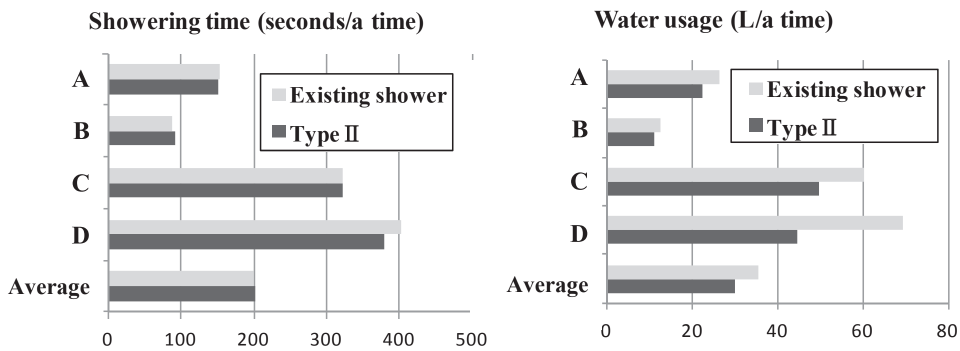


Fig. 9 Bathing patterns difference in showering time and water usage according to showerhead characteristics

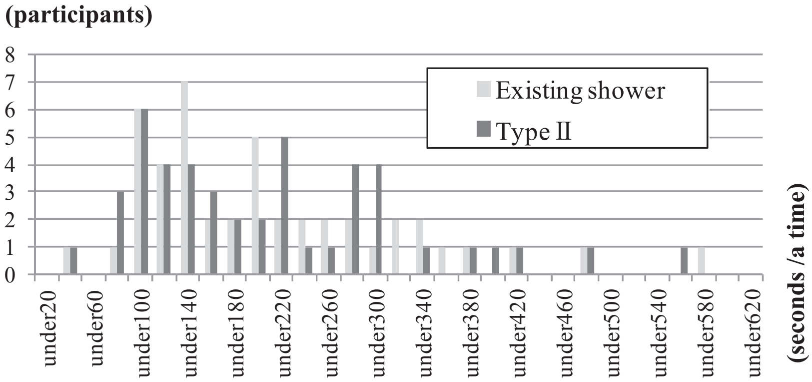


Fig. 10 Showering time distribution in the home test

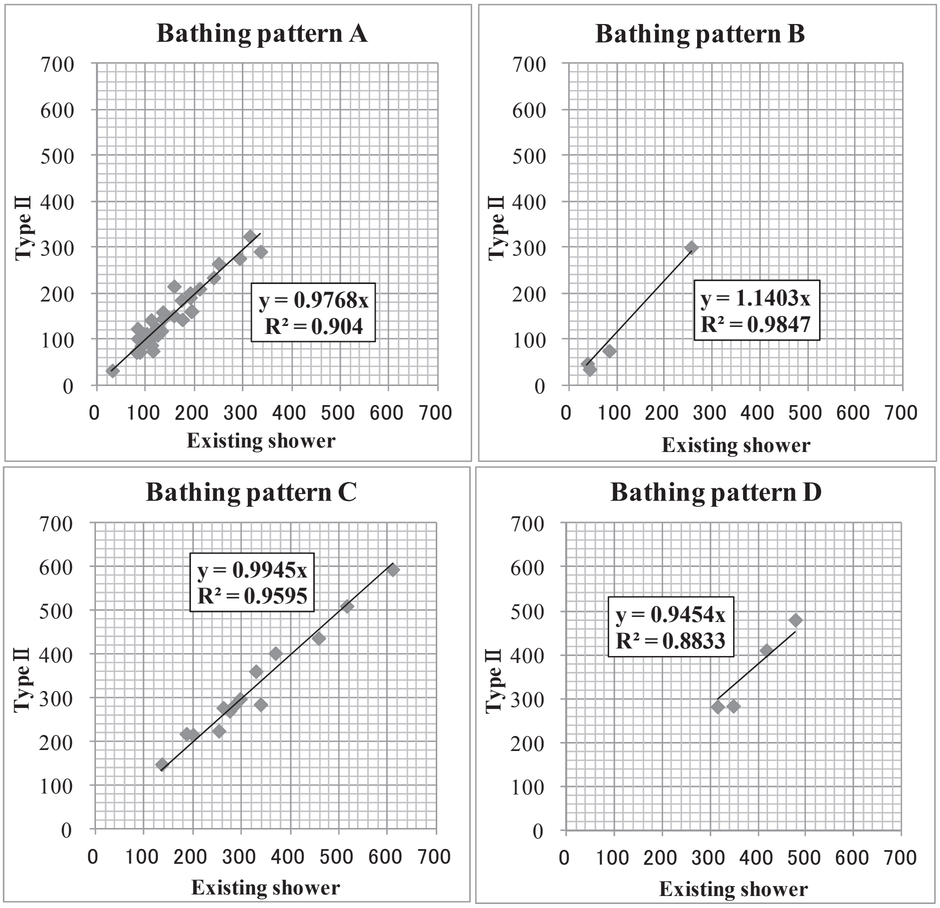


Fig. 11 Showering time distribution in the home test

The showering time distribution is shown in **Fig. 10**. There was unevenness due to individual participants, and for bathing pattern difference, the connection with the two variables of Type II was confirmed. As shown in **Fig. 11**, for all bathing patterns there is adaptation of the two variables. Accordingly, the t-test for the 'existing' shower and Type II shower was carried out. **Table-7** demonstrates that there was no significant difference according to showerhead characteristics. The results from the home experiments, did not change, although the optimum flow rate of the showerheads did. This was also shown in the laboratory experiments.

Table-7 Testing significant difference for showerhead characteristics （bathing patterns）

Significance level：0.05

	Bathing pattern A		Bathing pattern B	
	Existing shower	Type II	Existing shower	Type II
Average (seconds/a time)	153.498	151.17	105.208	114.33
Dispersion	4944.084	4795.8	10459.840	15601
Number of observations	35	35	4	4
Pearson Correlation	0.952		0.996	
Hypothetical average and difference	0		0	
Latitude	34		3	
t	0.635		-0.730	
P(T<=t) unilateral	0.265		0.259	
t limit value unilateral	1.691		2.353	
P(T<=t) bilateral	0.530		0.518	
t limit value bilateral	2.032		3.182	

t limit value_bilateral>|t|{or P（T<=t） _bilateral>0.05}

Significance level：0.05

	Bathing pattern C		Bathing pattern D	
	Existing shower	Type II	Existing shower	Type II
Average (seconds/a time)	322.254	323.54	389.375	364.29
Dispersion	17052.642	15373	5257.563	9558.6
Number of observations	14	14	4	4
Pearson Correlation	0.982		0.982	
Hypothetical average and difference	0		0	
Latitude	13		3	
t	-0.192		1.678	
P(T<=t) unilateral	0.425		0.096	
t limit value unilateral	1.771		2.353	
P(T<=t) bilateral	0.851		0.192	
t limit value bilateral	2.160		3.182	

t limit value_bilateral>|t|{or P（T<=t） _bilateral>0.05}

4 Conclusion

In this research we measured showering time in a laboratory and in homes in order to investigate difference according to showerhead characteristics. Following this, it was found that when used at the optimum flow rate, even if water volume changes, showering time does not change due to comfort and effective washing.

Moreover, in our research we evaluated the change in showering time according to showerhead characteristics. As such, “showering time” as a bathing action has not been modeled. In the future, research into the modeling of shower behavior will be carried out in order to set water volume use in showers to save energy, and lower carbon usage.

5 References

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6 Presentation of Authors

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