Study on water conservation by water saving fixtures

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Abstract

For the purpose of evaluating the performance of water saving fixture, water and energy conservation effects of water saving fixtures were examined by subject experiment. Water saving fixtures are thermostatic mixing faucet and shower head with stop button for shower in a bathroom, and spray flow and aerator flow faucet and stop valve by foot switch or sensor for dishwashing in a kitchen.
The effect of thermostatic mixing faucet compared with two valve faucet is that thermostatic mixing faucet could save water when adjusting hot water temperature and flow rate to optimum condition. The effect of shower head with stop button is that hot water could be saved by using stop button on shower head to stop hot water easily when unnecessary. The effect of spray flow and aerator flow faucet is that optimum flow rate is decreased by using these faucets. The effect of stop valve by foot switch or sensor is that hot water could be saved by using stop valve to stop hot water easily when unnecessary.
As a result of subject experiment, water was saved 1.0L by using thermostatic mixing faucet when hot water temperature and flow rate were adjusted each time to optimum condition. Hot water was saved 14.1L by using shower head with stop button. Hot water was reduced by 27.3% compared with using normal shower head. Hot water was reduced 29.1% by using spray flow faucet, and 3.7% by using aerator flow faucet. Hot water was reduced 8.3% by using stop valve by foot switch, and 5.2% by using stop valve by sensor. These water saving fixtures are effective for water and energy conservation.

Keywords
Water saving fixture, Thermostatic mixing faucet, Showerhead with stop button, Spray flow faucet, Aerated flow faucet, Sensor stop valve, Foot switch stop valve

1 Introduction

For the purpose of evaluating the performance of water saving fixture, water and energy conservation effects of water saving fixtures were examined by subject experiment. We used subjects to evaluate a shower faucet that was expected to cut hot water use. The experiment determines the ability of a thermostatic mixing faucet to reduce the amount of water wasted in adjustment of temperature and flow rate. We also performed a shower experiment to determine the water saving effect of a showerhead with an on/off button.
We also used subjects to evaluate a kitchen faucet that was expected to reduce hot water use. Subjects used a faucet with flow pattern options of spray flow or aerated flow, and with on/off control systems that included a foot switch stop valve and a sensor stop valve. An experiment using a combination of the flow pattern and the on/off control function with the highest water saving performances was also conducted.

2 Effect of Thermostatic Mixing Faucet

2.1 Experimental method

Table 1 summarizes the experiment and Figure 1 indicates the types of shower faucet used in the experiments. The experiments were conducted in a prefabricated bathroom unit installed in laboratories. The waiting room and dressing room were air-conditioned to 23°C in winter and 26°C in summer.
Water temperature and flow rate were adjusted by the two different shower faucets, a two-valve faucet and a thermostatic faucet, to determine the amount of water wasted. Undressed subjects adjusted the water temperature and flow rate by spraying shower water onto their hands and other parts of their bodies and then reported when they had obtained their desired temperature and flow rate. The amount of hot and cold water used up until the time the subject declared that the adjustment was finished was considered to be the amount of water wasted.
The temperature of the hot water output from the electric water heater was preset at 60°C, and the main hot water pipe was filled with hot water before the experiments began. The water temperature of cold water supply, hot water supply and after mixing, and the flow rate of cold and hot water supplies were measured at intervals of 2 seconds.

Table 1 - Summary of the experiment for shower faucet

Case		Winter	Summer
Experiment period		2003/2/8-3/8 2004/3/1-3/18	2003/8/15-9/8 2004/7/20-8/10
Number of subjects	Male	27	22
	Female	28	24
	Total	55	46
Number of subjects by usual usage faucet	Two valve faucet	35	35
	Thermostatic faucet	15	7
	Other	5	4

left : Showerhead with on/off button right : Standard showerhead	left : Thermostatic mixing faucet right : Two valve mixing faucet
	

Figure 1 - Shower faucets for shower experiment

2.2 Experimental results

Figure 2 and table 2 show the average amount of water wasted. Figure 3 and table 2 show the amount of water saved and water saving rate in the experiments by the use of a thermostatic faucet versus the two-valve faucet depend on the types of faucet the subjects uses at their houses. The water saving effect of the thermostatic faucet was confirmed in all cases. A classification of the types of faucets being used at the subjects' houses showed that subjects who used thermostatic get lager amount of water saved than those who used two-valve faucets especially in winter. On average, there was no seasonal difference in the amount of water saved. The average amount of water saved by controlling the shower temperature and flow rate per single operation by using thermostatic mixing faucet was about 1.0 L.

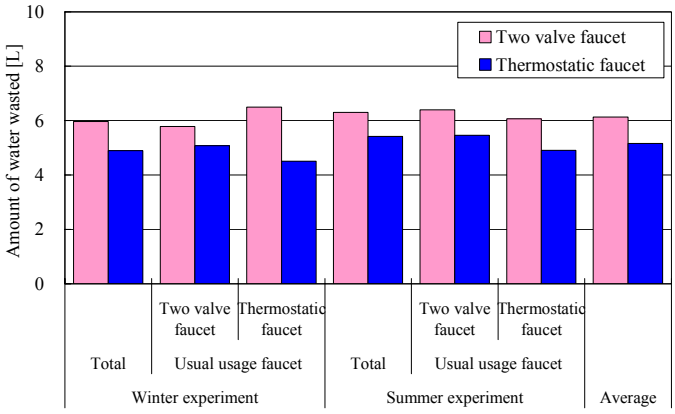

Figure 2 - Amount of water wasted

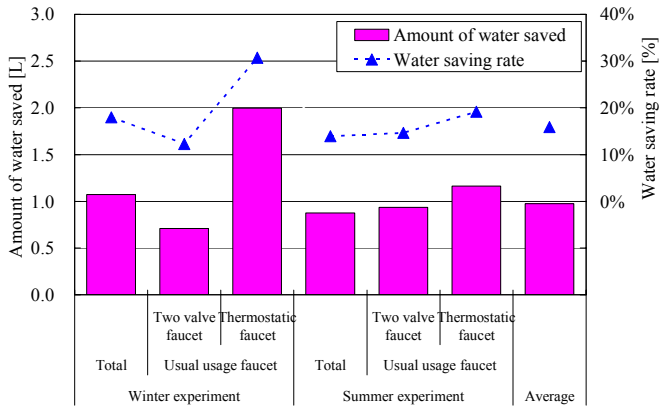

Figure 3 - Amount of water saved and water saving rate

Table 2 - Water saving effect of thermostatic mixing faucet

Case	Subject		Amount of water wasted [L]		Amount of water saved [L]	Water saving rate
			Two valve faucet	Thermostatic faucet		
Winter experiment	Total		5.97	4.89	1.07	18.0%
	Usual usage faucet	Two valve faucet	5.79	5.08	0.71	12.3%
		Thermostatic faucet	6.50	4.50	2.00	30.7%
Summer experiment	Total		6.30	5.42	0.88	13.9%
	Usual usage faucet	Two valve faucet	6.39	5.46	0.94	14.6%
		Thermostatic faucet	6.06	4.90	1.16	19.2%
Average			6.13	5.16	0.97	15.9%

3 Effect of Showerhead with Stop Button

3.1 Experimental method

The amount of hot water consumed when taking a shower was compared when using two types of showerhead, a standard type and one with a stop button. The standard showerhead and the stop button one were used along with a water-saving spray plate for all types of shower head. Subjects washed their faces, hair, and bodies and reported through an intercom when they had completed each washing activity. Subjects were told to shower for as long as usual when they used the standard type of showerhead. When they used the showerhead with the stop button, they were instructed to turn off the hot water supply when they did not need water. The experiments were conducted on 2 days. A thermostatic faucet was used with both types of showerhead. Before each experiment began, the water was heated up so that the subjects did not have to waste water by running the faucet while waiting for hot water to reach the showerhead. The experimental bathroom and subjects are the same as that of experiment of thermostatic mixing faucet in section 2.

3.2 Experimental results

Figure 4 shows the total amount of water consumed in each shower experiment. Figure 5 indicates the amount of water saved and water saving rate by season and sex. In all the cases, the amount of water consumed decreased when using the showerhead with the stop button, thus confirming the water-saving effect of this device. On average, amount of water consumed is 51.8L using standard showerhead. Compare to this, it is 37.7L using showerhead with stop button. Male subjects, who consumed more water than females, achieved a higher water saving rate. The water saving rate and amount of water saved in male subjects are 33.9% and 18.3L. Those in female subjects are 20.1% and 10.0L. The water saving rate and amount of water saved for males and females combined is 27.3% and 14.1L.
Figure 6 shows the flow rate, and Figure 7 shows the time for hot water output. In the case of male subjects, the showerhead with the stop button had a slightly lower flow rate. And it took shorter time for hot water output by both male and female subjects. On average, both of the showerhead with the stop button reduced the time for hot water output by about 24%, a value that had a large water-saving effect. The optimum temperature to the subjects of hot water using the showerhead with the stop button was 1.5 °C lower than using the standard showerhead (Figure 8). These differences in flow

rate and water temperature could be attributable to the impact of the subjects' adjustments of flow rate and temperature and to the frequencies with which they turned off the shower; however, these issues are still under review.

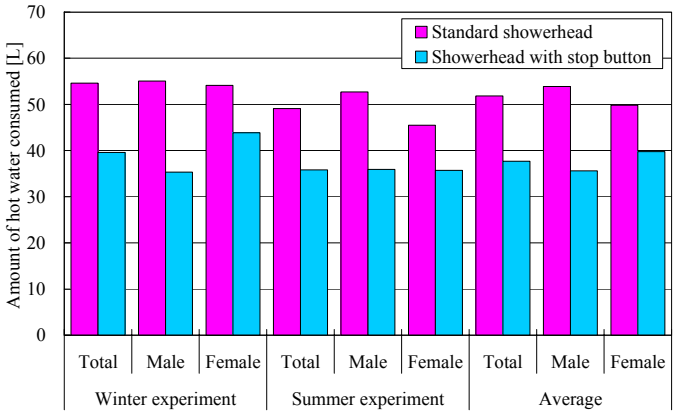

Figure 4 - Amount of water consumed

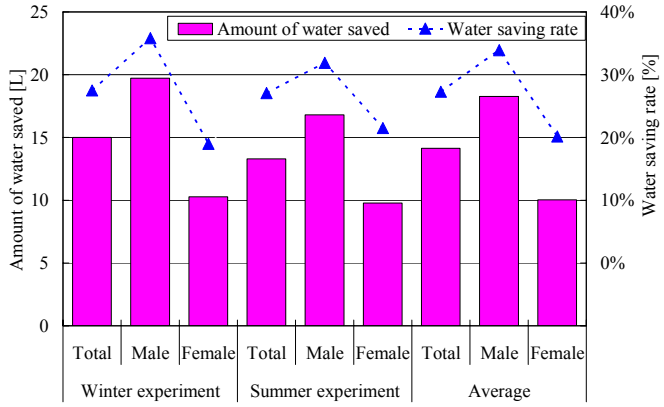

Figure 5 - Amount of water saved and water saving rate

Table 3 - Water saving effect of showerhead with stop button

Case		Amount of water consumed [L]		Standard deviation [L]		Amount of water saved [L]	Water saving rate
		Standard showerhead	Showerhead with stop button	Standard showerhead	Showerhead with stop button		
Winter experiment	Total	54.6	39.6	20.3	14.6	15.0	27.5%
	Male	55.0	35.3	21.2	15.3	19.7	35.8%
	Female	54.1	43.8	19.5	13.9	10.3	19.0%
Summer experiment	Total	49.1	35.8	14.2	12.1	13.3	27.1%
	Male	52.7	35.9	17.3	14.5	16.8	31.9%
	Female	45.5	35.7	11.1	9.8	9.8	21.5%
Average	Total	51.8	37.7	17.3	13.4	14.1	27.3%
	Male	53.9	35.6	19.2	14.9	18.3	33.9%
	Female	49.8	39.8	15.3	11.9	10.0	20.1%

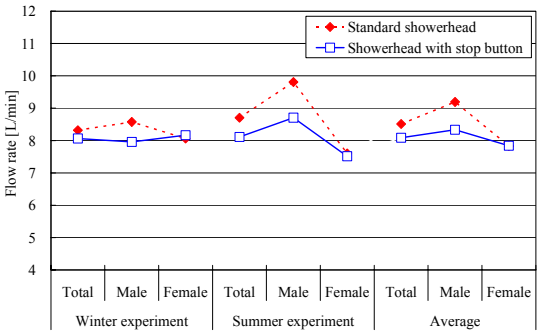

Figure 6 - Flow rate

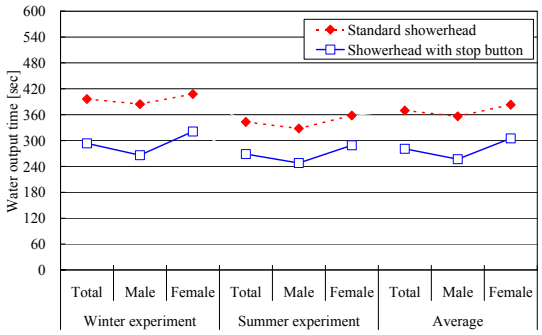

Figure 7 - Hot water output time

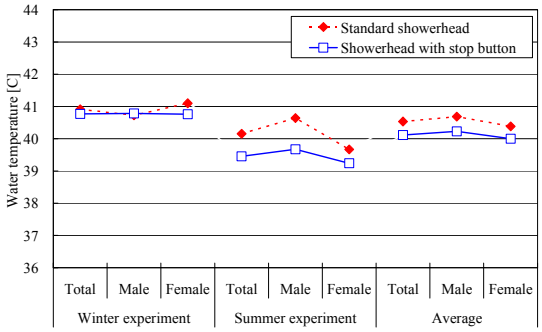

Figure 8 - Hot water temperature

4 Effect of water saving kitchen faucet by flow pattern for dishwashing

4.1 Experimental method

Two different experiments, an experiment using different flow patterns and one using different on/off control functions were performed. A straight flow faucet and single lever faucet were used as standards, as shown in Figure 9 and 10. Other conditions used in the experiment are; spray or aerated as a water flow pattern, and an automatic infrared sensor stop valve and a foot switch stop valve as a form to stop the water. Each of these devices was evaluated for water saving performance.

Table 4 summarizes the experiment. The subjects were housewives aged from 38 to 63 years; 22 subjects in the flow pattern experiment and the on/off control function experiment conducted in winter, 24 in the flow pattern experiment in summer and 20 in the on/off control function experiment in summer. 12 subjects in the winter experiment and 22 subjects in the summer experiment performed both the flow pattern experiment and the on/off control experiment on different days. The experiments were conducted using a kitchen in the laboratory. The temperature of the hot water output from the electric water heater was preset at 60 °C, and the hot water pipe to the faucet was filled with hot water before the experiments began so that the subjects did not have to waste water by running the tap while waiting for hot water to reach the faucet. The water temperature of cold water supply, hot water supply and after mixing, and the flow rate of cold and hot water supplies were measured at intervals of 2 seconds. Each experimental session was videotaped to check for kinds of dishwashing act.

Each subject washed dishes using each faucet device once. The experiment was performed using three different flow patterns or three different on/off control functions

on the same day, and the order of each device was varied across the subjects. A sponge, scrubbing brush, detergent, washing bowl with the capacity of 5 litter, paper towel, and rubber gloves were given to each subject for use as needed. The subjects were instructed to wash exactly as they routinely did. They regulated the hot water temperature and flow rate in both the flow pattern and the on/off control function experiments at their own discretion. They were also told to use the sensor stop valve or foot switch stop valve when turning off the tap, and to turn off the tap as frequently as possible when they were not using water. Table 5 shows the types of tableware and foods for contaminations for dishwashing experiment. Four place settings (a total of 44 items) were allocated to each subject per load. The types of dishes and contamination method complied with the methods of testing performance of quality housing components for dishwashers by the Center for Better Living, Japan.

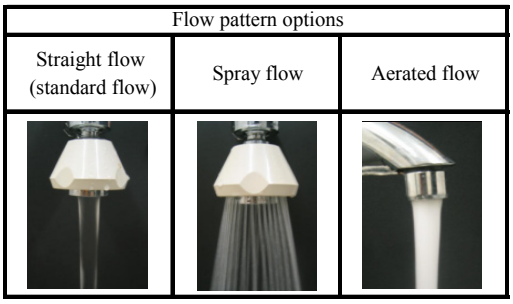

Figure 9 - Flow patterns of faucet

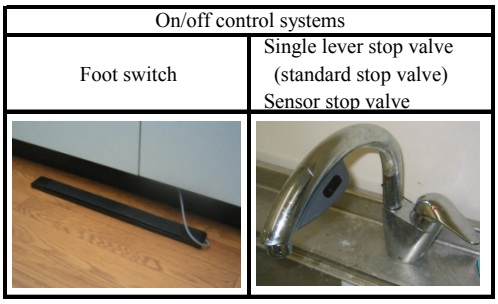

Figure 10 - On/off control stop valves

Table 4 - Summary of the experiment for kitchen faucet

Case	Flow pattern experiment		On/off control function experiment		Water saving fixtures combination experiment
	Winter experiment	Summer experiment	Winter experiment	Summer experiment	Winter experiment
Experiment period	2003/12/16 - 12/28	2004/8/23 - 9/10	2003/12/16 - 12/28	2004/8/23 - 9/10	2005/1/11 - 1/14
Water saving fixture	Standard flow		Standard stop valve		Standard faucet
	Spray flow		Sensor stop valve		Water saving fixtures in combination
	Aerated flow		Foot switch stop valve		
Number of subjects	22	24	22	20	10

Table 5 - Tableware for dishwashing

Types of tableware	Tableware (Foods for contaminations)
Glasses	Glass (Milk, Tomato juice), Teacup (Green tea)
Plates	Large plate (Curry, Law egg), Medium plate (Pork cutlet with sauce), Small plate (Ham and eggs)
Bowls	Rice bowl (Rice), Soup bowl (Miso soup)
Eating irons	Chopsticks (Rice), Spoon (Curry, Law egg) Knife and fork (Pork cutlet with sauce, Ham and eggs)

1 place setting consists of each tableware.

4.2 Experimental results of flow pattern experiment

Figure 11 and table 6 indicates the amount of water consumed. Figure 12 and table 6 shows the amount of water saved and water saving rate in the flow pattern experiment. For the standard flow pattern, the amount of water consumed during the summer was greater than in the winter. On the other hand, the faucet with the spray flow showed a

reversed trend. On average, amount of water consumed using standard flow was 31.5L, that using spray flow was 22.1L, and that using aerated flow was 30.3L. Water saving effect was confirmed using spray flow. The water saving rate and amount of water saved compared with the standard flow pattern was 16.9% and 5.0L in the winter and 41.3% and 13.9L in the summer. However, in an interview after the experiment some of the subjects said that spray flow faucet were inconvenient to use because of water splash. The aerated flow gave 8.6% and 2.9 L of water-saving rate and amount of water saved in the summer, but in the winter they did not have any effect on water use. The average water saving rate and amount of water saved was 29.1% and 9.4L for the spray flow faucet and 3.7% and 1.3L for the aerated flow one. The flow rate, hot water output time and hot water temperature are shown in the figure 13 to 15. The faucet with the spray flow had a lower flow rate. There were no significant differences in the hot water output time or the hot water temperature.

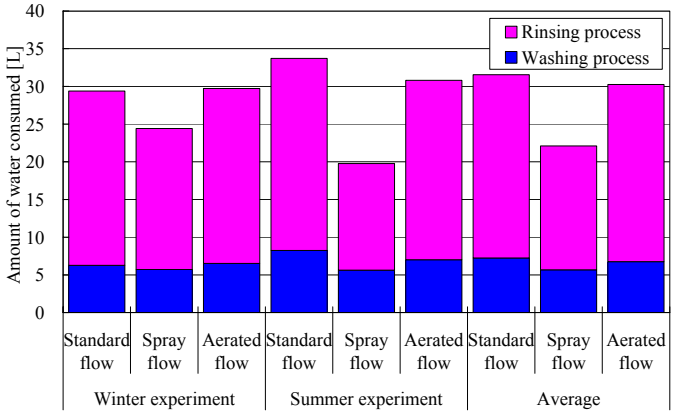

Figure 11 - Amount of water consumed in flow pattern experiment

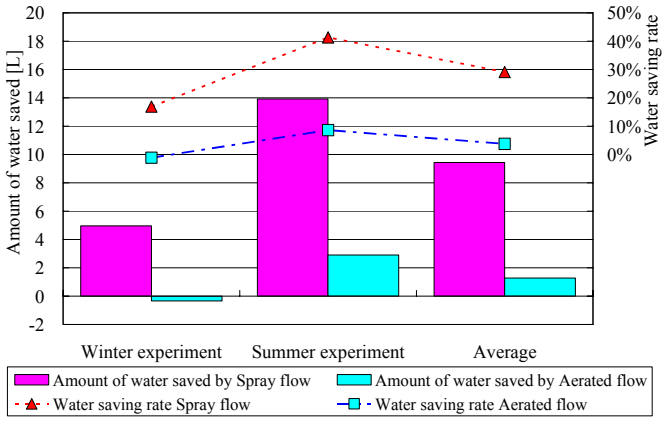

Figure 12 - Amount of water saved and water saving rare in flow pattern experiment

Table 6 - Water saving effect in flow pattern experiment

		Standard flow	Spray flow	Aerated flow
Winter experiment	Amount of water consumed [L]	29.4	24.4	29.7
	Amount of water saved [L]	-	5.0	-0.3
	Water saving rate	-	16.9%	-1.1%
Summer experiment	Amount of water consumed [L]	33.7	19.8	30.8
	Amount of water saved [L]	-	13.9	2.9
	Water saving rate	-	41.3%	8.6%
Average	Amount of water consumed [L]	31.5	22.1	30.3
	Amount of water saved [L]	-	9.4	1.3
	Water saving rate	-	29.1%	3.7%

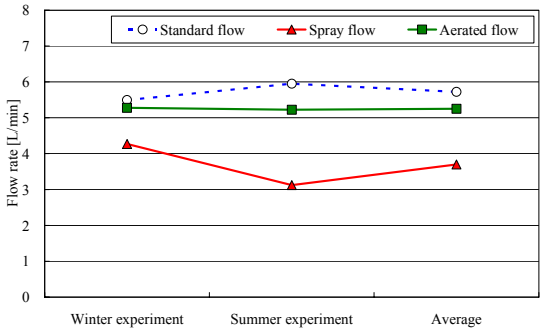

Figure 13 - Flow rate in flow pattern experiment

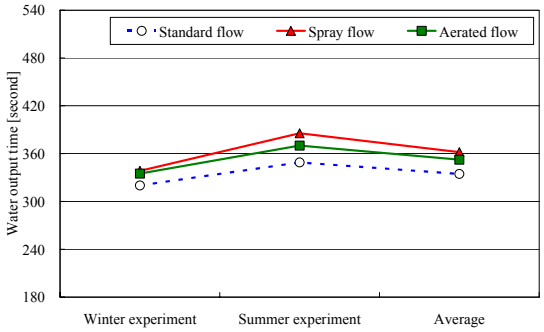

Figure 14 - Water output time in flow pattern experiment

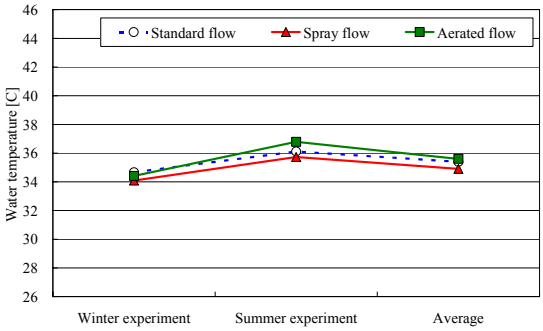

Figure 15 - Water temperature in flow pattern experiment

4.3 Experimental results of On/off control function experiment

Figure 16 and table 7 indicates the amount of water consumed. Figure 17 and table 7 showed the amount of water saved and the water saving rate in the on/off control function experiment. There was no seasonal difference. On average, amount of water consumed for standard stop valve was 31.5L, that for sensor stop valve was 29.8L and that for foot switch stop valve was 28.9L. The water saving rate and amount of water saved were 5.2% and 1.7L for the sensor stop valve, 8.3% and 2.6L for the foot switch stop valve. The flow rates, hot water output time, hot water temperature are shown in the figure 18 to 20. The sensor stop valve or foot switch stop valve was expected to reduce output time, but this reduction was only about 15 seconds. It was about 5% of total output time. These results might be attributable to the frequent on/off control of the water by the subjects, who were motivated by their increased awareness and reflected their routine behavior.

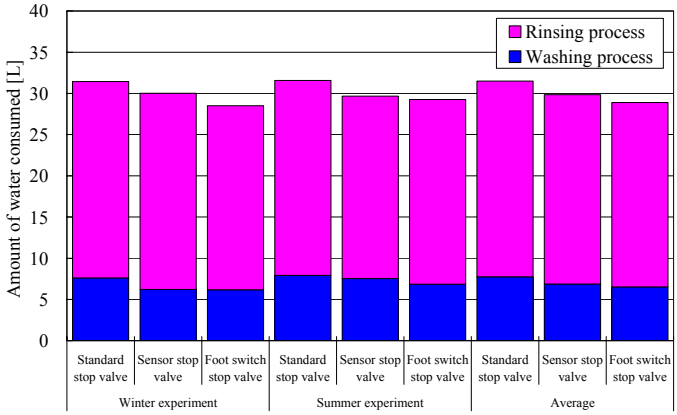

Figure 16 - Amount of water consumed in on/off control function experiment

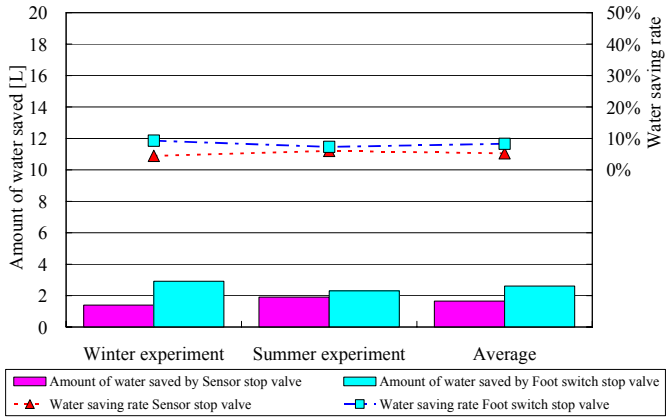

Figure 17 - Amount of water saved and water saving rare in on/off control function experiment

Table 7 - Water saving effect in on/off control function experiment

		Standard stop valve	Sensor stop valve	Foot switch stop valve
Winter experiment	Amount of water consumed [L]	31.4	30.0	28.5
	Amount of water saved [L]	-	1.4	2.9
	Water saving rate	-	4.5%	9.3%
Summer experiment	Amount of water consumed [L]	31.6	29.7	29.3
	Amount of water saved [L]	-	1.9	2.3
	Water saving rate	-	6.0%	7.3%
Average	Amount of water consumed [L]	31.5	29.8	28.9
	Amount of water saved [L]	-	1.7	2.6
	Water saving rate	-	5.2%	8.3%

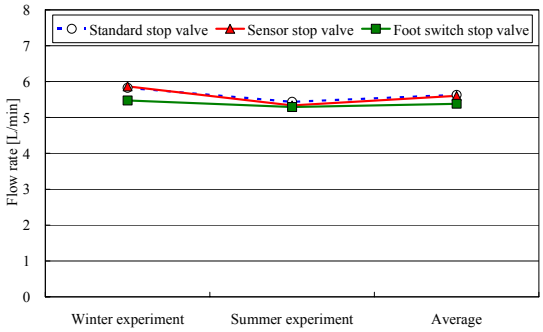

Figure 18 - Flow rate in on/off control function experiment

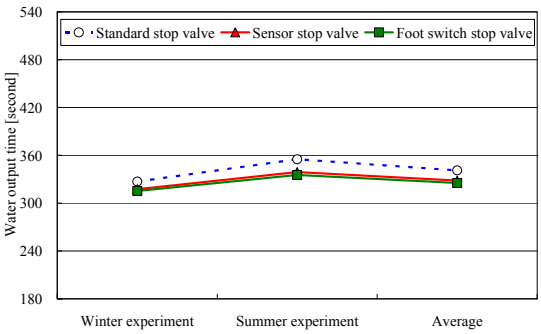

Figure 19 - Water output time in on/off control function experiment

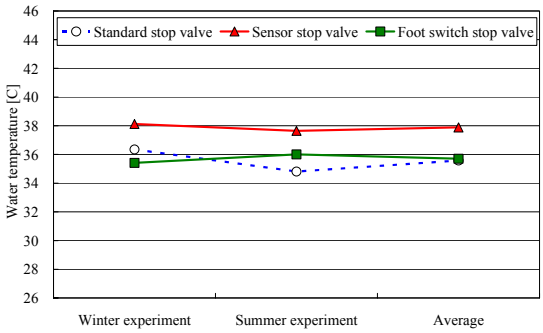

Figure 20 - Water temperature in on/off control function experiment

5 Effect of different types of water saving fixtures in combination

5.1 Experimental method

An experiment was conducted using a faucet with a spray flow and a foot switch stop valve in combination: both had proved effective in conserving water in the flow pattern experiment and the on/off control function experiment. The summery of experiment is shown in table 4. Ten subjects who had consumed amounts of water close to the average using a standard faucet in the summer experiment were assigned to the winter experiment. An experiment using a standard device was also performed. The other experimental conditions were the same as those in the on/off control function experiment.

5.2 Experimental results

Figure 21 and table 8 shows the amount of water consumed and flow rate. Amount of water consumed for standard faucet was 29.5L, and that for water saving fixture in combination was 16.5L. The water saving rate and amount of water saved was 44.0% and 13.0L. The additive effect of the water saving rate from the flow pattern experiment and that from the on/off control function experiment was confirmed.

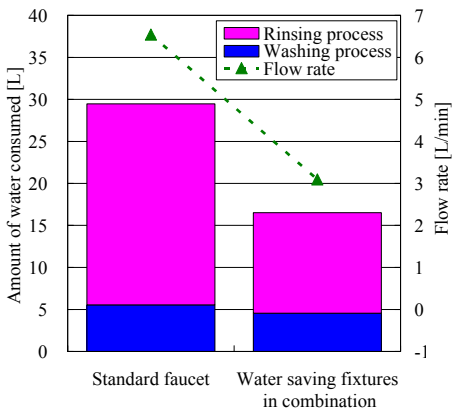

Figure 21 - Amount of water consumed and flow rate in water saving fixtures combination experiment

Table 8 - Water saving effect in water saving fixtures combination experiment

	Standard faucet	Water saving fixtures in combination
Amount of water consumed [L]	29.5	16.5
Amount of water saved [L]	13.0	
Water saving rate	44.0%	
Flow rate [L/min]	6.5	3.1
Water temperature [C]	34.6	36.4

6 Conclusion

We conducted an experiment using water saving shower faucets to determine its hot water saving effects, and we obtained the following results.

1. The saving of 1.0L of water per single adjustment was achieved when subjects used a thermostatic faucet instead of a two-valve faucet to regulate shower water temperature and flow rate.
2. On average, 27.3% (14.1 L) water saving rate was achieved by using a showerhead with a stop button.

The following findings were obtained from the experiments using different types of kitchen faucet.

1. The water saving rate of each device was as follows: spray flow faucet, 29.1% (9.4 L); aerated flow faucet, 3.7% (1.3 L); sensor stop valve, 5.2% (1.7 L); and foot-switch stop valve, 8.3% (2.6 L).
2. For the spray flow faucet, the flow rate and the amount of water consumed were lower in summer than in winter; however, there was no seasonal difference for other devices.
3. The combination of spray flow faucet and foot switch stop valve achieved water saving rate of 44.0% (13.0 L), confirming the additive effect.

7 References

1. M.Nagaishi, M.Otsuka, Examination of the water saving effect of the faucet with water aerator, AIJ Journal of Technology and Design, No.13, pp.141-146, 2001.7
2. T.Kondo et al., Study on methods of designing shower heads, AIJ Journal of Architecture and Planning, No.563, pp.61-67, 2003.1

8 Presentation of Author

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