# Study on Suitable Size of Feed Piping

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This study is intended to aid in selection of pipe diameters to suit the flow conditions in sanitary fixtures, in consideration of the trend of water conservation. We used equipment simulating a lavatory in an office building to conduct experimental trials with pipes of different diameters. In this experiment, we verified the influence of differences in simultaneous utilization ratio and pipe length, and the water feed pressure required to meet the standard values. For the purpose of reducing pipe diameter, the western-style flush valve type toilet that uses a large flush water flow rate and pressure needs to be changed to the low-tank type or the tankless type. This is also important in view of water conservation, energy saving and low-carbon effects.

## Introduction

In recent times, there is a progressive trend toward adoption of water-conserving sanitary fixtures. Toilet bowls have remarkably reduced their flush-water volume; urinals and hand washers have reduced their water flow rate. However, their water feed piping has a minimum diameter of 20 mm, which is the same as for conventional piping. This makes the pipe diameter relatively large with respect to the water flow rate required for the sanitary fixtures. In Europe, use of piping with diameter 20 mm or less is accepted under the standard. Such a shift to appropriate pipe diameters is desirable in Japan too. In actual design work, load unit of 10 or less cannot be determined with the water feed fixture load unit method that is widely applied as a simplified method for determination of pipe diameter. Also, it has been pointed out that the safety factor is considerably large. Because of the need to cope securely with the load requirement, designers are inclined to provide excess margins in flow rate and pressure design. As a cause of this tendency, it can be supposed that designers' awareness of flow rate and pressure adjustment is less than that for air conditioning design. Reduction of pipe diameter and usage of resin piping enables extension of construction service life and aims for a low-carbon society. These actions raise expectations of increase in corrosion resistance, improvement in construction efficiency, reduction in CO<sub>2</sub> emission involved in transportation, machining and construction, and reduction in construction wastes. Since the action required for repair and conversion of existing equipment as well as for new construction is easy, contribution to reduction in construction LCCO<sub>2</sub> can also be expected.

In the previous paper<sup>1</sup>), we conducted a simplified experiment with a sample pipe of 13 mm diameter by using experimental equipment simulating an approx.10,000 m<sup>2</sup> lavatory in an office building. This issue reports on the extensive trials that we conducted using the same experimental equipment and varying parameters such as pipe diameter, water feed pressure and simultaneous utilization ratio.

This experiment and analysis were intended to form a part of the activities of the subcommittee for study on water feed piping and hot water piping (chief examiner: Yoshiaki Matsumura)" of The Society of Heating, Air-Conditioning and Sanitary Engineers of Japan.

# 2. Outline of experiment

# 2.1 Purpose of experiment

Generally, flush valve type toilet bowls have been used in non-residential buildings in Japan. However, the flow conditions of flush valve type toilet bowls require 0.07 MPa dynamic water pressure and 107 L/min flow rate. In this study, in view of the aspects of water conservation and energy saving, low tank type toilet bowls or tankless toilet bowls (tank combination type) are proposed. For low tank type toilet bowls, flow conditions of 0.05 MPa dynamic water pressure and 10 L/min flow rate are defined. By using the low tank type toilet bowls, which can reduce dynamic water pressure and flow rate in comparison with flush valve type toilet bowls, both the pipe diameter and the water feed pump capacity can be reduced. In consideration of these conditions, we propose that use of low tank type toilet bowls can reduce consumption of both water and power, enabling load reduction on public infrastructure. Assuming that piping with smaller diameters will proliferate in the future, we conducted this experiment for the purpose of basic data collection.

#### 2.2 Conditions of experiment 2.2.1 Experimental equipment

To verify conformity to the flow conditions for each sanitary fixture, we conducted the experiment for flow rate and dynamic water pressure measurements by using sample pipes of diameter 16 mm, 13 mm and 10 mm. The experimental equipment enables pressure feeding of water stored in the water feed tank by using a pressurizing device comprising a compressor, pressure tank and pump. The pump flow rate was adjusted by the frequency setting. For the piping system, a water feed header was used, and the sample pipes in the downstream of the header were connected to the low tanks of western-style toilet bowls, flush valves of urinals, and hand washer faucets. For the water feed piping from the pressurizing device to the header, 50 mm diameter HIVP pipes were used. The experimental equipment simulates a lavatory in an office building, and contains thirteen sanitary fixtures in total: two western-style toilet bowls, three urinals and two hand washers for the men's room, and three western-style toilet bowls and three hand washers for the ladies' room. Fig. 1 shows the experimental equipment.

## 2.2.2 Standard values of sanitary fixtures

As standard values, flow conditions of the sanitary fixtures must be suitable for actual situations. For this purpose, hearing values from the sanitary fixture manufacturers are adopted in this study. **Table 1** lists standard values of the sanitary fixtures. As reference values, the values given in the SHASE-S-206 technical requirements that have been applied in the design affaires are also shown in the table. For urinals, 30 L/min flow rate is used in the design affairs. The hearing value of flow rate is 13 L/min, which is half the design value. Also, as for hand washers, the flow rate used in the design affairs is approx. twice the hearing value.

Table 1 Standard values for sanitary fixtures

	Standard v	alue for sanit	tary fixtures	Reference value	Remark	
Fixture	Dynamic water pressure	Flow rate	Water filling time	SHASE-S-206		
	(MPa) (L/min)		(sec)	requirement		
Low-tank type toilet bowl	0.05	-	40	10	With toilet seat	
Tank-less toilet	0.05	10-13	-	10-13	Small tank combination type	
Urinal flush valve	0.07	13	-	30		
Hand washer faucet (1)	0.05	4	-	8	Automatic faucet	
Hand washer faucet (2)	0.05	2.5	-	-	Automatic faucet/highly water conservation type	

## 2.2.3 Method of experiment

A common header was used for both the men's and the ladies' rooms. Also, combinations of 40 mm and 50 mm header diameters, 16 mm, 13 mm and 10 mm pipe diameters, and 5 m and 10 m pipe lengths were used. Simultaneous utilization ratio was provided in three patterns: 100%, 48% and 16%. For the simultaneous utilization ratio of 100%, two different hand washer faucet flow rates (4.0 L/min and 2.5 L/min) were applied; for 48%, three urinals and four western-style toilet bowls were operated; and, for 16%, only two urinals were operated. Water feed pressure was in the range of 0.10 MPa (initial pressure) to 0.40 MPa (final pressure). As measuring points, flow rate just before the header, header pressure, and dynamic water pressure and flow rate close to the sanitary fixtures were measured. The sanitary fixtures were operated manually. For urinals, the flush button was pressed for one second. For the western-style toilet bowls, the "large volume" flush lever was operated once. The hand washer faucet flow rate was switched between the 4.0 L/min and 2.5 L/min settings by using the constant flow rate valve. For the measuring method, electromagnetic flow sensor and pressure converter were provided close to each sanitary fixture for flow rate and dynamic water pressure measurements. Measured values were recorded with MEMORY HIGH LOGGER and a notebook PC for data recording. Immediately after operation of the urinals and the western-style toilet bowls, temporary pressure drop occurs. Therefore, a mean value for a certain time after pressure stabilization was adopted as an experimental value. Fig. 2 shows photographs of the experimental equipment.

With the low tank type and the tankless type (small tank combination type), required water pressure is 0.05 MPa and flow rate is 10 to 13 L/min, showing that the water feed characteristics of the two tank types are similar. Therefore, in this experiment, western-style toilet bowls of low tank type were used. Evaluation of low tank type toilet bowls is based on the water filling time. However, flow rate measurement was also conducted so that the measured value can also be applied to the tankless type (small tank combination type). The sample pipes were metal reinforced polyethylene pipes, and pipe joints for the same pipes were used. Table 2 shows the outline of the experiment.

#### 3. Results of the experiment

Results of the experiment with the western-style toilet bowls and the urinals are shown below. Each dynamic water pressure/flow rate is an experimental value and includes the resistance of the measuring instrument.

# 3.1 Dynamic water pressure and flow rate (Simultaneous utilization ratio: 100%)

For the pipe length of 5 m, relations among dynamic pressure, flow rate, water filling time and water feed pressure at 100% simultaneous utilization ratio as the worst condition are shown in **Fig. 3-1** through **Fig. 3-4**. With the western-style toilet bowls,



Fig. 1 Outline of experimental equipment



Item





Fig. 2 Experimental equipment (Photograph)

Table 2 Outline of experiment				
Outline	Remark			
Vestern-style toilet howl (low tank)				

1)	Sanitary fixture	Western-style toilet bowl (low tank) Urinal flush valve Hand washer faucet	Hand washer faucet 2.5 L/min•4.0 L/min
2)	Pipe material	Metal reinforced polyethylene pipe Pipe joint for the above Bronze casting header	
3)	Pipe diameter	10 mm, 13 mm, 16 mm	
4)	Pipe length	5 m, 10 m	Piping to each fixture is the same length.
5)	Header diameter	50 mm, 40 mm	50 mm header is custom-made.
6)	Piping system	Common to men's and ladies' toilets	
7)	Simultaneous utilization ratio	100% 48% 16%	<ol> <li>48%</li> <li>Prediction from fixture utilization based on SHASE-S-206</li> <li>16%</li> <li>Fixture water feed load unit method based on</li> </ol>
		[1] Maan value for 20 seconds after	SHASE-S-206
		stabilization of dynamic water pressure and flow rate for toilet bowl	
8)	Measured value	[2] Water filling time for toilet bowl Time after start to end of water feed	
		[3] Mean value for 3 seconds after stabilization of dynamic water pressure and flow rate for urinal	
9)	Measuring method	Mean value of three measurement values	

measurement results for all pipe diameters satisfied the standard dynamic water pressure of 0.05 MPa. To meet the standard value of water filling time of 40 seconds, required water feed pressures for 16 mm, 13 mm and 10 mm pipe diameters were 0.10 MPa, 0.05 MPa and 0.20 MPa, respectively. No difference was found with respect to the header diameter, and a similar tendency was observed with the 16 mm and 13 mm pipe diameters. However, with the 10 mm pipe diameter, a slightly different tendency was noticed. For the urinals, the 16 mm and 13 mm pipe diameters required water feed pressure of 0.10 MPa, while the 10 mm pipe diameter required water feed pressure of 0.15 MPa, to meet the standard dynamic water pressure of 0.07 MPa. To meet the standard flow rate of 13 L/min, 0.10 MPa water feed pressure was required with the 16 mm pipe diameter, 0.20 MPa with 13 mm, and 0.35 MPa with 10 mm.

Tendency by the difference in header diameter and pipe diameter was found to be similar to that of western-style toilet bowls. Regarding water feed pressure, large influence was seen with urinals rather than with western-style toilet bowls.



Fig. 3-1 Water feed pressure and dynamic water pressure (Western-style toilet bowl)



Fig. 3-2 Water feed pressure, flow rate, and water filling time (Western-style toilet bowl)



Fig. 3-3 Water feed pressure and dynamic pressure (urinal)



How rate (L/min)

Fig. 3-4 Water feed pressure and flow rate (urinal)

3.2 Flow rate and dynamic water pressure by water feed pressure To verify influence of difference in simultaneous utilization ratio of urinals based on the results given in the previous section 3.1, relations between dynamic water pressure and flow rate are shown in Figs. 3-5 through 3-7. The experimental values were obtained with different header diameters (40 mm and 50 mm) and different simultaneous utilization ratios at each water feed pressure (100% utilization of hand washer faucet at 2.5 L/min and hand washer faucet at 4.0 L/min, 48%, and 16%). For the experimental values on different header diameters, no remarkable difference is found due to the difference in header diameter in any of dynamic water pressure, flow rate or water filling time, as shown in Figs. 3-1 through 3-4. Thus, the experimental values for 40 mm and 50 m header diameters are expressed by mean values. Regarding simultaneous utilization ratio according to different pipe diameters, no remarkable variations are found. This result shows that simultaneous utilization has little influence.



Fig. 3-5 Relation between dynamic water pressure and flow rate of urinal (Pipe diameter: 16 mm)



Fig. 3-6 Relation between dynamic water pressure and flow rate of urinal (Pipe diameter: 13 mm)



Fig. 3-7 Relation between dynamic water pressure and flow rate of urinal (Pipe diameter: 10 mm)

With the 16 mm pipe diameter, there is no remarkable difference according to the pipe length, and no influence of pipe resistance is observed. Water feed pressure of 0.10 MPa to 0.15 MPa is required relative to the standard value. For 0.20 MPa or higher water feed pressure, dynamic water pressure increases but flow rate is stabilized. This seems to be the effect of the constant flow rate valve in the fixtures. With the 13 mm pipe diameter, there are differences in dynamic water pressure and flow rate according to the pipe length, and the differences are remarkable at 0.20 MPa or higher water feed pressure. Water feed pressure of 0.15 MPa to 0.20 MPa is required relative to the standard value. As in the case with the 16 mm pipe diameter, the flow rate stabilizes around 15.0 L/min at 0.25 MPa or higher water feed pressure. With the 10 mm pipe diameter, remarkable differences arise in dynamic water pressure and flow rate according to the pipe length. Water feed pressure of 0.35 MPa to 0.40 MPa is required relative to the standard value. The relation between dynamic water pressure and flow rate in this case is different from those with 16 mm and 13 mm pipe diameters.

### 3.3 Estimation of water feed pressure

As described in the previous section 3.2, we conducted detailed analysis to estimate the water feed pressure required for the header to meet the standard value with each pipe diameter. We determined the standard deviation and the ratio to the standard value. **Tables 3-1** through **3-3** show the results for each pipe diameter. Data quantity (N) is the total number of experimental values for 100% simultaneous utilization ratio (hand washer faucet at 2.5 L/min and 4.0 L/min), 48% and 16%, and 40 mm and 50 mm header diameters. The ratio to the standard value is defined as a ratio to the minimum value. However, for the water filling time for the western-style toilet bowl, the ratio to the standard value means a ratio to the maximum value, which is intended for evaluation by the service level.

Since the experimental equipment uses the header system, the water feed pressure must meet the standard values of both western-style toilet bowls and urinals. With the 16 mm pipe diameter, the water feed pressure required to meet the standard values is 0.15 MPa for both 5 m and 10 m pipe lengths. With the 13 mm pipe diameter, it is 0.20 MPa for both 5 m and 10 m pipe lengths. For the western-style toilet bowls with 13 mm pipe diameter, the standard values can be met at 0.15 MPa water feed pressure. Therefore, we can also suggest the method of using 13 mm pipe diameter for the western-style toilet bowl piping and 16 mm for the urinal piping, with the header's water feed pressure at 0.15 MPa. With both 16 mm and 13 mm pipe diameters, the experimental results show that the dynamic water pressure must be 1.5 to 1.9 times higher than the standard value in order to meet the standard flow rate. With the 10 mm pipe diameter, the results show that the water feed pressure required to meet the standard value is 0.40 MPa with the 5 m pipe length and 0.4 MPa or more with the 10 m pipe length. To meet the standard flow rate, the dynamic water pressure must be 2.5 to 3.0 times higher than the standard value.

#### 4. Conclusion

In this experiment, we verified the influence of simultaneous utilization ratio and pipe length and the water feed pressure required to meet the standard values. Through reduction of the pipe diameter, we can expect to see reduction in  $CO_2$  and  $LCCO_2$  as well as savings in the materials and labor required. In view of these aspects, we intend to proceed with further analysis including trial calculation.

#### **Reference document**

 Yoshiaki Matsumura, et al.: Study on Selection of Suitable Pipe Diameter for Water Conservation, Collection of papers from scientific presentation meeting of The Society of Heating, Air-Conditioning and Sanitary Engineers of Japan (2012.09) PP.1195–1198

Table 3-1 Summary of experimental results (Pipe diameter: 16 mm	)
[Unit: Dynamic water pressure (MPa), Water filling time (sec), Flow rate (L/min)	l

Water feed pressure (MPa)	Pipe length (m)	Fixture	Item	Data quantity N	Mean value	Standard deviation σ	Minimum value	Maximum value	Ratio to standard value
	-	Western- style toilet bowl	Dynamic water pressure	6.0	0.09	0.005	0.08	0.09	1.60
			Water filling time	6.0	38.78	0.890	37.87	40.36	1.01
	5.0	Urinal	Dynamic water pressure	8.0	0.09	0.004	0.09	0.10	1.22
0.10			Flow rate	8.0	13.15	0.325	12.64	13.58	0.97
0.10		Western-	Dynamic water pressure	6.0	0.08	0.003	0.08	0.09	1.60
	10.0	style tollet bowl	Water filling time	6.0	40.29	0.745	39.40	41.52	1.04
		Urinal	Dynamic water pressure	8.0	0.08	0.004	0.08	0.09	1.09
			Flow rate	8.0	12.90	0.625	11.64	13.97	0.90
	5.0	Western- style toilet bowl	Dynamic water pressure	6.0	0.13	0.005	0.13	0.14	2.52
			Water filling time	6.0	35.36	0.396	34.92	35.94	0.90
		Urinal	Dynamic water pressure	8.0	0.13	0.006	0.12	0.14	1.71
0.15			Flow rate	8.0	15.23	0.482	14.68	16.20	1.13
		Western- style toilet bowl	Dynamic water pressure	6.0	0.13	0.002	0.12	0.13	2.47
	10.0		Water filling time	6.0	36.29	0.479	35.48	36.73	0.92
	10.0	Urinal	Dynamic water pressure	8.0	0.12	0.005	0.11	0.12	1.53
			Flow rate	8.0	15.21	0.651	14.14	16.44	1.09

Table 3-2 Summary of experimental results (Pipe diameter: 13 mm) [Unit: Dynamic water pressure (MPa), Water filling time (sec), Flow rate (L/min)]

Water feed pressure (MPa)	Pipe length (m)	Fixture	Item	Data quantity N	Mean value	Standard deviation σ	Minimum value	Maximum value	Ratio to standard value
		Western- style toilet bowl	Dynamic water pressure	6.0	0.11	0.004	0.10	0.12	2.07
			Water filling time	6.0	35.92	0.383	35.30	36.32	0.91
	5.0	Urinal	Dynamic water pressure	8.0	0.11	0.006	0.10	0.12	1.39
0.15			Flow rate	8.0	12.45	0.540	11.58	13.05	0.89
0.15		Western-	Dynamic water pressure	6.0	0.10	0.004	0.09	0.10	1.84
	10.0	style toilet bowl	Water filling time	6.0	37.72	0.595	36.90	38.60	0.97
		Urinal	Dynamic water pressure	8.0	0.09	0.005	0.08	0.09	1.14
			Flow rate	8.0	11.56	0.357	11.06	12.09	0.85
	5.0	Western- style toilet bowl	Dynamic water pressure	6.0	0.15	0.006	0.14	0.16	2.80
			Water filling time	6.0	33.04	0.388	32.30	33.52	0.84
		Urinal	Dynamic water pressure	8.0	0.14	0.008	0.13	0.16	1.87
0.20			Flow rate	8.0	14.11	0.346	13.44	14.80	1.03
	10.0	Western- style toilet bowl	Dynamic water pressure	6.0	0.14	0.004	0.13	0.14	2.68
			Water filling time	6.0	34.46	0.163	34.18	34.72	0.87
	10.0	The second	Dynamic water pressure	8.0	0.12	0.004	0.11	0.13	1.62
		Urinai	Flow rate	8.0	13.59	0.281	13.26	14.08	1.02

Table 3-3 Summary of experimental results (Pipe diameter: 10 mm) [Unit: Dynamic water pressure (MPa), Water filling time (sec), Flow rate (L/min)]

Water feed pressure (MPa)	Pipe length (m)	Fixture	Item	Data quantity N	Mean value	Standard deviation σ	Minimum value	Maximum value	Ratio to standard value
	50	Western- style toilet bowl	Dynamic water pressure	6.0	0.19	0.005	0.18	0.20	3.68
			Water filling time	6.0	29.73	0.305	29.23	30.08	0.75
	5.0		Dynamic water pressure	8.0	0.19	0.006	0.17	0.20	2.49
0.25		Urmai	Flow rate	8.0	12.98	0.290	12.41	13.29	0.95
0.55		Western-	Dynamic water pressure	6.0	0.16	0.002	0.16	0.17	3.20
	10.0	style toilet bowl	Water filling time	6.0	32.43	0.398	31.87	32.92	0.82
		Urinal	Dynamic water pressure	8.0	0.16	0.007	0.15	0.17	2.15
			Flow rate	8.0	11.74	0.461	11.15	12.74	0.86
	5.0	Western- style toilet bowl	Dynamic water pressure	6.0	0.22	0.004	0.21	0.22	4.24
			Water filling time	6.0	27.97	0.176	27.70	28.20	0.71
			Dynamic water pressure	8.0	0.21	0.004	0.21	0.22	2.95
0.40		Urinal	Flow rate	8.0	13.95	0.186	13.63	14.22	1.05
		Western- style toilet bowl	Dynamic water pressure	6.0	0.19	0.004	0.18	0.19	3.60
	10.0		Water filling time	6.0	30.73	0.424	30.30	31.28	0.78
	10.0		Dynamic water pressure	8.0	0.18	0.009	0.17	0.20	2.46
		Urmal	Flow rate	8.0	12.60	0.396	12.11	13.46	0.93