

# AMOUNT OF MOISTURE PRODUCED INSIDE BATHROOM AND APPURTENANT CHANGING ROOM

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## ABSTRACT

In recent years, the aspect and behavior inside a bathroom and an appurtenant changing room have been changing. With these changes, the thermal insulation quality of a dwelling has improved, so it seems that the amount of moisture generated in a dwelling has changed. In this study, amount of moisture produced in a bathroom and a changing room was surveyed in order to grasp the thermal and humid environment in bathroom and a changing room. From the result of the survey, it was found that the amount of moisture in bathing was bigger than before. It was considered that the amount of adhesion moisture was depended on the way of bathing, and the balance of exhausted moisture by ventilation and remaining moisture in the atmosphere was depended on of ventilation rate. The survey was conducted in two different size bathrooms (1200×1600, 1600×1600). Influence of a bathroom size was deliberated.

## INTRODUCTION

In recent years, the humidity and thermal environment of the bathroom has changed dramatically with the diversification of bathroom equipment, increasingly higher level of insulation, high airtight homes. With the shifts in perspectives and objectives of bathing, bathing behavior has also changed (Such as increase of bathing frequency and establishing of showering). However there are few researches of moisture production inside a bathroom which depend on a modern Japanese life style. (Nagai et al. 2003, Ito et al. 2003, Ito et al. 2004, Otani et al. 2006) To exhaust the moisture produced inside a house efficiently, appropriate ventilation plan, which includes an understanding of the source and the amount of moisture production, is necessary. The objectives of this paper are to survey the humidity and thermal environment of modern conditions of bathing and to examine the size of bathroom on humidity and thermal environment and the moisture production.

## METHOD OF EXPERIMENT

### Summary of laboratory

Summary of laboratory is shown in Table 1. The experiment was performed in two of different size bathrooms and changing rooms that are located in a controlled artificial climate room. The walls of the unit type bathroom are composed of plastic boards, which do not absorb moisture, a section of empty space, insulation and composite material. The ceiling and walls of the changing room are insulated and the material of floor is wood. The dimensions of the T-1216 laboratory are width 1150mm, depth 1600mm, and height 2000mm and of the changing room are width 1200mm, depth 1200mm, height 2300mm. The dimensions of the Y-1616 are width 1600mm, depth 1600mm, and height 2100mm and for the changing room are width 1600mm, depth 1600mm, height 2400mm. There are four vents in the lower part of the folding door to the bathroom in T-1216 laboratory. And there are one vent in the lower part of the sliding door to the bathroom in Y-1616. Both laboratories have a bathroom dryer on a ceiling of bathroom.

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Table 1 Summary of laboratory

		T-1216	Y-1616
Volume of bathroom		3.6 [m <sup>3</sup> ]	5.8 [m <sup>3</sup> ]
Floor space of bathroom		0.8 [m <sup>2</sup> ]	1.2 [m <sup>2</sup> ]
Volume of changing room		3.3 [m <sup>3</sup> ]	5.8 [m <sup>3</sup> ]
Ventilation rate	High	119 [m <sup>3</sup> /h] (33 [ACH] )	130 [m <sup>3</sup> /h] (22 [ACH] )
	Low	65 [m <sup>3</sup> /h] (18 [ACH] )	95 [m <sup>3</sup> /h] (16 [ACH] )

### Measurement items and ventilation quantity

Schematic of test bathrooms and measurement positions is shown in Figure 1, and the measurement items and methods are shown in Table 2. The vertical distribution of the temperature and humidity in the upper and lower areas of both the bathroom and changing room were measured at 3 positions. The temperature of the ceiling and each of the walls and the humidity below the ceiling of both the bathroom and changing room were also measured. The temperature and humidity in a vent in the doors of the bathroom was measured in assuming that the temperature and humidity of the air entering the bathroom and the air leaving the changing room was same. The temperature and humidity of the air leaving the bathroom was measured in the exhaust duct connected to the ventilation fan. During the experiment, the windows were sealed to minimize the amount of air flowing in and out through any openings besides exhaust duct and vents in the doors. The amount of air flow for the ventilation located on the ceiling can be switched from 119 m<sup>3</sup>/h in high ventilation to 65 m<sup>3</sup>/h in low ventilation in T-1216 laboratory, and from 130 m<sup>3</sup>/h in high ventilation to 95 m<sup>3</sup>/h in low ventilation in Y-1616 laboratory. These values were checked by exploratory experiment (Watanabe et al. 2006).

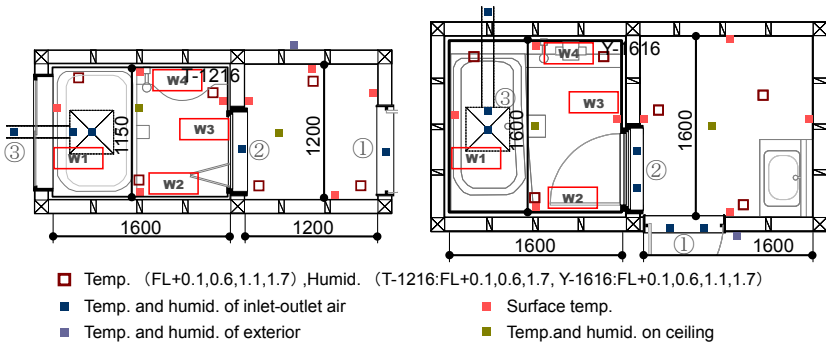


Figure 1 Schematics of test bathrooms and measurement positions

Table 2 Measurement items and methods

Contents	Measurement points and remarks
Temperature distributions	3 points in both rooms.
Humidity distributions	3 points in both rooms The point's data hit against hot water during bathing was deleted.
Surface temp.	4 points in bathroom and changing room. 1point on the ceiling
Temp. and humid. of exterior	1 point in artificial climate room
Temp. and humid. of inlet-outlet air	1 point in exhaust duct, 1 point in a vent of bathroom door, 1 point in a vent of changing room door
Volume rate of supply water	Setting flow meter at the header of boiler
Volume rate of exhaust water	Measuring weight of tank filled with exhaust water
Moisture attached to wall	Measuring weight of paper used for wiping water left on surface of wall

### Computational method of the amount of moisture produced

The amount of moisture produced was calculated by summing up the amount of moisture that was contained in air and was adhered to the wall. The amount of moisture adhered to the wall was wiped off with kitchen papers and was measured by the weight change of the papers. The amount of moisture in air was calculated by the amount of moisture that remained in the bathroom and exhausted by ventilation. The amount of moisture exhausted by ventilation was calculated by amount of ventilation and air temperature and humidity at supply and exhaust openings.

### Method of experiment and experiment cases

The bathing participants were total of 14 healthy men in 20's and each bathed under various cases as shown in Table 3. After maintaining a fully steady condition previous to the experiment, the bathing participants entered the bathroom and bathed. To prevent any differences by participant, instructions on how to open/close the door and the use of bathroom equipment were explained to the participants.

Ventilation during bathing was set in three levels, High, Low and Off. In cases of High and Low ventilation the strength of ventilation was kept same both during and after bathing. In the case of Off, the fan was switched on to the High, immediate after moving out to a changing room. Despite the strength of ventilation, the fan was on for 20 minutes after moving out to the changing room.

The time used to open and close the door was 8 seconds in standard, and set the four type of length (4, 8, 20, 40 seconds). Quantity of moisture moved into changing room was calculated by summing up the amount of moisture that remained in the changing room and exhausted by ventilation.

Table 3 Experiment cases

Laboratory	Bathing style	Temp and humid of exterior	Ventilation during bathing	Length of opening a door [s]
T-1216	Showering	28°C75%	High, Low, Off	8
			High, Off	4
		20°C50%	Low	8
			High	4
	Bathing in tub	10°C30%	Low, Off	8
			High, Low, Off	8
		20°C50%	High, Off	4
			Low	8
			High, Off	4
Y-1616	Showering	20°C50%	High, Low	4, 8, 20, 40
			Off	8
	Bathing in tub		High, Low	4, 8, 20, 40
			Off	8

### Bathing style

As shown in Figure 2,3 the scheduling and two styles of bathing (showering and bathing in tub) were decided by using the investigated summertime average (A society for the study of bathing culture,1999, 2000). During the experiment, participants were not allowed to change the flow rate and the temperature of hot-water for shower. Since the relative humidity of the bathroom was below 90% after the ventilation during 20 min, it was decided to enter the bathroom to measure the water adhered to the ceiling, walls, and floor. For showering, body washing was performed in an upright standing position for 10 min. For bathing in the bath tub, the water in the tub was not reheated and the cover for the bath tub was opened right after the experiment participant entered the bathroom. The participant was to run the shower for 9 minutes and stay in the bath tub for 7 minutes. The participant was to wash in a seated position and to rinse with a shower after leaving the bath tub. Then, participant closed the cover for the bath tub. The water in the bath tub was drained after measuring the moisture attached to the bath tub.

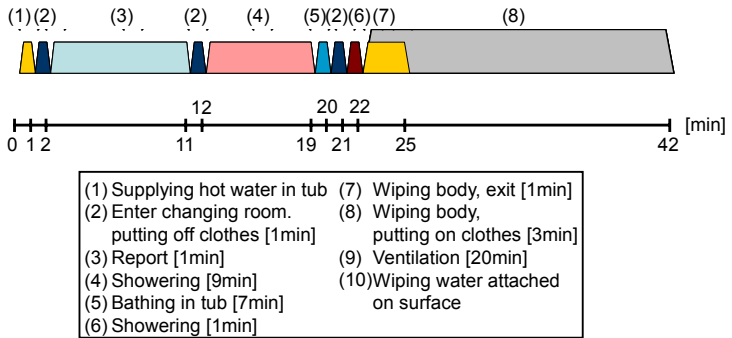


Figure 2 Schedule for bathing in tub style

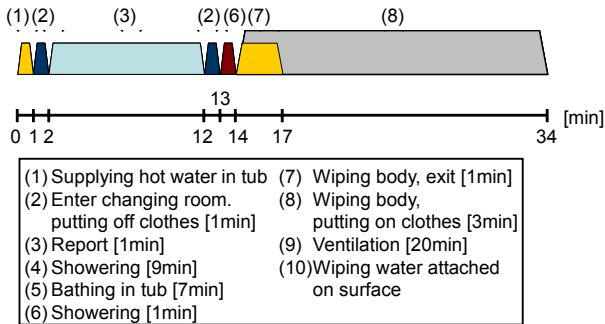


Figure 3 Schedule for showering style

## RESULTS ANALYSIS AND DISCUSSION

### Thermal environment and humidity in the bathroom and changing room

The results of the average of all points measured for the temperature and the humidity inside the bathroom and changing room, in case of bathing in tub, are shown in Figure 4. The blue colored area in the figures shows time period of showering. The red colored area shows time period of staying in the changing room. During bathing, the relative humidity of the bathroom reached 100% right after opening the cover for the bath tub and letting the shower run, regardless of the operation for the ventilation and the condition of the exterior. After the bathing, relative humidity of changing room rose with the moving of participant to the changing room in every case. The humidity of changing room increased the most in Off and then following in Low and in High. Increase of temperature and humidity in a bathroom and changing room was less quickly and declination was more quickly in Y-1616 than T-1216.

The temperature in the T-1216 bathroom of the cases of bathing in tub was 2°C higher in High, 8°C higher in Low than Y-1616, and about the same in Off. And the temperature in the T-1216 bathroom of the cases of showering was 7°C higher in Low than Y-1616, and about the same in High and Off. But the increase of temperature in a changing room in the cases of T-1216 was greater than Y-1616.

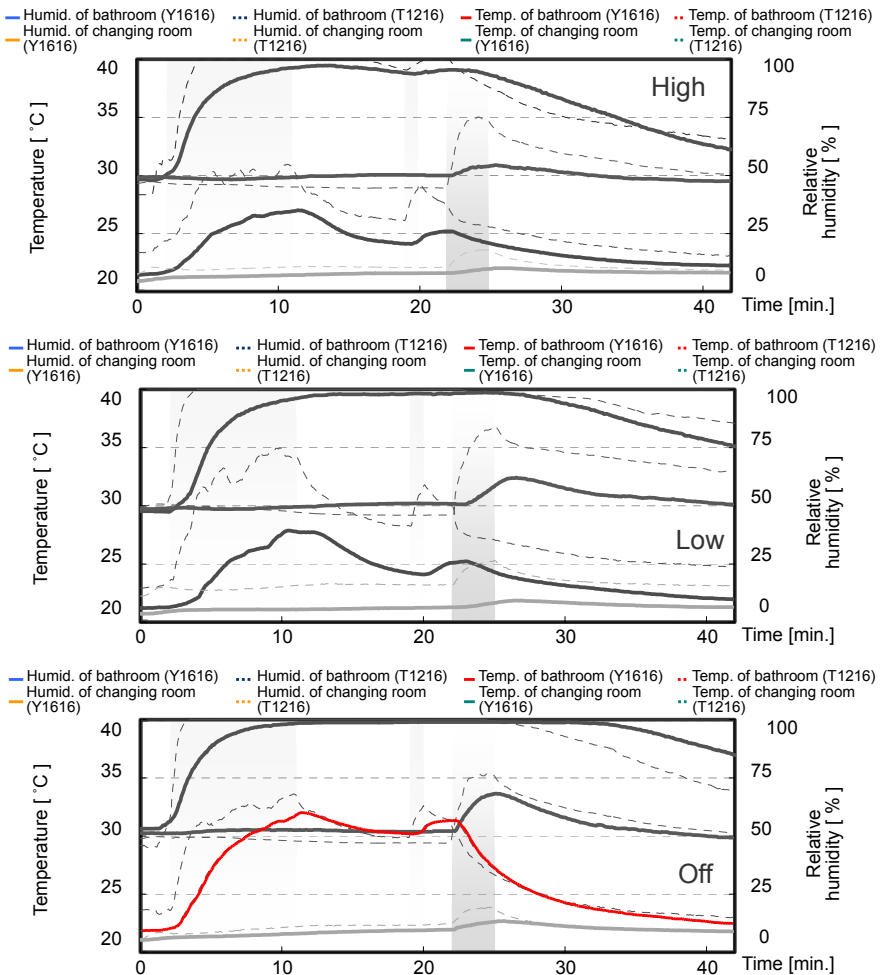


Figure 4 Temperature and Humidity inside the bathroom and changing room

### Quantity of moisture attached to surface

Measurement results for the quantity of moisture attached to each surface, in the cases of bathing in tub, are shown in Figure 5. Comparing T-1216 with Y-1616, the amount of moisture attached to the surfaces in T-1216 was greater than Y-1616. Because of the difference of floor material, there was difference of amount of moisture attached to floor between T-1216 and Y-1616. So the result of calculating of the amount of moisture attached to floor of Y-1616 supposed to consist of the same material of T-1216 (the tint part of the figure), was that the amount of moisture attached to floor of Y-1616 was increased to 200g more and greater than T-1216.

Measurement results for the sum of quantity of moisture attached to the surfaces, in two styles of bathing, are shown in Figure 6. The amount of moisture attached to the surfaces of T-1216 were 450-680g, while Y-1616 were 200-430g. The amount of T-1216 was 250g greater than Y-1616.

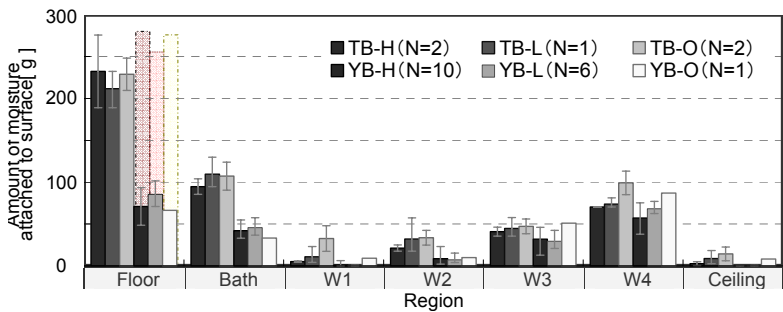


Figure 5 Amount of moisture attached to each surface

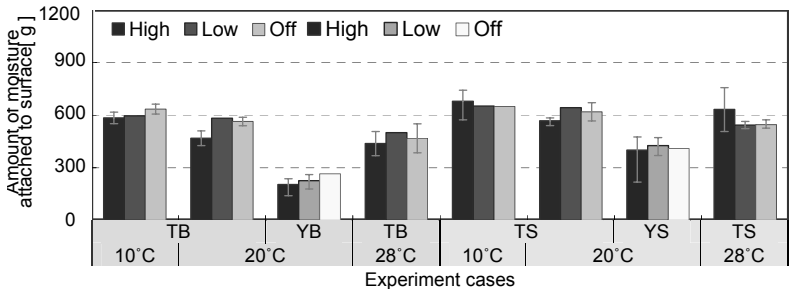


Figure 6 Amount of moisture attached to surface

TB:T-1216,Bathing in tub YB:Y-1616,Bathing in tub TS:T-1216,Showering  
YS:Y-1616,Showering H:High L:Low O:Off

### Quantity of moisture production during bathing

The calculated total quantity of moisture production and each value of moisture production by bathing style, exterior conditions and ventilation conditions are shown in Figure 7. The quantity was 900-1300g (the average was 1100g) regardless of the cases. It was greater than 403g which is a previous data from literature (Nagai et al. 2003), because a previous data wasn't calculated the amount of moisture exhausted by ventilation. In Y-1616 the amount of moisture released through ventilation occupied 70% of the quantity of moisture production, while it occupied 50% in T-1216. If the floor of Y-1616 is supposed to consist of the same material of T-1216 (the amount of moisture attached to floor becomes 200g greater), the quantity of moisture production of Y-1616 is about the same amount of T-1216.

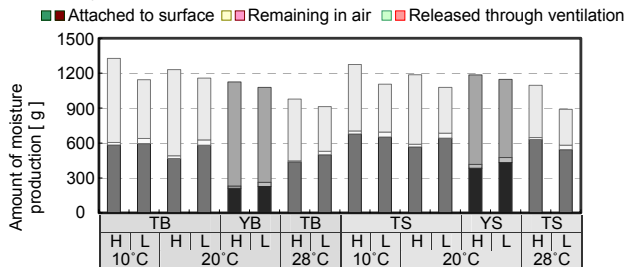


Figure 7 The calculated total quantity of moisture production

TB:T-1216,Bathing in tub YB:Y-1616,Bathing in tub TS:T-1216,Showering  
YS:Y-1616,Showering H:High L:Low O:Off

## Quantity of moisture moved into changing room

The calculated amount of moisture moved into changing room in the cases of Y-1616 was shown in Figure 8. Amount of moisture moved into changing room was calculated by the sum of the amount of moisture released through ventilation of changing room after leaving a bathroom and the amount of moisture remaining in changing room air. The amount of moisture moved into the changing room was 20-50g. It was within 35-125g, the range of a previous simulated data (Otani et al.2006).The amount in the bathing in tub style was more than in the showering style, especially in the case of 8 seconds used to open and close the door. The length of the time used to open and close the door became longer, the amount of moisture moved into changing room became greater.

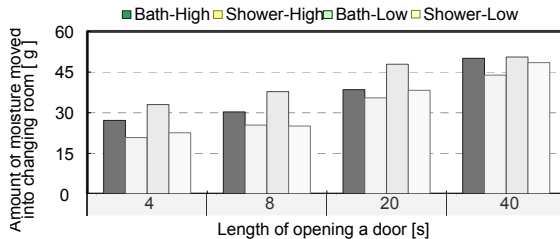


Figure 8 Amount of moisture moved into changing room

## CONCLUSION

The objective of this paper was to understand the thermal environment and the humidity around the bathroom, in consideration of actual modern lifestyles. The influence of the size of bathroom and the bathing style and the use of the ventilation to thermal environment and humidity around the bathroom was considered. The results are follows,

- 1) During bathing, the relative humidity of the bathroom reached beyond 100% right after opening the cover for the bath tub and letting the shower run. After the bathing, relative humidity of a changing room rose with the moving of participant out to the changing room in every case. It seems that the size of bathroom doesn't influence much to the temperature in the bathroom. But the increase of temperature in the changing room in the cases of T-1216 was greater than Y-1616.
- 2) The amount of moisture attached to the surfaces of T-1216 were 450-680g, Y-1616 were 200-430g. Comparing T-1216 with Y-1616, the amount of moisture attached to the surfaces in T-1216 was greater than Y-1616, because of the difference of surface material.
- 3) The quantity of moisture production during bathing was 900-1300g (the average was 1100g) regardless of the cases. It was greater than 403g which is a previous data from literature. In Y-1616 the amount of moisture released through ventilation occupied 70% of the quantity of moisture production, while it occupied 50% in T-1216.
- 4) The amount of moisture moved into changing room was 20-50g. It was within the range of a previous data. As the length of the time used to open and close the door became longer, the amount of moisture moved into changing room became greater.

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