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Study on Health and Comfort in Buildings based on Home Thermal Comfort Survey

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Abstract: Thermal comfort referred to the satisfaction of human beings with the surrounding environment. This report aimed at investigating thermal comfort in the domestic space. By comparing the internal condition recorded by data logger with provided external conditions, discuss the factors affecting the condition difference between inside and outside, then analysis the rationality of Predicted Mean Vote (PMW) comparing to activity diary, followed by suggestions to improve the building thermal performance.

Keywords: Thermal Comfort; Relative Humidity; Psychrometric Chart.

1. Introduction

Figure 1. (a): the location of Goldsmid House

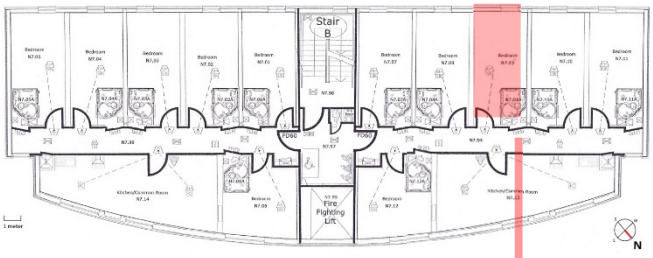

Figure 1. (b): plan layout of the entire floor

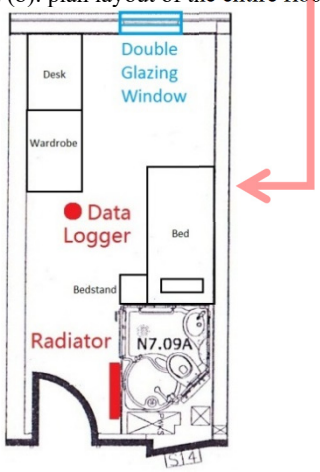

Figure 1. (c): plan layout of the test room

The proposed room was an en-suite bedroom, on the seventh floor in Goldsmid House. Figure 1 (a) showed the location of the building, near Victoria Station. Figure 1 (b) illustrated the plan layout of one floor and Room N709 highlighted in red was the target. The red spot in Figure 1 (c) provided the data logger position, one meter above the floor, and the radiator was placed at the entrance of the room. [1]

The operation fluid temperature in the radiator was supposed to be between 35℃ and 45℃. The thickness of external concrete wall was 350 mm. The double-glazing window 1×2 m^2 is the only opening exposure to environment directly.

2. Results

The data logger recorded the temperature and relative humidity (RH) in the living space in every fifteen minutes during six days. Once two parameters were obtained, the condition was determined by plotting points in Psychrometric Chart. In Figure 2, the enclosed irregular quadrilateral was the thermal comfort zone (RH 30-70%, temperature 20-26℃). The thick blue dots indicated each recorded condition. It revealed that most points were distributed along the line of 40 % RH and were located in the comfort zone, which meant that pleasant thermal performance was predominant during testing period [2].

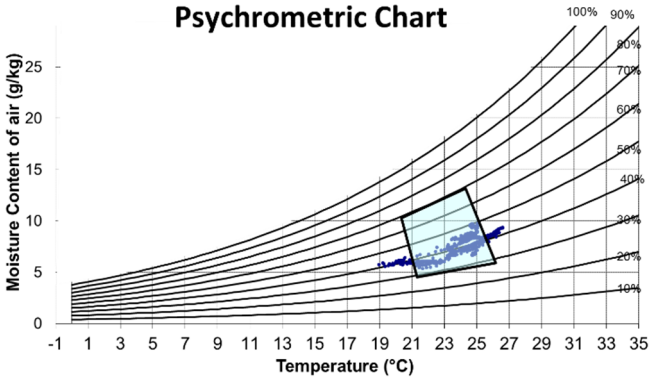

Figure 2. Psychrometric Chart with comfort zone and condition plots

2.1. Analysis on Overall Monitoring Duration

One point should be mentioned was that on the first day, the data logger was placed on the ground, leading to a slightly

lower temperature. However, the parameter variation responded reasonably to realistic situation. The occupied time was highlighted in yellow in the charts. According to Figure 3 and 4, and activity diary in Table 1, after owner entering the room, the situation changed immediately by equipment internal heat and human sensible heat (relevant with temperature), and breathing (relevant with moisture content). Consequently, the room temperature went up together with internal absolute humidity although outside condition reduced. Additionally, both were higher than the corresponding outdoor values [3].

It was interesting that every time when the window was opened in the morning, displayed by black dots in Figure 3 and 4, the internal temperature and absolute humidity fell rapidly to get close to the external ones. A representative example of window open/close effect was fire practice occurring on 19/10/2011 morning, with the detailed schedule in Table 2 and line chart in Figure 5.

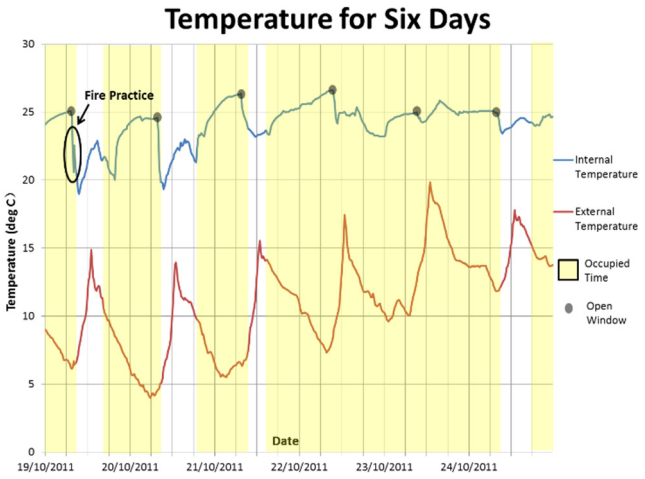

Figure 3. internal and external temperatures for six days

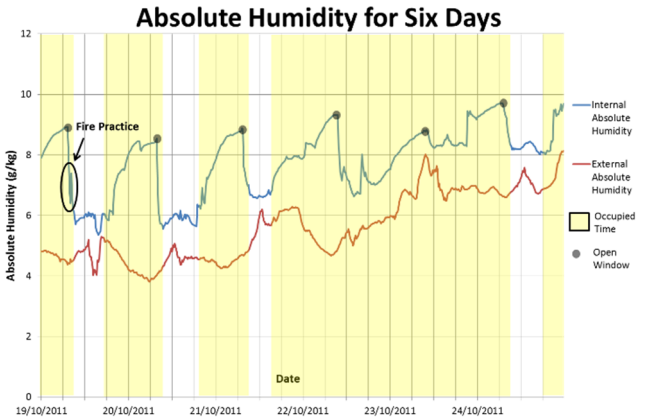

Figure 4. internal and external absolute humidity for six days

The inside temperature and absolute humidity fast responded to the window open/close while the outside condition remained stable in Figure 5. Raising controllable ventilation rate through opening at 7.30 am and 8.15 am significantly mitigated the difference in both absolute humidity and temperature between inside and outside. Accordingly, the target room was supposed to be airtight, which meant it had a quite low infiltration rate (or uncontrollable ventilation rate).

Table 1. activity diary for six days

Date / time	19/10/2011	20/10/2011	21/10/2011	22/10/2011	23/10/2011	24/10/2011
0.00-1.00				Shower		
1.00-2.00						
2.00-3.00						
3.00-4.00						
4.00-5.00						
5.00-6.00						
6.00-7.00						
7.00-8.00	Eating	Eating	Boiling water			
8.00-9.00	Fire practice		Eating			
9.00-10.00					Eating	
10.00-11.00				Eating		
11.00-12.00						
12.00-13.00						
13.00-14.00						
14.00-15.00						
15.00-16.00				Shower		
16.00-17.00	Boiling water					
17.00-18.00						
18.00-19.00	Shower					
19.00-20.00		Boiling water				
20.00-21.00		Shower				Shower
21.00-22.00					Shower	
22.00-23.00						
23.00-24.00						

non occupied close radiator open window	
open window close radiator	
open window open radiator	
close window close radiator	
close window open radiator	

Table 2. Window open/close during fire practice

Activity	Window open (get up)	Window close (fire alarm, leave the room)	Window open (all-clear, go back)
Time	7.30 am	8.00 am	8.15 am

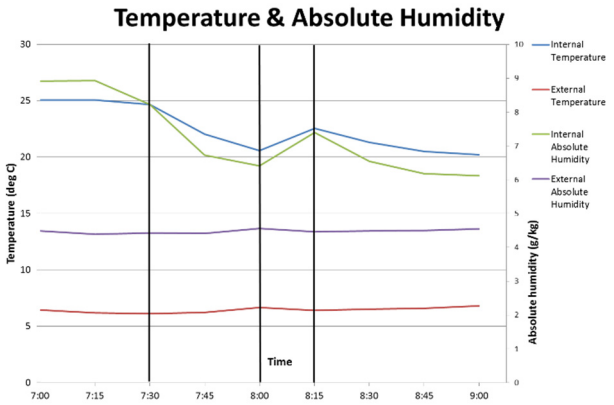

Figure 5. Temperature and absolute humidity (7.00-9.00 am, 19/10/2011)

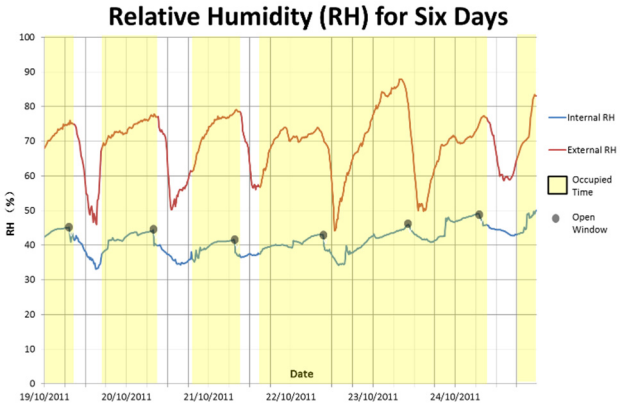

Figure 6. Internal and external relative humidity (RH) for six days

In terms of RH, since it measured the saturation level of water vapor in air of a certain temperature and warm air could hold more moisture content, lowering RH was a result of increasing temperature or decreasing absolute humidity [4]. Even though both parameters lessened when window opened in previous charts, internal RH decreased in Figure 6,

probably because the interior absolute humidity change overweighed temperature effect.

2.2. Analysis on one-day Performance

22/10/2011 was selected for one-day investigation since the occupant spent the entire day in the room.

Table 3. activity diary on 22/10/2011

Time	Activity
0:30	Have a shower
9:30	Get up and open window
10:00	Close radiator
10:40	Eat noodles in soup
15:50	Have a shower

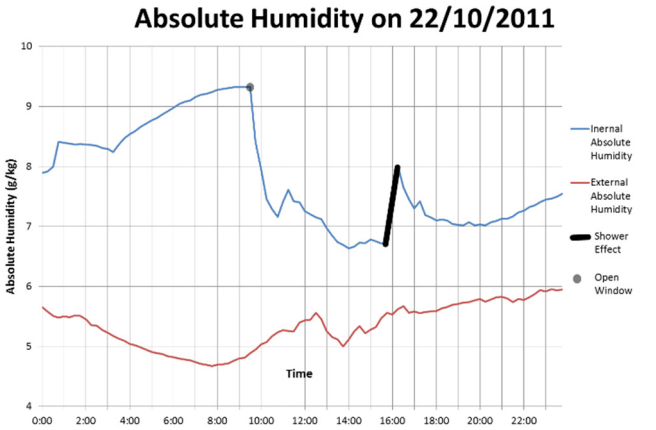

Figure 7. internal and external absolute humidity on 22/102011

Referring to Table 3 and observing the time point 9:30 am (the black dot) in three figures, the effect by opening window was inconformity with previous finding in six-day analysis.

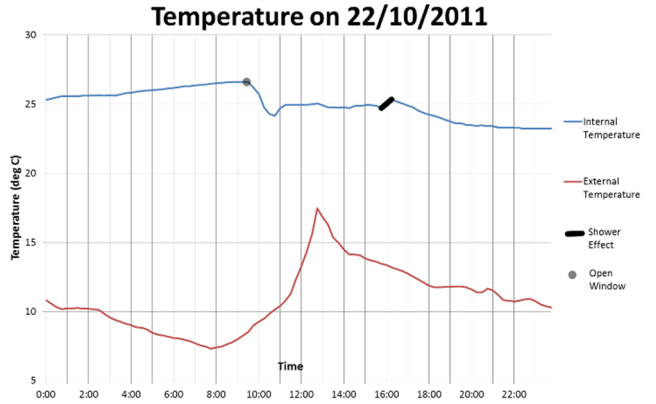

Figure 8. internal and external temperature on 22/10/2011

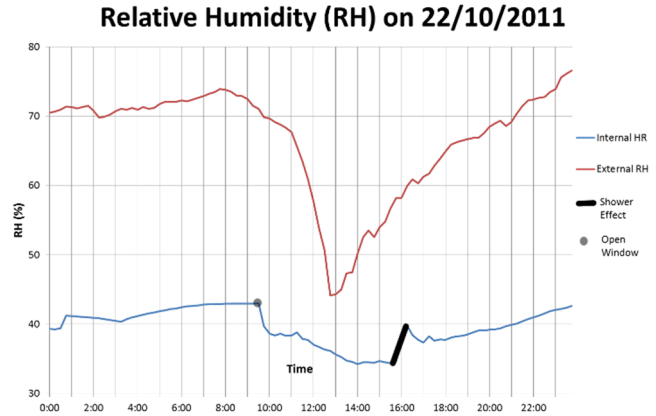

Figure 9. internal and external HR on 22/10/2011

Other activities, such as shower and eating, produced massive water vapor, driving the internal absolute humidity to grow dramatically. The alteration caused by shower at 15.50 was an appropriate instance. It created a sudden sharp peak of internal situation in Figure 7. The internal temperature enhanced as well in Figure 8 because of the latent heat released by warm vapor [3]. The increasing internal HR in Figure 9 revealed the growth of moisture content acted a dominant role again in HR fluctuation rather than air temperature. Apart from above, the effect of heating system was hard to explain since the liquid temperature was quite low and the continuous decrease of room temperature in Figure 8 after 10.00 am maybe still caused by window opening.

2.3. Analysis on PMV

Choose the certain time from 19.00 to 20.00, during which the resident always felt neutral. Estimations of metabolic rates and clo values were listed below in Table 4, including other input and results. It was assumed the mean radiant temperature equaled to the indoor air temperature, and the wind speed was set as default value 0.1 m/s. ±0.5 difference between PMV and comfort vote was acceptable because of the uncertainty caused by the estimations and assumptions.

Table 4. PMV calculation and comfort vote

Time: 19.00-20.00						
Date	19/10/2011	20/10/2011	21/10/2011	22/10/2011	23/10/2011	24/10/2011
Clothing (clo)	0.65	0.65	0.9	0.9	0.9	0.65
Air temperature (°C)	20	23	25	23	25	25
Activity (met)	1.2	1.2	1	1	1	1.2
RH (%)	41	36	40	39	42	49
PMV	-1	-0.3	0.3	-0.3	0.3	0.3
Comfort vote	0	0	0	0	0	0
Absolute difference	1	0.3	0.3	0.3	0.3	0.3

It was logical to see the large difference in the first day, since the data logger on the floor gave, a lower temperature as mentioned before leading to the inaccuracy of PMV result. Other differences with the value 0.3 seemed reasonable. It was noted that PMV could be an indication of thermal satisfaction level in this case.

3. Suggested Improvements

The internal condition was fairly sensitive to opening and human activities since the building was already airtight. The heating system cannot work properly sometimes due to the central control. Nevertheless, replacing the radiator under the window, which was closer to where the occupant stayed, would be better in order to improve the energy efficiency. The current position seemed far from the main activity space [5].

4. Conclusion

Human activities considerably influenced internal condition. In this nonleaky building, the ventilation rate, mainly depending on manually controlled opening, became the major element. When window was open, by exchanging the air, the thermal condition inside would get close to outside. Taking shower or having meals contributed greatly to the moisture content which enhanced interior RH though the temperature raised to some extent as well. The effect of heating system on/off seemed not as significant as former factors since the low operation temperature. But thermal comfort can be improved if replacing the radiator below the window near the main activity region.

References

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