EVALUATION OF PERFORMANCE OF VAV SYSTEM IN SUPER ENERGY CONSERVATION BUILDING

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Abstract

This paper describes the performance of the VAV System installed in the Super Energy Conservation Building. The concentrations of CO, CO_2 and dust were examined when the tightness of the VAV System was changed. A survey of occupants by questionnaire was also made. The results of the examinations and the survey were the following. (1) Good temperature and air current distributions were obtained even when the VAV System was throttled down. (2) The concentration of dust increased when the VAV System was closed tighter. The minimum air volume of the VAV System, considered from the concentration of dusts, is suitable at 6 to $8m^3/h.m^2$. (3) It is useful for energy conservation to control the minimum air volume of the VAV System upon detection of dust concentration.

1. Construction and Energy Consumption

Construction of the main building of Ohbayashi Corporation Technical Research Institute(Fig.1) was started in April 1981 and completed in April 1982 as an office building designed for super energy conservation within the limits of economical feasibility while maintaining proper living environment and office functions. An outline of the building is shown in Table 1. Table 2 outlines the heating and air conditioning system. Fig 2 is the heating and air conditioning heat source system diagram.

The measured total energy consumption per unit area(m^2) for one year starting from April 1982 is shown in Fig.3. Since the only energy source of this building is electricity, the measured value has been converted to primary energy based on electricity consumption. For this conversion, 1kw=10.24MJ/h is used. The recorded energy consumption of the whole building is $362.4MJ/m^2/year$, the initial target.

Considering that the energy consumption of a general building of the same scale in Japan is approximately $1580MJ/m^2/year$, the recorded value is only one fourth of the ordinary value, thus proving that this building is really a super energy saving building.

Energy consumption other than air conditioning is generally constant through the year. The maximum consumption of these has been occupied by lighting. 9% of the total energy consumption is for automatic control, which hinders promotion of energy conservation. The energy consumption for sanitary and ventilation use is low. The equipment included in the ca-

tegory "Others" are EDP equipment, and copying machines.

2. Outline of Measurement

Variable air volume systems are applied to the air conditioning system of super conservation building. The air conditioning of the building consists of a single air duct with the VAV System for the interior zone, and fan coil units for the northern and southern perimeter zones. Each zone uses separate air handling unit with active carbon filter. The air volume is varied by varying the fan speed. This building accomodates approximately 170 researchers and workers. Business hours during weekdays are 9 a.m. to 5 p.m. and from 9 a.m. to noon on Saturdays.

The VAV System also has some drawbacks. Odor or dust content increases when air volume is throttled down. Therefore, investigations were made on the tightness of the VAV System with the following parameters: concentration of CO(p.p.m.), CO_2(p.p.m.), dust(mg/m^3), dry bulb temperature(˚C), relative humidity(%), air velocity of occupied room(m/s), supply air volume(m^3/h) and inlet outside air volume(m^3/h). Questionnaires were distributed to the occupants for additional information. Dry bulb temperature was measured by anemometers at the air outlet, various points in the room and at the return air grille. Fig.4 shows the plan of 2nd and 3rd floors of Ohbayashi Corporation Research Institute. Fig.5 shows the measuring points of room air temperature and air velocity of this institute. This investigation was carried out in August 1983 during the cooling season. By varying the air volume (11.2, 8.4, and $6.1m^3/hm^2$), variation of room temperature and air velocity were measured at various points shown on Fig.5. One can observe the results on Table 4. Downward airflow was provided with diffusers with adjustable deflector. When the air volume of the VAV terminal was ($11.2m^3/hm^2$), the neck velocity and the face velocity were measured at 1.7m/s and 0.45m/s respectively. By throttling the air flow, as shown on Table 4, the air velocity and the temperature in the room are moderate. This is due to the well insulated building structure which isolates itself from the influence of outdoor conditions. The measurement data of the concentration of dust, CO_2, CO are shown with average values on Table 3. The relation between VAV air volume(m^3/hm^2) of the fan coil terminal at "High" speed is shown on Fig.6. It is apparent that the dust concentration greatly depends on the number of occupants and the activities that they are engaged in. During the measurement, it was a difficult task to fix a given condition. Nevertheless, it was found to be obvious that the increase of dust concentration was enhanced by throttling the air flow of the VAV terminal. There were areas where the concentration of CO_2 exceeded 1000p.p.m. which is the permissible value of Pettenkoffer. These in particular, were areas where the occupants were smoking. If one excludes these areas, the average concentration of CO_2 decreases to 900p.p.m. The concentration also is dependent on the volume of the fresh air intake. In the case of dust concentration, the perimeter zone has a lower value than the interior zone. This is greatly influenced by the fan coil terminals installation in the perimeter. However, if the fan coil units are throttled down to "Low" the VAV air volume is $6m^3/hm^2$, the dust concentration at the perimeter zones increased. "Low" operation of the fan coil units must therefore by prevented. One can conclude that the minimum air volume needed for this building is between 6 to $8m^3/hm^2$ with the fan coil terminals set at "High' speed around the perimeter zones. A survey was conducted during the throttling of the air volume without notifying the occupants of the operation of the VAV terminal. The results of the survey are shown on Table 6. It is apparent that the throttling of the VAV terminal has no influence on the sensation felt by the occupants concerning room temperature and air flow distribution. Although the concentration of dust increased proportionally with the air volume of the VAV terminal, the survey indicates that the occupants have not noticed this difference. When the air volume was throttled down to $6m^3/hm^2$ on the VAV terminal,there were no changes as to the sense of ambience of the occupants. The survey was separately conducted for the occupants at the perimeter and the interior zones. Nevertheless, the survey shows no difference between the two groups. Table 6, therefore, shows the results of the survey of the entire building.

3. Conclusion

A survey by a questionnaire was conducted to measure the indoor comfort on the parameters such as room temperature, air flow distribution, room ambience by varying the air volume of the VAV terminal. The following are the conclusion from the survey.

(1) The distribution of room temperature and air flow are satisfactory even during throttling of the VAV terminal.
(2) By throttling, the dust concentration increases in the room. If the dust concentration is taken into account, the minimum air volume should be between 6 and $8m^3/hm^2$. One must also change the operation of the fan coil terminal. The "High" speed operation of the fan coil terminals around the perimeter zones tend to keep the dust concentration down. In regards to the concentration of CO_2 and CO, there are no serious problems resulting from the throttling of the VAV terminal since there are adequate intakes of fresh air anyway.
(3) The dust concentration substantially increased by throttling the air flow of the VAV terminal. However, from the survey, the occupants have felt no difference in regard to the room ambience. Therefore, it is evident that there are no relation between the VAV air volume and the senses of the occupants as long as the temperature, humidity, and the air velocity are kept at comfort levels.
(4) In the VAV System, lowering the air volume is prefered to save the consumption of energy by the fans. However, with the VAV System and the fan coil units on the interior and the perimeter zones respectively, one can define the minimum air volume by the dust concentration and not by the temperature and air flow distribution.
(5) The dust concentration depends on the number of occupants and their activities. Therefore, controlling the minimum air flow by measuring the dust concentration in a room is the best way to save energy.

When the building load is taken into account, the VAV supply air volume can be regarded as the minimum air volume for intermediate and winter seasons. The fan power consumption also would be influenced by this minimum air volume setting. Since the minimum air volume is defined by the dust concentration, the minimum supply air would also be determined with the same criteria.

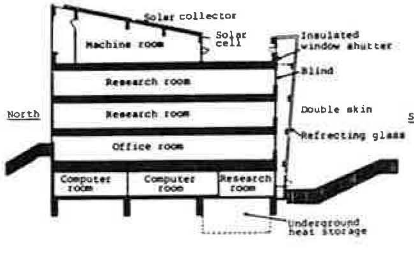


Fig.1 Section

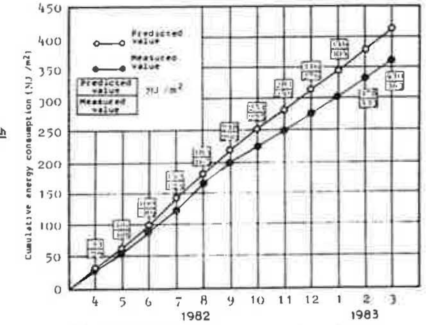


Fig.3 Energy consumption of entire building

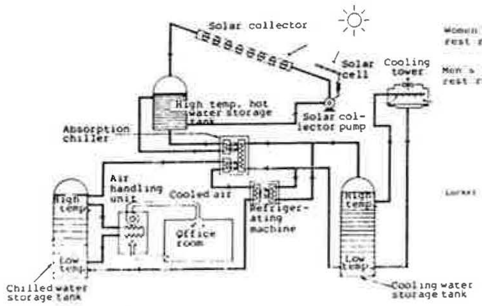


Fig.2 Air conditioning heat source system diagram (Summer)

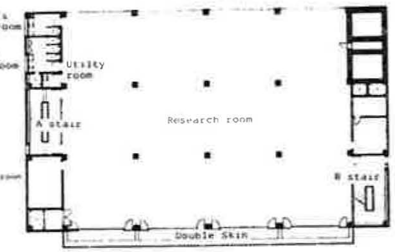


Fig.4 Plan of 2nd and 3rd floors

Table-1 An outline of the building

Location	:	Kiyose, Tokyo
Building area	:	$886.85m^2$
Gross floor area	:	$3,776m^2$
Structure	:	Reinforced concrete construction
Number of floors	:	1 story below and 3 stories above ground
Typical floor height	:	3.2m

Table-2 Outline of heating and air conditioning system

Air conditioning heat source	:	Absorption chiller 10RT Heat reclaim heat pump 10RT/15RT
Effective collector area	:	$220m^2$
Heat storage tank	:	$70m^3$ x 2
Air conditioning system	:	Int.— VAV system Per.— 4-pipe system F.C.U.

Table 3: Air volume of Fan Coil Unit

Floor	Air volume	Air volume per unit m^3/h	Air volume per floor area $m^3/h.m^2$
3	High/Low	660/295	8.2/3.7
2	High/Low	465/185	5.8/2.3

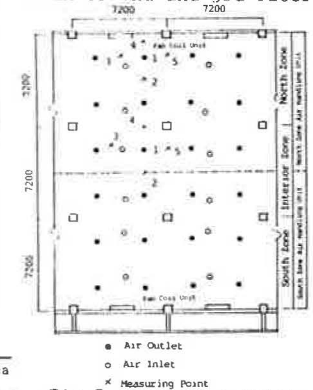


Fig.5 Measuring points of room air temperature and air velocity

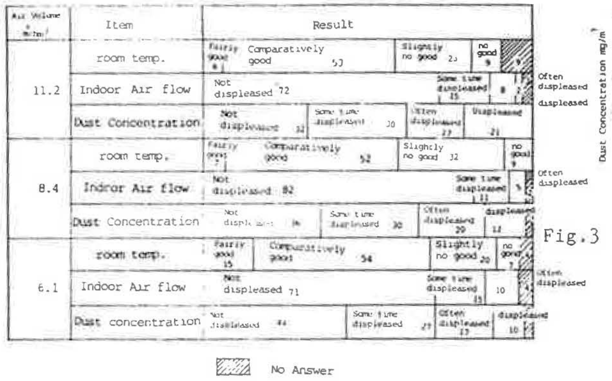
Table 4: Distribution of room air temperature and air velocity

Zone	No.	Measuring point	11.2 / 21.8 / HIGH: Air velocity	11.2 / 21.8 / HIGH: Air temp.	8.4 / 20.7 / HIGH: Air velocity	8.4 / 20.7 / HIGH: Air temp.	6.1 / 19.5 / HIGH: Air velocity	6.1 / 19.5 / HIGH: Air temp.	6.1 / 21.2 / LOW: Air velocity	6.1 / 21.2 / LOW: Air temp.
Northern Zone	1	Upper	0.37	24.5	0.35	22.9	0.11	25.1	0.11	26.0
		Middle	0.16	24.5	0.14	24.0	0.11	25.0	0	26.0
		Lower	0.26	24.5	0.13	23.9	0.12	25.0	0.02	26.2
	2	Upper	0.16	24.5	0.21	24.4	0.13	24.9	0.01	27.0
		Middle	0.16	24.7	0.12	24.3	0.07	25.0	0.05	26.9
		Lower	0.15	24.7	0.14	24.1	0.12	25.0	0.05	26.1
	3	Upper	0.13	27.1	0.48	22.2	0.44	23.9	0	27.1
		Middle	0.15	26.0	0.11	23.6	0.11	24.2	0	26.9
		Lower	0.20	25.5	0.05	24.1	0.01	24.5	0.05	24.8
	4	Upper	0.22	24.6	0.16	25.0	0	25.9	0	27.1
		Middle	0.16	24.5	0.11	24.9	0.05	25.9	0	27.1
		Lower	0.17	24.4	0.12	24.8	0.05	25.8	0.04	26.0
	5	Upper	-	-	0.11	25.1	0	26.3	0	27.3
		Middle	-	-	0.14	24.9	0	26.1	0.04	27.2
		Lower	-	-	0.12	25.0	0.10	25.8	0.01	26.0
Interior Zone	1	Upper	0.21	25.0	0.05	25.3	0	25.9	0	27.5
		Middle	0.17	24.9	0.05	25.2	0.01	26.0	0.01	27.3
		Lower	0.10	24.9	0.13	25.1	0	26.0	0.12	27.1
	2	Upper	0.14	25.0	0.05	25.0	0	26.0	0	27.3
		Middle	0.16	25.0	0.12	25.2	0.03	26.0	0	27.5
		Lower	0.17	24.8	0.15	24.9	0.04	25.9	0	26.9
	3	Upper	0	27.5	0.12	25.1	0	26.1	0	27.3
		Middle	0.08	26.4	0.15	25.2	0.07	26.1	0.08	27.2
		Lower	0.12	25.8	0.16	25.2	0.07	26.0	0.09	27.0
	4	Upper	0.12	25.0	0.14	25.0	0	26.0	0.05	27.2
		Middle	0.12	25.0	0.12	25.0	0.02	26.0	0.15	27.2
		Lower	0.12	25.0	0.16	24.9	0.12	26.0	0.08	27.0
	5	Upper	0.18	27.5	0.11	25.3	0	26.1	0	27.2
		Middle	0.21	26.5	0.12	25.5	0.15	26.2	0.04	27.2
		Lower	0.21	26.0	0.13	25.6	0.15	26.0	0.10	26.9

Table 5: Measured concentration of dust CO_2 and CO

VAV air volume $m^3/h.m^2$	FCU air volume	Dust concentration mg/m^3: Average	Dust concentration: Interior zone	Dust concentration: Perimeter zone	CO_2 concentration ppm	CO concentration ppm	Occupants
11.2	HIGH	0.12	0.12	0.12	780	2.0	97
10.8	LOW	0.15	0.16	0.15	770	2.8	91
8.4	HIGH	0.15	0.15	0.14	770	2.4	70
*8.6	LOW	0.14	0.15	0.14	600	2.4	88
6.1	HIGH	0.14	0.15	0.13	990	2.6	62
6.1	LOW	0.24	0.26	0.22	1020	3.0	61

Table 6. Survey of the occupants (Questionnaire)



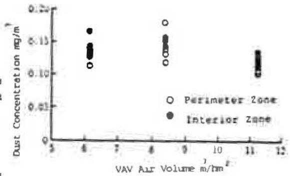


Fig.3 The relation between concentration of dust and VAV air volume

SYMPOSIUM

Controls: Source Modification and Air Cleaning