# Air Conditioning Simulation

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## 1.Introduction

In Japan in recent years, utilization of VAV air conditioners is increasing for accomplishment of an air conditioning project owing to their simplicity in structure, low cost, availability for energy conservation, etc. On the other hand, the number of buildings designed to have atrium is also in a trend of increase. However almost none of VAV devices for air conditioning in office in individual buildings are available with the ventilation pipes except with the discharging pipes. “The air conditioning system accordance with the variable air volume method” allows not only the air volume in each room to be changed but also the pressure to be concurrently altered. Despite the above, no consideration is made in performing the pressure control individual office. In almost all of the business buildings in Japan, much importance is hardly attached to the said pressure problems. However it seems likely that the pressure problems are considered with respect to the Century Tower Building designed by Foster Associates at the time of its design. We, the authors of this paper, constructed a computation model based on a variety of information concerning the building, and attempted to make calculation taking up a building having a large-scale atrium as an example with the use of “Heat and Air Environment calculation program” developed by us. With the room pressure problem during the time when the VAV air conditioning attempt is in progress and the problematic points of the air current directed toward the atrium, a method to solve such problems and deal with such problematic points was examined.

## 2.Outline of the calculation program

In constructing buildings in recent years, research for performance of the buildings is made in advance of starting the construction. Meanwhile even just for the purpose of the preparatory research, simulation technology is exhibiting rapid progress. In case of executing construction design, surrounding air current situation is often available in light environment, or with large-size buildings. However simulation is seldom made with the air environment or air currents in buildings in advance of the setup, notwithstanding that the air environment in the building in which people reside is a matter of importance. On the other hand, realization of good air environment exercises much influence also on the heat environment. The heat environment simulation programs in recent years include in themselves problem of air currents. However heat computation is regarded as a pivotal point of the problems, and almost all of the projects are quite simple ones with which none of air volume calculation, crack air volume computation, and heat balance calculation, and fans, filters, cooling coils, etc. as air conditioner elements can be installed. Thus calculation of the heat/air environment of the system can be made in accordance with a calculation formula almost the same as the one utilized at the time of designing air conditioners. The said program makes its possible to do simulation ranging from small-scale buildings to large-scale construction.

## 3. Outline of the computation formula

The program in question can arbitrarily make plans for ducts, cracks, FANs, and cooling coils, and makes it possible to control and calculate the temperature, humidity, pressure, $CO_2$ gas concentration in an arbitrary room. Removal heat quantity calculation of the air handling unit (hereafter abbreviated as AHU) is made in connection with sensible heat and latent heat based on convection current heat conduction computation.

The volume of air flowing through the ducts, cracks, and open mouth is calculated in accordance with Darcy-Wysbach’s formula. In other words, the said calculation is made by the local pressure loss and friction loss. Crack air volume calculation is made by parallel plate approximation of laminar airflows, and Colebrook’s calculation formula is used for friction resistance in the duct air volume computation. Change of the turbulent flow friction coefficient caused by the change of Reynolds number (hereafter abbreviated as *Re* number) is hyperbola-approximated, and the duct inside roughness and the friction coefficient by the *Re* number are calculated by applying them to Darcy-Wysbach’s formula. For that purpose, the friction coefficient in the duct air volume calculation is divided into 6 types of the Re number regions including laminar flow (Table 1). Meanwhile with the static

pressure air volume curve of the FAN which is hyperbola-approximated in consideration of the static pressure and air volume, a curve to allow the axis of the hyperbola whose axis comes to the minus side of the air volume to correspond to minus values of the static air volume one by one is selected.

## 3.1 Approximated ducts

In this paper , a duct which branches and blows out into the same room was approximated by a single turbulent flow duct. First all, approximation was made on the assumption that the temperature is 20.0 °C. After the duct was constructed, re-calculation made with the coefficient dependent on the temperature in the program corresponding to the change of the temperature and humidity together with change of the air volume. The air volume change by the *Re* number change according to the temperature change in connection with the duct constructed at this stage to be approximated is the same as that of the original turbulent flow duct. This is due to the fact the turbulent flow friction coefficient $\lambda$ is based equation shown below.

$$\lambda=r_0+(r_1/Re)+(r_2/Re^2) \quad (1)$$

This is furthermore due to the fact that the approximated duct has a term $r_0$ equivalent to the local pressure loss except $r_1$, and has a term of $r_2$ equivalent to a team which is to be a unit of the pressure in the formula of the pressure loss. In addition to the above, the coefficients of $r_0$, $r_1$, and $r_3$ make calculation of the data of the 6 groups (Table 1) corresponding to the *Re* number with respect to the individual ducts at the time of reading the duct data as described before and is in possession of the said data.

## 3.2 Calculation formula of the room pressure and room temperature

Calculation of the room pressure $P_i$ [pa] in the room $i$ in question is made as shown below from its pressure difference $\Delta P_{i,j}$ on the assumption that the pressure in the room j where open mouths, cracks ducts, etc. are connected is known.

$$P_i=\sum_{j=1}^{N}((\Delta P_{i,j}+P_j)s_j/(b_{i,j}+\sqrt{b_{i,j}^2+4\cdot a_{i,j}|\Delta P_{i,j}|}))/\sum_{j=1}^{N}(s_j/(b_{i,j}+\sqrt{b_{i,j}^2+4\cdot a_{i,j}|\Delta P_{i,j}|})) \quad (2)$$

$$\Delta P_{i,j}=(P_j-\rho_j\cdot g\cdot h_j)-(P_i-\rho_i\cdot g\cdot h_i)+\delta P_h-\delta P=a_{i,j}\cdot v^2+b_{i,j}\cdot v \quad (3)$$

$$\delta P_h=\rho_d\cdot g\cdot(h^*_j-h^*_i) \quad (4)$$

$\delta P$: Term concerning $r_2$ in Eq. (1)

$\rho_k$: Density of air passing though the open mouths, cracks, ducts, etc. [kg/m$^3$]

$s_k$: Representative area the open mouths, cracks and ducts

$v$: Passing air average speed of the open mouths, cracks, ducts, etc. [m/s]

$\rho_d$: Duct passing air density [kg/m$^3$]

$h_k$: Height from the floor to the pivotal point of a duct open mouth [m]

$h^*_k$: Absolute height [m]

$k$: Express $i$ or $j$. Volumetric flow ranging from $j$ to $i$ is plus.

The calculation formula of the room temperature was obtained from the stationary heat balance equation. This is a heat equilibrium formula of the heat balance of the sensible heat and latent heat of the room inflow/outflow air and the heat balance on the wall surface together with in-room generated heat quantity and in-room generated vapor quantity. On the other hand, the vapor are given by the in-room generated heat quantity on the simulation contains the sensible heat and latent heat together with the heat generation from the equipment and apparatus and solar-radiated inflow heat quantity. The calculation formula of the room temperature $t$ is as shown below.

$$t=[\{(\sum hP_{in,j}\cdot q_{in,j}-G\cdot w\cdot R_w)+h_q+\sum\alpha_k\cdot A_k\cdot t_{s,k}\}]/[G\cdot\{c_p(t)+w\cdot c_v(t)\}+\sum a_k\cdot A_k]$$

Where $G$ is given as shown below.

$$G=\sum q_{in,j} \quad (6)$$

$q_{in,j}$ : Volume of air flowing from the $j$ chamber to the camber in question [kg/s]

$a_k$: Convection heat conductivity in the inside of the chamber on the k-th wall in the chamber in question [kW/(m$^2$·K)]

$A_k$: Area of the k-th wall in the chamber in question [m$^2$]

$t_{s,k}$: Surface temperature in the inside of the k-th chamber of the chamber in question [°C]

$hp_{in,j}$: Enthalpy heat quantity [kJ/kg] of air flowing into the chamber though the ducts/cracks

$h_q$: In-room generated heat quantity [kW]

$c_p(t)$ : Isopiestic specific heat [kJ/(kg·K)] to be changed according to temperature, approximately 1.01kJ/ (kg·K)

$c_v(t)$ : Vapor specific heat [kJ/(kg·K)] to be changed according to temperature, approximately 1.8282 kJ / (kg·K)

$R_w$: Vapor latent heat quantity [kJ/kg], 2500.132 kJ/kg

$w$: Absolute humidity [kg/kg]

## 4. Calculation model

The data of the Century Tower were available for the calculation model of this time, and were constructed based on the obtained information (Figs. 1 and 2). The information is for construction of the 5$^{th}$ and 6$^{th}$ floors of the building. The structure of the building, which is fundamentally the same as that of the Tower except the 1$^{st}$ and 2$^{nd}$ floors, was designed with respect to the 3$^{rd}$ floor through the 10$^{th}$ floor in accordance with the said information. On the other hand, the offices are placed symmetrically with the atrium as their boundary point. The ducts, which are constructed based on the

information, are used by approximating then as described before. FAN data is constructed based on the information by being hyperbola-approximated as referred to before(fig. 3). No design of the elevator halls was formed.

## 4.1 Performance of the AHU for simulation

The AHU is constructed by a combination of an air cooling coil and an FAN. Coil specification are read by the data. It is possible to incorporate plural AHUs whose specification are different from each other into a single typo of simulation. Calculation results allow the individual data of the AHU to be outputted. Performance of the cooling coil of the AHU is shown in Fig. 4.

## 4.2 Pressure control in a room

Settlement of the pressure control was made with respect to the individual systems having respectively an air conditioner. Which this simulation for example, the damper after the ventilating flows were combined was designed to be regulated for the 3rd and 4th floors. In addition, when no heat was generated and no inflow of the outer air was seen, pressure control was made by means of the return VAV of the individual rooms with respect to the individual rooms.

## 4.3 Pressure settlement method to obstruct the atrium flow in case that the atrium is devoid of heat road

In case that the temperature and humidity in a room are controlled and the atrium is devoid of the heat load from the glass and wall of the atrium, the atrium flow can be obstructed by designation the pressure settlement values of the individual floors as the values in accordance with the calculation formula shown below. When indoor and outdoor temperature difference is brought about in the inside and outside of the room. However when the outer atmosphere on the earth is taken up as a criterion, the pressure difference $\delta P'_h$ is given as shown below.

$$\delta P'_h = gh/v(t_i, w_i) - gh/v(t_o, w_o) \quad (7)$$

$$v(t,w) = 287.055 \cdot (273.15+t) \cdot (0.9995+1.60777 \cdot w)/101325.0 \quad (8)$$

$g$= 9.80665m/s$^2$, $h$: Height [m],

$v(t,w)$: Specific volume assessed from dry-bulb temperature and absolute temperature [m$^3$/kg]

$t$: Dry-bulb temperature

$w$: Absolute humidity $i$: inside $o$: outside

By taking up a value of a height in accordance with the calculation formula shown above as a criterion, a control target value is determined. Utilization of the said value for the pressure control in the individual rooms makes it possible to liberate the flow from being directed from the individual floors to the atrium. However in case that difference is noted with the air density of the individual floors, the density difference and the open mouth position are related with each other. From this reason, it is necessary to make calculation with respect to the individual cases.

## 4.4 Calculation result

The individual Case patterns are listed in Tables 2. No difference is noticed with the north and south buildings for Case 1 though 5, and a symmetrical result is obtained. Therefore the result is described exclusively with the north building. In this connection, the result of the AHU and inputted heat quantity is tabulated exclusively with the 3rd and 4th floors owing to the restriction of the pages in this paper. On the other hand, the values of the atrium ventilation, stairs ventilation, and open mouth inflow quantity are given as the sum of the inflow and outflow owing to the restriction of the page in this paper. Therefore even in case that the numerical values are low, exchange air quantity is sometimes abundant.

### 4.4.1 Operation with the unrectified air conditioning design data

Although no operation of the air conditioning design is made as a system because the design is made with respect to the individual elements, investigation can be made to check to see if the performance strictly in accordance with the settled settled design is obtained by the operation by means of simulation. First of all, operation is made as Case 1 by being devoid of entire heat generation quantity. The outer atmosphere temperature at that time is 20°C, whereas the outer atmosphere relative humidity is 50%. As a result of the calculation, the volumetric flow from the FAN is obtained as design prediction values. None of natural ventilation is caused because no heat is generated, and no flow is produced on the upper and lower floors.

### 4.4.2 Heat input operation(room pressure control)

Case 2 reveals that control is made with the area of the glass window facing the outer atmosphere 92.642m$^2$, room temperature as 26°C, relative humidity as 50% and $CO_2$ gas concentration as 999ppm under the condition that the heat quantity applied to the individual offices is 24.5kW in Case 1. The crack of the sash was determined to be 22.5m long with the stability floor, whereas the 2 horizontal cracks with a length of 22.5m and 16 vertical cracks with a length of 2.96m were determined. Meanwhile with the mezzanine floor, 3 horizontal cracks with a length of

22.5m and 16 vertical cracks with a length of 2.97m were determined. For the room pressure settlement value in Eq. (7) is used so that the flow on the upper and lower floors will be reduced.

### 4.4.3 Applied heat quality reduction (room pressure control available and room pressure control unavailable)

Case 3 reveals that the applied heat quantity to be given to the individual offices was determined to be 17.15kW as 30% reduction in Case 2. Also for the pressure settlement in Case 3, the pressure settlement value in Eq. (7) is used likewise in Case 2. Even under the condition that the applied quantity is reduced 30%, the state of equilibrium in the room can be maintained by performing room pressure control.

Case 4 reveals that the applied heat quantity given to the individual offices is determined to be 17.15kW as 30% reduction, but this is the case that no pressure control is performed and affairs are physically the same as the duct state in Case 2. Under the condition that the applied heat quantity is reduced 30% and the affairs are the same in Case 2, the room pressure becomes too low.

### 4.4.4 Inputting the heat and window cracks to the atrium

To the prevision Case, the atrium unit was devoid of heat load and was placed in a closed state. In Case 5, the heat load brought about by solar radiation and window crack(air-tight sash)data are inputted into the atrium. The atrium has heat load. Therefore when the temperature is higher than in the lower part, it is necessary for the upper room pressure settlement value to be reduced by the amount of the temperature elevation corresponding to the pressure reduction quantity.

### 4.4.5 In case that the heat quantity is increased exclusively with the 3$^{rd}$ floor of the north building

Case 6 reveals that increased heat quantity more than in other room was supplied exclusively to the 3$^{rd}$ floor of the north building. The generated heat quantity in the room is 24.5kW with the 3$^{rd}$ floor of the north building, whereas the quantity is 17.15kWwith the other floors. Difference is noted with the heat generation quantity, and difference is likewise noted with the volume of air to be supplied to the room for the purpose of the temperature control of the 3$^{rd}$ and 4$^{th}$ floors of the north building. However since room pressure is controlled, the factors including the flow to the atrium are kept low enough without being different from the state in Case 5.

## 5.Conclusions

(1) It is possible, it is said, foe the VAV unit to correspond to the change, provided that the variation in the heat quantity is as small as 30%.However it is necessary for the variation of the room pressure to be checked. When no correspondence to the room pressure control is made, dangerous pressure lowering liable to allow the room pressure to be lowered to the extent of the outer barometric pressure more than 200Pa is seen.

(2) Also in case that cracks, e.g. windows are in existence, no mitigation of the room pressure lowering can be reached with the air-tight windows in this simulation. As long as the said result is taken into account, a considerable amount of the cracks to mitigate the room pressure lowering becomes necessary.

(3) When the atrium where space is connected with the offices is devoid of heat load, it is possible for the flow directed toward the atrium to be reduced as seen in Case 2.

(4) When the atrium where space is connected with the offices is in possession of heat load and no control is made with the atrium room temperature at the same office room temperature, a flow is produced in the atrium. In Case 5, production of ascending air current together with elevation of the temperature in the upper part was seen. When vigilant to the atrium temperature, room pressure control on the individual floors is possible. Despite the above, temperature difference is noted with the offices and the atrium. Thus exchange of air is brought about as seen in Case 5.

(5) When increase of heat land is seen exclusively with the south office on 3$^{rd}$ floor, pressure balance compels a large amount of air to be directed toward the atrium exclusively with return damper. In that, occasion, control of the individual floors makes it possible to reduce the flow. Meanwhile from the Comparative results in Case 5 and 6, it is explained that the outcomes with which almost none of difference is noted wore obtained with the floors except the floors providing the heat land with change. From this reason, it is imagined that just a small amount of influence in to be exercised on the other floors provided that room pressure control is continuously performed.

## Reference

1.ASHRAE Handbook, Fundamentals Volume, American Society of Heating,Refrigerating and Air-Conditioning Engineers,Inc,Atlanta,GA,1989

2. Ian Ranbot and Colin Davis,"Century Tower" , Water Mark publications(UK), September, 1992, Japanese Edition

3.Uichi INOUE, "Air-Conditioning Handbook", Maruzen Inc.,January, 1996,Japanese

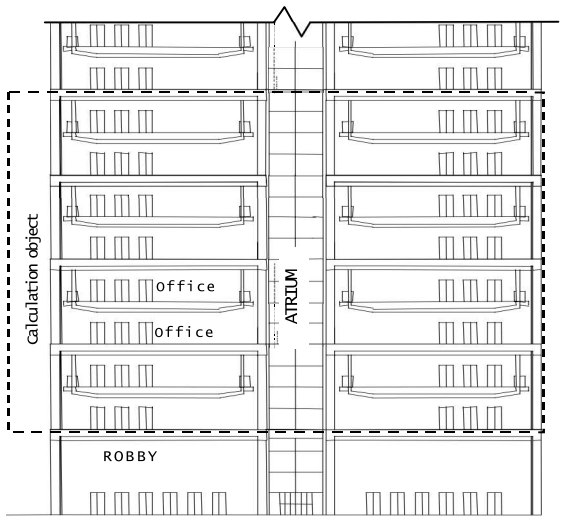


**Figure 1 Sectional view**

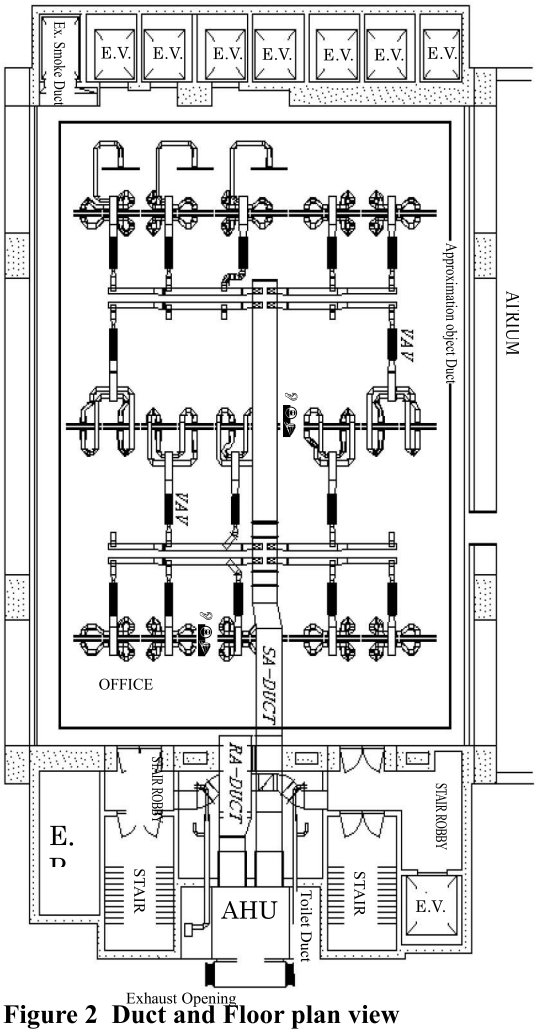


**Figure 2 Duct and Floor plan view**

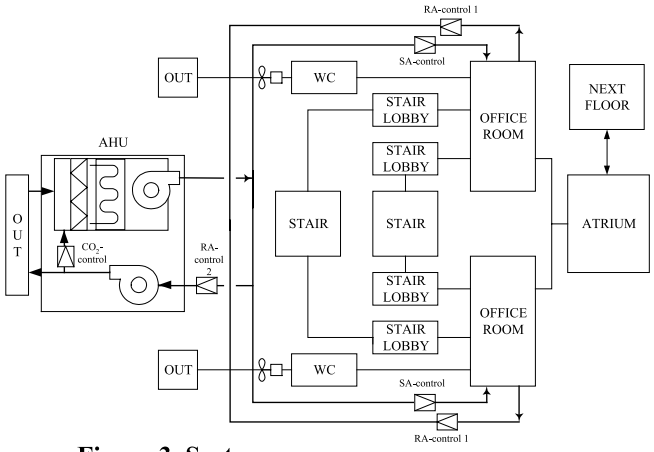


**Figure 3 System**

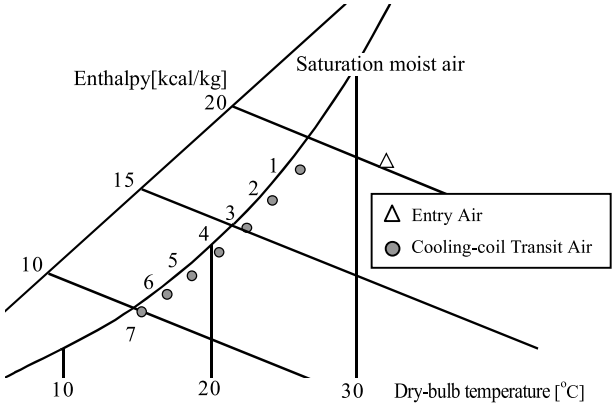


**Figure 4 Cooling-coil transit air condition**

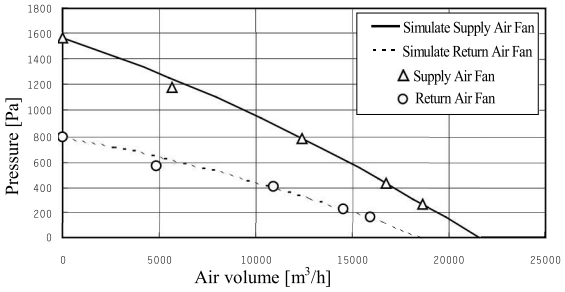


**Figure5 The air volume of Fan**

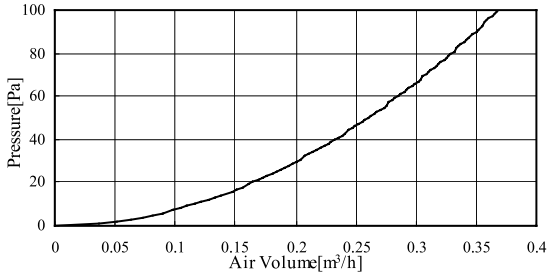


**Figure 6 The air volume of Fix sash**

| | 1 | 2 | 3 |
|---|---|---|---|
| 1 | Laminar flow. | | |
| 2 | 1000 | 4000 | 8000 |
| 3 | 8000 | 16000 | 40000 |
| 4 | 40000 | 80000 | 200000 |
| 5 | 200000 | 400000 | 1000000 |
| 6 | 1000000 | 2500000 | 7500000 |

**Table 1 Reynolds areas**

## Table2 Simulation Calculation result

| | | Case1 | Case2 | Case3 | Case4 | Case5 | Case6_N | Case6_S |
|---|---|---|---|---|---|---|---|---|
| Supply-air VAV | Condition | - | ON*1 | ON | ON | ON | ON | ON |
| Return-air VAV | Condition | - | ON | ON | ON | ON | ON | ON |
| RA-SA VAV | Condition | - | ON | ON | - | ON | ON | ON |
| ATRIUM ↑ Glass | Condition | - | - | - | - | ON | ON | ON |
| Temperature | ℃ | 20 | 30.6 | 30.6 | 30.6 | 30.6 | 30.6 | 30.6 |
| Relative humidity | % | 50 | 61.4 | 61.4 | 61.4 | 61.4 | 61.4 | 61.4 |
| $CO_2$ concentration | ppm | 350 | 350 | 350 | 350 | 350 | 350 | 350 |
| 3th-4th AHU | | | | | | | | |
| The amount of cooling-coil cold water | l/min | - | 250 | 250 | 250 | 250 | 250 | 250 |
| The number of cooling-coil trains | line | - | 8 | 8 | 8 | 8 | 8 | 8 |
| Cold-water inlet-port temperature | ℃ | - | 8.481 | 9.396 | 9.166 | 9.395 | 8.954 | 9.393 |
| Cold-water outlet temperature | ℃ | - | 14.059 | 14.118 | 13.879 | 14.118 | 14.106 | 14.120 |
| Cooling-coil load | kW | - | 97.291 | 82.365 | 82.208 | 82.349 | 89.872 | 82.453 |
| The amount of latent heat | kW | - | 25.585 | 25.585 | 25.583 | 25.586 | 25.547 | 25.583 |
| Amount condensation of water | kg | - | 36.830 | 36.830 | 36.238 | 36.843 | 36.805 | 36.840 |
| Input data | | | | | | | | |
| Stability The amount of heating | kw | - | 24.5 | 17.15 | 17.15 | 17.15 | 24.5 | 17.15 |
| Stability Outer wall sensible-heat acquisition | kW | - | 1.314 | 1.314 | 1.314 | 1.314 | 1.314 | 1.314 |
| Stability Staying-in-the-room number | person | - | 50 | 50 | 50 | 50 | 50 | 50 |
| Stability Human body occurrence heat quantity | kW | - | 5.83 | 5.83 | 5.83 | 5.83 | 5.83 | 5.83 |
| Stability Human body occurrence steam quantity | kg/h | - | 5.358 | 5.358 | 5.358 | 5.358 | 5.358 | 5.358 |
| Stability $CO_2$ occurrence quantity | $m^3/h$ | - | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 |
| Mezzanine The amount of heating | kW | - | 24.5 | 17.15 | 17.15 | 17.15 | 17.15 | 17.15 |
| Mezzanine Outer wall sensible-heat acquisition | kW | - | 1.314 | 1.314 | 1.314 | 1.314 | 1.314 | 1.314 |
| Mezzanine story Staying-in-the-room number | person | - | 50 | 50 | 50 | 50 | 50 | 50 |
| Mezzanine Human body occurrence heat quantity | kw | - | 5.83 | 5.83 | 5.83 | 5.83 | 5.83 | 5.83 |
| Mezzanine Human body occurrence steam quantity | kg/h | - | 5.358 | 5.358 | 5.358 | 5.358 | 5.358 | 5.358 |
| Mezzanine $CO_2$ occurrence quantity | $m^3/h$ | - | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 | 1.12 |
| Supply-air FAN occurrence heating value | kW | - | 7.2 | 7.2 | 7.2 | 7.2 | 7.2 | 7.2 |
| Return-air FAN occurrence heating value | kW | - | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 | 3.6 |
| 3th-4th Floor | | | | | | | | |
| Stability Temperature | ℃ | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 |
| Stability Relative humidity | % | 50.0 | 50.0 | 49.6 | 50.0 | 50.0 | 49.6 | 50.0 |
| Stability $CO_2$ concentration | ppm | 350 | 999 | 976 | 999 | 999 | 979 | 999 |
| Mezzanine Temperature | ℃ | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 | 26.0 |
| Mezzanine Relative humidity | % | 50.0 | 50.0 | 50.5 | 50.0 | 50.0 | 50.5 | 50.0 |
| Mezzanine $CO_2$ concentration | ppm | 350 | 999 | 1022 | 999 | 999 | 1026 | 999 |
| Stability | Pa | 53.259 | 9.09 | 9.09 | -202.97 | 7.20 | 7.30 | 7.30 |
| WC (Stability) | Pa | 51.786 | 7.85 | 7.85 | -203.00 | 5.97 | 6.07 | 6.07 |
| Mezzanine story | Pa | 53.259 | 7.95 | 7.95 | -204.09 | 6.14 | 6.20 | 6.21 |
| WC (Mezzanine) | Pa | 51.786 | 6.72 | 6.72 | -204.12 | 4.92 | 4.98 | 4.99 |
| Supply air (Stability) | kg/h | 9,652 | 9,456 | 7,068 | 6,994 | 7,061 | 9,519 | 7,070 |
| Return air (Stability) | kg/h | 9,189 | 9,049 | 6,663 | 7,166 | 6,559 | 8,876 | 6,450 |
| Toilet exhaust (Stability) | kg/h | 460 | 409 | 409 | -143 | 407 | 407 | 407 |
| Atrium discharge *2 | kg/h | -0.8 | 1.4 | 3.6 | -35.3 | -405.23 | -511.22 | -486.98 |
| Aperture inflow (Stability) | kg/h | 2.5 | -0.8 | -0.8 | 5.2 | -0.66 | -0.67 | -0.67 |
| Stairway discharge *2 | kg/h | 0.0 | 0.2 | 0.2 | 29.6 | 154 | 136.85 | 136.76 |
| Supply air(Mezzanine) | kg/h | 9,650 | 9,456 | 7,068 | 6,994 | 7,059 | 6,201 | 7,090 |
| Return air (Mezzanine) | kg/h | 9,186 | 9,047 | 6,658 | 7,167 | 6,564 | 7,009 | 6,454 |
| Toilet exhaust (Mezzanine) | kg/h | 460 | 408 | 408 | -143 | 406 | 406 | 405 |
| Atrium discharge *2 | kg/h | -0.5 | -1.0 | -2.2 | -25.1 | -360.3 | -403.4 | -460.76 |
| Aperture inflow (Mezzanine) | kg/h | 3.1 | -0.9 | -0.9 | 6.5 | -0.72 | -0.72 | -0.72 |
| Stairway discharge *2 | kg/h | 0.0 | 0.1 | 0.1 | 24.1 | 136.65 | 127.22 | 126.25 |
| Supply-air temperature | ℃ | 20 | 15.64 | 15.79 | 15.58 | 15.78 | 15.71 | 15.79 |
| Supply-air humidity | % | 50 | 89.59 | 87.04 | 86.91 | 87.02 | 88.49 | 87.04 |

| 5th-6th Floor | | Case1 | Case2 | Case3 | Case4 | Case5 | Case6_N | Case6_S |
|---|---|---|---|---|---|---|---|---|
| Stability Temperature | ℃ | 20.0 | 26.0 | 26.0 | 26.0 | 25.99 | 26.0 | 26.0 |
| Stability Relative humidity | % | 50.0 | 50.0 | 50.0 | 50.0 | 49.97 | 50.0 | 50.0 |
| Stability $CO_2$ concentration | ppm | 350.0 | 999.0 | 999.0 | 999.0 | 999 | 999 | 999 |
| Mezzanine Temperature | ℃ | 20.0 | 26.0 | 26.0 | 26.0 | 25.99 | 26.0 | 26.0 |
| Mezzanine Relative humidity | % | 50.0 | 50.0 | 50.0 | 50.0 | 49.98 | 50.0 | 50.0 |
| Mezzanine $CO_2$ concentrution | ppm | 350.0 | 999.0 | 999.0 | 999.0 | 999 | 999 | 999 |
| Stability | Pa | 53.259 | 6.82 | 6.82 | -205.18 | 5.33 | 5.33 | 5.33 |
| WC (Stability) | Pa | 51.786 | 5.59 | 5.59 | -205.21 | 4.12 | 4.12 | 4.12 |
| Mezzanine story | Pa | 53.259 | 5.68 | 5.68 | -206.30 | 4.34 | 4.34 | 4.34 |
| WC (Mezzanine) | Pa | 51.786 | 4.46 | 4.46 | -206.32 | 3.13 | 3.13 | 3.13 |
| Supply air (Stability) | kg/h | 9,652 | 9,456 | 7,069 | 6,992 | 7,080 | 7,090 | 7,090 |
| Return air (Stability) | kg/h | 9,189 | 9,051 | 6,668 | 7,149 | 6,666 | 6,731 | 6,731 |
| Toilet exhaust (Stability) | kg/h | 460 | 406 | 406 | -144 | 405 | 405 | 405 |
| Atrium discharge *2 | kg/h | 0.8 | 1.38 | 6.37 | -27.68 | -220.52 | -158.83 | -159.36 |
| Aperture inflow (Stability) | kg/h | 2.52 | -0.63 | -0.63 | 5.21 | -0.53 | -0.53 | -0.53 |
| Stairway discharge *2 | kg/h | 0 | 0.09 | 0.21 | 17.66 | 98.61 | 100.6 | 100.81 |
| Supply air(Mezzanine) | kg/h | 9,650 | 9,456 | 7,069 | 6,993 | 7,069 | 7,077 | 7,077 |
| Return air (Mezzanine) | kg/h | 9,186 | 9,049 | 6,655 | 7,151 | 6,674 | 6,739 | 6,739 |
| Toilet exhaust (Mezzanine) | kg/h | 460 | 405 | 405 | -144 | 404 | 404 | 404 |
| Atrium discharge *2 | kg/h | -0.55 | -1.36 | -7.26 | -8.3 | -97.11 | -43.44 | -43.2 |
| Aperture inflow (Mezzanine) | kg/h | 3.14 | -0.68 | -0.68 | 6.51 | -0.54 | -0.54 | -0.54 |
| Stairway discharge *2 | kg/h | 0 | 0.01 | -0.19 | 7.92 | 55.05 | 56.76 | 57.08 |
| Supply-air temperature | ℃ | 20 | 15.64 | 15.79 | 15.58 | 15.78 | 15.79 | 15.79 |
| Supply-air humidity | % | 50 | 89.59 | 87.04 | 86.9 | 87.05 | 87.06 | 87.06 |
| 7th-8th Floor | | | | | | | | |
| Stability Temperature | ℃ | 20.0 | 26.0 | 26.0 | 26.0 | 26 | 26.0 | 26.0 |
| Stability Relative humidity | % | 50.0 | 50.0 | 50.0 | 50.0 | 49.93 | 50.0 | 50.0 |
| Stability $CO_2$ concentration | ppm | 350.0 | 999.0 | 999.0 | 999.0 | 999 | 999 | 999 |
| Mezzanine Temperature | ℃ | 20.0 | 26.0 | 26.0 | 26.0 | 26 | 26.0 | 26.0 |
| Mezzanine Relative humidity | % | 50.0 | 50.0 | 50.0 | 50.0 | 49.94 | 50.01 | 50.01 |
| Mezzanine $CO_2$ concentration | ppm | 350.0 | 999.0 | 999.0 | 999.0 | 999 | 999 | 999 |
| Stability | Pa | 53.259 | 4.54 | 4.54 | -207.38 | 3.55 | 3.55 | 3.55 |
| WC (Stability) | Pa | 51.786 | 3.33 | 3.33 | -207.40 | 2.35 | 2.35 | 2.35 |
| Mezzanine story | Pa | 53.259 | 3.41 | 3.41 | -208.48 | 2.67 | 2.66 | 2.66 |
| WC (Mezzanine) | Pa | 51.786 | 2.20 | 2.20 | -208.51 | 1.47 | 1.46 | 1.46 |
| Supply air (Stability) | kg/h | 9,652 | 9,456 | 7,069 | 6,989 | 7,149 | 7,151 | 7,152 |
| Return air (Stability) | kg/h | 9,189 | 9,054 | 6,681 | 7,132 | 6,846 | 6,824 | 6,825 |
| Toilet exhaust (Stability) | kg/h | 460 | 404 | 404 | -145 | 403 | 403 | 403 |
| Atrium discharge *2 | kg/h | -0.8 | 1.92 | 15.97 | -13.55 | 60.56 | 32.71 | 32.6 |
| Aperture inflow (Stability) | kg/h | 2.52 | -0.46 | 0.46 | 5.24 | -0.27 | -0.37 | -0.31 |
| Stairway discharge *2 | kg/h | 0 | 0.06 | 0.43 | 3.04 | 16.44 | 18.13 | 18.37 |
| Supply air(Mezzanine) | kg/h | 9,650 | 9,456 | 7,069 | 6,990 | 7,117 | 7,123 | 7,123 |
| Return air (Mezzanine) | kg/h | 9,186 | 9,052 | 6,649 | 7,134 | 6,859 | 6,836 | 6,836 |
| Toilet exhaust (Mezzanine) | kg/h | 460 | 403 | 403 | -145 | 402 | 402 | 402 |
| Atrium discharge *2 | kg/h | -0.55 | -1.09 | -15.91 | 18.13 | 325.63 | 286.15 | 286.19 |
| Aperture inflow (Mezzanine) | kg/h | 3.14 | -0.43 | -0.43 | 6.54 | -0.34 | -0.34 | -0.34 |
| Stairway discharge *2 | kg/h | 0 | -0.02 | -0.49 | -12.32 | -87.47 | -81.92 | -81.77 |
| Supply-air temperature | ℃ | 20 | 15.64 | 15.79 | 15.58 | 15.77 | 15.79 | 15.79 |
| Supply-air humidity | % | 50 | 89.59 | 87.04 | 86.9 | 87.12 | 87.14 | 87.14 |
| 9th-10th Floor | | | | | | | | |
| Stability Temperature | ℃ | 20.0 | 26.0 | 26.0 | 26.0 | 25.98 | 26.0 | 26.0 |
| Stability Relative humidity | % | 50.0 | 50.0 | 50.0 | 50.0 | 50.02 | 49.99 | 49.99 |
| Stability $CO_2$ concentration | ppm | 350.0 | 999.0 | 998.0 | 999.0 | 998 | 998 | 998 |
| Mezzanine Temperature | ℃ | 20.0 | 26.0 | 26.0 | 26.0 | 25.98 | 26.0 | 26.0 |
| Mezzanine Relative humidity | % | 50.0 | 50.0 | 50.0 | 50.0 | 50.05 | 50.02 | 50.02 |
| Mezzanine $CO_2$ concentrution | ppm | 350.0 | 999.0 | 1000.0 | 999.0 | 1000 | 1000 | 1000 |
| Stability | Pa | 53.259 | 2.27 | 2.27 | -209.55 | 2.05 | 2.00 | 2.00 |
| WC (Stability) | Pa | 51.786 | 1.07 | 1.07 | -209.58 | 0.85 | 0.80 | 0.80 |
| Mezzanine story | Pa | 53.259 | 1.14 | 1.14 | -210.64 | 1.25 | 1.21 | 1.21 |
| WC (Mezzanine) | Pa | 51.786 | -0.06 | -0.05 | -210.66 | 0.05 | 0.02 | 0.02 |
| Supply air (Stability) | kg/h | 9,652 | 9,456 | 7,069 | 6,982 | 7,253 | 7,265 | 7,265 |
| Return air (Stability) | kg/h | 9,189 | 9,054 | 6,682 | 7,115 | 6,780 | 6,872 | 6,872 |
| Toilet exhaust (Stability) | kg/h | 460 | 401 | 401 | -145 | 401 | 401 | 401 |
| Atrium discharge *2 | kg/h | -0.8 | 0.4 | 14.1 | 29.2 | 232.74 | 292.66 | 287.36 |
| Aperture inflow (Stability) | kg/h | 2.5 | -0.2 | -0.2 | 5.3 | -0.22 | -0.22 | -0.22 |
| Stairway discharge *2 | kg/h | 0.0 | -0.1 | 0.3 | -14.5 | -156.72 | -147.09 | -147.01 |
| Supply air(Mezzanine) | kg/h | 9,650 | 9,456 | 7,069 | 6,983 | 7,184 | 7,195 | 7,195 |
| Return air (Mezzanine) | kg/h | 9,186 | 9,052 | 6,651 | 7,118 | 6,797 | 6,889 | 6,889 |
| Toilet exhaust (Mezzanine) | kg/h | 460 | 400 | 400 | -146 | 400 | 400 | 400 |
| Atrium discharge *2 | kg/h | -0.6 | -3.3 | -15.7 | 74.7 | 466.1 | 525.14 | 525.14 |
| Aperture inflow (Mezzanine) | kg/h | 3.1 | -0.1 | -0.1 | 6.6 | -0.14 | -0.14 | -0.14 |
| Stairway discharge *2 | kg/h | 0.0 | -0.3 | -0.6 | -45.5 | -216.54 | -210.54 | -210.47 |
| Supply-air temperature | ℃ | 20 | 15.64 | 15.79 | 15.57 | 15.77 | 15.78 | 15.78 |
| Supply-air humidity | % | 50 | 89.59 | 87.04 | 86.88 | 87.26 | 87.26 | 87.26 |

*1 ON works so that it may become the given conditions.

*2 ↑ Office flow is made into +.