Development of HVAC System to Lower the Conveyance Energy and Building Height

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Key words: HVAC system, Conveyance energy, Energy saving, Building height, Aerodynamic design, Induction mechanism, Increasing air volume

ABSTRACT: The new HVAC system is developed to lower the conveyance energy and building height using IAV (Increasing Air Volume) technique. IAV units which are equipped in each zone carry out air-conditioning and supply fresh air by induction of outdoor air in main duct. The design program which decides size of OAHU and IAV unit according to air conditioning load and fresh air demand of each zone is presented. The control system is developed to operate efficiently HVAC system and IAV unit, so that individual zone operation and well-deal with partial load and IAQ problem are possible. The new system is investigated in model building and makes more profit in conveyance energy, size of air conditioning facilities room and building height than VAV system. But in construction cost it is worse by about 15 percentage.

Nomenclature

C_P : pressure coefficient
D : nozzle diameter [mm]
EA : exhaust air
i : enthalpy [kJ/kg]
OA : outdoor air
p : pressure [mmAq]
Q : air flow rate [m^3/h]
RA : return air
SA : supply air
t : dry-bulb temperature [℃]
U : air velocity [m/s]
x : absolute humidity [kg/kg]

Greek symbols

ρ : density [kg/m^3]

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Subscripts

in : nozzle inlet
out : nozzle outlet

1. Introduction

As natural resources get exhausted together with the rapid advance of industrialization and environmental contaminants produced by energy conversion process emerge as a global problem, the high efficiency of the HVAC system applied to buildings becomes the most important subject in building design. The amount of energy consumption for air conditioning accounts for 40 to 50% of the total energy consumption of the modern buildings. The conveyance energy, accounting for about 40% of energy consumption of air conditioning, takes up around 16 to 20% of the total energy consumption of the buildings. To save energy, it is required to develope a new HVAC system by enhancing the conveyance efficiency required for building air conditioning.[1-3]

In the meantime, buildings in large cities get higher to make more space available, which requires a plan for lowering construction expenses by reducing the floor height and improving the economic value. For that purpose, it is necessary to develope a new HVAC system that can reduce the building height by minimizing the space where the duct system of air conditioning is installed, and improve the economic efficiency of buildings.[4-5]

In this paper, the development of the HVAC system will be described, which can reduce the conveyance energy required for air conditioning and reduce the floor height of buildings.

2. Overview of the HVAC system

A new HVAC system can reduce the required power for conveyance system of air conditioning because it uses water instead of air as a main carrier medium of heating and cooling, which is transfered to the heating & cooling coil built in IAV air conditioning unit that is distributed and installed in the ceiling of the indoor air conditioning zone. It can also adjust the amount of fresh air required in each air conditioning zone accurately and secure the air volume required for air conditioning economically, because it uses the air volume increasing technology by nozzle to induce fresh air at the IAV air conditioning unit where the quantitative induction is available, and to blow fresh air to the air conditioning zone with indoor circulating air. In other words, the new HVAC system can (1) adjust a room temperature and humidity according to the characteristics of heating and cooling load for each room, and (2) provide a pleasant living environment by offering the required amount of fresh air for each room exactly in accordance with requirements and make great contribution to the better Indoor Air Quality (IAQ).

On the other hand, the new HVAC system can curtail the cross section of the duct required for air conditioning by drastically reducing the pneumatic conveying volume. When it comes to steel frame structure, IAV air conditioning unit and duct system can be installed in free space between steel frame beams so that it is possible to reduce the construction expensses and drastically lower the floor height of buildings.

2.1 Configuration of the HVAC system

The newly developed HVAC system is configured as shown in the Fig. 1. The hot & cold water suppliers for indoor air conditioning load and outdoor air handling unit (OAHU), which deal with the required amount of fresh air and provide to the air conditioning zone, can be installed in the air conditioning room of each floor. The IAV air conditioning unit, the individual unit of the newly developed HVAC system

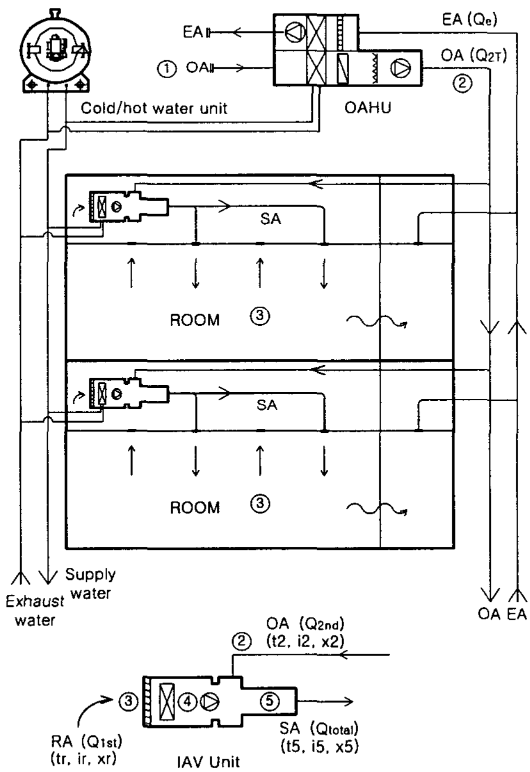

Fig. 1 Schematic diagram of HVAC system.

Table 1 Design state of HVAC system

Item		Mark	DB temp.	Enthalpy	Moisture content	Air flow rate
Outdoor		①	t_0	i_0	x_0	-
OAHU outlet		②	t_2	i_2	x_2	Q_{2T}
Room		③	t_r	i_r	x_r	-
IAV unit	1st air (RA)	③	t_r	i_r	x_r	Q_{1st}
	2nd air (OA)	②	t_2	i_2	x_2	Q_{2nd}
	Coil outlet	④	t_4	i_4	x_4	-
	Supply air (SA)	⑤	t_5	i_5	x_5	Q_{total}

tem, is installed in the air conditioning zone. The IAV air conditioning unit is equipped with a supply fan, a heating & cooling coil and a filter, so it eliminates dust caused by indoor air circulation through the unit, and heats & cools air to a required temperature to blow out indoors. On the other hands, it also blows fresh air offered from OAHU with indoor circulation air by induction effect of internal pressure difference in nozzle with connect to supply fan. Along with this, for the purpose of designing the HVAC system and optimal operation, the HVAC system consists of the program for designing the capacity of the air conditioning equipment according to the air conditioning load and the required amount of fresh air, and the control system that can optimally adjust the amount of fresh air supplied and controls the indoor temperature and humidity for each room. Table 1 shows the design state of the newly developed HVAC system.

2.2 Design of the HVAC system

Figure 2 indicates the psychrometric chart upon cooling system of the newly developed HVAC system. As the figure shows, upon cooling it cools and dehumidifies the required fresh air at a temperature around 17℃ DB and 90% RH in OAHU and indoor circulating air at a little lower state points (absolute humidity, dry bulb temperature, enthalpy) than the above condition in the IAV air conditioning unit installed for each zone. And the indoor circulating air is supplied to air conditioning zone along with the induced fresh air. Each number in Fig. 2 represents the followings.

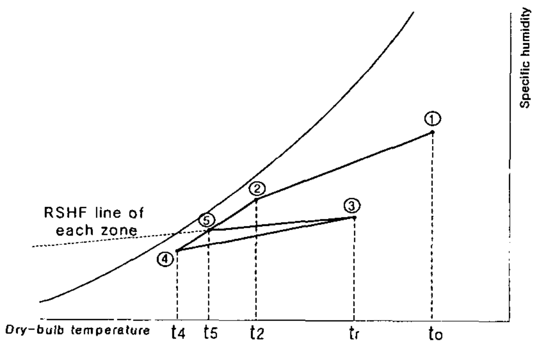

Fig. 2 Psychrometic chart of HVAC system for cooling.

① State point of outdoor air design conditions
② State point of OAHU cooling coil outlet air
③ State point of indoor design conditions
④ State point of IAV air conditioning unit cooling coil outlet air
⑤ State point of IAV air conditioning unit exist air (State point of mixed air of ② and ④)
①→② Cooling and dehumidifying process through OAHU cooling coil
③→④ Cooling and dehumidifying process through IAV cooling coil
⑤→③ State change in indoor space

Figure 3 indicates the psychrometric chart of heating process when the IAV air conditioning unit is installed in the perimeter zone. For case of the interior zone, the indoor circulating air

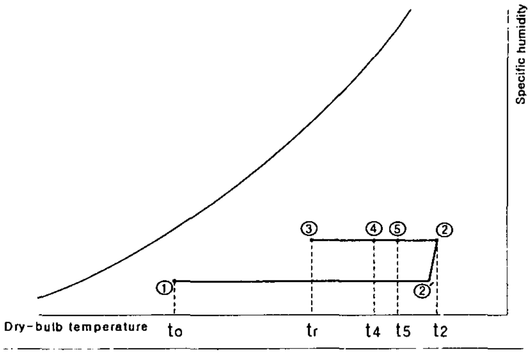

Fig. 3 Psychrometic chart of HVAC system for heating.

is not heated at the IAV air conditioning unit, and only the fresh air is heated and humidified in OAHU up to the state of taking charge of both outdoor and indoor heating load and is supplied to each air conditioning room. After the fresh air is mixed to the indoor circulating air at IAV air conditioning unit, the mixed air is blown out indoors. In the figure, each sign indicates the followings.

①→②' Heating process through OAHU Heating Coil
②'→② Heating and humidifying process through OAHU humidifier
③→④ Heating process through IAV Heating Coil
⑤→③ State change in indoor space

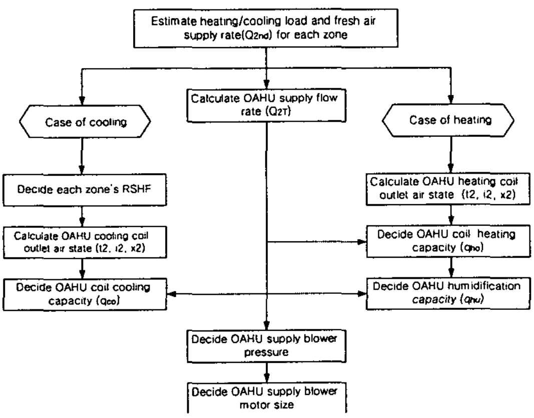

Fig. 4 Flow chart for selection of OAHU.

Figure 4 indicates the flow chart to select the capacity of the air conditioning device for outdoor fresh air handling. For each case of the cooling, heating and humidifying times, it determines the supply air volume of the air conditioning device, the state of outlet air, the heat capacity of the cooling coil, and the specifications of the supply fan and the motor. Figure 5 shows the flow chart to select the capacity of the IAV air conditioning unit in air conditioning zone. It also classifies the cooling, heating and humidifying times to determine the indoor circulating air volume of the IAV air conditioning unit, the outlet temperature of the cooling coil and its cooling heat capacity, and the static pressure of the fan.

3. Development of the IAV conditioning unit

The IAV air conditioning unit is an individual unit of a new HVAC system, and it should have its intended performance to make the HVAC system operate effectively.

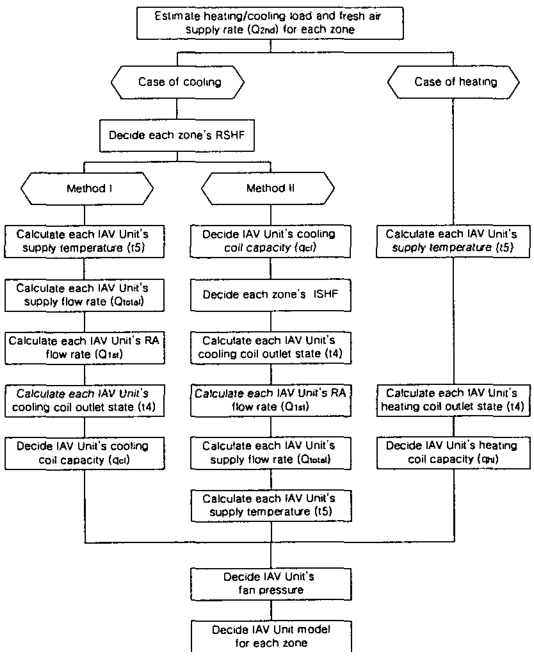

Fig. 5 Flow chart for selection of IAV unit.

The IAV air conditioning unit plays a role to handle the heating & cooling load of the air conditioning zone, and supply the fresh air by inducing it from OA duct. To that end, the IAV air conditioning unit is designed as follows. In other words, it consists of a structure that circulates the first air (primary air, indoor circulating air) of handling the indoor heating & cooling load by the fan installed in the IAV air conditioning unit, induces and mixes the second air (secondary air, outdoor fresh air) by using the blowing energy of the first air, and supply the mixed air to air conditioning zone. At this time, the first air is cooled or heated by passing through the heating & cooling coil.

In the development of the IAV air conditioning unit, the key issue is to develope the controlling technology that can determine the supply air volume required for satisfying the heating & cooling load of the air conditioning zone, and fresh air volume requied for maintaining the indoor air quality at the same time. To that end, it realizes the intended performance by applying the induction mechanism of nozzle's pressure[6-7] drop to the design of the IAV air conditioning unit. In other words, it attaches the nozzle to the front end of the fan within the IAV air conditioning unit to generate the pressure difference between indoor circulating air and fresh air, and adjusts the pressure difference by attaching the automatic damper to the connection duct where fresh air is supplied, so that it can control the induced volume of fresh air. Figure 6 shows the conceptual map of the IAV air conditioning unit. Each part of the figure represents the followings: ① indoor air inlet, ② indoor air circulation controlling damper, ③ air filter, ④ air cooling coil, ⑤ air heating coil, ⑥ fan, ⑦ nozzle and induction chamber, ⑧ differential pressure damper for adjusting the volume of fresh air, ⑨ diffuser for reacquiring the static pressurec ⑩ discharge duct, ⑪ air outlet, and ⑫ duct for supplying outdoor fresh air (OA).

3.1 Design of the air induction structure

To analyze the IAV air conditioning unit's performance of outdoor fresh air induction, we conducted the numerical simulation and an actual test for the flow field within the basic model consisting of nozzle and induction chamber, and evaluated the effect of the nozzle's geometrical configuration and flow characteristics on the models' induction process. We also presented the basic data required for design of the IAV air conditioning unit by finding out the induction rate according to the pressure drop by nozzle and the flow speed at the nozzle throat.

Figure 7 indicates the three-dimensional analysis model of the IAV air conditioning unit. When it comes to the evaluation of induction performance, we inquired into both flow phenomenon and induction performance by changing the nozzle configuration (Diameter ratio of inlet and outlet, $D1 : D2$) and the flow rate of the first air. Figure 8 to Figure 10 show the results of numerical simulation in case the di-

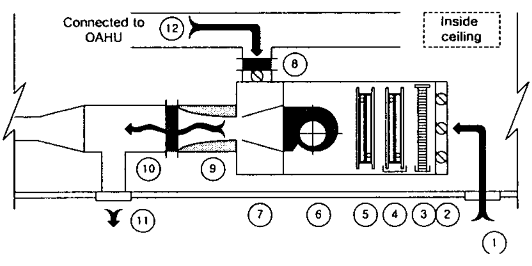

Fig. 6 Schematic diagram of IAV unit.

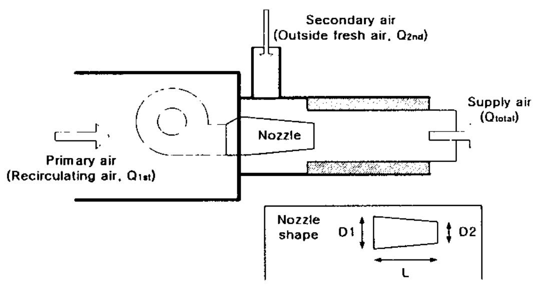

Fig. 7 Analysis model of IAV unit.

ameter of nozzle inlet and outlet is 250 : 175 (mm), and the fan speed of fist air is 500 CMH.

Figures 8 and 9 illustrate the velocity vector in each cross section. Being blown into the nozzle inlet, the first air is accelerated in speed and decreased in pressure while passing through

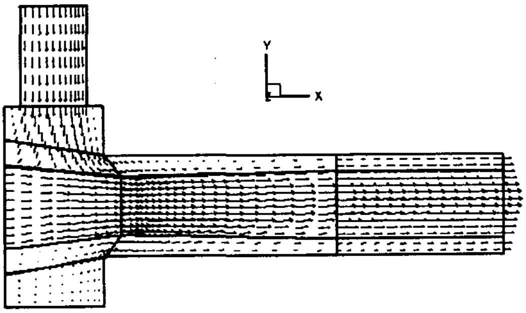

Fig. 8 Velocity vectors on center plane.

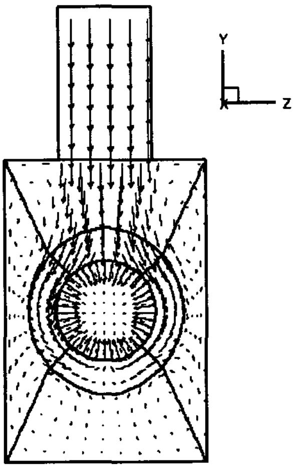

Fig. 9 Velocity vectors on y-z plane.

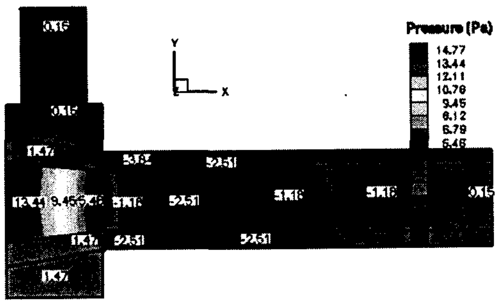

Fig. 10 Pressure contours on center plane.

the nozzle. And the resulted pressure drop of the first air generates the pressure difference between nozzle outlet and the outside to induce the second air to the induction duct and to mix second air with first air in the chamber. This induction effect can be indicated as the induction ratio (K, Q_{2nd}/Q_{total}), which is the proportion of induced air to the entire mixed air. Figure 10 illustrates the pressure distribution on the X-Y section. The pressure coefficient, C_P is defined as follows as the dimensionless number that can be applied to the internal flow field.

$$C_P = \frac{p_{in} - p_{out}}{\rho U_{out}^2} \tag{1}$$

Here, the subscript *in* and *out* represent the inlet and outlet section of the nozzle respectively.

Figure 11 is a graph that shows the flow rate of the second induced air to flow rate of the first air. It illustrates the comparison between results of numerical simulation and experiment data according to the shape of the nozzle. It suggests that the flow rate of induced air for each nozzle shape increases in proportion to the flow rate of the first air.

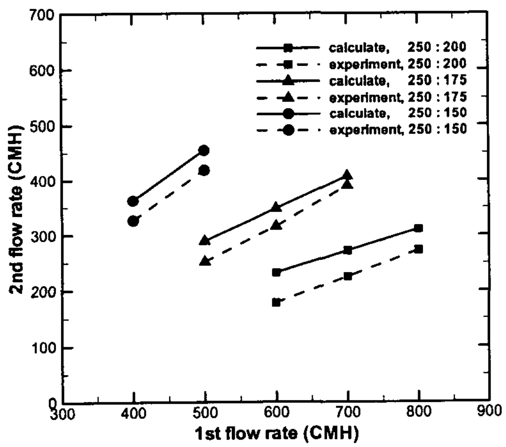

Fig. 11 Relation of 1st flow rate to 2nd flow rate.

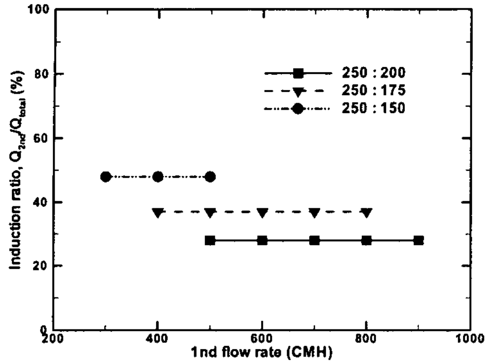

Fig. 12 Induction ratio for 1st flow rate and nozzle shape.

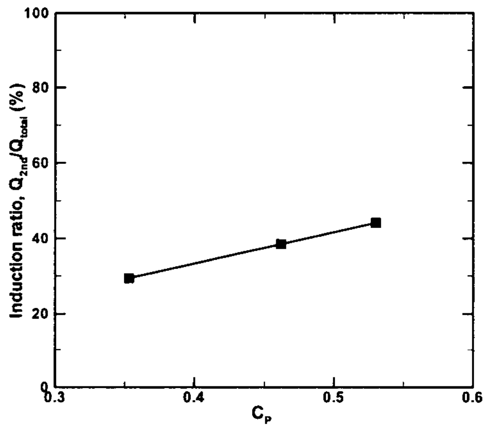

Fig. 13 Induction ratio for C_P.

Figure 12 illustrates the induction ratio according to the flow rate of the first air. Once the nozzle shape is determined, the flow rate of first air is in proportion to pressure drop like the Bernoulli equation, so the induction ratio of the nozzle becomes constant. Meanwhile, Fig. 13 shows that the induction ratio simply becomes the function of the dimensionless number; pressure coefficient that indicates the flow characteristics including the nozzle shape. As the figure shows, the induction ratio is in proportion to the C_P, the pressure coefficient of flow.

3.2 Manufacturing and performance-evaluating of the standard IAV air conditioning unit

Based on the research of the basic induction structure of the IAV air conditioning unit and test results of a prototype, we manufactured the standard IAV air conditioning unit applicable to an actual HVAC system for each model and conducted a test on performance and reviewed its applicability. To make the IAV air conditioning unit a real product, first it is necessary to have a model that can cope with the air conditioning load of various air conditioning zones, and to secure the fresh air induction performance appropriate to the air conditioning space for maintaining IAQ. It is also necessary to take a measure to minimize the operation noise, develope the low pressure-loss and high efficient filter, and reduce the unit weight and the installation size. In consideration of those matters, we manufactured the standard model of the IAV air conditioning unit and presented its specifications in Table 2. The standard model is based on the supply flow rate in a range of between 1,200 CMH and 2,700 CMH, and de-

Table 2 Specification of IAV unit

Specification		Model					
		IAV1200	IAV1500	IAV1800	IAV2100	IAV2400	IAV2700
Air flow (m^3/h)		1,200±150	1,500±150	1,800±150	2,100±150	2,400±150	2,700±150
Unit external static pressure (mmAq)		12	12	15	15	15	15
Cooling capacity (kcal/h)	Sensible	4,200	5,250	6,300	7,350	8,400	9,450
	Total	6,000	7,500	9,000	10,500	12,000	13,500
Heating capacity (kcal/h)		8,400	10,500	12,600	14,700	16,800	18,900
Water flow (lpm)		20	25	30	35	40	45
Motor power (HP)		1/3	1/3	1/2	1/2	3/4	3/4

signed to secure 10 to 35% of the fresh air induction ratio.

The standard IAV air conditioning unit is designed for being installed in the ceiling within the 500 mm in height and is equipped with the damper for adjusting the induction ratio of the fresh air. It is also equipped with the trap to discharge the condensation water well upon cooling and has acoustic absorbent/noise proof to maintain operational noise below 45 dB.

Figures 14 and 15 illustrate the design drawing for manufacturing the standard IAV1800 model and the unit manufactured accordingly.

Figure 16 illustrates the schematic diagram of experimental apparatus for induction performance test of the standard IAV air conditioning unit. The pressure (P_{oa}) of OA duct was kept in some range using inverter. Flow Measuring Systems (FMS) were set up in induction duct and discharge duct for measuring Q_{2nd} and Q_{total}, and Pressure Transducers were used for measuring P_{oa}, P_{unit} and P_{dis}. As the opening rate of differential pressure damper was changed, the flow rate and pressure for each points were measured and saved in datalogger.

Figure 17 shows the performance curve of the IAV1800 model. The IAV air conditioning unit operates in connection with the entire HVAC system and the discharge duct system for air distribution after unit. So, as a result of the test, the operation performance of each IAV air conditioning unit is influenced by the difference (ΔP, $P_{dis}-P_{unit}$) between the pressure (P_{dis}) of the discharge duct and pressure (P_{unit}) of the

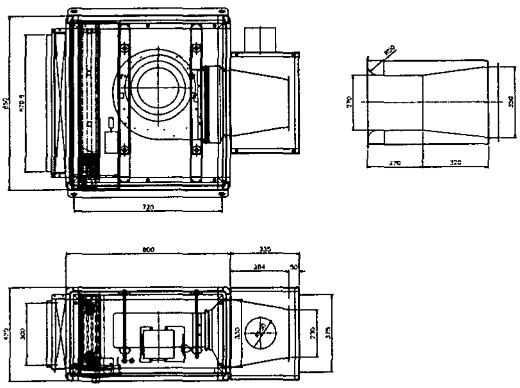

Fig. 14 Design drawing of standard IAV unit.

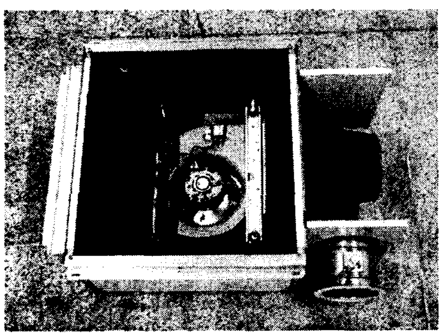

Fig. 15 Standard IAV1800 unit.

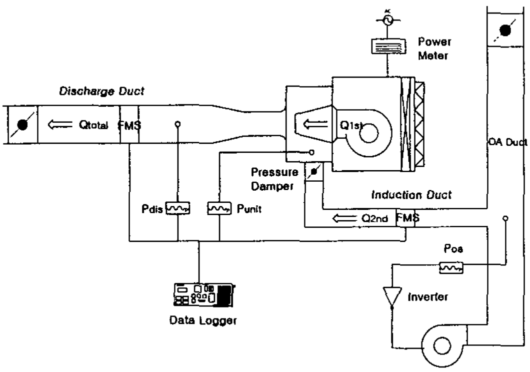

Fig. 16 Schematic diagram of experimental apparatus.

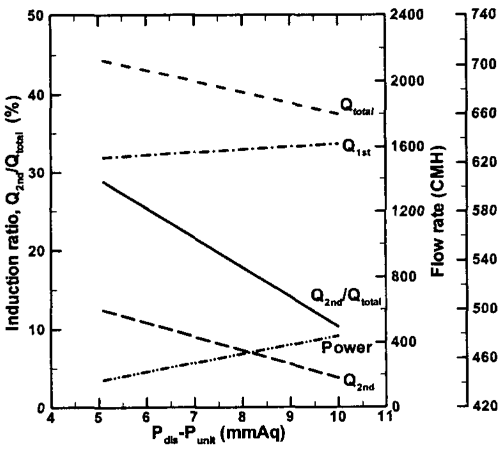

Fig. 17 Performance charts of IAV1800 unit.

mixing chamber after damper along with the induction structure of a unit. Therefore, as the figure shows, in any given IAV air conditioning unit, it is possible to indicate each flow rate, induction performance and power consumption as being based on the difference of static pressures between P_{dis} and P_{unit}, and to conduct the operation control for the IAV air conditioning unit by using this performance curve.

4. Evaluation of application of the HVAC system

4.1 Application of the HVAC system

To find out the applicability and operational characteristics of the new HVAC system that can reduce the conveyance energy and secure the economically efficient building, and present the good method of popularization, we conducted a heating & cooling test by installing an new HVAC system in simulator modeling after the air conditioning zone of buildings. We presented an installation model of the HVAC system by installing the duct system and the piping system appropriate for the IAV air conditioning unit and HVAC system, and also intended the simulator for being used for the purpose of the operation and applicability test by having heating & cooling operation test device and operation controller including the adjustment of induction ratio of fresh air. Figures 18 and 19 show the outline of the simulator and the actually installation.

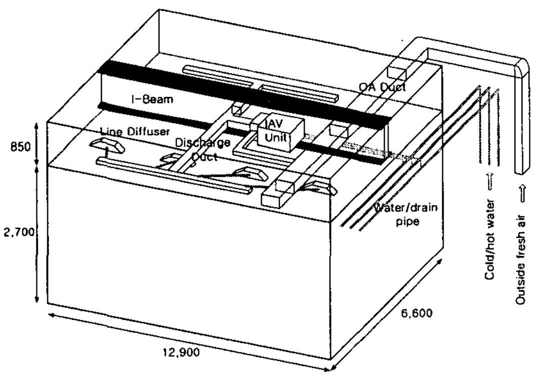

Fig. 18 Schematic diagram of simulator.

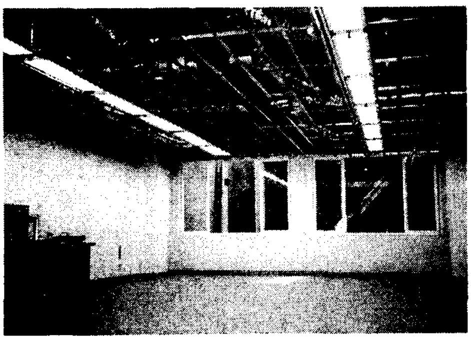

Fig. 19 Inside view of simulator equipped with new HVAC system.

From the performance chart of IAV air conditioning unit installed in simulator, the relations of induction ration (K, %) and pressure difference (ΔP, mmAq) is established as follows.

$$K = C_1 \Delta P + C_2, \quad C_1 = -7.09 \quad C_2 = 39.2 \qquad (2)$$

For evaluating the control ability of induction flow rate, air flow rate for each duct and induction ratio were measured as pressure difference were changed. Figure 20 to 22 show the results of the one of experimental cases, i.e. pressure difference is 1.3 mmAq and induction ratio is 30%. Figure 20 illustrates the change of opening rate of differential pressure

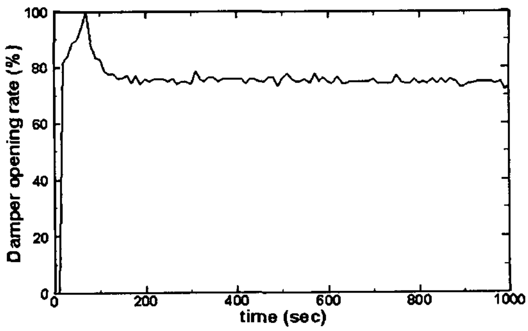

Fig. 20 Change of opening rate of differential pressure damper for time.

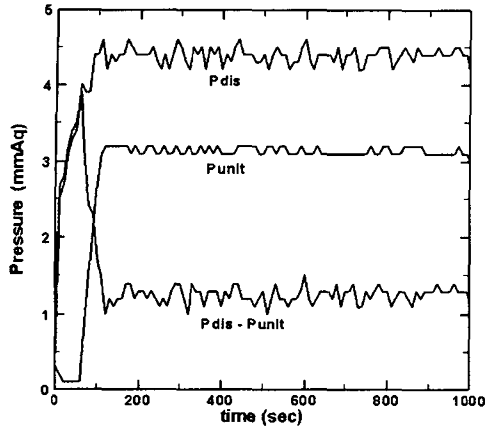

Fig. 21 Change of pressures for time.

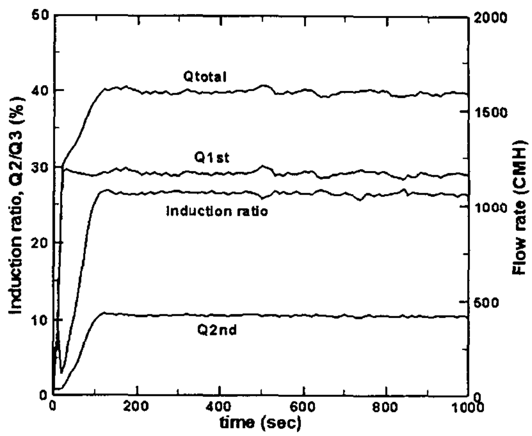

Fig. 22 Change of flow rate and induction ratio for time.

damper for time. 0% of opening rate means damper is closed completely and 100% of opening rate means open completely. While starting, opening rate increased rapidly and after control process of induction structure, opening rate was kept to about 75%. Figure 21 illustrates the change of P_{unit}, P_{dis} and ΔP ($P_{dis}-P_{unit}$) for time. As IAV air conditioning unit working, P_{unit} and P_{dis} went up together and after about 100 seconds, two values were kept in constant to a some extent. And pressure difference followed well 1.3 mmAq of design value. Figure 22 illustrates the change of Q_{total}, Q_{1st}, Q_{2nd} and induction ratio, K. for time. As shown in figure, induction ratio was kept to about 27% with a little error for design value.

In the meantime, we manufactured the capacity selection program of air conditioning device for maximizing the usability of the new HVAC system, so that engineers may design the newly developed HVAC system easily. The equipment capacity selection program is roughly classified into outdoor fresh air handling unit (OAHU) and IAV air conditioning unit. By doing so, it is possible to calculate the spec. of OAHU such as flow rate, coil capacity and fan size, and analyze the state point on the psychrometric chart according to the heating & cooling load of buildings and the required amount of fresh air, and it is also designed for making easy the calculation of spec. of IAV air conditioning unit and the selection of model of it.

4.2 Comparison with the existing HVAC system

To evaluate the applicability and economic efficiency of the new HVAC system, we conducted the design of the new HVAC system by using the equipment capacity selection program for common office buildings. We also

Table 3 Specification of model building

Location	Seoul (latitude: north 37'34")
Type	Commercial office
Ground flow area	1,774 m^2 (537 py.)
Air conditioning area	Office: 1,267 m^2, Corridor and Elev. Hall: 245 m^2
Story height	4 m
Ceiling height	2.7 m
Structure	Steel structure curtain wall

Table 4 Design conditions of outdoor air

Season	DB temp. (℃)	RH (%)	Enthalpy (kJ/kg')	Moisture (kg/kg')
Summer	31.2	63.6	78.17	0.0183
Winter	−11.3	63	−9.17	0.008

Table 5 Design room conditions

Season	DB temp. (℃)	RH (%)	Enthalpy (kJ/kg')	Moisture (kg/kg')
Summer	26	50	0.0440	0.01263
Winter	20	40	0.0243	0.00831

Table 6 Design conditions of cooling load

Room	Person/m^2	Lighting load (W/m^2)	OA load (W/m^2)	Occupants (W/person)	
				SE	LA
Office	0.1	20	29	57	62
Corridor, Elev. Hall	0.1	20	-	57	62

compared and reviewed those results with the variable air volume conditioning system-applied design results. Table 3 show the overview of a model building, while Table 4 and Table 5 indicate the design criteria for outdoor air temperature & humidity and indoor air temperature & humidity. And Table 6 indicate the design conditions of cooling load. Based on those conditions, we analyzed the heating & cooling load for each time zone by ASHRAE 1992 CLTD/SCL/CLF, and presented those results to Table 7.

Table 8 to Table 11 suggest that the conveyance energy of the newly developed HVAC system decreases 40% against that of the variable air volume conditioning system. The actual size of air conditioning is reduced 50%, whereas the floor height is lowered 250 mm.

However, as for the construction expenses of mechanical facilities, the new HVAC system is increased 15% over that of the variable air volume conditioning system, because the expenses

Table 7 Cooling and heating load for each time

Item		Cooling load (W)						Heating load (W)
Type		Area person kW	Sensible				LA	
			Time (hour)					
			11	13	15	17		
Outside	Roof	0 m^2	0	0	0	0		0
	Wall	467 m^2	826	1,494	2,113	2,735		6,694
	Partition	63 m^2	101	101	101	101		609
	Glass	207 m^2	31,540	36,176	27,854	19,829		23,778
Inside	Occupants	152 person	8,662	8,662	8,662	8,662	9,369	
	Lighting		37,732	37,732	37,732	37,732		
	OA		36,807	36,807	36,807	36,807		
Infiltration			0	0	0	0	0	21,399
Total load			115,667	120,972	113,268	105,866	9,369	52,480

Table 8 Conveyance energy for each system (kW)

Item	New system	VAV system
AHU (OAHU)	3.7	15
IAV unit	4.5	-
FCU	1.12	1.12
Total	9.32	16.12

Table 9 Size of air conditioning facilities room

Item	New system	VAV system
Size of room	15.9 m^2	33.2 m^2

Table 10 Construction costs for each system (₩)

Item	New system	VAV system
Duct construction costs	63,019,834	83,721,508
Pipe construction costs	56,546,266	26,714,444
Equipments costs	87,926,265	70,155,775
Total costs	207,492,365	180,591,727

Table 11 Building height for each system

Item	New system	VAV system
Story height (Including ceiling height, 2.7 m)	3.8 m	4.05 m

for piping construction and air conditioning device increase.

In the meantime, it is meaningful to point out difference between Conventional Induction Unit system (IDU system) and new HVAC system. Two systems have the induction process as core mechanism, but application scope, induction structure and control ability are great different in two systems. In IDU system, working flow rate and heating & cooling capability are limited because first air (outdoor fresh air) is conveyed from OAHU to induction unit in condition of high speed and high pressure. So IDU system is suitable for the load of perimeter zone. And for simple induction structure of nozzle, individual unit operation and accurate induction control are difficult in IDU system. On the other hand, IAV air conditioning unit in new HVAC system is equipped with the fan, so new HVAC system has wide range of working flow rate and can be designed for main HVAC system of building. Adopting the induction structure using pressure-difference control, new HVAC system is capable of accurate contorl of induction flow rate. Also new HVAC system can be operated individually for condition of each zone.

5. Conclusions

As large-scale buildings like skyscrapers are actively constructed, it is required to develope a new HVAC system that can improve the economic efficiency of buildings, for example, reducing the construction expenses and using the space more usefully based on an energy-saving design method and reduction of the facility-installed space. In this paper, we presented the development contents and applicability evaluation of the new HVAC system that can enhance the energy saving and economic efficiency of buildings, and the conclusions are as follows.

(1) To reduce the conveyance energy for air conditioning, the new HVAC system uses hot & cold water as a main carrier medium, and uses an air volume increasing technology to minimize the installation space of the air conditioning duct and reduce the floor height of buildings.

(2) As far as the configuration of the HVAC system is concerned, both hot & cold water supplier and air conditioner for outdoor fresh air handling are installed at the main air conditioning room, and the individual IAV air conditioning unit is installed at each air conditioning zone. And both the design of the HVAC system and selection of equipment capacity are conducted according to heating & cooling load and the required amount of fresh air for each air conditioning zone.

(3) The IAV air conditioning unit is the air conditioning unit of a new concept that performs the heating & cooling of each room, and induces outdoor fresh air as much as it is necessary to supply indoors. We found out the basic structure of a unit by using the aerodynamical analysis means.

(4) A controlling system is developed for operating the entire HVAC system and each IAV air conditioning unit. By doing so, people can operate this system individually at each room, and cope with the load fluctuation and maintain the indoor air quality.

(5) As a result of conducting an actual design by applying the new HVAC system to a model building, it is found that the new one has advantages over the existing variable air volume conditioning system in terms of conveyance energy, the actual size of air conditioning and floor height of building, but generates the construction expenses of mechanical facilities by 15% higher.

Acknowledgements

This research was performed for Energy Technology R&D Program by the Korea Energy Management Corporation and in cooperation with Mirae Engineering Co., Ltd. and Dawon A.C Co., Ltd.

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