Total/Sensible Heat Exchanger based on adsorption by ion power

HI-PANEX-ION

Technical Brochure

Passion for Green Innovation

SEIBU GIKEN

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A. Heat exchanger cassette “HI-PANEX-ION”

1. Introduction

As environmental issues, such as global warming, depletion of ozon layer, and sick-house syndrome (sick building), have been getting much attention in recent years, enhancement of IAQ(Indoor Air Quality), together with energy saving, is urgently required in the air-conditioning community. In order to meet this requirement, Seibu Giken developed and has started to market a completely new type of heat exchanger named “HI-PANEX-ION” based on desorption by ion power in 1998.

Based on the fact that Seibu Giken has been the pioneer in commercialization of the heat exchanger in Japan since 1975, “HI-PANEX-ION” was developed fully utilizing various technologies and know-hows accumulate during the course of vast research expertise for honeycomb-structured dehumidifiers (by specially developed silica-gel) and volatile organic compounds recovery (using specially developed zeolites) rotors.

“HI-PANEX-ION”, which is based on desorption by ion power, adsorbs moisture by hydration force, which is a different adsorption mechanism from others such as for silica-gel (capillary adsorption and other actions） , resulting in the special feature of no accumulation nor transfer of odor. Even though odor may be exhausted into a room from such sources as humidifiers for the room or dusts accumulated in piping ducts, it can be quickly taken away to outdoor. Sick-house syndrome due to formaldehyde released from building materials in newly built houses or chemical substances such as solvents has gained much attention in recent years. However, these chemicals are less adsorption-transferred and more quickly taken away to outdoors in “HI-PANEX-ION” compared with the silica-gel type, resulting in more energy saving and enhancement of IAQ.

2. History of developments of heat exchanger rotors

1975 Commercialization of heat exchanger rotors, aided by the Innovative Technology Development Fund from the Japanese Ministry of Trade and Industry

（Ⅰ）A type of wash-coated lithium-chloride in asbestos paper

1978 Production and sales of a heat exchanger named “Thermo-lung”, by a joint venture with other company

（Ⅱ）A type of wash-coated lithium-chloride in flameproof paper

1981 Development and commercialization of an aluminum-based heat exchanger rotor named “HI-PANEX”

（Ⅲ）A type of aluminum-sheet + coated fine grain silica-gel

1989 Development and commercialization of a ceramic-based heat exchanger rotor

(Ⅳ) A type of ceramic-sheet + synthesized silica-gel

1998 Development and commercialization of a heat exchanger rotor based on desorption by ion power

(Ⅴ) A type of aluminum-sheet + coated fine-powdered ion-exchange resin

※ Total heat exchanger rotors using asbestos paper might have been shipped until 1981.

3. Structure of HI-PANEX-ION

3-1. Compact design, simple and tough

The main body has a very simple structure.

The rotor is made of specifically fabricated aluminum sheets which, together with a casing, a driving motor and a driving belt, constitute the HI-PANEX-ION. This rotor is slowly rotated at about 20~24 rpm. This rotor is divided into a supply zone and an exhaust zone of air, and the exhaust heat contained in the exhaust air is transferred and accumulated in the rotor element. Thus transferred heat is supplied to the supply air at the supply zone after rotating half of the circumference of the rotor. In this way, only air is ventilated while most energy of heat and moisture contained in the exhaust air is circulated back to the room. In addition, the rotor is subject to the counter flows at each half of the circumference of the rotor rotation, resulting in a self-refreshing action against blocking of the honeycomb structure.

3-2. Specifically made aluminum rotor

The secret in the high-efficiency heat exchange action of HI-PANEX-ION lies in the rotor element. (Figure 1) The material for the element is a high-purity aluminum sheet (for a special design aiming at anti-corrosion, a sheet after an anti-corrosion treatment is used), on which ion-exchange resins having high moisture adsorption/desorption capability and agents against bacteria and molds are strongly coated. This material is put in place alternately to form a corrugated (wave-shaped) and a liner (plain-shaped) sheets as shown in Figure 2, which is then formed into a cylindrical shape to make a rotor. The shape of the rotor is selected so that it has an extremely high surface area (total surface area after expansion is 2000-3000 m^2/m^3) and at the same time yields the least pressure loss of air passing through it, resulting in an extremely high heat transfer coefficient by the mixture of laminar and turbulent flows passing through it. In this way, the sensible heat (temperature) and the latent heat (humidity) are exchanged at high efficiency, by the aluminum sheets and ion-exchange resins, respectively.

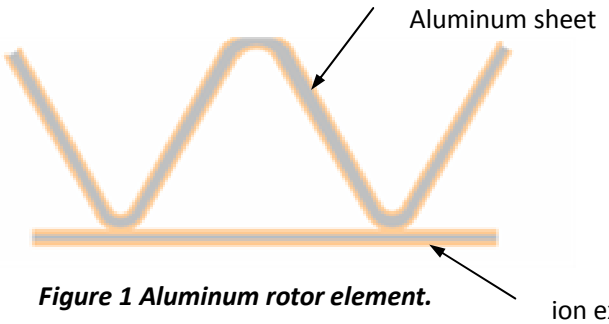


Figure 1 Aluminum rotor element.

4. Special features of HI-PANEX-ION

a. High efficiency in heat exchange

Ion-exchage resins having a strong adsorption capability are uniformly and strongly coated over the surface of aluminum sheets, resulting in high stability, durability and efficiency.

b. Little odor transfer

Because ion-exchange resins are used as the latent heat (moisture) exchange agent, odor accumulation/transfer is much reduced compared with the conventional types using silica-gel.

※For more detail, please refer to ”B. About adsorption by ion power” in page 40.

c. Anti-bacteria/mold effects

Because anti-bacteria/mold agents are used, IAQ (Indoor Air Quality) is enhanced.

d. Good anti-corrosion characteristics

Because the surface of aluminum sheets is covered with adhesive agent for ion-exchange resins, anti-corrosion characteristics are good. If special anti-corrosion capability is required, it is possible to make an anti-corrosion treatment over the surface of the aluminum sheets.

e. Chemically stable adsorbents

For HI-PANEX-ION rotors, ion-exchange resins having a high chemical stability are used. Even if process air contains such aggressive molecules as hydrogen sulfates or oxygen sulfates, efficiency deterioration does not occur, and customers can use the system with confidence.

f. Flame resistance (compliant ASTM E84)

The rotor element is made of incombustible aluminum sheets, resulting in customers' confidence in its use. **FSI**(Flame spread index) : 0 , **SDI**(Smoke developed index) : 25

g. High strength

Compared with conventional products using various fiber papers, HI-PANEX-ION suffers much less expansion and contraction due to temperature variation, and no deterioration in strength even in use at high humidity, resulting in high strength.

h. Exceptionally high energy saving

Because of the recovery of exhaust heat during ventilation, running cost for air conditioning is much reduced. <Reduction of carbon dioxide emission: 14 ton-C/year/unit (PAC-2900T)>

i. Many models exist and order-made specification is possible.

There are 20 models in the standard specification. Orders by special specifications can be accepted.

5. Materials of rotors for HI-PANEX-ION and its applications

Table1

Type	Material	Heat exchange	Features	Applications	Operation temperature(Note1)
PA	Aluminum sheet	Hygroscopic	Air-conditioning desiccant cooling corrosion resistance	office building,research facility school,hall,hospital,hotel	-20 - 60℃
				various ships、pool factory・animal laboratory	
		Non-hygroscopic			
		Hygroscopic	Resistance corrosion	various ships、pool factory・animal laboratory	-20 - 60℃

(Note1) In case of use in a state where it is close to the limits indicated below please inquire us.

6. Specification table of HI-PANEX-ION

Table2

	Model	Airflow(m^3/h) Face velocity(2 - 5m/s)	Motor 3Φ/200V 50/60Hz	Weight (kg)	Dimension(mm)		
					A	B	C
1	PAC- 500T-U	540 ～ 1,720	0.1	90	800	340	520
2	PAC- 600T-U	790 ～ 2,610		105	900	340	630
3	PAC- 700T-U	1,150 ～ 3,580		115	1000	340	730
4	PAC- 800T-U	1,700 ～ 4,680		125	1100	340	830
5	PAC- 950T-U	2,150 ～ 6,600		140	1200	340	980
6	PAC-1050T-U	2,540 ～ 7,600		140	1200	340	1050
7	PAC-1100T-U	3,040 ～ 9,150		150	1300	340	1150
8	PAC-1200T-U	3,500 ～ 10,850	0.2	160	1400	340	1250
9	PAC-1300T-U	4,200 ～ 12,690		190	1500	340	1350
10	PAC-1500T-U	5,600 ～ 16,470		235	1700	340	1550
11	PAC-1700T-U	7,250 ～ 21,140		315	1900	340	1750
12	PAC-1900T-U	9,000 ～ 26,370		360	2100	340	1950
13	PAC-2150T-U	11,700 ～ 33,700	0.4	390	2350	420	2200
14	PAC-2400T-U	14,400 ～ 39,980		700	2700	500	2480
15	PAC-2600T-U	17,100 ～ 47,050		760	2900	500	2680
16	PAC-2900T-U	21,400 ～ 58,710	0.75	890	3200	500	2980
17	PAC-3100T-U	24,200 ～ 67,190		1030	3400	550	3180
18	PAC-3500T-U	31,000 ～ 85,670	1.5	1280	3800	600	3580
19	PAC-3900T-U	38,500 ～ 106,580		1490	4200	600	3980
20	PAC-4200T-U	44,500 ～ 123,750		1650	4500	600	4280

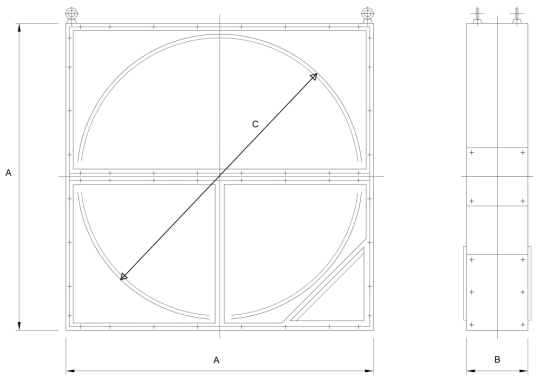


Figure 2

PA C – 1500 T

① ② ③ ④

① **Material of element** — **PA : Aluminum sheet**

② **Category of product** — **C : Casette**

U: Unit

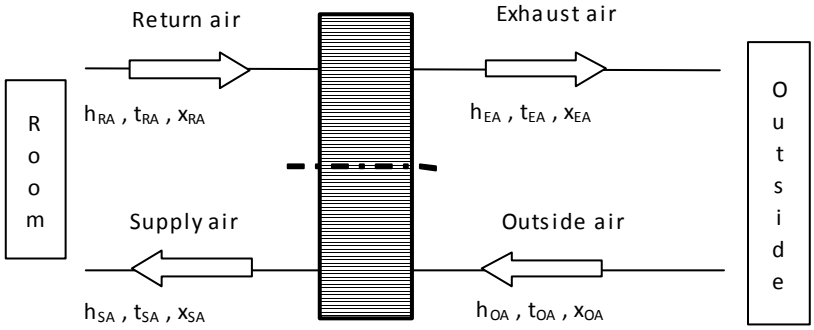
③ **Diameter of rotor element**

④ **Application of product** — **T : Total heat**

S : Sensible heat

7. Efficiency of HI-PANEX-ION

Efficiency of HI-PANEX-ION is obtainable from the formulae shown below, by referring to Figure 3. If the flow rates of supply and return air are the same, the efficiencies for both the supply and return sides become the same.



h : enthalpy (total heat) kJ/kg(DA) t : dry bulb temperature C°

x : absolute humidity kg/kg(DA)

Figure 3

Table 3

	Efficiency (Supply air)	Efficiency (Exhaust air)
Sensible heat exchange efficiency (temperature)	$\eta_t = \frac{t_{OA} - t_{SA}}{t_{OA} - t_{RA}} \times 100\%$	$\eta_t = \frac{t_{EA} - t_{RA}}{t_{OA} - t_{RA}} \times 100\%$
Latent heat exchange efficiency (moisture)	$\eta_x = \frac{x_{OA} - x_{SA}}{x_{OA} - x_{RA}} \times 100\%$	$\eta_x = \frac{x_{EA} - x_{RA}}{x_{OA} - x_{RA}} \times 100\%$
Total heat exchange efficiency (enthalpy)	$\eta_h = \frac{h_{OA} - h_{SA}}{h_{OA} - h_{RA}} \times 100\%$	$\eta_h = \frac{h_{EA} - h_{RA}}{h_{OA} - h_{RA}} \times 100\%$

* The sensible heat exchange efficiency η_t and the latent heat exchange efficiency η_x are both close to the total heat exchange efficiency η_h, thus one may put $\eta_t \fallingdotseq \eta_x \fallingdotseq \eta_h$ for practical applications.

The heat exchanger HI-PANEX-ION has a special function of recovering both sensible heat (temperature) and latent heat (moisture) during ventilation at high efficiency.

The working principle of HI-PANEX-ION in its exhaust recovery is explained using Figure 4. This figure illustrates the heat recovery in summer on a psychrometrics chart. If a sensible heat exchanger is used to recover heat between **OA** (outside air) and **RA** (room air), the heat recovery is effective only for the sensible heat (temperature difference) and the amount of recovered heat is depicted by **R'**.

If HI-PANEX-ION is employed for the heat recovery, the recovered heat is effective for both the sensible (temperature difference) and latent (moisture) heats (thus, a total heat exchanger) with the amount of recovered heat depicted by **R** and the load for an air conditioner to be reduced to **L**, enabling much larger heat recovery to be made. By employing HI-PANEX-ION, the intake air in summer is supplied to a room after outside air is pre-cooled and dehumidified while preheated and humidified in winter, resulting in large energy saving and thus offering ideal energy saving equipment.

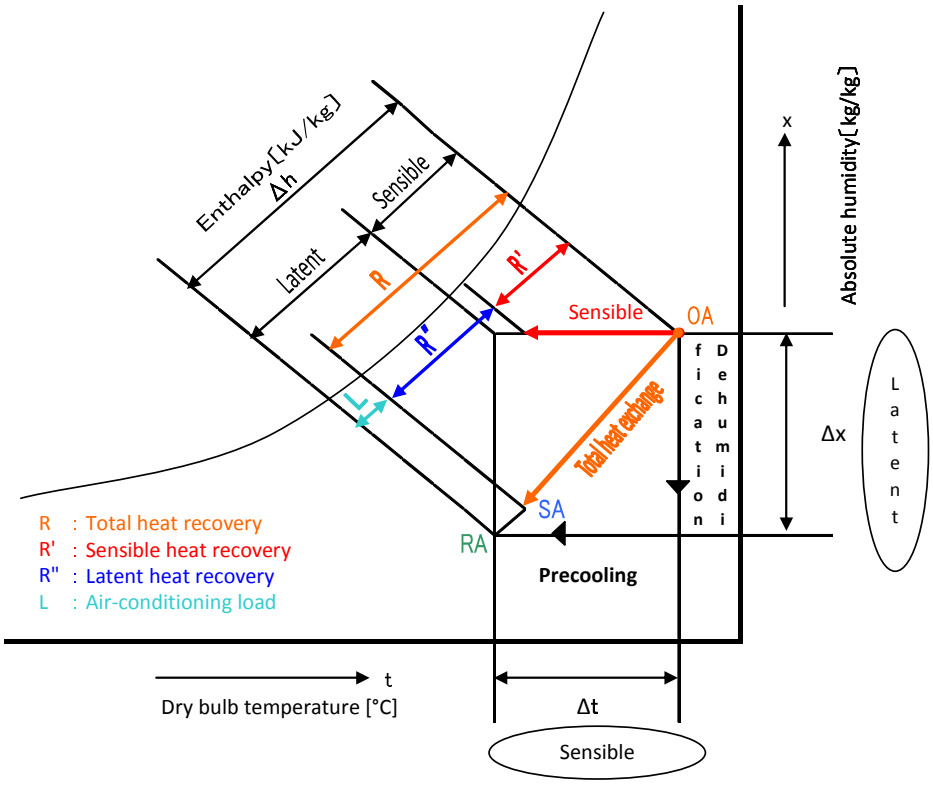


Figure 4

8. Selection from different models of HI-PANEX-ION

Figure 5 shows the model selection diagram drawn based on the European Standards (EUROVENT).

<How to read model selection diagram>

(Remark) The following explanations, based on Figure 6, are given only to show the principle of the model selection, drawn on the JIS (Japanese Industrial Standards), which is slightly different from the European Standards (EUROVENT).

8-1. For equal air flow rates

In case when air flow rates for supply and exhaust air are the same, enter the air flow rates in m3/h in the ordinate in the model selection diagram and find a most suitable model for your use by taking into account of the diameter of the rotor element in the model type. Here, select a model so that the face velocity of the rotor element in the abscissa be around 2.0-5.0 m/s. Once the model is selected in this way, extrapolate the intersection of the flow rate with the model type upward to the table above for the equal air flow rates (1.0) to get the efficiency A and downward to come to the point B from which one gets the static pressure loss in the ordinate. Confirm that the face velocity C in the abscissa to be around 2.0-5.0 m/s.

<Example>

Table 4

	Supply air	Exhaust air
Air flow rate	30,000 m^3/h	30,000 m^3/h
Model	PAC-2900T	
Efficiency	76 %	76 %
Static pressure loss	140 Pa	140 Pa
Face velocity	2.8 m/s	2.8 m/s

8-2. For different air flow rates

①In case when air flow rates for supply and exhaust air are different, enter the two air flow rates in m^3/h in the ordinate in the model selection diagram and find a most suitable model for your use by taking into account of the diameter of the rotor element in the model type, and seeing the model to satisfy your two flow rates. Here, select a model so that the face velocity of the rotor element in the abscissa be around 2.0-5.0 m/s.

②Then, calculate the ratio of air flow rates of the supply and exhaust air as follows :

$$\text{Ratio of air flow rate} = \frac{\text{air flow rate for supply air}}{\text{air flow rate for exhaust air}}$$

④Once the model is decided, extrapolate the intersection of the supply air flow rate with the model upward to the table above for the calculated ratio of air flow rates to get the efficiency **D**.

⑤Extrapolate the intersections of the two air flow rates with the model type downward to come to the points **E** and **B** from which one gets the static pressure losses in the ordinate. Confirm that the face velocities F and C in the abscissa to be around 2.0-4.5 m/s.

⑥If you want to know the efficiency of the exhaust side, calculate the inverse of the above air flow rates (air flow rate for the exhaust air/ air flow rate for the supply air). Then, extrapolate the intersection of the exhaust air flow rate with the model type upward to the table above for the inverse of the air flow rates to get the efficiency of the exhaust side to **G**.

Figure 5

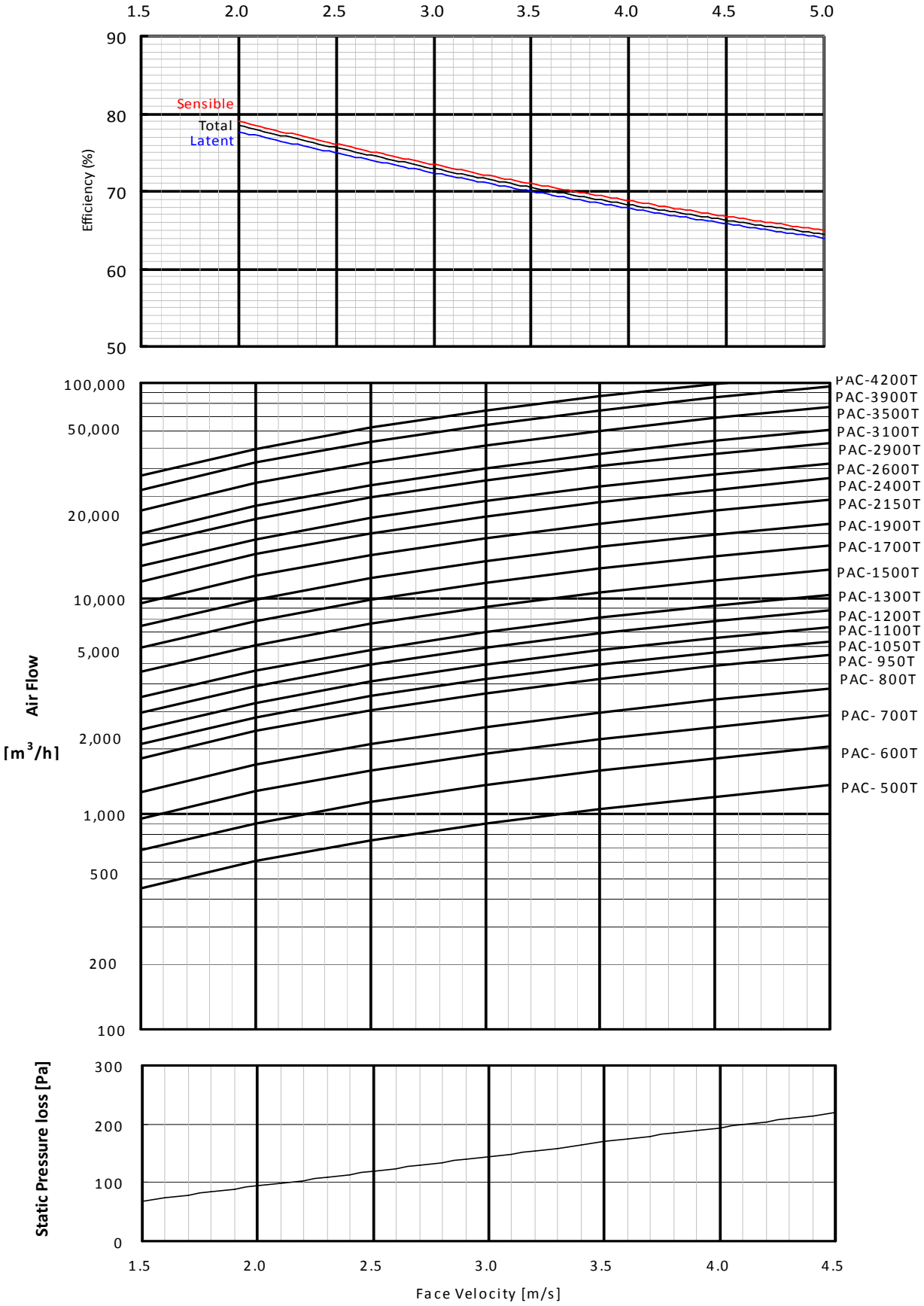
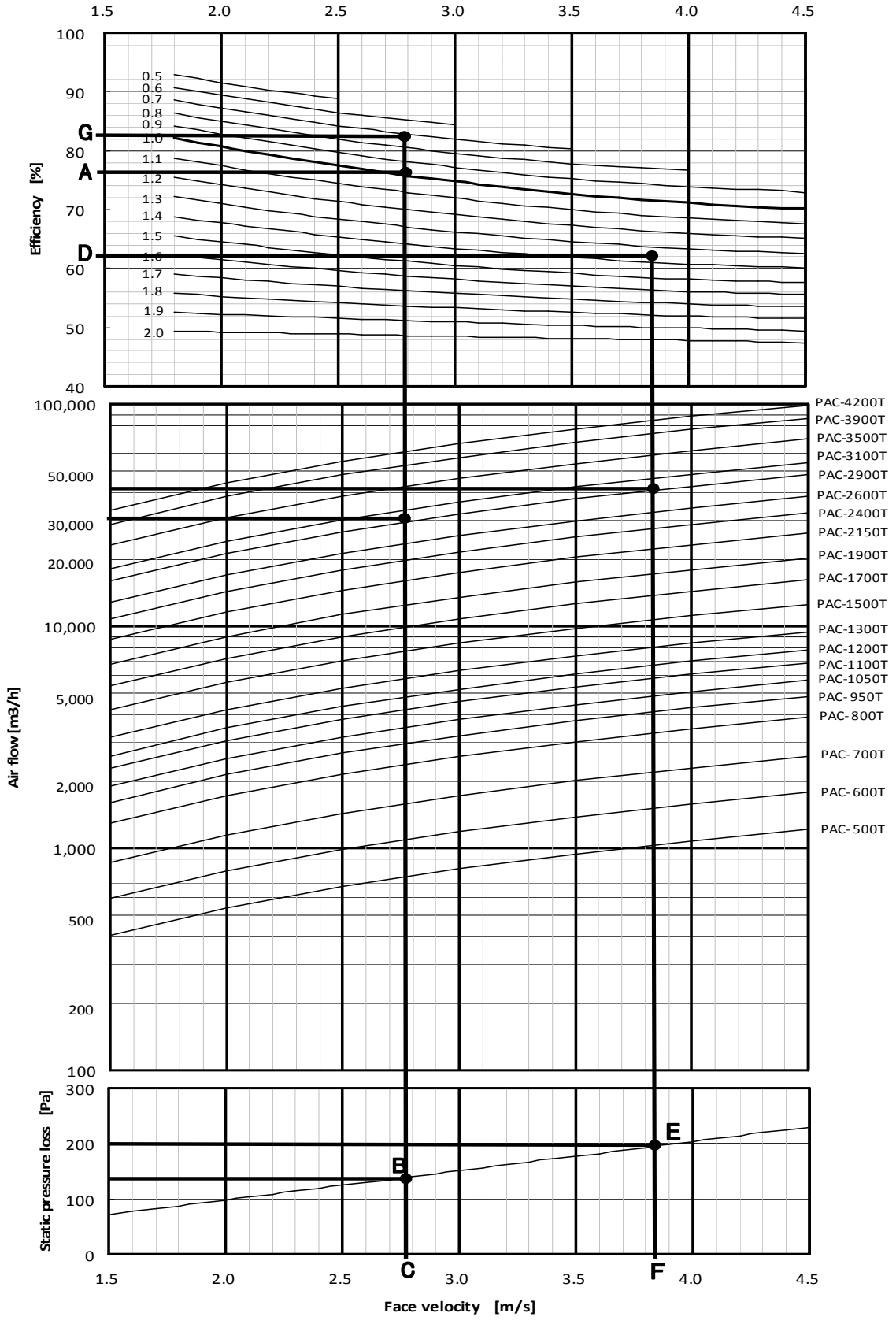

1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
90
80
70
60
50
Sensible
Total
Latent
Efficiency (%)
100,000
50,000
20,000
10,000
5,000
2,000
1,000
500
200
100
Air Flow
[m³/h]
PAC-4200T
PAC-3900T
PAC-3500T
PAC-3100T
PAC-2900T
PAC-2600T
PAC-2400T
PAC-2150T
PAC-1900T
PAC-1700T
PAC-1500T
PAC-1300T
PAC-1200T
PAC-1100T
PAC-1050T
PAC- 950T
PAC- 800T
PAC- 700T
PAC- 600T
PAC- 500T
300
200
100
0
Static Pressure loss [Pa]
1.5
2.0
2.5
3.0
3.5
4.0
4.5
Face Velocity [m/s]

Figure 6


1.5
2.0
2.5
3.0
3.5
4.0
4.5
Efficiency [%]
100
90
80
70
60
50
40
G
A
D
0.5
0.6
0.7
0.8
0.9
1.0
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2.0
Air flow [m3/h]
100,000
50,000
30,000
20,000
10,000
5,000
2,000
1,000
500
200
100
PAC-4200T
PAC-3900T
PAC-3500T
PAC-3100T
PAC-2900T
PAC-2600T
PAC-2400T
PAC-2150T
PAC-1900T
PAC-1700T
PAC-1500T
PAC-1300T
PAC-1200T
PAC-1100T
PAC-1050T
PAC- 950T
PAC- 800T
PAC- 700T
PAC- 600T
PAC- 500T
Static pressure loss [Pa]
300
200
100
0
B
E
C
F
Face velocity [m/s]

9. Examples of application of HI-PANEX-ION

In case a single room is air-conditioned, please refer to the diagram shown in Figure 7.

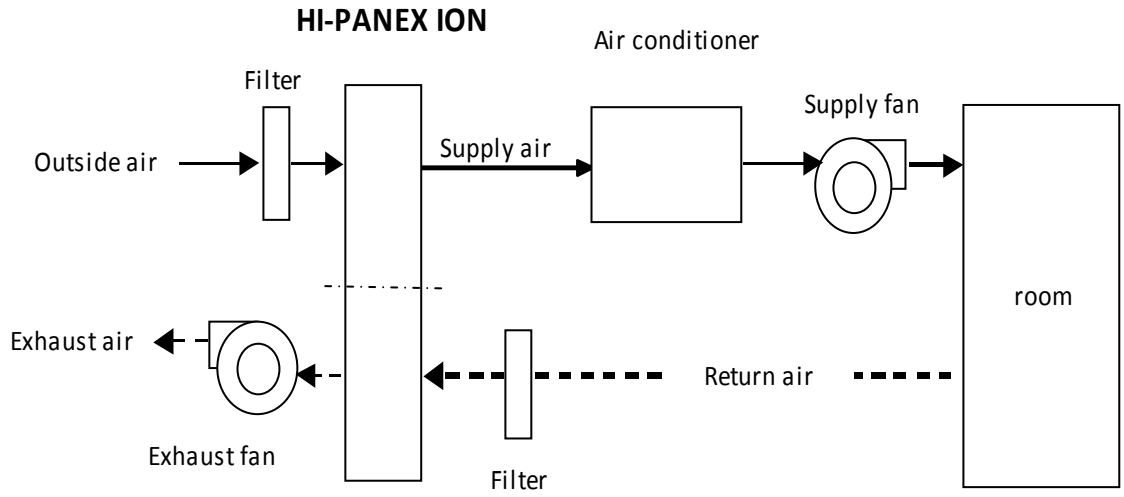


Figure 7

In case multiple rooma are air-conditioned using a single HI-PANEX-ION, please refer to the diagram shown in Figure 8.

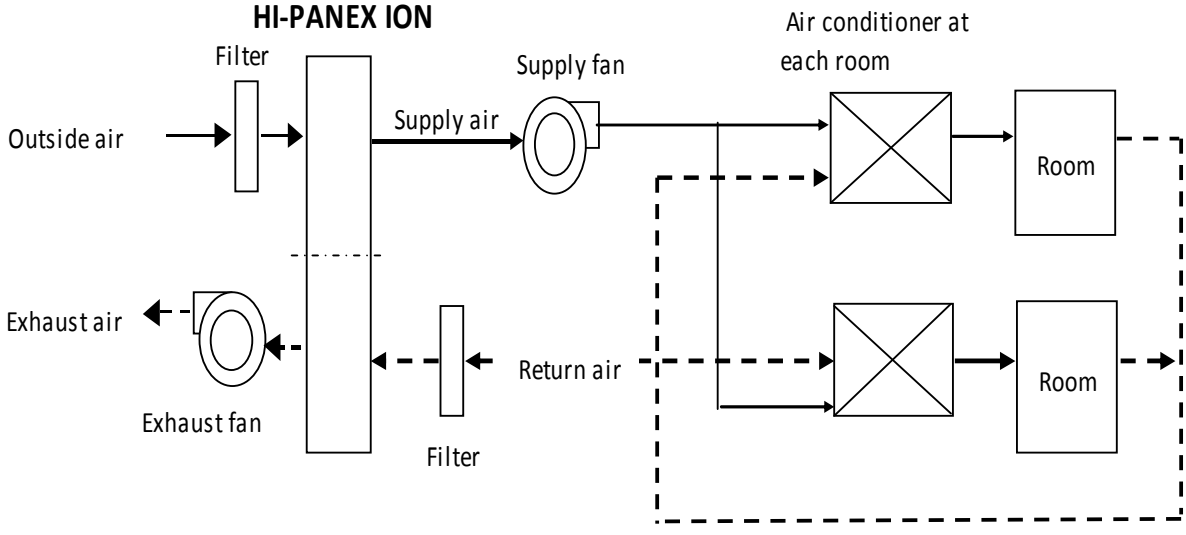


Figure 8

10. Choice and example of load calculations for HI-PANEX-ION

10-1. Flow rates of process air and conditions of the air

①Flow rates

Supply air Q_B	41,000 m^3/h
Exhaust air Q_A	30,000 m^3/h

$$\text{air flow ratio} = \frac{Q_B}{Q_A} = \frac{41{,}000}{30{,}000} = 1.37$$

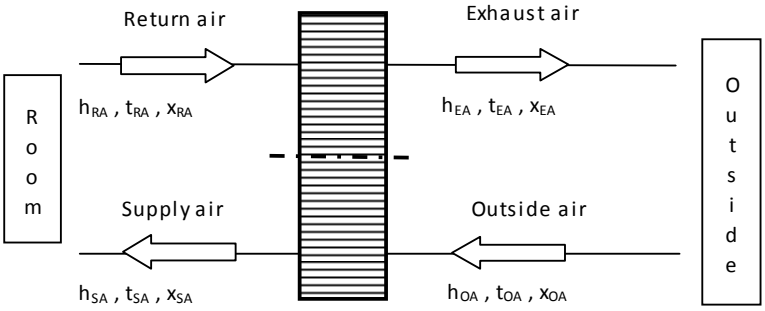


Figure 9

②Conditions of the air

Table 5

		Dry bulb temperature	Wet bulb temperature	Relative humidity	Absolute humidity	Enthalpy
		℃DB	℃ WB	%RH	kg/kg(DA)	kJ/kg(DA)
Summer	Outside air (OA)	32.6	27.7	70	0.0218	88.74
	Room air (RA)	26.0	18.6	50	0.0105	52.95
Winter	Outside air (OA)	1.0	- 3.7	27	0.0011	3.77
	Room air (RA)	22.0	15.4	50	0.0082	42.91

10-2. Selection of HI-PANEX-ION

From the model selection diagram in page 12, we select PAC-2900T for the above conditions. Please refer to page 10 for the method of the model selection from different models of HI-PANEX-ION.

10-3. Performances of HI-PANEX-ION PAC-2900T

Table 6

	Face velocity	Efficiency of total heat	Static pressure loss
Supply side	3.85 m/s	62 %	200 Pa
Exhaust side	2.80 m/s	82 %	140 Pa

10-4. Calculations for the supply air

Table 7

		Formulae	Calculations	Conditions at the exit
Summer	Dry bulb temperature t_{SA} ℃ DB	$t_{SA} = t_{OA} - (t_{OA} - t_{RA})\ \eta t$	32.6 – (32.6 - 26.0) × 0.62	28.5 ℃ DB
	Absolute humidity x_{SA} kg/kg(DA)	$X_{SA} = xoa - (x_{OA} - x_{RA})\ \eta x$	0.0218 – (0.0218 - 0.0105) × 0.62	0.0148 kg/kg(DA)
	Enthalpy h_{SA}kJ/kg(DA)	$h_{SA} = h_{OA} - (h_{OA} - h_{RA})\ \eta h$	88.74 – (88.74—52.95) × 0.62	66.55 kJ/kg(DA)
Winter	Dry bulb temperature t_{SA} ℃ DB	$t_{SA} = t_{OA} - (t_{OA} - t_{RA})\ \eta t$	1.0 +(22.0—1.0) × 0.62	14.0 ℃ DB
	Absolute humidity x_{SA} kg/kg(DA)	$X_{SA} = x_{OA} - (x_{OA} - x_{RA})\ \eta x$	0.0011+(0.0082 - 0.0011) × 0.62	0.0055 kg/kg(DA)
	Enthalpy h_{SA}kJ/kg(DA)	$h_{SA} = h_{OA} - (h_{OA} - h_{RA})\ \eta h$	3.77+(42.91 - 3.77) ×0.62	28.04 kJ/kg(DA)

10-5. Load calculations for air conditioning

Table 8

		Formulae and calculations	Loads
During cooling in summer	Cooling load when HI-PANEX-ION is not used	$q = \gamma \times Q(h_{OA} - h_{RA)}$ = 1.2 × 41,000(88.74 - 52.95) / 3,600	489.1 kW
	Cooling load when HI-PANEX-ION is used	$q = \gamma \times Q(h_{OA} - h_{RA}) \times (1 - \eta_h)$ = 1.2 × 41,000(88.74 - 52.95) ×(1 - 0.62) / 3,600	185.9 kW
	Load saving by the use of HI-PANEX-ION	$\Delta q = \gamma \times Q\ (h_{OA} - h_{RA}) \times \eta_h$ = 1.2 × 41,000(88.74 - 52.95) × 0.62 / 3,600	303.3 kW

During heating in winter	Heating load when HI-PANEX-ION is not used	$q = \gamma \times Q(h_{RA} - h_{OA})$ $= 1.2 \times 41{,}000(42.91 - 3.77) / 3{,}600$	534.9 kW
	Heating load when HI-PANEX-ION is used	$q = \gamma \times Q(h_{RA} - h_{OA}) \times (1 - \eta_h)$ $= 1.2 \times 41{,}000(42.91 - 3.77) \times (1 - 0.62) / 3{,}600$	203.3 kW
	Load saving by the use of HI-PANEX-ION	$\Delta q = \gamma \times Q(h_{RA} - h_{OA}) \times \eta_h$ $= 1.2 \times 41{,}000(42.91 - 3.77) \times 0.62 / 3{,}600$	331.6 kW

11. Economy of HI-PANEX-ION (1)

Table 9

	Design conditions (for a general building)
Place	A district in Tokyo
Building size	Medium-sized building (8,000 m^2)
Cooling	Electricity cost 23 Yen/kWh　2.56 Yen/1,000 kJ（assuming COP=2.5）
Heating	Heavy oil　83 Yen/ℓ　2.41 Yen/1,000 kJ
Flow rate of supply air Q_B	41,000 m^3/h（683 m^3/min）
Flow rate of exhaust air Q_A	30,000 m^3/h（500 m^3/min）
Flow rate ratio	Q_B/Q_A = 41,000/30,000=1.37
Indoor conditions	Summer 26.0 ℃ DB　50 %RH　52.95 kJ/kg winter　22.0 ℃ DB　50 %RH　42.91 kJ/kg
Outdoor conditions	Summer 32.6 ℃ DB　70 %RH　88.74 kJ/kg Winter　1.0 ℃ DB　27 %RH　3.77 kJ/kg
Operating hours	7:30-17:30

11-1. Selection of HI-PANEX-ION

From the model selection diagram in page 12, we select PAC-2900T for the above conditions and read the following figures for the model. Please refer to page 10 for the method of model selection from different models of HI-PANEX-ION.

Table 10

	Face velocity	Efficiency (total heat)	Static pressure loss
Supply air	3.85 m/s	62 %	200 Pa
Exhaust air	2.80 m/s	82 %	140 Pa

11-2. Balance in yearly operating (running) costs is obtainable as follows;

①Yearly outdoor loads for the above indoor conditions are obtainable from Figure 9 (page 15) as follows:

Summer 18,500 [kJ/(m^3/h・year)]
Winter 51,000 [kJ/(m^3/h・year)]

②Yearly outdoor loads for the air flow rate of 41,000 m^3/h (683 m^3/min) are obtained as follows:

Summer 41,000×18,500 = 758,500,000 (kJ/year)
Winter 41,000×51,000 = 2,091,000,000 (kJ/year)

③The yearly electricity and fuel costs for cooling and heating the outdoor air for the above conditions are as follows:

Summer 758,500,000×2.56 Yen/1,000 kJ=1,941,760 Yen
Winter 2,091,000,000×2.41 Yen/1,000 kJ=5,047,674 Yen

④Reductions in the yearly electricity and fuel costs by the use of HI-PANEX-ION are as follows:

Summer 1,941,760×0.62=1,203,891 Yen
Winter 5,047,674×0.62=3,129,558 Yen
Total 4,333,449 Yen

⑤Increases in power costs due to supply/exhaust fans and the driving motor for HI-PANEX-ION are as follows:

Table 11

	Supply fan	Exhaust fan	Driving motor for the rotor	Total
Power	7.5kW	5.5kW	0.4kW	13.4kW

Summer 13.4 kW×3.5 months×30 days×10 hours=14,070 kWh
Winter 13.4 kW×5.0 months×30 days×10 hours=20,100 kWh
Total (14,070+20,100)×23 Yen/kWh=785,910 Yen

⑥Balance of yearly operating costs is as follows:

4,333,449 Yen - 785,910 Yen = 3,547,539 Yen (≒€35,000≒$47,000)

11-3. Balance in equipment (initial cost) is obtainable as follows;

・Reductions of sizes in refrigerating machine and cooling tower

(88.74 - 52.95) kJ/kg×0.62×41,000 m^3/h×1.2 / 3600 / 3.516 kW≒86.2USRT

・Reduction of boiler power

(42.91 - 3.77)kJ/kg×0.62×41,000 m^3/h×1.2 / 3600=331.6 kW

Table 12

Increase		Decrease	
HI-PANEX-ION 1 set	4,400,000 Yen	Refrigerating machine (86.2 USRT×80,000 Yen/USRT)	6,896,000 Yen
Delivery and installation costs	500,000 Yen	Cooling tower (86.2 USRT×14,000 Yen/USRT)	1,206,800 Yen
Ducting works	1,500,000 Yen	Works for pumps and ducts (including thermal insulation)	600,000 Yen
Installations of supply/exhaust fans	2,000,000 Yen	Boiler and ancillaries (331.6×6 Yen/kcal)	1,711,272 Yen
increase in machine room(construction)	2,100,000 Yen	Coils for air conditioner (6 rows×250,000 Yen/row)	1,500,000 Yen
Duct shaft	2,000,000 Yen	Various works/constructions (electricity, delivery, and installation)	400,000 Yen
Electrical works	300,000 Yen		
Total	12,800,000 Yen	Total	12,314,072 Yen

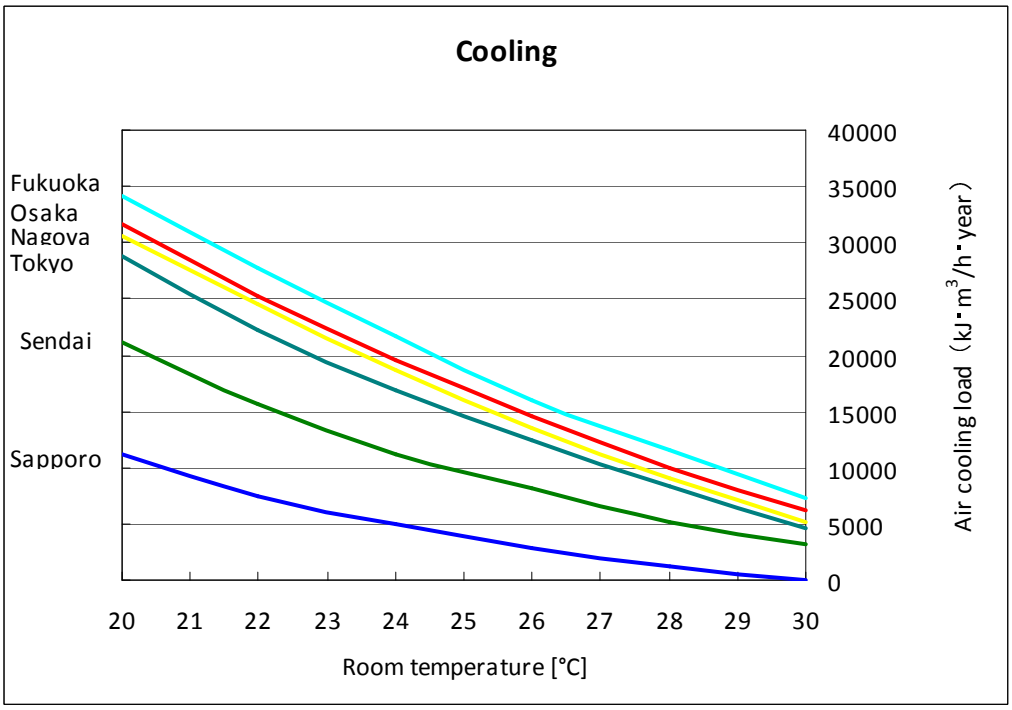
・Increase in equipment costs 12,800,000 Yen - 12,314,072 Yen = 485,928 Yen

・Balance in operating costs 3,547,539 Yen/year

As shown above, the increase in equipment costs is minimal. Thus, the use of HI-PANEX-ION yields an advantage resulting from the saving in operating costs.

Figure 10 Yearly outdoor loads at various locations in Japan

- Operating hours : 9:00-18:00
- Indoor humidity 50 %RH
- Source: Committee of Standard Meteorology of Japan Society of Air Conditioning and Hygiene Engineering (yearly averages)



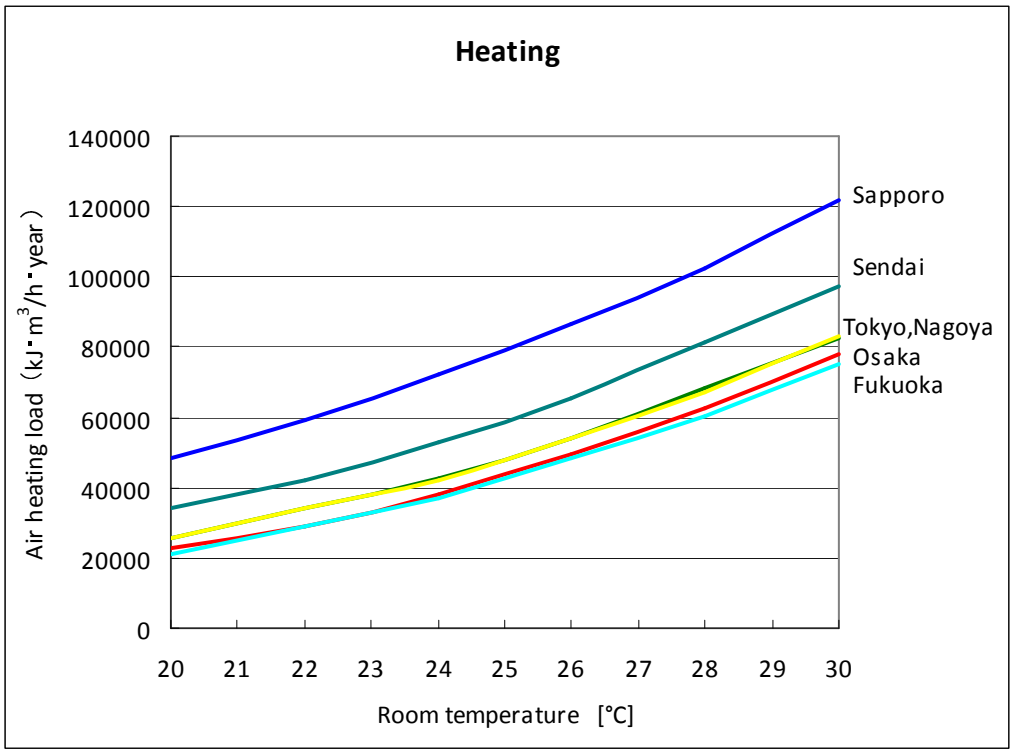
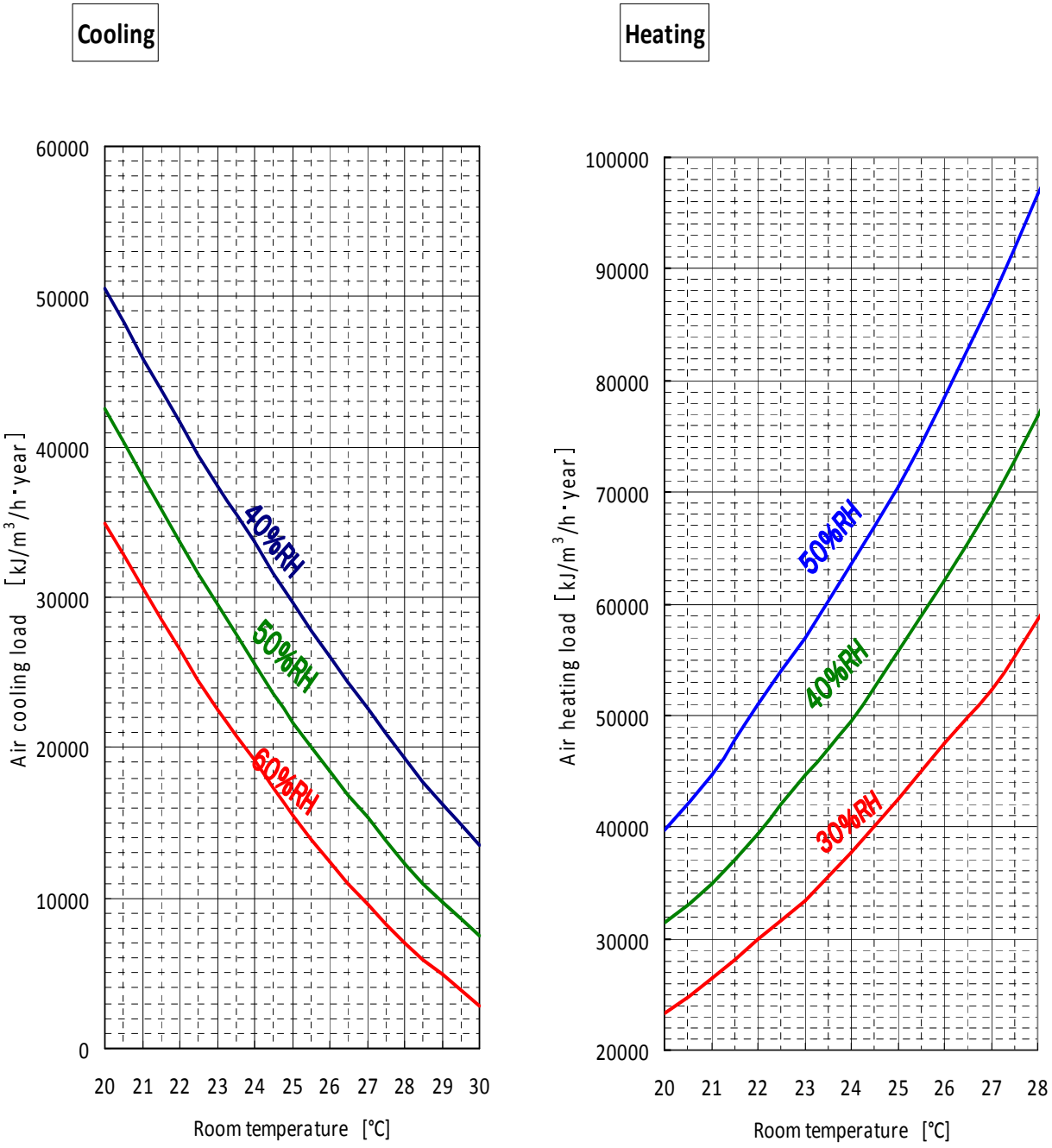


Figure 11 Yearly outdoor loads in Tokyo at various indoor conditions

- Operating hours 7:30-17:30
- Source for meteorological data: Committee of Standard Meteorology of Japan Society of Air Conditioning and Hygiene Engineering (yearly averages)



12. Economy of HI-PANEX-ION (2)

The use of HI-PANEX-ION reduces the power requirements for cooling and heating in air conditioning as shown below.

12-1. Air flow rates and conditions of air

① Air flow rates

Supply air	18,000 m3/h
Exhaust air	16,400 m3/h

$$\text{Air flow ratio} = \frac{18{,}000}{16{,}400} = 1.1$$

②Conditions of air

Table 13

	Items	Dry –bulb temperature	Wet-bulb temperature	Relative humidity	Absolute humidity	Enthalpy
		℃ DB	℃ WB	%RH	kg/kg(DA)	kJ/kg(DA)
Summer	Outdoor air (OA)	32.6	27.7	70	0.0218	88.74
	Room air (RA)	26.0	18.6	50	0.0105	52.95
Winter	Outdoor air (OA)	1.0	- 3.7	27	0.0011	3.77
	Room air (RA)	22.0	15.4	50	0.0082	42.91

12-2. Indoor loads for cooling and heating in air conditioning

(Excluding outdoor loads)

Table 14

	Load for sensible heat	Load for latent heat	Total load	Sensible heat fraction
	kJ/h	kJ/h	kJ/h	S.H.F.
Cooling load in summer	858,130	150,696	1,008,826	0.85
Heating load in winter	979,524	0	979,524	1.00

12-3. Choice of HI-PANEX-ION

From the model selection diagram in page 12, we select PAC-1900T for the above condition.

Table 15

	Face velocity	Efficiency total heat	Static pressure loss
Supply air	4.00 m/s	68 %	200 Pa
Exhaust air	3.64 m/s	75 %	180 Pa

12-4. Conditions of the exit supply air

<Please refer to 10-4. Calculations for supply air in page 16>

Table 16

		Numerical calculations	Exit conditions
Summer	Dry-bulb temperature	32.6 - (32.6—26) × 0.68	28.1 ℃ DB
	Absolute humidity	0.0218 - (0.0218 - 0.0105) × 0.68	0.0141 kg/kg(DA)
	Enthalpy	88.74 - (88.74 - 52.95) × 0.68	56.87 kJ/kg(DA)
Winter	Dry-bulb temperature	1.0 + (22.0 - 1.0) × 0.68	15.3 ℃ DB
	Absolute humidity	0.0011 + (0.0082 - 0.0011) × 0.68	0.0059 kg/kg(DA)
	Enthalpy	3.77 + (42.91 - 3.77) × 0.68	30.39 kJ/kg(DA)

12-5. Loads for cooling and heating in air conditioning <Please refer to 10-5.calculations of outdoor loads for cooling and heating in page 17>

Table 17

		Numerical calculations	Loads
Summer	No HI-PANEX-ION	1.2×18,000×(88.74 - 52.95)	773,064 kJ/h
	Use of HI-PANEX-ION	1.2×18,000×(88.74 - 52.95) × (1 - 0.68)	247,381 kJ/h
	Saving by use of HI-PANEX-ION	1.2×18,000×(88.74 - 52.95) × 0.68	525,684 kJ/h
Winter	No HI-PANEX-ION	1.2×18,000×(42.91 - 3.77)	845,424 kJ/h
	Use of HI-PANEX-ION	1.2×18,000×(42.91 - 3.77) × (1 - 0.68)	270,536 kJ/h
	Saving by use of HI-PANEX-ION	1.2×18,000×(42.91 - 3.77) × 0.68	574,888 kJ/h

12-6. Load calculations of air conditioner

Table 18

	Items	No HI-PANEX-ION	Use of HI-PANEX-ION
Summer	Discharging temperature (t_d)	From S.H.F.=0.85, let us assume t_d=16 ℃.	
	Discharging flow rate	$Q = \frac{858{,}130\text{kJ/h}}{1.2\times0.24\times(26.2-16)\times4.186} \fallingdotseq 71{,}200\ m^3/h$	
	OA (outdoor air) ratio	OA ratio = 18,000÷71,200 = 0.253	
	Load for cooling (excluding outdoor load)	1,008,826 KJ/h	
	Outdoor load	773,064 kJ/h	247,381 kJ/h
	Total load for cooling	1,781,890 kJ/h	1,256,207 kJ/h
Heating in winter	Discharging temperature (t_d)	$t_d = 22+\frac{979{,}524\ \text{kJ/h}}{1.2\times0.24\times4.186\times71{,}200\ m^3/h} \fallingdotseq 33.4\,C°$	
	Discharging flow rate	71,200 m^3/h	
	OA (outdoor air) ratio	0.253	
	Load for humidification	L = 18,000×1.2×(0.0082 - 0.0011)=154 kg/h	L = 18,000×1.2×(0.0082 - 0.0059)=50 kg/h
	Load for heating (excluding outdoor load)	979,524 kJ/h	
	Outdoor load	845,424 kJ/h	270,536 kJ/h
	Total load for heating	1,824,948 kJ/h	1,250,060 kJ/h

12-7. Calculations of capacities of cooling and heating systems

Table 19

	Items	No HI-PANEX-ION	Use of HI-PANEX-ION
Refrigerating machine	Capacity (QR) K : safety factor QC: load of refrigerating machine	QR = K · QC = 1.05×494.96 = 519.8 kW (148 USRT)	QR = K · QC = 1.05×348.95 = 366.5 kW(104 USRT)
	Flow rate of cooling water	1,490 ℓ/min	1,050 ℓ/min
	Exit temperature of cooling water	7 ℃	7 ℃
	Inlet temperature of cooling water	12 ℃	12 ℃
	Reduction in capacity	——————————→	Reduced by 44 USRT (30 %)
Cooling tower	Capacity (QCT)	QCT = 193 RT	QCT = 135 USRT
	Flow rate of cooling water	1,950 ℓ/min	1,360 ℓ/min
	Exit temperature of cooling water	32 ℃	32 ℃
	Inlet temperature of cooling water	37 ℃	37 ℃
	Reduction in capacity	——————————→	Reduced by 58 USRT
Boiler	Capacity (QB) K1: loss coefficient in piping K2:preaheating coefficient Qh: load for heating	QB = K1 · K2 · Qh = 1.05×1.25×506.93 = 665.35 kW	QB = K1 · K2 · Qh = 1.05×1.25×347.24 = 455.75 kW
	Flow rate of warm water	1,370 ℓ/min	940 ℓ/min
	Exit temperature of warm water	80 ℃	80 ℃
	Inlet temperature of warm water	73 ℃	73 ℃
	Reduction in capacity	——————————→	Reduced by 191.68 kW(30 %)
Humidifier	Capacity	154 kg/h	50 kg/h
	Reduction in capacity	——————————→	Reduced by 104 kg/h

※ The use of HI-PANEX-ION enables the requirements of capacity for cooling and heating systems to be reduced as shown above.

13. Controls in the intermediate seasons

13-1. Necessity of controls in the intermediate seasons

Inside any room, there generally exist internal heat sources arising from, for example, human bodies and lighting sources. HI-PANEX-ION enables lost heats during ventilation to be recovered at such high efficiencies as 70-80 %. Therefore, when outdoor temperature is below room temperature in the intermediate seasons of spring and autumn, one may comfortably carry out air-conditioning using the above-mentioned internal heat sources without air heaters. (Refer to Figures 12 and 13)

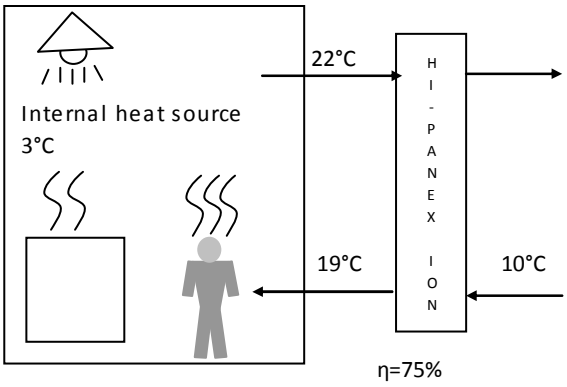


Figure12 HI-PANEX-ION enables comfortable air-conditioning to be made using internal heat sources without air

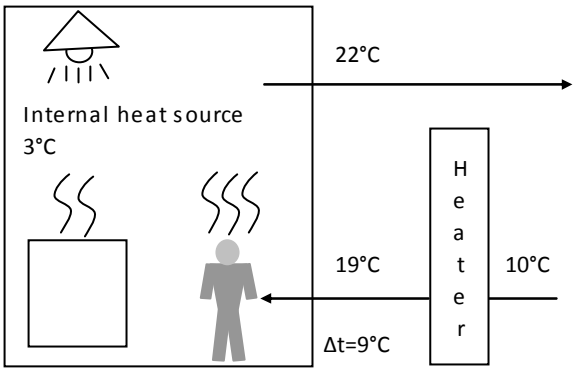


Figure13 If HI-PANEX-ION is not employed, outdoor air has to be heated to 19 °C using an air heater.

However, if the temperature difference between outdoor and room is small, the room temperature may become too high to necessitate air cooling. ○

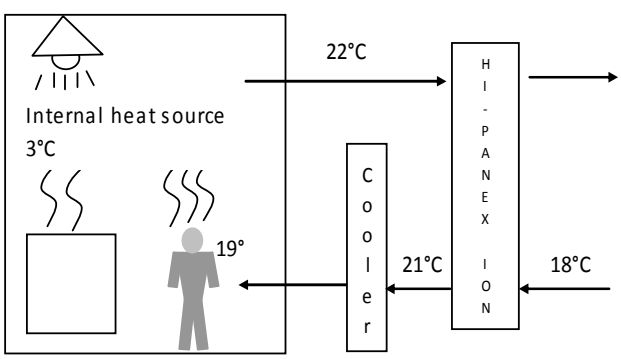


Figure14

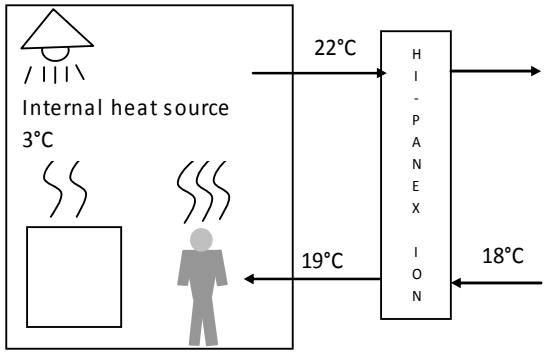


Figure15

· If HI-PANEX-ION operates in full power when outdoor temperature is 18 ℃, the exit temperature after HI-PANEX-ION becomes 18 ℃+3 ℃ = 21 ℃ if the air is directry supplied to the room, thus an air cooler becomes necessary to supply the air at 19 ℃ to the room from 21 ℃. (Figure 14)

However, controls by ON-OFF or bypass of HI-PANEX-ION enables the heat recovery efficiency to be reduced, and comfortable air-conditioning to be carried out without the use of air cooler. (Figure 15)

13-2. How to control heat recovery efficiency

① ON - OFF control

This method is illustrated in figure 16, and controls the amount of recovered heat by switching from operation to stop of the HI-PANEX-ION intermittently. Thus, the room temperature varies depending on outdoor conditions. On the other hand, the rotor is intermittently rotated so that blocking of honeycomb element may be avoided.

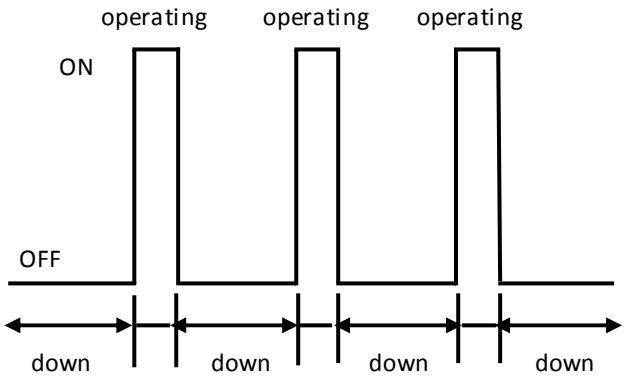


Figure16

・Timer setting for OFF period
from 0 to 180 min.
(Recommended value : 55-60 min.)

・Timer setting for ON period
from 0 to 30 min.
(Recommended value : 3-5 min.)

② Bypass control

The amount of heat recovery can also be controlled, as shown in Figure 17, by changing the amount of air flow through HI-PANEX-ION using a bypass route. The requirements for fabrication of bypass ducts, damper control, and associated space are the disadvantages of this method, compared with the above ON-OFF control.

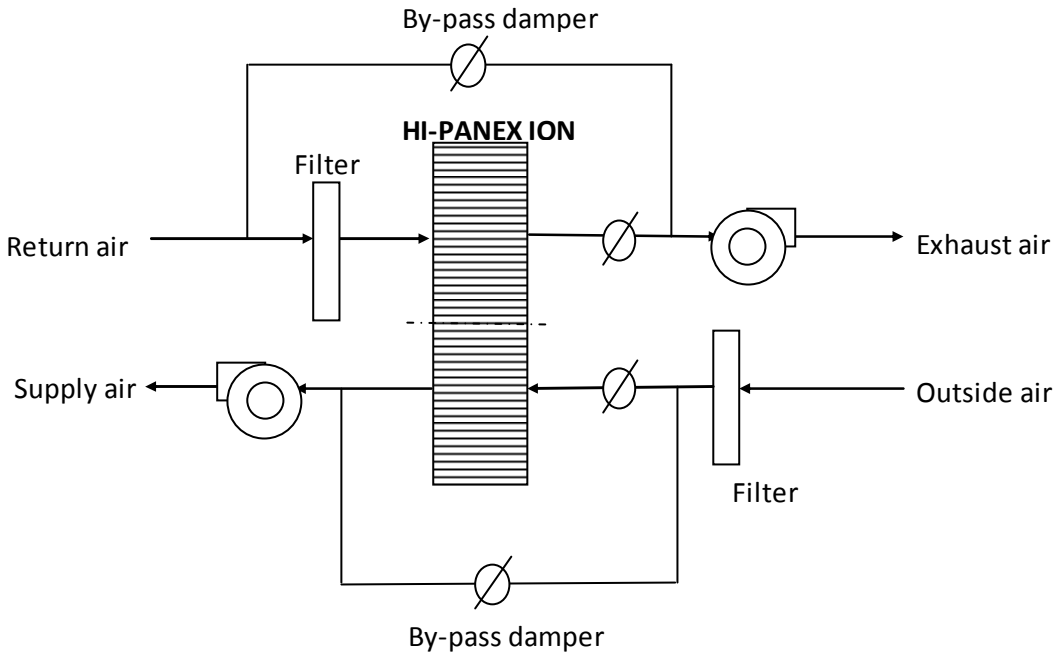


Figure17

14. Remarks at installation and operation of HI-PANEX-ION

Please take care of the following points when HI-PANEX-ION be used.

14-1. About air filter

Supply air and exhaust air flow in the opposite directions through the rotor element. Thus, the air flow through the element changes its direction every half rotation by the rotor rotation at about 20 rpm, resulting in almost no dust accumulation in the rotor during a usual air conditioning. Namely, there is a self-refreshing action in HI-PANEX-ION. However, it is advisable to install a filter, appropriate for sizes of dusts present in air, so that HI-PANEX-ION be used for a long time without trouble.

- **Filter for outdoor air**

  Because coarse dusts may cause blocking of the inlet side of the honeycomb elements, install a dust filter (class G4 or equivalent).

- **Filter for exhaust air**

  Because exhaust air may contain dusts arising from human hairs and clothes, install a dust filter (class G4 or equivalent).

(Note) In case exhaust air may contain oil mists, ink mists or exhaust gas from spraying booths is sent through HI-PANEX-ION, remove these items by installing a filter at the return air side before the rotor element, so as not to cause its blocking due to adhesion of these items onto the element.

- **Installation of filters at air conditioning for hospitals**

  In case of air conditioners for hospitals when supply air is fully obtained from outdoor air, install a high-quality filter (including HEPA) at the downstream side of HI-PANEX-ION to be prepared for the presence of suspended bacteria both in outdoor air and exhaust air. The arrangement as shown in Figure 18 is generally recommended

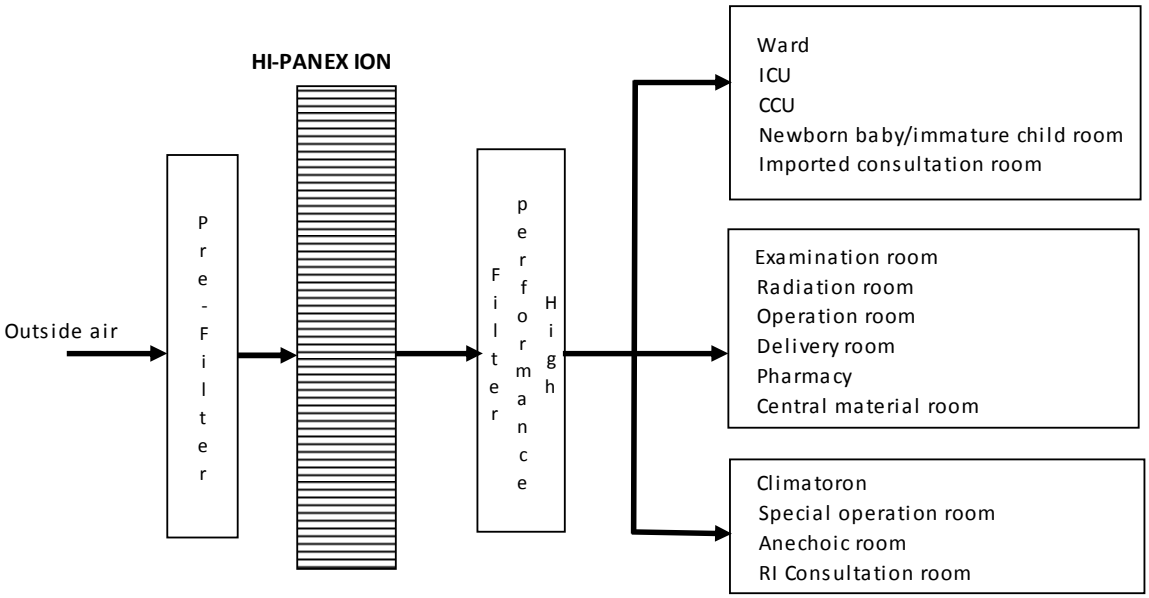


Figure18

14-2. Temperature range of process air during operation

Please operate HI-PANEX-ION in the temperature range of process air shown in ”Materials of rotors for HI-PANEX-ION and its applications” in page 7.

14-3. About special exhaust gases

If some special gases or solvents be contained in exhaust gases in special-purpose air conditioning other than usual one, those may be harmful to the rotor element depending on gas species and their concentrations. Thus, contact us each of these cases beforehand.

14-4. About rotor rotation and fan operation

If air is flown through the rotor element of HI-PANEX-ION while the rotor is not being rotated, blocking of the rotor element may occur. Thus, operate both the rotor in rotation and supply and exhaust fans simultaneously using an interlock between them, in order to avoid such blocking.

14-5. About a gallery for supply air intake

If the rotor element is subjected to water droplets (such as rain water droplets), it may incur efficiency deterioration or damage of the rotor. Thus, please take full care during design of a gallery for supply air intake. For example, install a water reservoir between the supply air intake and the rotor element so that water droplets, even though they may sneak into intake ducts, do not reach the rotor.

14-6. About thermal insulation of chambers and ducts

If HI-PANEX-ION is installed at a place with temperature similar to outdoor air, a thermal insulation is necessary for the room sides of supply and exhaust ducts, so as to avoid thermal losses.

14-7. About operation in cold districts

Temperature of outdoor air may become below freezing in winter in cold districts, resulting in crossing of the saturation curve during total heat exchange (heat and moisture exchanges with room air) to form dews or ices in the rotor element, as shown in Figure 19. This may incur efficiency deterioration of heat exchange, or even damage a part of the rotor element at the worst case. For such circumstances, preheat the outdoor air (OA) to (OA') so that crossing of the saturation curve does not occur.

① **Pre-heating control**

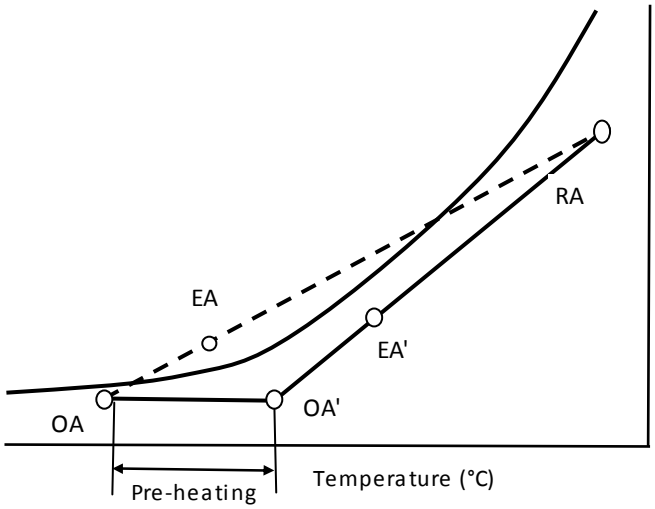


Figure 19

②**Control of rotation speed**

There is a method of controlling the efficiency of total heat exchangers by changing the rotating speed utilizing the efficiency characteristics of HI-PANEX-ION . That is, by controlling the rotating speed, the room can be cooled down by feeding the fresh air through HI-PANEX-ION

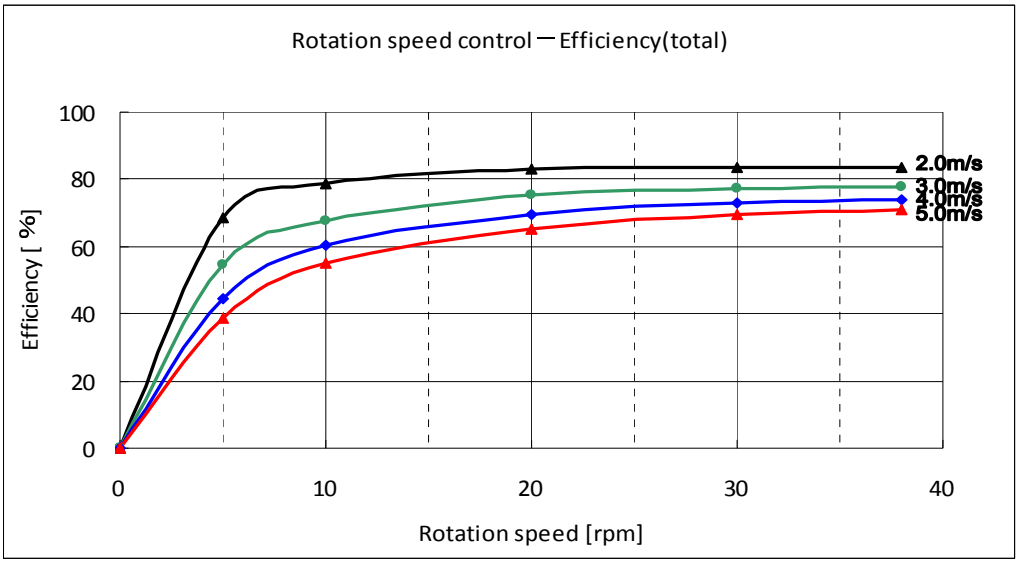


Figure 20

14-8. About special installation of the system

・Outdoor installation

If HI-PANEX-ION is installed outdoor, it is subject to a special specification, and please contact us beforehand.

Also, please take note of the following points during installment.

①Build a roof so as for water not to fall or to be stored on HI-PANEX-ION.

②Use corking materials through a pair of flanges so as for water not to sneak in.

③Fully seal the gap of all connecting ducts.

Avoid sneaked water through ducts etc. to reach the rotor element.

・Horizontal installation

If HI-PANEX-ION is installed horizontally, it is subject to a special specification, and please contact us beforehand.

14-9. About ducting

We offer horizontal and vertical types of HI-PANEX-ION depending on the arrangements of supply and exhaust air, as shown in Figure 21. Please indicate your choice when ordering. The standard arrangement is horizontal.

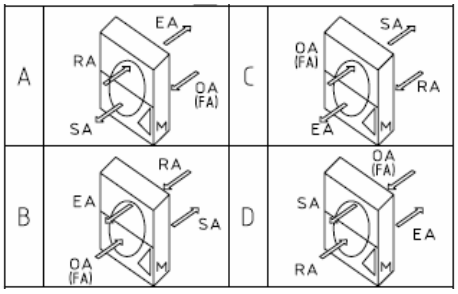


Figure 21 Horizontal type

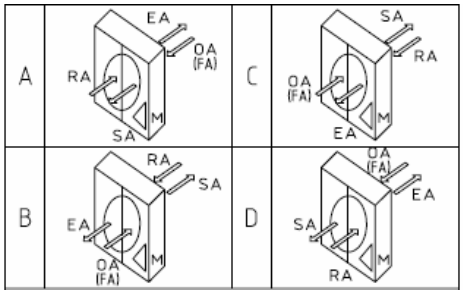


Figure 22 Vertical type

14-10. About combinations of HI-PANEX-ION with process fans

There are various possible arrangements of combinations of HI-PANEX-ION with process fans as shown below. Please select the most appropriate arrangement for your air conditioning scheme.

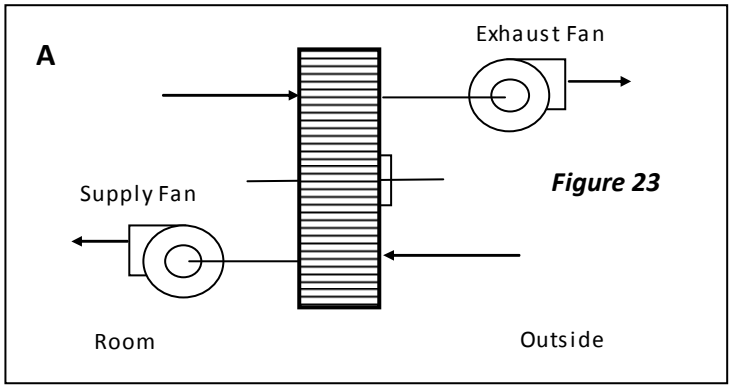


Figure 23

A) The requirement of the static pressure in the supply air to be above that in the exhaust air so as for the latter not to be transferred to the former, by the proper choices of fan capacities for the supply/exhaust air. This is the most recommended arrangement. During the design of this arrangement, please add the amount of air flow through a purge to the capacity of the exhaust fan.

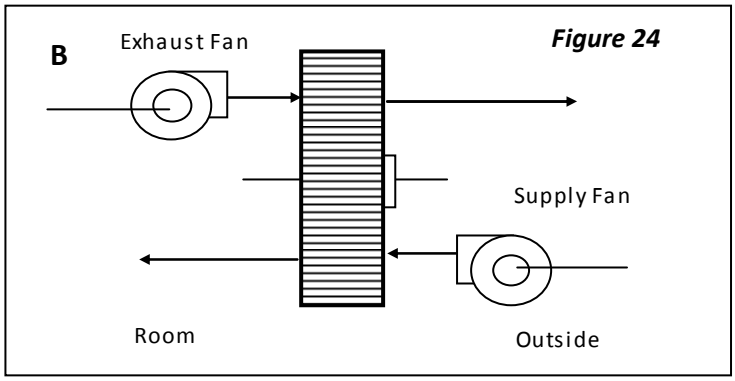


Figure 24

B) The static pressure relations are the same as shown for A), but both pressures are above ambient, requiring the capacities of both process fans to be a little larger than for A). This arrangement may cause an inlet air flow inequality into the heat exchange element arising from ducting arrangement. During the design of this arrangement, please add the amount of air flow through a purge to the capacity of the exhaust fan.

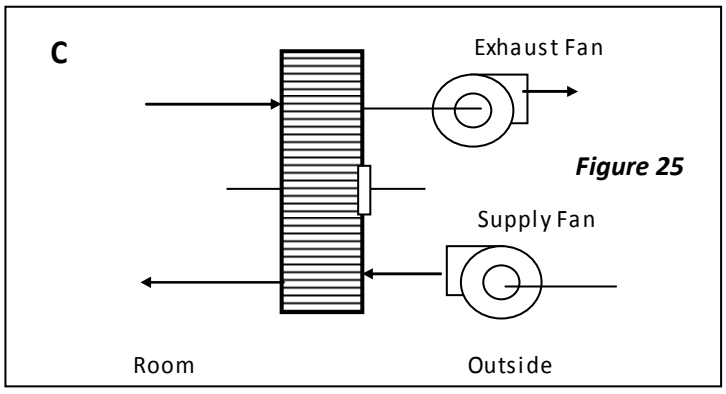


Figure 25

C) The static pressures on both sides of HI-PANEX-ION satisfy the conditions of supply air>return air>exhaust air, resulting in the complete removal of the possibility of exhaust air to be transferred into supply air. However, the fan capacity for the supply air has to be large, and this arrangement is uneconomical. During the design of this arrangement, please add the amount of air flow through a purge to the capacities of both supply exhaust fans.

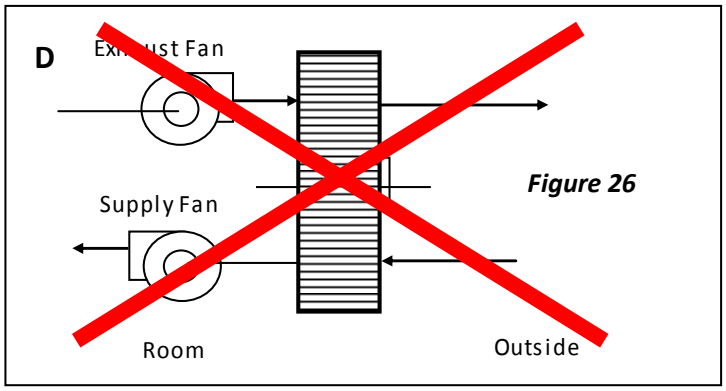


Figure 26

D) The static pressures on both sides of HI-PANEX-ION satisfy the conditions of return air>exhaust air > supply air, resulting in the possibility of exhaust air to be transferred into supply air. Please avoid this arrangement in principle.

14-11. About positions of installation of supply/exhaust air mouths

If the mouths for outdoor air intake and exhaust air outlet are too close, exhausted air may be taken into supply air. Thus, please take note of the following points in planning the places of those mouths.

a) Take care to arrange the two mouths at different heights.
If there is no height difference, exhausted air might be taken into the mouth for supply air depending upon wind directions even though the two mouths be separated for more than 10 m. Mixing of exhaust air into supply air can be avoided if the mouth for exhaust air is arranged above that for supply air for the distance of more than three times the opening of the mouths.

b) Avoid arranging the mouth for supply air near to chimneys and cooling towers.

c) Take care also for the arrangement for supply air to chimneys and cooling towers of neighboring buildings.

14-12. About odor transfer

Odor accumulation and transfer during the operation of HI-PANEX-ION has been minimized by the use of ion exchange resin as a moisture adsorbent for latent heat (moisture) exchange. Additionally, an installment of a purge (transfer prevention by rotation) has almost eliminated odor transfer.

*For more details, please refer to "□. About ion exchange resin as a moisture adsorbent" in page 47.

14-13. About inspection mouths

Install four inspection mouths (outdoor, supply, return and exhaust sides) into connecting ducts for checking the rotor condition.

15. About leakage and odor transfer

"Leak" is an air leak caused by pressure differences between the return and supply zones or those between the exhaust and outdoor zones, while "transfer" is termed as the amount of air taken from return into supply zones due to rotor rotation. The transfer can be avoided by installing a purge. (Please refer to "Principle of a purge" in page 36.) The return leak rate and the outdoor leak rate are shown, respectively, in Figure 27 and 28 against the pressure difference among return and supply air ΔP_1 (= P_{SA}- P_{RA}) and that among exhaust and outdoor air ΔP_2(= P_{OA} – P_{EA}).

・Air flow rate through a fan

If ΔP2＞0, a leak into the exhaust side results, and please add the amount of the outdoor leak rate shown in Figure 28 into the air flow rate of the process air for a supply or an exhaust fan in designing the specification of the fan.

$$Q = Q_S \times \frac{100+R}{100}$$

Q : air flow rate of process fan (m^3/min)

Q_S : standard air flow rate (m^3/min)

R : leak rate (%)

・Modification of the leak rate due to different models

These figure were obtained from measurement results on PAC-950T. Please modify the results for rotors of different diameters as shown below. (These values do not include the amount of air taken in due to rotor rotation.)

$$\ell_D = \ell \times \frac{0.98}{D}$$

D : diameter of rotor at hand (m)

ℓ : leak rate for PAC-950T

ℓ_D : leak rate for the rotor at hand

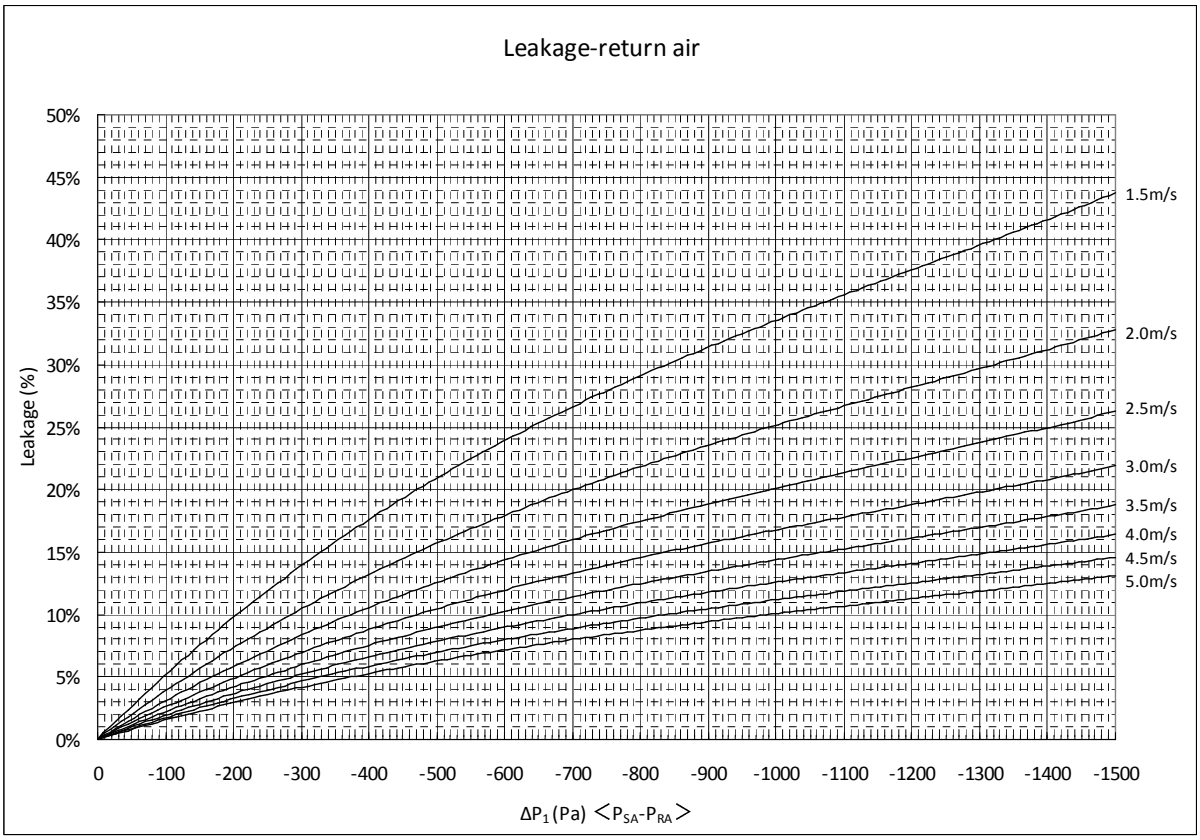


Figure 27

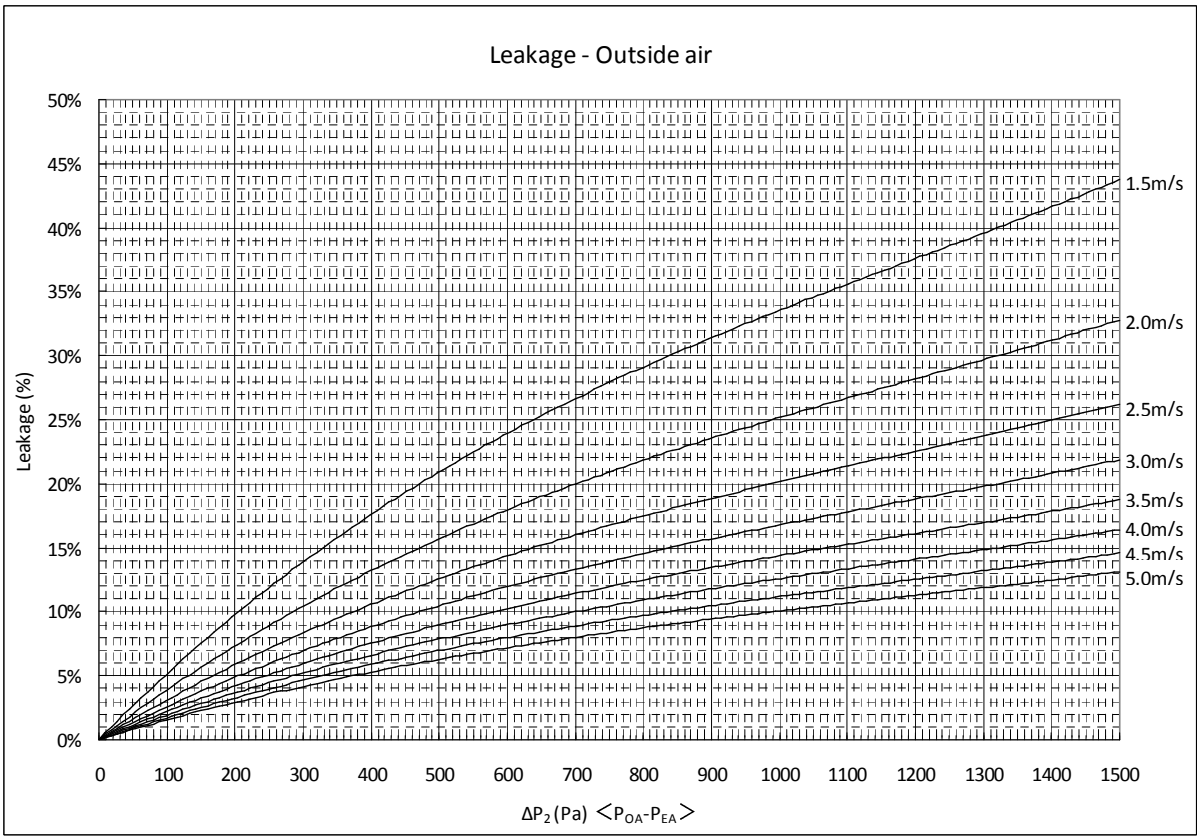


Figure 28

15-1. About a purge

・Necessity of a purge

Air conditioners in usual buildings normally employ a scheme of circulation air with only a fraction of it being ventilated with outdoor air. In this situation, there arises no problem for a small amount (a few %) of exhausted air to be transferred into supply air However, air conditioners for animal experimental rooms and hospitals may employ a scheme of complete ventilation. In these latter situations, a purge may become necessary, in order for exhaust air to be prevented from being transferred into supply air.

・Principle of a purge

The problem of transfer occurs at the point where the rotor rotates from the exhaust side to the supply side, and the exhaust air at the point E moves along the line E-E' as the rotor rotates (Figure 29). Thus, this transfer can be avoided by moving the purge zone into the point E' so that the exhausted air existing along E-E' is pushed back into the return air by some fraction of outdoor air (Figure 30).

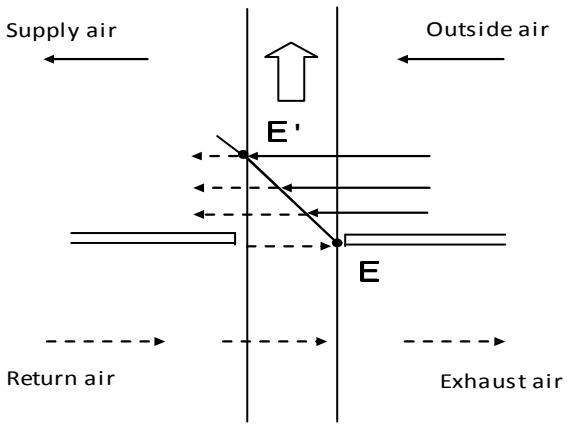


Figure 29

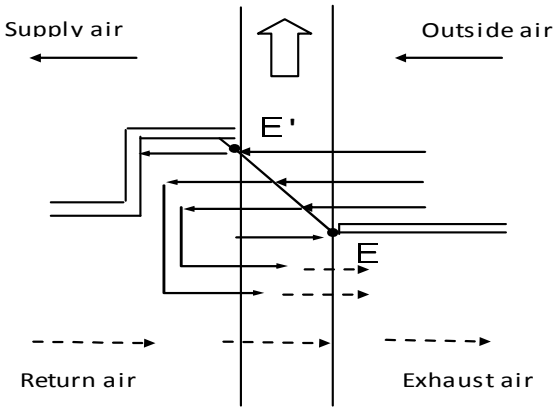


Figure 30

・Air flow rate for a purge

The amount of air to be flown through a purge is decided by the pressure difference between the exhaust air and the supply air (P_S-P_E).

・In order to accomplish a complete purge, please make sure that the pressure at the exhaust air P_E is lower than that at the supply air P_S by more than 100 Pa. Figure 31 shows the relationship between pressure difference (P_S - P_E) and the amount of air to be flown through a purge. In designing the capacities of fans for supply/exhaust air, please add the air flowing through a purge into the process air. Whether this air addition is to be made for a fan for supply or exhaust side depends on the fan configuration. Please refer to "About Combinations of HI-PANEX-ION with process fans" in page 32 about to which this addition be made.

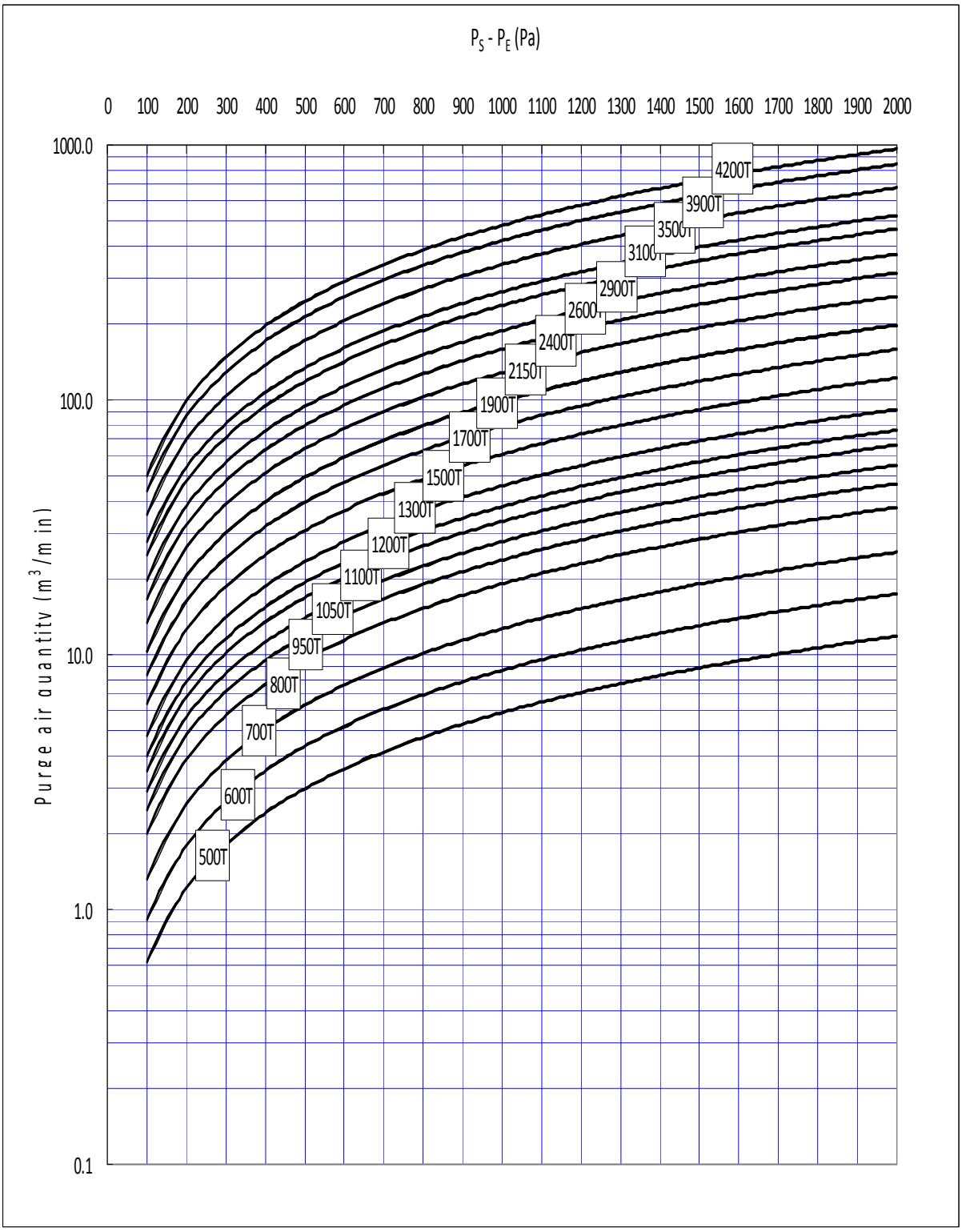


Figure 31 **Relationship between purge air flow rates and pressure differences**

15-2. Transfer of exhaust air during the rotor rotation（in case a purge zone is not installed）

Because HI-PANEX-ION employs the principle of total heat exchange using a rotating rotor, there arise possibilities of two air flows (supply air and exhaust air) being transferred during a zone switchover by rotor rotation （supply zone$\overset{\rightarrow}{\leftarrow}$exhaust zone）. There is no problem of supply air being transferred into exhaust air, but it is not desirable for exhaust air to be transferred into supply air.

The amount of transferred air from exhaust air to supply air depends on the number of revolution per minute (rpm) and the width of the rotor.

The amount of transferred air Q_R : $Q_R = S \times L \times N \times VP (m^3/min)$

The amount of flow rate of supply air : $Q_{SA} = {}^1/_2 S \times v \times 60 (m^3/min)$

The transfer rate R :

$$R = \frac{QR}{QSA} \times 100\% = \frac{S \times L \times N \times VP}{{}^1/_2 S \times v \times 60} \times 100\%$$

$$= \frac{L \cdot N \cdot Vp}{30v} \times 100\%$$

S : Sum of rotor front areas for supply air and exhaust air (m^2)

L : Rotor width (m)

N : Rotor revolution (rpm)

V_P : Porosity rate of the element

V : Face velocity of the element (m/s)

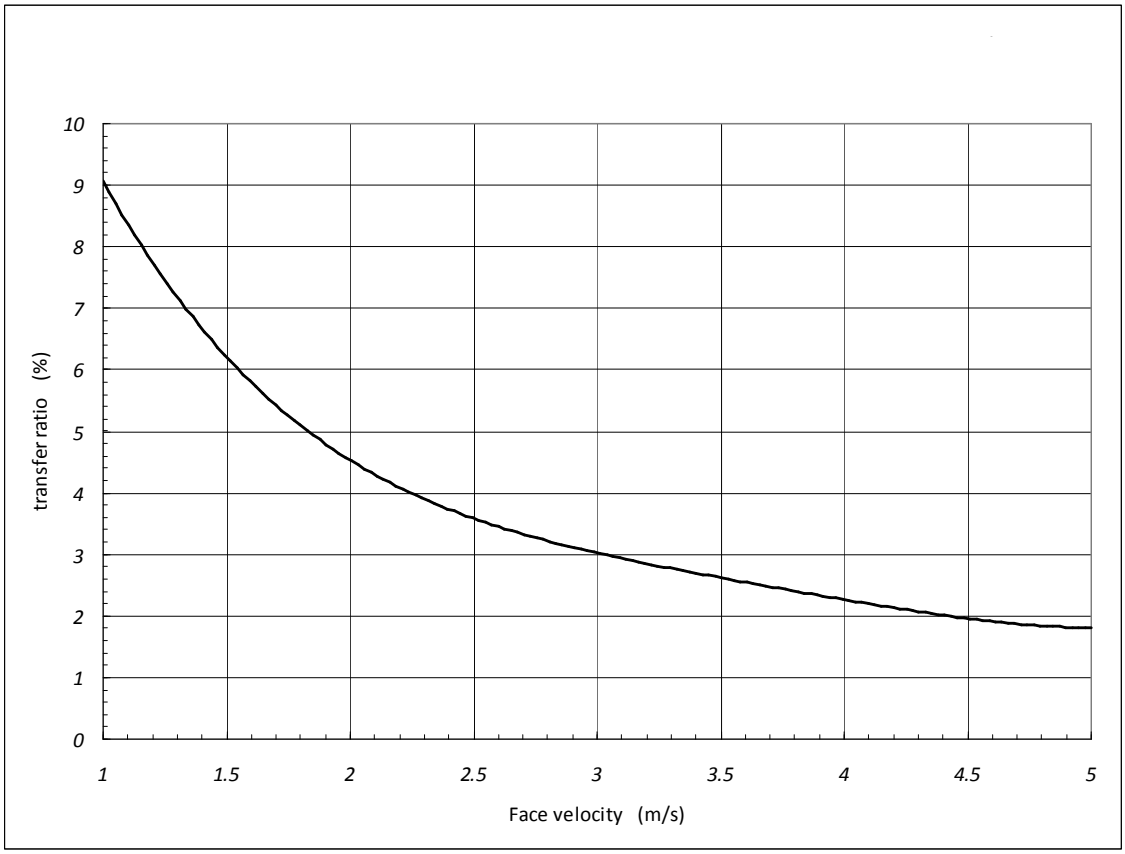


Figure 32 Relationship between the transfer ratio and the face velocity

· Rotor revolution 20 rpm

· Width of the element 0.20 m

· Porosity rate of the element 0.85

B. About adsorption by ion power

1. Origin of odor transfer in heat exchangers

The process of odor transfer in a heat exchanger is believed to be from the following steps:

1) Molecules causing odor in room air are accumulated in an adsorbent (silica-gel).

2) When the outside humidity suddenly increases, moisture adsorption in the adsorbent increases with resultant expulsion of odor molecules due to the exchange adsorption phenomenon, thus the odor being released to the room. There may be a case of a humidifier to be a source of odor.

3) The odor released into the room is again adsorption-transferred in the heat exchanger, and not exhausted into outside air, with lingering odor presence in the room.

The origin of odor appearance is illustrated in Figure 33.

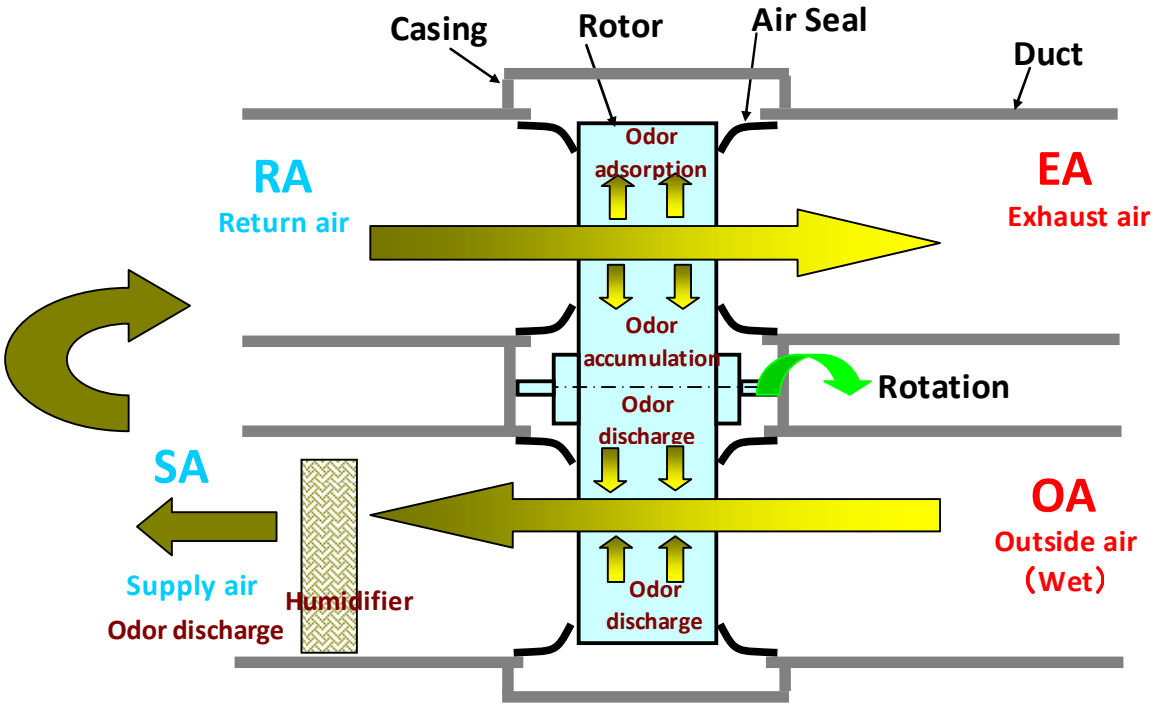


Figure 33

＊HI-PANEX-ION employs an ion-exchange resin as an adsorbent, with much less odor accumulation and transfer, thus almost eliminates odor appearance. In addition, even if odor molecules may be produced from some equipment/materials, they are quickly exhausted into outside air.

2. Performance of prevention of odor transfer and accumulation

HI-PANEX-ION employs, as its latent heat (humidity) adsorbent, an ion-exchange resin which does not adsorb molecules causing odor, in place of an older type employing silica-gel, with resultant particular characteristics of much less odor transfer and accumulation.

2-1. Test of odor adsorption and transfer

【Method of test】

Figure 34 illustrates an experimental arrangement, where various odor-causing molecules were generated and their concentrations C_{oa}, C_{sa} and C_{ra} were measured at several locations. For these measurements, the Kitagawa-type gas detector was used for ammonia and formaldehyde, and the Shimadzu gas chromatograph GC-14A was employed for isopropyle alcohol.

<Calculation of odor transfer ratio>

$$\text{Odor transfer} = \frac{C_{sa}-C_{oa}}{C_{ra}-C_{oa}} \times 100[\%]$$

[Test conditions]

Air conditions are assumed to be for those of summer.

Outdoor air (OA)	30-35 ℃	50 %-80 % RH
Room air (RA)	27± 1 ℃	50 % RH ± 10 %
Face velocity at the element		2.0 - 5.0 m/s

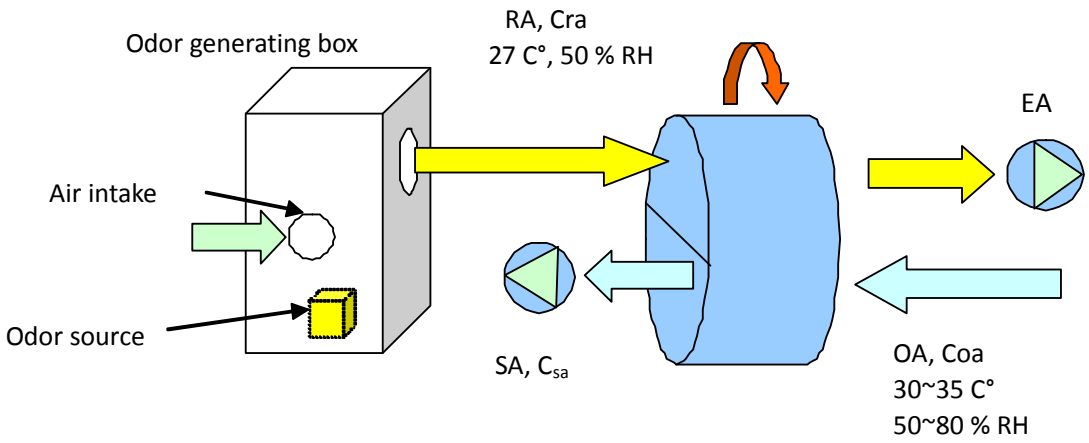


Figure 34

2-2. Comparison of odor transfer caused by VOC (Volatile organic compounds)

a) Relations of face velocities at the element with odor transfer ratio

As shown below, odor transfer is almost eliminated for heat exchangers by ion power.

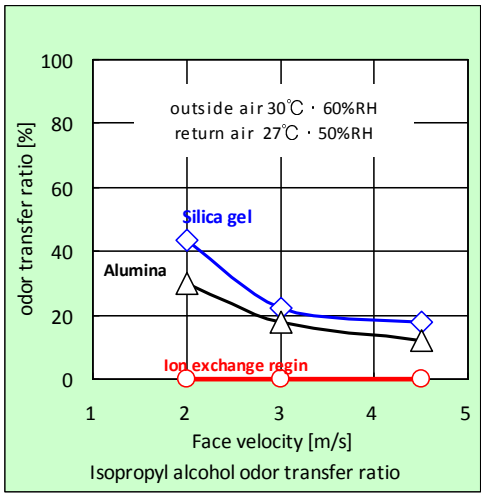


Figure 35

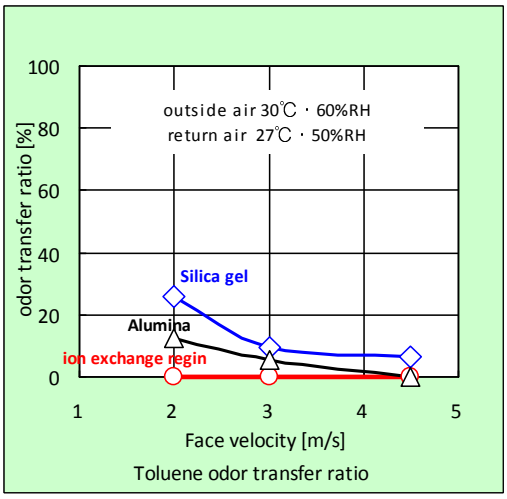


Figure 36

b) Relations of VOC concentrations with odor transfer ratio.

As shown below, odor transfer due to VOC is almost eliminated for heat exchangers by ion power, and this is independent of VOC concentrations.

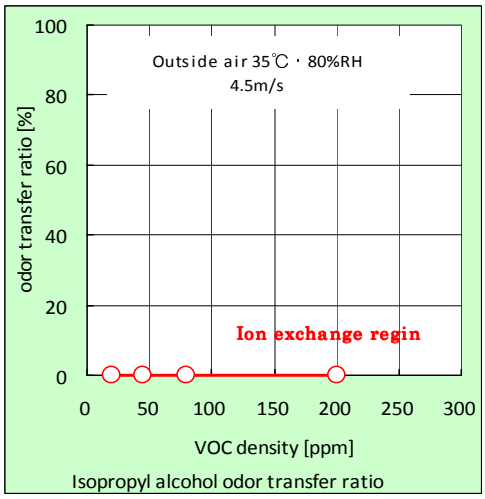


Figure 37

c) Odor transfer ratio for other VOC

As shown below, odor transfer ratios for other various VOC are below detection limit. (Table 20)

Table 20 Table showing odor transfer ratios for other various VOC.

VOC	VOC density	transfer ratio %
IPA	20ppm	ND
	45ppm	ND
	80ppm	ND
	200ppm	ND
Ethanol	70ppm	ND
Methanol	40ppm	ND
Acetone	45ppm	ND
MEK	40ppm	ND
Toluene	40ppm	ND
Xylene	30ppm	ND
Styrene	50ppm	ND
Ethyl acetate	180ppm	ND
Butyl acetate	33ppm	ND

* Air flow rate at test 4.5 m/s.
* With a purge installed.
* Almost no dependence on outdoor air temperature.
* ND : Below detection limit(0.5 ppm).

2-3. Comparison of odor transfer caused by ammonia

a) Relations of transfer ratios with face velocities
In the conventional air flow speeds at 3-4 m/s, the odor transfer ratios for ion-exchange resin are 1/3-1/4 of those for silica-gel.

b) Relative humidity and transfer ratios
Transfer ratios for silica-gel tend to increase with increasing outdoor humidity, while those using ion-exchange resin are not affected by humidity.

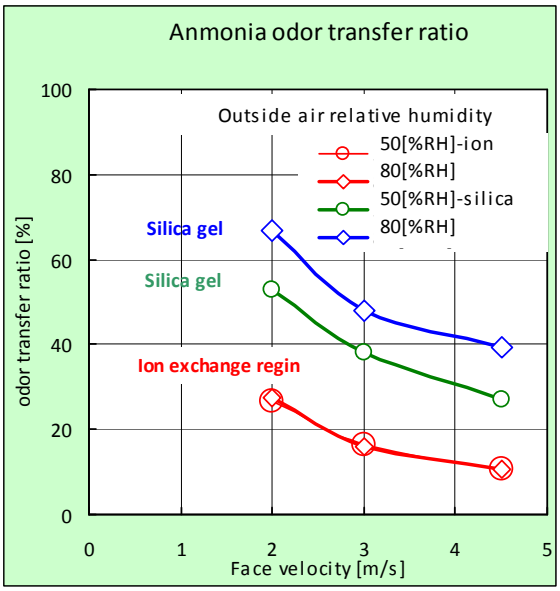


Figure 38

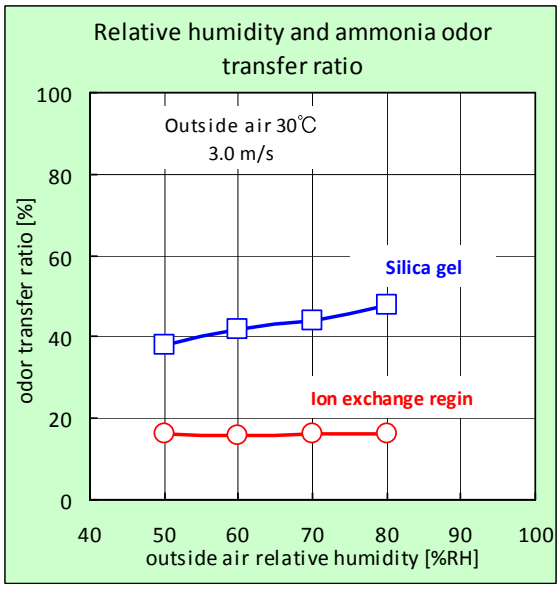


Figure 39

c) Comparison of transfer ratios for various adsorbents It is generally believed that synthetic zeolite does not adsorb odor due to molecular screening, but it adsorbs ammonia molecules, whose diameter (2.6Å) is smaller than that for water molecules(2.8 Å).

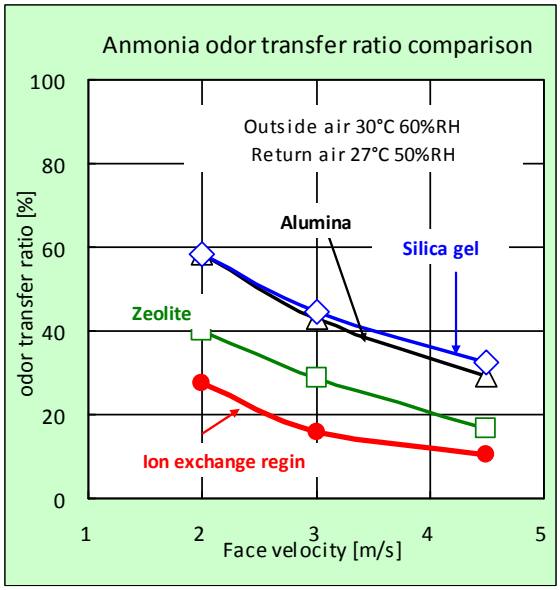


Figure 40

2-4. Experimental tests of odor adsorption and its release

Conventional heat exchangers using silica-gel tend to release molecules causing odor during a rapid increase in humidity after being used in environments with much odor presence in air. This is because the odor-causing molecules are gradually accumulated during a normal operation, which are then released by an exchange adsorption process during the rapid increase in humidity. This process of humidity increase usually occurs during the rainy season or at the onset of rainfall when an outdoor humidity increases. The resultant odor molecules are released into supply air then into a room, resulting in a very bad consequence. HI-PANEX-ION eliminates this shortcoming, and comparison experiments between the two have yielded good results for this new product.

【Experimental method】

Molecules causing odor were adsorbed and accumulated in the experimental arrangement shown in Figure 41, and then released by passing through high humidity air with resultant odor-causing molecules to be measured, in the following procedures.

1) First, the rotor rotation was stopped, and air containing four major offensive odor causers, namely ammonia, hydrogen sulfide, methyl mercaptan, and trimethylamine, were passed through the stationery rotor. The duration of the air passage was one hour for the first half circumference, and another one hour for the other half after rotating the rotor for a half of the circumference, totaling two hours altogether.
2) After eliminating the odor causers, the test machines were operated in an usual heat exchanger mode under low humidity conditions(OA : 35 ℃ / 30 %RH. RA : 27 ℃ / 30 % RH). The operations were carried out until odor could not be detected both in supply air (SA) and room air (RA).
3) After confirming odor not to be detected any more, the humidity in OA were raised to(30 ℃ / 80 % RH), odor being released into the SA side was checked by five panel persons (three males and two females) by their noses, and marked by six-stages odor indication method.

Table 21 The six-stages odor indication method

Strength of odor	The level of odor	Ref. Ammonia concentrations
0	No smell	
1	Barely detectable smell	0.1 ppm
2	Weak smell yielding distinguishable source	0.6 ppm
3	Easily detectable smell	2 ppm
4	Strong smell	10 ppm
5	Fierce smell	40 ppm

【Test result】

At low humidity	When humidity was raised
35 °C / 30 % RH	30 °C / 80 % RH

Table 22

	Odor intensity
silica gel	**0**
ion adsorption	**0**

⇒

⇒

	Odor intensity
silica gel	**1.5**
ion adsorption	**0.6**

The strength of odor is a mean value of 5 panelists

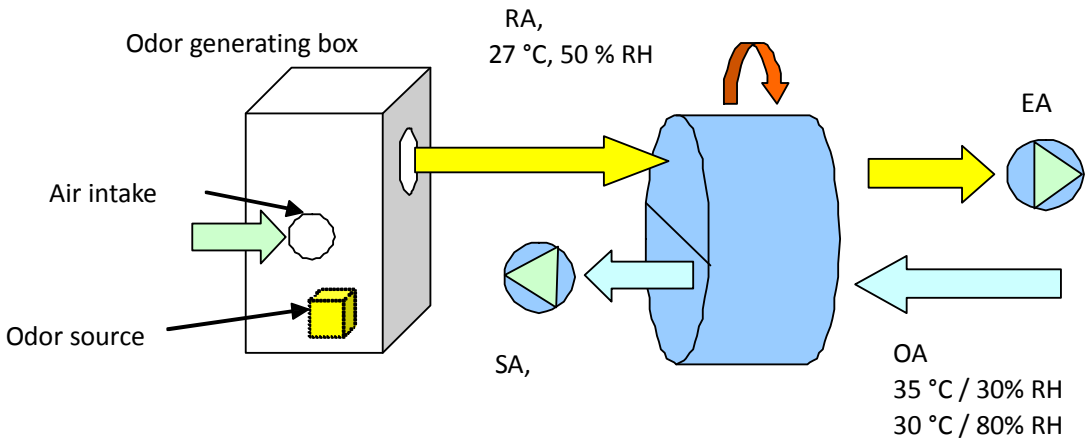


Figure 41 Experimental arrangement

3. About anti-bacteria and anti-molds

Heat exchangers by ion power employ a new types of adsorbent, together with agents against bacteria and molds, resulting in a complete solution of the odor problem with a true contribution to improvement in IAQ (indoor air quality). Because the agents against both bacteria and molds are chemically stable and are not consumed, they can exert their actions semi-infinitely under normal conditions of air conditioning. In addition, they are insoluble in water, and it is possible to wash them using water. However, it may be possible to lower their activities when being washed in a large amount of water. If necessary, we may provide water-washing and wash-coating of the agent again in-situ.

The actions of anti-bacteria and molds are exerted once bacteria or molds directly touch the surface of the honeycomb structure (prohibitive actions of their breeding and existence), and are not to kill them while air is passing through the honeycomb. For applications which deliberately require killing or keeping off bacteria, please install a specially prepared filters. The structure of the honeycomb surface is made as shown in Figure 42. Because a layer of agents against bacteria and molds completely covers the surface, with resultant actions of anti-bacteria and anti-molds at any place.

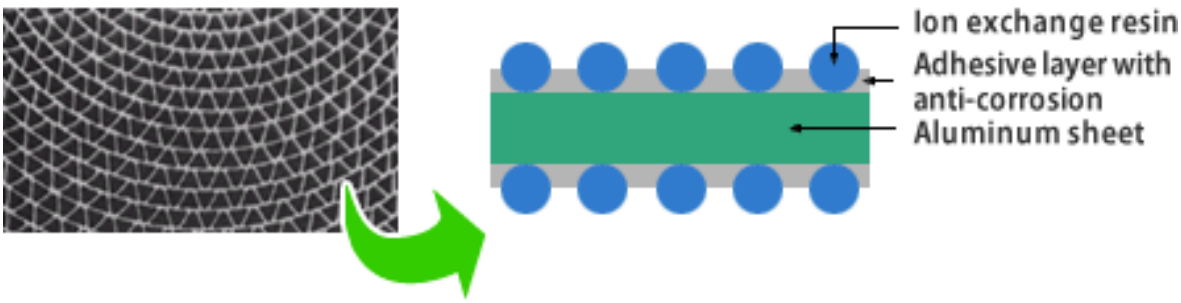


Figure 42 Structure of a honeycomb surface

4. About ion-exchange resin

4-1. Structure of ion-exchange resin

The ion-exchange resin used in heat exchangers by ion power is a stylen-divinylbenzene copolymer. The resin itself does not possess a moisture-adsorbing capability, but a chemical reaction of introducing a sulfonic radical ($-SO_3H$) into it enables strong adsorption capability of moisture to be added. Because $-SO_3^-$ cannot freely move, it is called as "fixed ion". An electrically neutralizing positively charged H^+ ion against the ion-exchange radical is called as "counter ion", and can freely move. If the counter ion is H as in this case, it exhibits a strong acidity and can exchange an ion with other alkaline ion. For example, if NaCl is in contact with it, an ion exchange reaction occurs where Na+ is exchanged to form $-SO_3Na$ at the resin side and HCl is formed at the NaCl side. Because heat exchangers by ion power use a resin with a type where an ion-exchange radical is neutralized as $-SO_3Na$ which is very stable, an ion exchange usually does not occur under normal operation (such ions as NH_3^+ do not exchange). Figure 43 illustrates an artistic image of a structure of the ion-exchange resin.

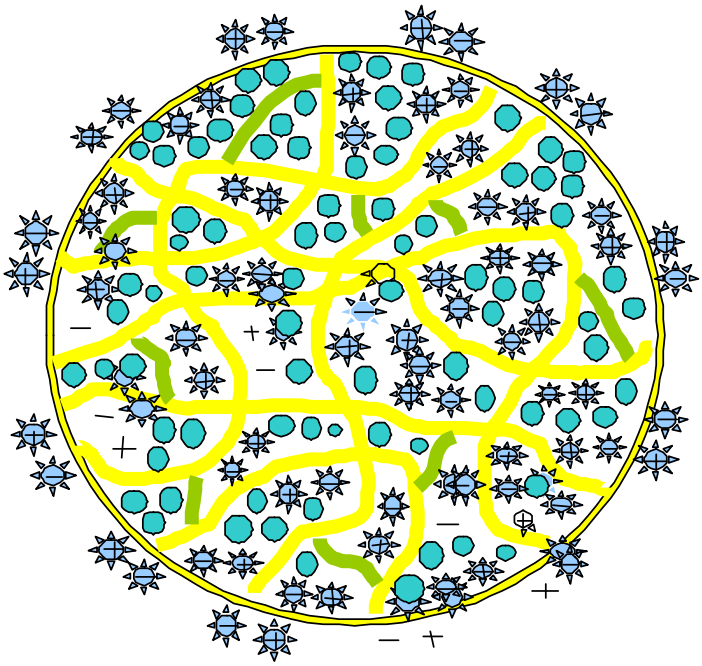


Figure 43 Structure of ion-exchange resin

4-2. Principle of adsorption (moisture absorption) in ion-exchange resin

SO_3^- and NA^+ ions in ion-exchange resin strongly absorb humidity, and moisture in air is adsorbed in it to look like being surrounded by water molecules. (Refer Figure 44) H_2O is a polar molecule, with the O side being charged δ- and the H side being charged δ+. Therefore, Na^+ is attracted electrically to the O side of H_2O, and SO_3^- is attracted to the H side to be neutralized. The water thus contained in resin by ion power is called as "combined water".

In addition, because ion-exchange resin is regarded as an electrolyte with relatively high concentration, it tends to absorb water by the self-dilution process (Figure 45). The water thus adsorbed (absorbed) by osmotic pressure is called "free water". Thus, ion-exchange resin absorbs water by two actions and swell on. Once resin is swelling, chains in matrix is expanded with a resulting compressive force, and an equilibrium condition is reached between the water-absorbing force and the compressive force with the resultant water content at a certain level. One reference cites the compressive force in the resin to be nearly 200 atm, which means that an equivalently strong osmotic pressure acts to absorb water.

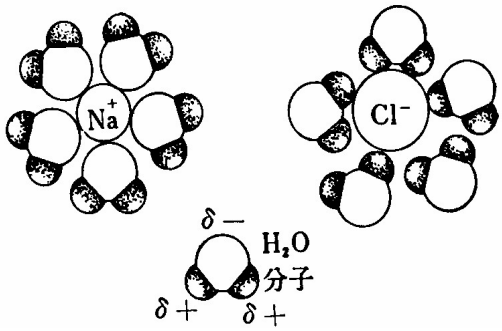


Figure 44 Hydration state of ions

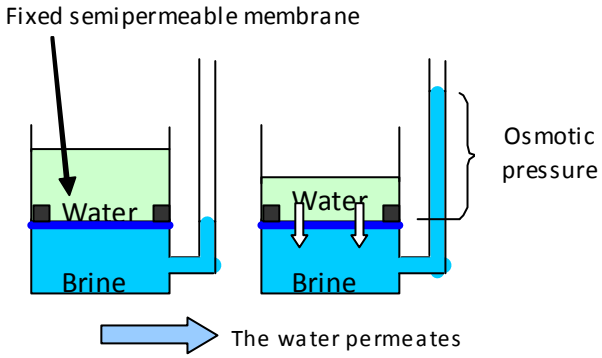
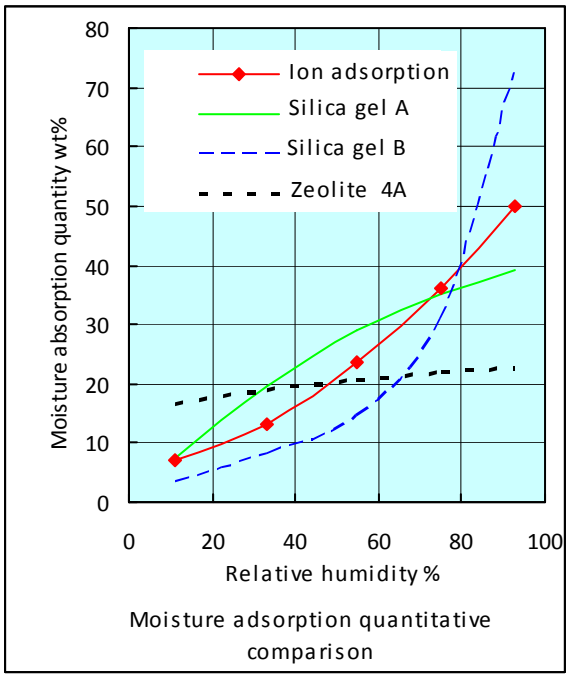
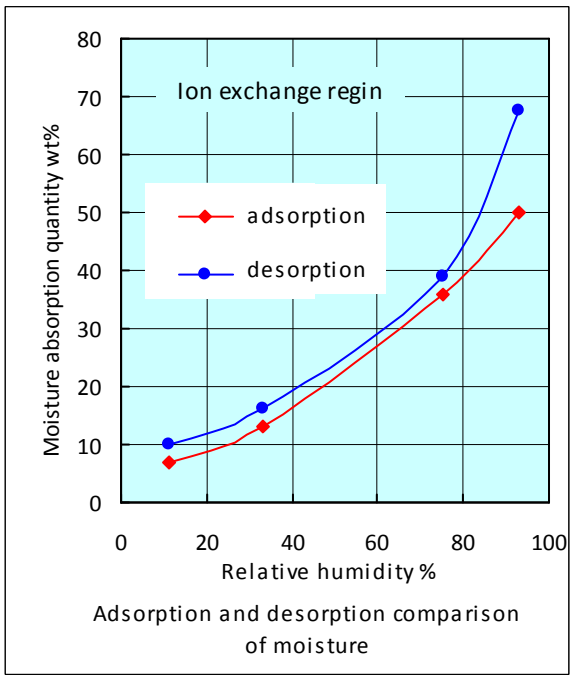


Figure 45 Explanation of osmotic pressure



Moisture adsorption quantitative comparison

Figure 46



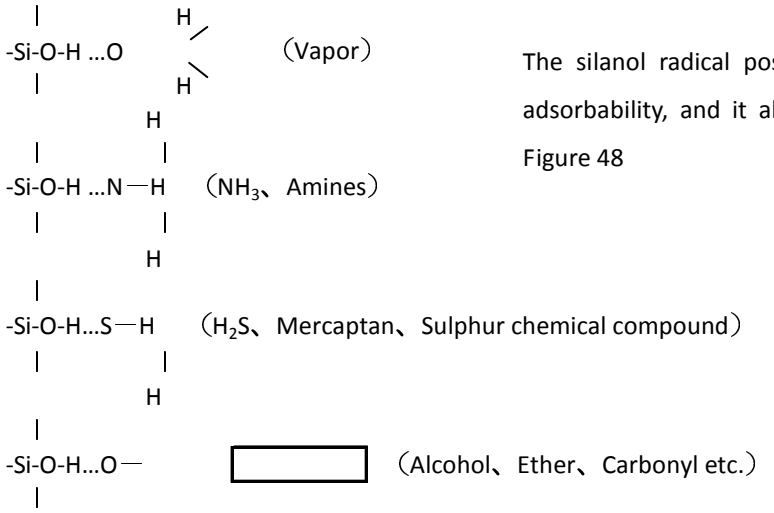
Adsorption and desorption comparison of moisture

Figure 47

4-3. Principle of odor adsorption

1) Prinsiple of odor adsorption in silica gel

A. The adsorption principle due to the siranol radical



The silanol radical possesses a very strong vapor adsorbability, and it also adsorb odoor,as show in Figure 48

Figure 48 The adsorption principle due to the silanol radical

B.Capillary adsorption

Capillary force acts to drive water and other liquids through a narrow tube, and small pores of around 3~100Å in silica-gel and other substances adsorb moisture contained even in air. Odor-causing molecules which are not adsorbed in silanol radicals may be partially adsorbed by capillary force (*Figure 49*)

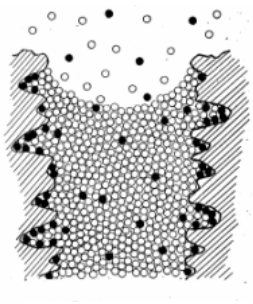


Figure 49 Adsorption in a small pore.

2) Odor adsorption in rotors using flame resistant paper

It may be anticipated that rotors using flame resistant paper be small in odor adsorption because they exchange latent heat (moisture) by wash-coating lithium chlorides, which does not have silanol radical nor capillary tube. However, cellulose and pulp, which constitute paper, have hydroxile radicals on their surfaces, resulting in odor adsorption by hydrogen bond similarly as silanol radicals.

4-4. Reasons for ion-exchange resin of not adsorbing odor

As explained in the previous section, ion-exchange resin adsorbs moisture by the principles of hydration force of ions and osmotic pressure. For the case of moisture adsorption by hydration force, ions are surrounded by water molecules with a strong force, and there is no possibility for other odor-causing molecules to get close to them. On the other hand, for the moisture adsorption by osmotic pressure, high density electrolytes, such as ion-exchange resin, try to adsorb moisture in order to lower their density, whereas odor-causing molecules tend to make the density higher, thus excluding the possibility of odor-causing molecules to be adsorbed there for this mechanism too. In addition, there is no small pores in ion-exchange resin at its dry condition thus eliminating a possibility of odor-causing molecules to be captured there, while small pores are formed filled with water molecules when it adsorbs moisture when it is captured by the mechanisms such as osmotic pressure. Even in the latter condition, however, the high internal pressure due to the swelling pressure, as depicted in Figure 50, almost prevents odor-causing molecules to be taken (dissolved) into the resin.

Table 23 Comparison of ion-exchange resin with other adsorbents

	ion-exchange resin	**silica-gel, zeolite, and alumina**
pore structure	**no small pore (gel-type)**	**have small pores**
principle of adsorption	**adsorption by hydration force and osmotic pressure** Resin adsorbs moisture against the swelling pressure, and the amount of water molecules taken into the resin is decided by the balance between the vapor pressure around it and the swelling pressure.	**cappillary adsorption** silanol radical adsorption **van der Waals adsorption**
principle of prevention of odor adsorption	The strong internal pressure (due to the swelling pressure) excludes a possibility of odor-causing molecules to be taken into the resin, while water molecules are adsorbed (taken in) due to the mechanisms described above.	**Synthetic zeolite has a function of molecular screening, but there is almost no effect on odor-causing molecules having small diameters, and these are adsorbed.**
odor adsorption	**odor adsorption almost non-existent**	**Possible odor adsorption**

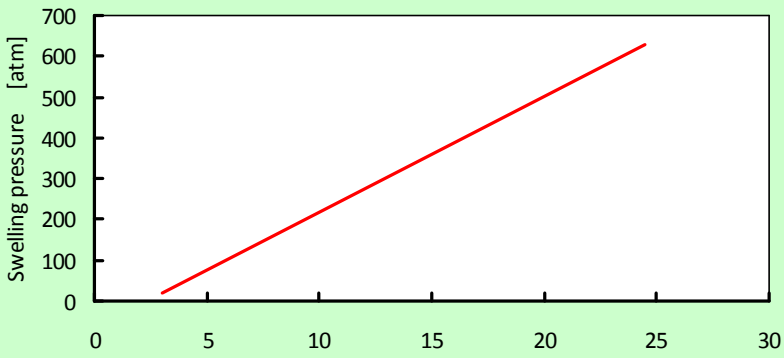


Figure 50 Relationship between swelling pressure and the degree of building a bridge in resin

F.Helfferich;"Ionexchange"McGraw-Hill Book Company,Inc.(1962)

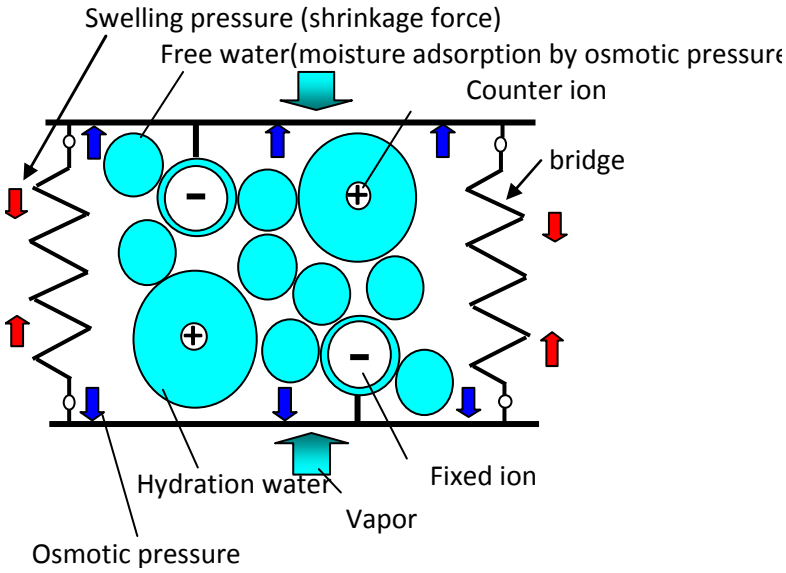


Figure 51 Pressure balance in ion - exchange resin

W.Buser,P.Graf and W.F.Grutter;Chimia,9,73(1955)

Seibu Giken Co.,Ltd. Head Office

3108-3 Aoyagi, Koga City, Fukuoka, 811-3134 JAPAN

TEL:2-942-3511

FAX:92-942-3761

http://www.seibu-giken.com

Seibu Giken DST AB

Avestagatan 33 163-53, Spånga,SWEDEN

TEL:46-8-445-7720

FAX:46-8-445-7739

http://www.dst-sg.com/

Seibu Giken America, Inc.

2929 Park Drive West,Owatonna,

MN 55060,U.S.A.

TEL:1-507-214-2715

FAX:1-507-214-2924

http://www.sgamerica.com/

Seibu Giken (Changshu) Co., Ltd.

8th Jin Lin Road,Changshu Southeast Development Zone,Jiahgsu 21500,P.R CHINA

http://www.seibu-giken.net.cn/

Shanghai Office

10A39, 41 Shanghai Mart 2299 Yan'an Road (West), Shanghai, CHINA

TEL : 86-21-6236-3005

FAX : 86-21-6236-30122