Sanyo Electric Co., Ltd.

Ventilation and Outdoor Air Treatment

Chapter 1 Humidification through Air Conditioning

"Humidity" is one of the four elements of air conditioning (temperature, humidity, airflow, and cleanliness), while humidity control consists of "dehumidification" and "humidification." During the summer cooling season, "dehumidification" occurs even without our awareness through "cooling/dehumidification" operations.

For winter "humidification," however, humidifiers must be intentionally built in and "humidity controllers (humidistats)" must be added when air conditioning systems are designed.

A variety of household humidifiers are on the market, and everyone seems to be aware of the necessity of humidification. Although you may already know this, let's take a brief look at the use of humidification and humidifiers in commercial air conditioning systems.

Chapter 2
Ventilation 4

Chapter 2 An Overview of Ventilation

For people to be able to maintain their health and comfort, "ventilation" in rooms is indispensable. But even with that understanding, a surprisingly large number of people seem to be unaware that it is also required by law.

<Ventilation design is covered in the Building Standards Law. Also, living-space air quality control standards are determined by laws such as the Law for Maintenance of Sanitation in Buildings (hereinafter referred to as the Building Management Law) and School Health Law.>

In this chapter we will learn about ventilation systems and ventilation computation methods, including taking a look at ventilation-related laws.

Chapter 3
Outdoor Air Treatment 16

Chapter 3 Outdoor Air Treatment

In mechanical ventilation systems, ventilation loads make up a large part of the air conditioning loads and have a large effect on air conditioner capacity. To conserve energy used by an air conditioning system and maintain a comfortable indoor environment, fresh outdoor air needs to be effectively treated and introduced indoors.
In this chapter we will learn about methods and equipment used to introduce the required amount of ventilation air.

Section 1 Outdoor air introduction methods

Section 2 Direct-expansion-coil outdoor air treatment unit

Section 3 High-Fresh

Section 1 Outdoor air introduction methods

There are a number of ways to introduce outdoor air through mechanical ventilation. Among these methods are heat recovery through total heat exchangers, mixing of indoor return air and outdoor air (OA), outdoor air treatment units, and Eco-Ice-min-supporting “Ventilation mo Guppy” indoor units. Using psychrometric diagrams, we will study the differences between the state points of these methods.

Section 2 Direct-expansion-coil outdoor air treatment unit

As one of the indoor units of a building Multi System, it can be used to formulate a total air conditioning system that includes ventilation. This energy-saving unit utilizes 100% outdoor air intake and is equipped with a total heat exchanger, enabling the outdoor air (supply air) to recover heat from the exhaust air. Let’s look at how it differs from an ordinary air conditioner.

Section 3 High-Fresh

This is an outdoor air treatment unit that is used in combination (connection) with the outdoor unit of a building Multi System.
This model utilizes 100% outdoor air intake and treats discharge air to room temperature level. Let’s look at how it differs from an ordinary air conditioner.

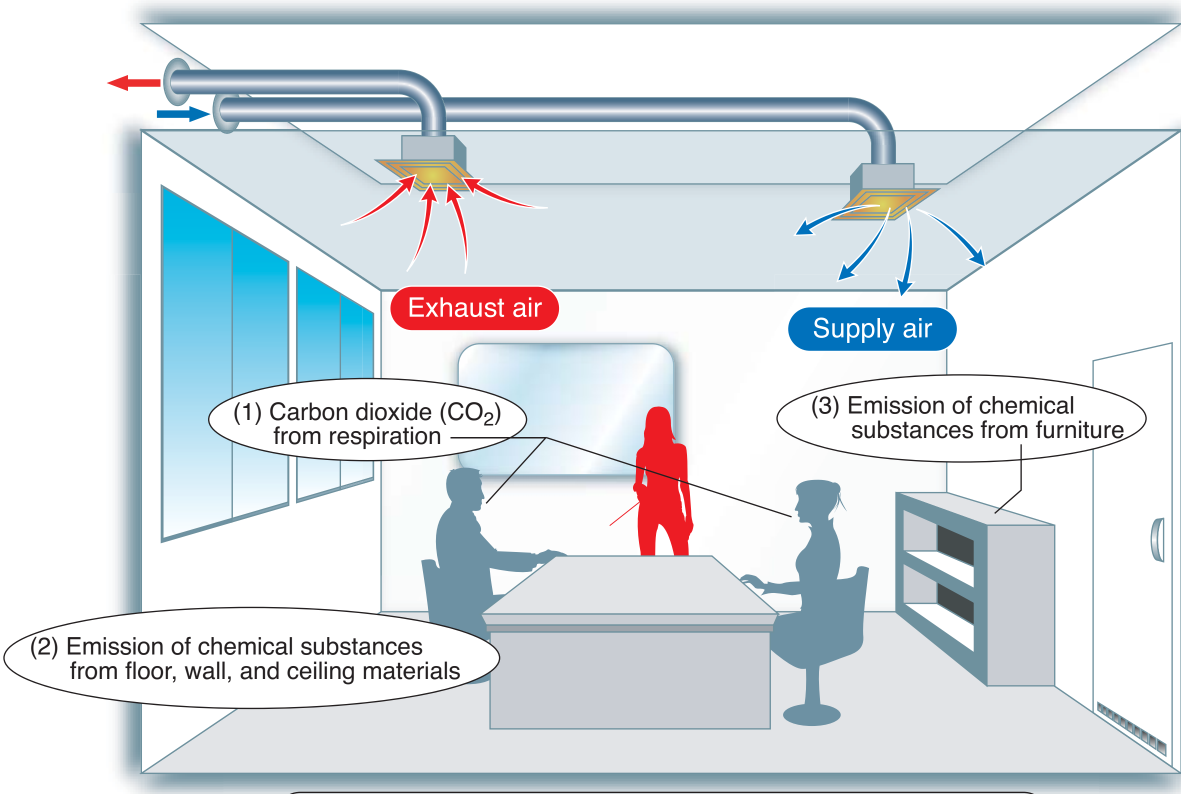
Chapter 2 Ventilation

1. Ventilation

Due to countermeasures for formaldehyde and other causes of sick house syndrome, the line of thinking regarding ventilation in rooms changed. In July 2003 the amended Building Standards Law was enacted.

Ventilation is the action of exhausting dirty indoor air and taking in fresh outdoor air.

Ventilation in rooms will be examined with respect to three factors, such as those shown in the figure below.
In the past, ventilation was considered from the aspect of (1) only. But as part of the sick house countermeasures, mechanical ventilation became mandatory for (2) and (3) as well (both residential housing and nonresidential buildings).



Sick house (sick building, sick school) countermeasures

First, ventilation is provided by ventilation fans to areas such as restrooms, hot-water service rooms, and kitchens. Rooms in general housing and small shops are often ventilated by ventilation fans, but in many other cases, natural ventilation is also provided through open windows and doors.

- Here we will think about ventilation intended for people in rooms. We know that air conditioning has four elements: temperature, humidity, airflow, and cleanliness. Room air cleanliness takes into account airborne dust and carbon dioxide (CO_2) concentration. Airborne dust is removed by an air filter.
- Carbon dioxide that is exhaled during human respiration is controlled by ventilation, and a required air ventilation rate per person has been established.
- As a result of the enactment of the amended Building Standards Law in July 2003, it became mandatory to install mechanical ventilation equipment in rooms as a countermeasure for sick house syndrome (or sick building/sick school syndrome in the case of buildings and schools). Along with that law, concentration control standards for formaldehyde, a chemical substance that typically causes sick house syndrome, were also established through various laws and regulations.

2. Ventilation-related laws

A number of laws apply to ventilation.

Building Standards Law **During building and design**

Ministry of Land, Infrastructure and Transport

In all rooms in buildings:

(1) **Windows, openings, and/or ventilation equipment shall be provided for ventilation.**

(2) **Health-related measures shall be taken to counter the emission of chemical substances.**
Ventilation equipment shall be installed in rooms.
(Added and executed in July 2003.)

* See the subsection 9. "Number of air changes in classrooms" for the formula used to compute the air ventilation rate necessary for (1) and (2) mentioned above.

Building Management Law **Maintenance**

(Law for Maintenance of Sanitation in Buildings) Ministry of Health, Labor, and Welfare

April 2003 to amendment enactment
Addition of standards for "quantity of formaldehyde"

- Total floor area: at least 3,000 m^2

Establishment of indoor environmental standards

- Control to reference standard or below (records, reports, on-site inspections, etc.)

School Health Law **Maintenance**

"School Environmental Health Standards" Ministry of Education, Culture, Sports, Science and Technology

February 2002 to amendment enactment
Addition of standards for "quantity of formaldehyde"

Following items as indoor environment acceptability standards:

- Heat environment: temperature, relative humidity, etc.
- Quantity of formaldehyde and volatile organic compounds
- Number of air changes

Standards for number of air changes in school classroom with 40 people and volume of 180 m^3:

- Preschool and elementary school: at least 2.2 times / h
- Junior high school: at least 3.2 times / h
- Senior high school: at least 4.4 times / h

A number of laws apply to ventilation. The governing legal authorities also vary. The primary legal provisions that pertain to ventilation are as follows:

- First, design is covered in the "Building Standards Law." There are two items that pertain to the design of ventilation for rooms: the long-established provision for "**Ventilation equipment for providing ventilation for persons in a room**" and the provision for "**Ventilation equipment for health measures against chemical substance emissions in rooms**," which was added with the amendment enactment in July 2003.
- The provision on "Health measures against chemical substance emissions in rooms" not only makes it mandatory to install ventilation equipment but includes restrictions on ceilings and restrictions on the use of construction materials used in buildings.
- Also, laws for **maintaining room air environment standards** include the Building Management Law and School Health Law, upon which the "School Environmental Health Standards" are based. In these laws, too, standards were added to control indoor concentrations of formaldehyde as a chemical substance.

3. Viewpoint of ventilation 1

Building Standards Law

- The viewpoint regarding ventilation for people varies according to the building construction.
- To provide ventilation to counter chemical substance emissions, <u>mechanical ventilation equipment is necessary for all rooms.</u>

Building construction	Ventilation for people ● **When people are present**	Ventilation for chemical substance emissions ● **Basically, 24-hour ventilation (housing)** ● **Intended for all rooms**
1. Area of window or opening that provides ventilation is at least 1/20 of living-space floor area	<u>Natural ventilation</u> through open window or opening	<u>Mechanical ventilation for each room</u> Required effective ventilation Vr (m^3 / h) Vr = nAh n: Number of air changes per hour Rooms in housing: 0.5 times / h Other rooms: 0.3 times / h A: Floor area of room (m^2), h: Height of ceiling in room (m)
2. For ratio of areas above: less than 1/20 3. Designated building (such as a playhouse, movie theater, performance hall, auditorium, public hall, or assembly hall)	<u>Mechanical ventilation</u> Effective ventilation V (m^3 / h) V = 20 Af / N Af: Floor area of room N: Area per person * In the formula for effective ventilation, (Af/N) is the number of persons in the room; therefore, the coefficient "20" is the air ventilation rate per person (m^3/h per person).	<u>In commercial and other nonresidential spaces, ventilation can be shut down when people are not present, such as at night and on nonworking days.</u> *** Even when construction materials that do not emit formaldehyde are used, there may be emissions from materials such as furniture. Therefore, in principle, it is mandatory for mechanical ventilation equipment to be installed in all rooms.**

Here is a summary of ventilation design from the Building Standards Law.
In the Building Standards Law and its enforcement ordinance, there are separate ordinance provisions for normal ventilation intended for people, and ventilation related to measures taken to counter chemical substance emissions.
*Text of Building Standards Law and enforcement ordinance pertaining to ventilation

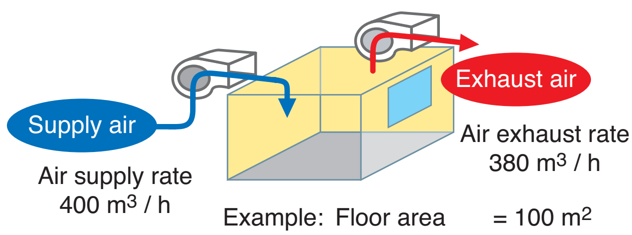
- The viewpoint regarding ventilation for people varies according to the building construction. Natural ventilation is also acceptable in rooms that have windows or other openings. In the past, natural ventilation seems to have been the norm for most housing, small shops, and schools.
- For ventilation that is related to measures taken to counter chemical substance emissions, the number of air changes is determined based on rooms in housing or other rooms (such as office and shop spaces), regardless of the building construction. Mechanical ventilation equipment is installed for every room.

What does "number of air changes" refer to?

Number of air changes
"How many times in one hour is the air in a certain room replaced?"
If the air changes 0.5 times / h, then half of the air is replaced in one hour.
(In other words, the air is replaced once every two hours.)
It is found by dividing the air ventilation rate by the volume of the room (or "air volume").
For example, in the figure below:

Number of air changes = Air ventilation rate/Volume of room
= 400 m^3 / h / 270 m^3
$\fallingdotseq$ 1.5 times / h

(If the air supply rate and air exhaust rate are different, the larger value is the air ventilation rate.)



Example: Floor area = 100 m^2
Ceiling height = 2.7 m
Volume of room = 100 × 2.7 = 270 m^3

4. <Reference> Amended Building Standards Law

As a result of the July 2003 amendment enactment (June 2002 establishment), “Health measures against chemical substance emissions” was added as shown in the right-hand table in the figure below.

Standards Law

Pertaining to Normal Ventilation

Article 28.2 In rooms, windows and other openings shall be installed for ventilation. The area of the portion that is effective for such ventilation shall be at least 1/20 of the floor area of the room. This requirement shall not apply, however, if ventilation equipment is installed in accordance with engineering standards established by government ordinance.

Health Measures against Chemical Substance Emissions

Article 28.2 Building materials and ventilation equipment used in buildings having rooms shall comply with engineering standards established by government ordinance, so that there will be no impediments to health caused by the emission of government-ordinance-designated chemical substances in rooms.

Enforcement Ordinance

Pertaining to Normal Ventilation

(Engineering standards for ventilation equipment)
Article 20.2 Engineering standards established by government ordinance in provisory clause of Article 28.2 of Law

1. The structure of ventilation equipment shall be in conformity with item a, b, c, or d below.

a. Natural ventilation equipment, in addition to complying with the provisions of Article 129.2.6.1, shall have the structure specified below.
(1) Effective cross-sectional area of exhaust pipe
(2) Effective opening area of supply air inlet and exhaust port
(3) In addition to meeting the provisions established in (1) and (2), the structure shall ensure ventilation that is effective for health.

b. Mechanical ventilation equipment (expect for that of a central control system), in addition to complying with the provisions of Article 129.2.6.2, shall have the structure specified below.
(1) The effective ventilation shall be not less than the value calculated from the following formula:
V = 20 Af / N
V: Effective ventilation (in cubic meters per hour)
Af: Floor area of room
(If there is a window or other opening that is effective for ventilation, it is the area calculated by taking the ventilation-effective area of the given opening, multiplying it by 20, and then subtracting that product from the floor area of the given room.) (in square meters)
N: Area per person, based on the actual conditions (For rooms in special buildings, use 3 if 3 can be taken. For other rooms, use 10 if the value exceeds 10.)

c. Air conditioning equipment of central control system

d. Equipment other than ventilation equipment having the structure specified in items a through c

Health Measures against Chemical Substance Emissions

(Engineering standards related to health measures against chemical substance emissions)
Article 20.6 Engineering standards established by government ordinance in Article 28.2 of the Law contain the following provisions related to ventilation equipment:

1. **Ventilation equipment whose structure conforms to one of the items below shall be installed in rooms.**

a. Mechanical ventilation equipment, in addition to complying with the provisions of Article 129.2.6.2, shall have the structure specified below.
(1) The effective ventilation (per cubic meter) shall be not less than the required effective ventilation calculated from the following formula:
Vr = nAh
Vr: Required effective ventilation (in cubic meters per hour)
n: Number of air changes per hour
Rooms in housing: 0.5; Other rooms: 0.3
“1. In this table, the term ‘rooms in housing’ refers to rooms in residences as well as hotel rooms, residence hall rooms, and shops that sell furniture or similar products (including hallways and other parts of buildings where ventilation is exchanged with such rooms through openings that are constantly open).”
A: Floor area of room (in square meters)
h: Ceiling height in room (in meters)

b. Mechanical ventilation equipment of system that purifies and supplies air in room

c. Air conditioning equipment of central control system

5. Viewpoint of ventilation 2

Here we will look at the relationship between “ventilation intended for people” and “ventilation related to measures taken to counter emissions of formaldehyde and other chemical substances.”

There are three points to consider.

<Point 1> Ventilation by windows and openings alone is insufficient!!
For rooms in housing and small shops that are ventilated by “natural ventilation,” “mechanical ventilation equipment” that provides not less than the following number of air changes shall be separately installed:
• Rooms in housing: 0.5 times / h.
• Nonresidential rooms (shops, offices, etc.): 0.3 times / h.

<Point 2> When installing mechanical ventilation equipment, satisfy the following two requirements:

(1) Secure the following number of air changes: “At least 0.5 time/hour for rooms in housing, and at least 0.3 time / hour for nonresidential rooms (such as offices)” as needed for chemical substance emissions.

(2) And secure an air ventilation rate of “at least 20 m^3 / hour per person,” based on the Building Standards Law.

● Generally, ventilation equipment that satisfies (2) will also satisfy (1). Note, however, that when it is used in large rooms in which there are few persons, the air ventilation rate in (1) may be larger.

<Point 3> In principle, mechanical ventilation equipment for chemical substance emissions shall be in operation 24 hours a day!!

For rooms in housing, a “24-hour ventilation system” should be used, based on the assumption that people are always present.

● At nighttime and on nonworking days when no one is present, it may also be possible to shut down the operation of nonresidential rooms (such as shops and offices) whose time of use is routinely limited. However, when operation resumes, it will be necessary to execute a “strong” notch operation or take other steps that can quickly reduce the concentration of chemical substances (formaldehyde) to the prescribed level.
<See page 257 of manual mentioned below.>

● For details on how to operate ventilation equipment for chemical substance emissions, see the following manual:
“Building Sick House Countermeasures Manual” that corresponds to the amended Building Standards Law – Building Standards Law/Housing Performance Indication System Explanation and Design Implementation Guide Manual –
Editing: Ministry of Land, Infrastructure and Transport, Housing Bureau, Building Guidance Division, Housing Production Division, others; Printing/issuing: Engineering documents

Let’s take another brief look at the three points pertaining to conventional ventilation and ventilation related to measures taken to counter emissions of formaldehyde and other chemical substances.

<Point 1> Rooms that are naturally ventilated by means of windows and other openings will be closed at times, such as at night. For this reason, mechanical ventilation equipment must be separately installed to control the emission of chemical substances. Rooms such as those in housing and small shops are thought to be applicable.

<Point 2> When mechanical ventilation equipment is installed, it is necessary to meet the following two requirements: attain the necessary number of air changes to discharge chemical substances, and attain an air ventilation rate of at least 20 m^3 / h per person.

<Point 3> In any event, chemical substances are emitted from items such as construction materials and furniture 24 hours a day. Therefore, ventilation aimed at discharging chemical substances from rooms is, in principle, a 24-hour operation system.

● However, it also appears to be possible to shut off ventilation operations in nonresidential rooms (such as shops and offices) when people are not present, such as at night and on nonworking days.
See the Sick House Countermeasures Manual for details.

6. Air ventilation rate per person

The basis of the air ventilation rate in rooms is the air ventilation rate per person.
According to the Building Standards Law, a value of 20 m^3 / h per person is used. Let's find out why.

The required air ventilation rate per person, V (m^3 / h), is calculated as shown below, using the carbon dioxide (CO_2) concentration in a room as a reference standard.

$$V (m^3 / h) = \frac{M}{K - K_O}$$

M: Quantity of CO_2 generated per person (m^3 / h per person)
See table below.

K: Allowable CO_2 concentration in room, 1,000 ppm = 0.001 m^3 / m^3
(This is the same as the value prescribed in the Building Management Law.)

K_O: CO_2 concentration in outdoor air, generally 300 ppm = 0.0003 m^3 / m^3

- Results of calculation of CO_2 generated per person (M) and air ventilation rate (adult)

	M (m^3 / h / person)	Ventilation rate (m^3 / h / person)
At rest	0.013	19 ⇒ 20
Extremely light work	0.022	31 ⇒ 30
Light work	0.030	43 ⇒ 40
Medium work	0.046	66
Heavy work	0.074	106

* The value of M above was taken from the "Building Equipment Design Guidelines," which was editorially supervised by the Government Buildings Department, Minister's Secretariat, Ministry of Construction.

Normally, a per-person air ventilation rate of 20 – 30 m^3 / h is used, but it is clear that this value will vary according to the amount of movement of each person.

The air ventilation rate in rooms is set at a value that will keep the concentration of carbon dioxide exhaled through human respiration (breathing) from rising. The reference standard is the air ventilation rate per person.

- Standard air consists of 21% oxygen and 78% nitrogen, with the remaining 1% composed of gases such as argon, carbon dioxide, neon, helium, and hydrogen. Although the concentration of carbon dioxide in the atmosphere naturally varies by location, it is said to be about 300 ppm.
- People inhale oxygen and exhale carbon dioxide. The quantity of carbon dioxide generated per person varies according to the amount of physical activity, as shown in the table above. Also, the allowable carbon dioxide concentration in a room is 1,000 ppm, the standard established by the Building Management Law, for instance.
- Based on these values, the air ventilation rate is sought for each work status. According to the Building Standards Law, the air ventilation rate per person is 20 m^3 / h. But generally a value of 20 – 30 m^3 / h is used.

7. Air ventilation rate formula

The air ventilation rate is determined by the "air ventilation rate per person" and "number of persons in the room."

This is the method used to compute the air ventilation rate for people in an ordinary living space.

(1) Finding the rate from the area per person N (m^2), based on an air ventilation rate per person of 20 (m^3 / h) (method established in the Building Standards Law)

$$V\ (m^3 / h) = 20\ (m^3 / h / person) \times \frac{A\ (m^2)}{N\ (m^2)}$$

A: Floor area (m^2)

● Yardstick for area per person (example) (m^2)

	Area / Person
Office	5
Inn or hotel	10
Playhouse, movie theater, public hall, or assembly hall	0.5 – 1
Hospital or medical treatment facility	5
Shop or restaurant	3
Department store	2

* Calculated using floor area at time of design and number of persons that can be accommodated at one time.

(2) Finding the rate from the air ventilation rate per person S (m^3 / h) and capacity p (number of persons)

$$V\ (m^3 / h) = S\ (m^3 / h / person) \times p\ (persons)$$

● Yardstick for ventilation rate per person (example) (m^3 / h)

	Recommended	Minimum
Office, shop, department store	25.5	17.0
Meeting room (smoking permitted)	85.0	51.0
Restaurant	25.5	20.0
Playhouse	25.5	17.0
Hospital	34.0	25.5

* Taken from “Building Equipment for Architects” by the Japan Federation of Architects & Building Engineers Associations.

(3) Finding the rate from the room’s required number of air changes n (times / h)

● For “emissions of chemical substances in rooms,” set the number of air changes at a minimum of 0.5 time / hour for rooms in housing, and 0.3 time / hour for other rooms.

● Other considerations include the number of air changes based on school environmental health standards.

$$V\ (m^3 / h) = n\ (times / h) \times A\ (m^2) \times h\ (m)$$

The air ventilation rate is determined by the “air ventilation rate per person” and “number of persons in the room.”

The air ventilation rate for people can be computed based on either the Building Standards Law or the capacity. Regardless of the method used, however, the computation is basically the same.

- In short the air ventilation rate is found by multiplying the number of persons in the room by the air ventilation rate per person. That is because the number of persons (p) is found by dividing the floor area A (m^2) by the area per person N (m^2).
- The computation method established in the Building Standards Law is a formula that is used when the area per person N (m^2) is provided and the air ventilation rate per person is assumed to be 20 (m^3 / h).
- The key point is determining the air ventilation rate per person. Let’s use the formula in the preceding item and the table above for reference. Generally, a rate of 20 – 30 m^3 / h per person is used. From a ventilation aspect, a large numerical value is preferable. But taking into consideration energy conservation, it may be preferable to use the value mentioned in the Building Standards Law, since the air conditioning load can become quite large.
- Also, the rate may be determined by the number of air changes, too. But as shown in the computation example in the next subsection, the air ventilation rate calculated in (1) and (2) may also be calculated in order to confirm the approximate number of air changes that will result. If the school air change standards are revised to the air ventilation rate per person, the result will be 10 – 20 m^3 / h per person. Thus, the level will be lower for elementary school children; but for high school students, the level will be the same as for adults.

8. Air ventilation rate computation (example)

Let's find the required air ventilation rate V (m^3 / h) for an example in which the floor area is the same but the usage and number of persons in the room are different.
(Use the formulas and numerical values from the preceding subsection.)

● **Computation of air ventilation rate based on number of persons in room**	Computation using method (1) (method established in Building Standards Law) **V (m^3 / h) = 20 (m^3 / h / person) × $\frac{A (m^2)}{N (m^2)}$**	Computation using method (2) From air ventilation rate per person S (m^3 / h) and persons in room p (number of persons) **V (m^3 / h) = S (m^3 / h / person) × p (persons)**
1) General office: example Floor area: 100 (m^2) Ceiling height: 2.7 (m) Persons in room: 20 Room volume: 100 × 2.7 = 270 m^3	Area per person: 100 m^2 / 20 persons = 5 m^2 / person V = 20 × (100 / 5) = 400 m^3 / h Number of air changes n (times / h): n = 400 / 270 ≒ 1.5 times / h	If air ventilation rate per person is set as 25.5 m^3 / h / person, then V = 25.5 × 20 = 510 m^3 / h Number of air changes n (times / h): n = 510 / 270 ≒ 1.9 times / h
2) Department store: example Floor area: 100 (m^2) Ceiling height: 3 (m) Persons in room: 50 Room volume: 100 × 3 = 270 m^3	Area per person: 100 m^2 / 50 persons = 2 m^2 / person V = 20 × (100 / 2) = 1000 m^3 / h Number of air changes n (times / h): n = 1000 / 300 ≒ 3.3 times / h	If air ventilation rate per person is set as 25.5 m^3 / h / person, then V = 25.5 × 50 = 1275 m^3 / h Number of air changes n (times / h): n = 1275 / 300 ≒ 4.25 times / h

* The difference between (1) and (2) below is the "air ventilation rate per person."

Don't forget this computation either!

● Examination of mechanical ventilation equipment for chemical substance emissions

V (m^3 / h) = 0.3 air changes (times / h) × A (m^2) × h (m): for nonresidential room

In case 1) above: V = 0.3 × 100 × 2.7 = 81 m^3 / h
In case 2) above: V = 0.3 × 100 × 3 = 90 m^3 / h

As computed above, installation of the mechanical ventilation equipment sufficiently clears the standards.

Using the formulas in (1) and (2) in the preceding subsection, we will compute the air ventilation rate based on the number of persons in the room. To simplify comparison, the same floor area will be used, but the intended usage and number of persons in the room will differ.

- The difference between the formulas in (1) and (2) is the air ventilation rate per person. According to the Building Standards Law, the value is 20 m^3 / h per person. But if the recommended value for offices and department stores, 25.5 m^3 / h per person, is used in (2), the air ventilation rate becomes approximately 1.3 times the value shown in (1). In the calculation of (2) for department stores, it may be better to have a somewhat larger air ventilation rate per person.
- Along with the air ventilation rates, the respective numbers of air changes were also computed. At a minimum, the value was shown to be 1.5 times / h, wasn't it? The number of air changes needed to counter chemical substance emissions as specified in the Building Standards Law was shown to be 0.3 times / hour for nonresidential spaces. Thus, the aforementioned air ventilation rate was sufficient.

9. Number of air changes in classrooms

The School Environmental Health Standards contain inspection and acceptability standards for air heat and air cleanliness, formaldehyde and volatile organic compounds, and the number of air changes.
This subsection will touch on the number of air changes.

● Air change standards for classrooms

For classroom with 40 persons and volume of 180 m^3:

- Preschool, elementary school ⇒ At least 2.2 times / hour
- Junior high school ⇒ At least 3.2 times / hour
- Senior high school ⇒ At least 4.4 times / hour

The Ministry of Education, Culture, Sports, Science and Technology has independent standards for schools.

The aforementioned number of air changes is computed from the carbon dioxide (CO_2) that is generated by respiration as indicated below.
(School Environmental Health Management Manual: “School Environmental Health Standards Theory and Practice” (March 2004), Ministry of Education, Culture, Sports, Science and Technology)

● For the number of air changes (n), if we assume that the air ventilation rate is V (m^3 / h) and the room’s volume is C (m^3), then:

n = V / C

● Also, the air ventilation rate V is:

$$V\ (m^3 / h) = \frac{M}{K_t - K_o}$$

M: Quantity of CO_2 generated per person (m^3 / h / person)

K: Allowable concentration of CO_2 in classroom after t hours
1,500 ppm = 0.0015 m^3 / m^3

K_O: CO_2 concentration in outdoor air

● Quantity of CO_2 generated per person (M)

Preschool and elementary school (lower grade) students	0.011 m^3 / h
Elementary (upper grade) and Junior high school students	0.016 m^3 / h
Senior high school students and adults	0.022 m^3 / h

<Computation example> High school classroom containing 40 persons and volume of 180 m^3:

● Air ventilation rate: V = 0.022 × 40 persons / (0.0015 – 0.0004) = <u>800</u> m^3 / h

● Number of air changes: n = 800 / 180 = <u>4.4</u> times / h

* For reference and details on School Environmental Health Standards, access the Internet for “School Environmental Health Management Manual” at this URL: http: //www.mext.go.jp (Ministry of Education, Culture, Sports, Science and Technology home page). Follow the links for the latest information.
You can also view the School Environmental Health Management Manual: “School Environmental Health Standards Theory and Practice” (March 2004).

MEXT = Ministry of Education, Culture, Sports, Science and Technology

School classrooms must comply with the “Building Standards Law” (Ministry of Land, Infrastructure and Transport). In addition, inspection methods, acceptability standards, and follow-up measures are established in the “School Environmental Health Standards” for classroom maintenance, based on Article 3 of the “School Health Law” of the Ministry of Education, Culture, Sports, Science and Technology.

● As shown above, there are air change reference standards for ventilation. Such standards are calculated from the quantity of carbon dioxide (CO_2) generated per student through respiration, and from the allowable concentration in the classroom.

● Carbon dioxide standards such as the outdoor air concentration and in-classroom allowable concentration differ according to the regulation, such as the Building Standards Law and Building Management Law.

- School Environmental Health Standards

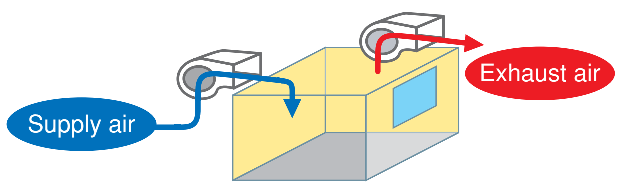
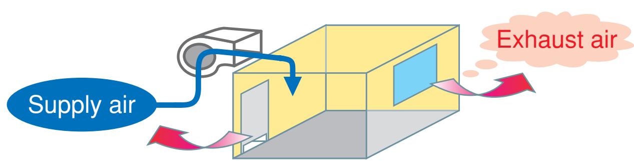
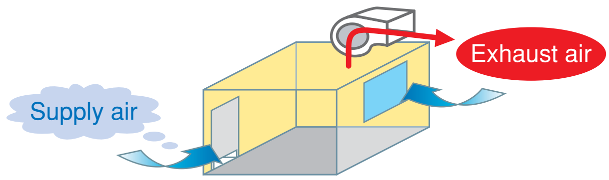
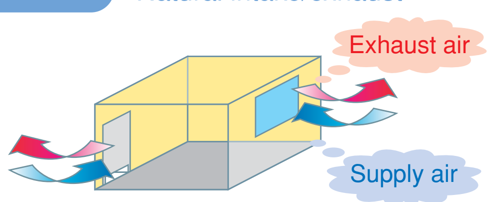
  The purpose of these standards, which are based on the School Health Law, is to ensure that environmental health inspections, follow-up measures, and day-to-day environmental health management are properly implemented and that school environmental health is maintained and improved.

Inspection methods and acceptability standards are in place for the air environment, including ventilation. The table below shows a summarized comparison with the Building Management Law for air heat and air cleanliness. Slight differences exist.

Heat and air cleanliness acceptability standards for classrooms		Building Management Law
Temperature	Winter: 10°C or above; summer: 30°C or below (Most desirable: 18 – 20°C in winter, 25 – 28°C in summer)	17 – 28°C
Relative humidity	30 – 80%	40 – 80%
Carbon dioxide (CO_2)	1500 ppm (0.15%) or less	1000 ppm
Carbon monoxide	10 ppm (0.001%) or less	10 ppm or less
Airflow	0.5 m / sec or less	0.5 m / sec or less
Airborne dust	0.10 mg / m^3 or less	0.15 mg / m^3 or less

10. Ventilation systems

Mechanical ventilation consists of type 1, type 2, and type 3 ventilation. To control chemical substance emissions, type 1 or type 3 ventilation is generally adopted.

Mechanical ventilation	Type 1 ventilation — Forced air intake/exhaust 	• Indoor pressure balance freedom • Total heat exchanger, High-Fresh + ventilation fan, direct-expansion-coil exterior air conditioner, and other systems
	Type 2 ventilation — Forced supply air and natural exhaust 	• Indoor can be given positive pressure • Can prevent inflow of dust from room surroundings (clean room or other designated usage)
	Type 3 ventilation — Forced exhaust and natural supply air 	Indoor air mechanically exhausted (also used for restrooms, lavatories, other local exhaust) • Indoor becomes negative pressure
	Natural ventilation — Natural intake/exhaust 	Achieved by opening/closing windows and doors (Type 1 and type 3 ventilation systems used in modern, well-insulated housing.)

Ventilation systems are broadly divided into “mechanical ventilation” and “natural ventilation” systems. The amended Building Standards Law made it mandatory to employ mechanical ventilation systems for chemical substance emissions.

- A mechanical ventilation system is a method that employs machinery (fans) to forcibly supply and/or exhaust air. Type 1 ventilation employs machinery to both supply and exhaust air. Most office buildings and large stores adopt this system. For energy conservation, it is recommended that a total heat exchanger and an air conditioner equipped with this system be adopted.
- Type 2 ventilation employs machinery for the air supply only. This system is also adopted to maintain positive pressure indoors in clean rooms, such as hospital operating rooms. Air is exhausted by natural exhaust.
- Type 3 ventilation employs mechanical means (such as ventilation fans) for exhausting only. This system is used widely, from households and schools to small- and medium-size offices and shops. In such cases, air is supplied naturally through the opening and closing of gaps, doors, and the like.
- Natural ventilation is a system that takes in and exhausts air from openings created by opening and closing windows and doors, for instance. In the future, rooms will require not only such natural ventilation but ventilation by mechanical equipment in order to counter formaldehyde and other chemical substance emissions.

- Carbon dioxide (CO_2) concentration

  Reference standards for the concentration of carbon dioxide in rooms have not been determined from the direct effect on the human body. Rather, standards for ventilation have been established from the viewpoint that as a person's respiration rate increases, not only will the amount of carbon dioxide increase but other pollutants will also likely increase. (Taken from the School Environmental Health Management Manual by the Ministry of Education, Culture, Sports, Science and Technology.)

<Carbon dioxide concentration>

Concentration		Effect
(%)	(ppm)	
0.03	300	Normal atmosphere
0.04 – 0.06	400 – 600	Urban outdoor air
0.07	700	Allowable concentration when many people are continuously in room
0.10	1,000	Building Standards Law, Building Management Law, and other standards
0.15	1,500	School ventilation standards and allowable concentration used in ventilation computations
0.5	5,000	Long-term safety limit (U.S. Occupational Health)
3	30,000	Work deterioration, physiological function deterioration, respiratory rate × 2
8	80,000	Deep breathing difficulty after 10 minutes

Summary

1. Ventilation is the action of exhausting dirty indoor air and taking in fresh outdoor air.
   For some time now, to prevent the concentration of carbon dioxide in a room from getting too high as a result of people breathing, a required air ventilation rate has been established. However, since July 2003, it has been an obligation to install ventilation equipment to counter the emission of formaldehyde and other chemical substances.
2. Ventilation is set forth in the "Building Standards Law," while laws such as the "Building Management Law" and "School Health Law" ensure that room (indoor) air environments are maintained. Thus, maintenance standards for indoor environments are established.
3. Compare and gain an understanding of the concepts of ventilation for people and ventilation for formaldehyde and other chemical substance emissions. Natural ventilation alone is no longer sufficient.
4. Air ventilation rates for people are calculated by finding information such as the air ventilation rate per person, area per person, and number of air changes.
   Try to remember rough numerical yardsticks for the air ventilation rate per person and number of air changes.
   If people-intended mechanical ventilation equipment is installed, the air ventilation rate for chemical substance emissions will be satisfactory in most cases.

Remember that air conditioning is a relevant aspect of air ventilation rate calculations.
Next, let's look at the treatment of outdoor air used for ventilation.

Chapter 3 Outdoor Air Treatment

Section 1 Outdoor air introduction methods

1. Outdoor air introduction and treatment methods (examples)

(1) Air intake and exhaust fans

Outdoor air is introduced directly through mechanical ventilation.

- Discharge generates drafty feel.
- Since indoor air conditioner also treats outdoor air load, capacity increases.
- Can turn ON/OFF without relation to air conditioner.

(2) Total heat exchanger

Energy-saving type 1 mechanical ventilation, with 60% – 70% heat recovery from exhaust air.

- Thirty to 40 percent of outdoor air load is carried by indoor air conditioner.
- Can turn ON/OFF without relation to air conditioner.

(3) Mixing by air conditioner

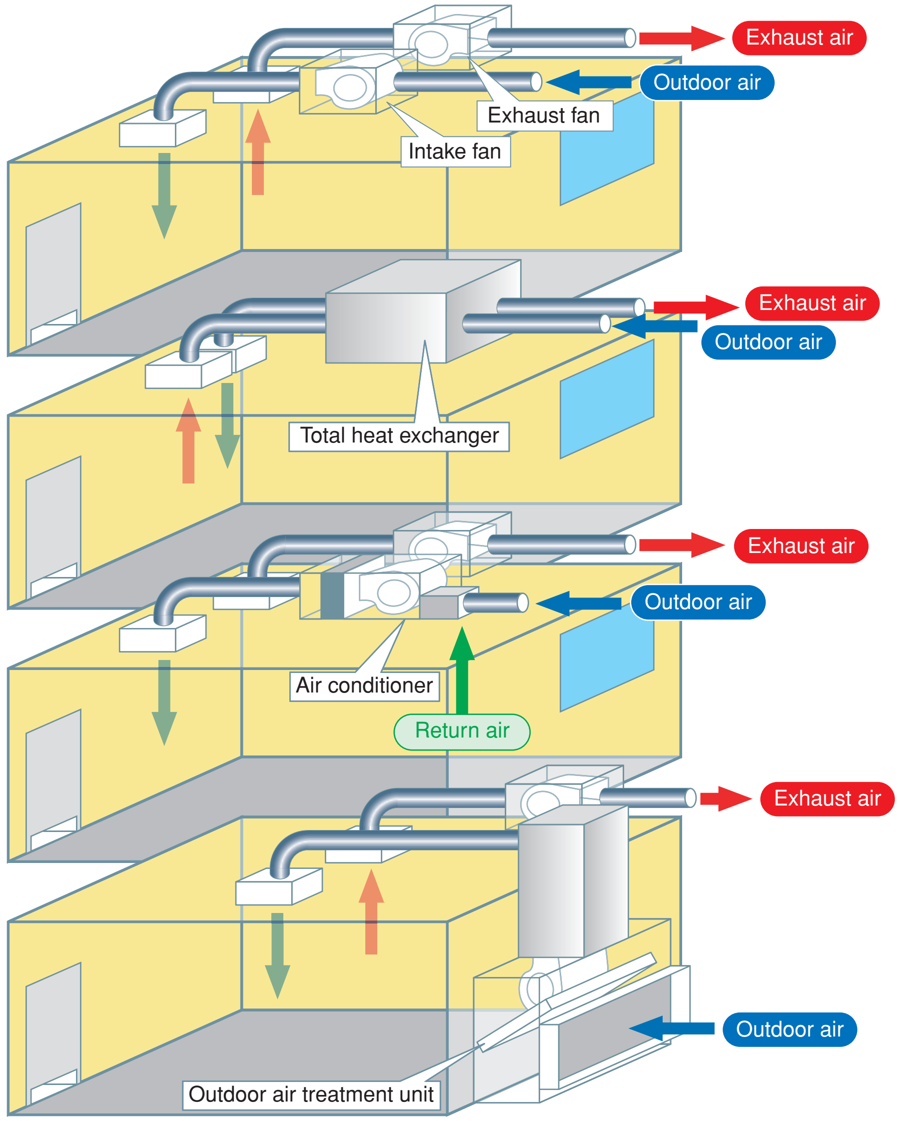
Outdoor air (supply air) and return air are mixed.

- Mixed air is treated by air conditioner.
- As with (1), capacity increases since indoor air conditioner also treats outdoor air load.
- Outdoor air is introduced only when air conditioner is ON.

(4) Outdoor air treatment unit

(All-Fresh and High-Fresh models)

- Can treat 100% outdoor air.
  (Cooling / dehumidifying and heating / humidifying)
- There is no outdoor air load on indoor air conditioner.
- Can turn ON/OFF without relation to air conditioner.



There are a variety of ways to ventilate, or introduce outdoor air.

(1) When outdoor air equivalent to the air ventilation rate is simply drawn indoors directly by an intake fan, there may be a drafty feel, caused by the difference in temperature between the outdoor air and room air. The outdoor air load is treated by an indoor air conditioner. Outdoor air can be introduced regardless of air conditioning.

(2) A total heat exchanger is an energy-saving device that can recover heat by causing an exchange of heat between the exhaust air and supply air. A typical example is Mitsubishi Electric's Lossnay. Our company has a "direct-expansion-coil outdoor air treatment unit" with built-in total heat exchanger which can accommodate a Multi System indoor unit.

(3) Intake outdoor air (supply air) mixes with return air from indoors, the air is either cooled or heated by an air conditioner, and the conditioned air is discharged into the room. Outdoor air intake ports are furnished, even for ceiling-suspended types and four-way / two-way ceiling cassette types.
Outdoor air is introduced only when the air conditioner is ON.

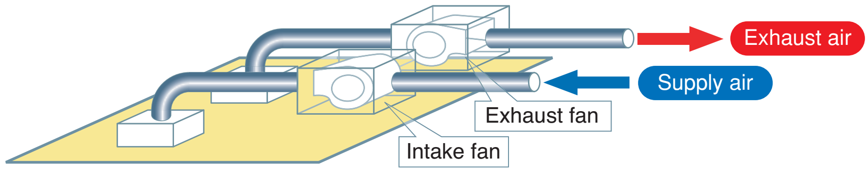
(4) This air conditioner treats outdoor air only. It includes conventional All-Fresh models (made-to-order products) and Multi System-supporting High-Fresh models.

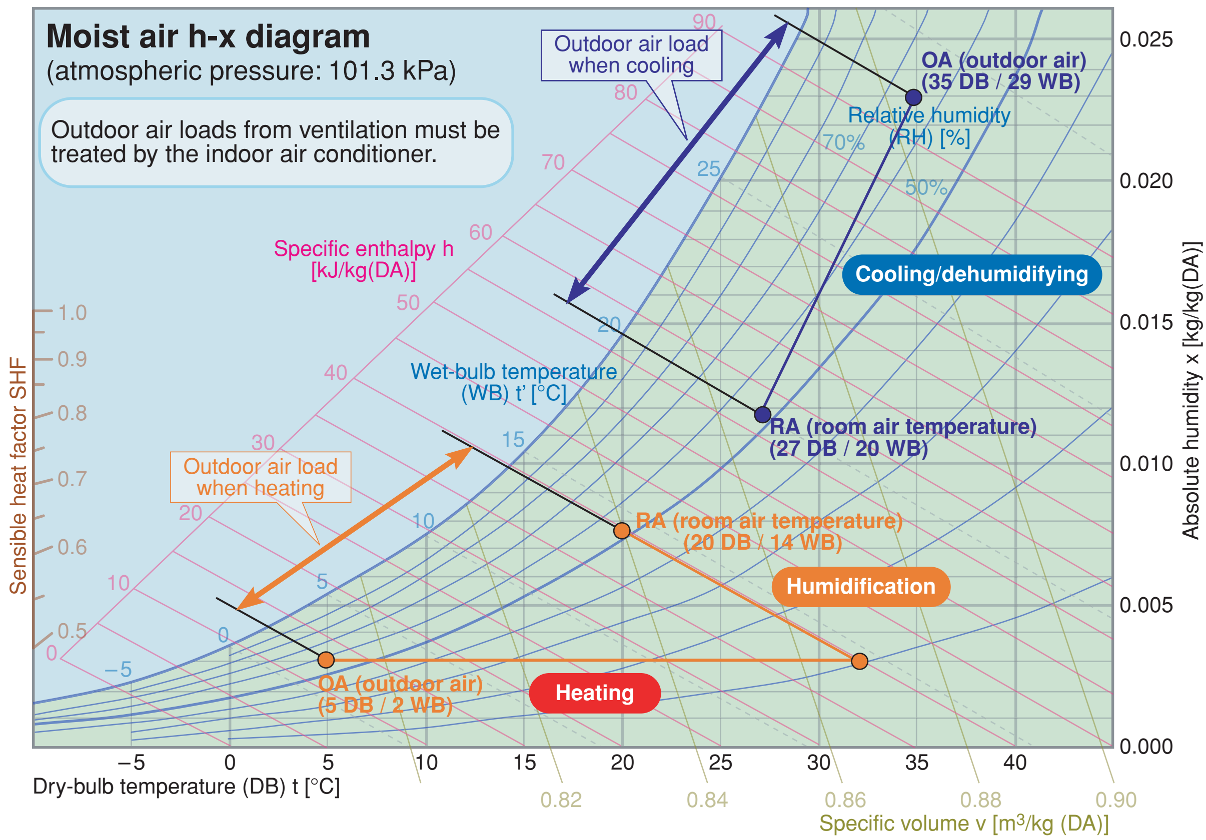
What is a good method to obtain fresh outdoor air and comfortable air conditioning? Let's look next at state changes and features of the various cases, using psychrometric diagrams.

2. Intake / exhaust fan ventilation

Ventilation by intake fans/exhaust fans

- Difference from room temperature is large, creating drafty feel.
- Indoor air conditioner also treats outdoor air load, causing capacity to increase.
- Regardless of air conditioner, intake/exhaust fan can operate.





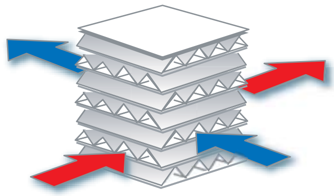
A psychrometric diagram shows the indoor / outdoor temperature that existed when outdoor air was drawn in by the intake fan. For the indoor / outdoor temperature, the total heat exchanger's JIS (B8628) conditions were used for reference.

- At a glance it is clear that there is a significant difference between the temperature and humidity of the air conditioned indoor air and the temperature and humidity of the outdoor air. When outdoor air is introduced by intake fan, air conditioning loads must be taken into account as described below.
- Outdoor air intake load when cooling:
  (Difference in OA and RA enthalpy) × Ventilation airflow
- Sensible heat load during heating: (Difference in OA and RA temperature) × Ventilation airflow
  Quantity of humidification: (Difference in OA and RA absolute humidity) × Ventilation airflow
- The air conditioner capacity must be determined from the indoor air conditioning load plus this ventilation load.
- When an office building introduces outdoor air, generally a total heat exchanger or outdoor air treatment unit treats the outdoor air (cools/dehumidifies in summer, and heats and humidifies in winter) and then blows it indoors.

3. Heat recovery with total heat exchanger

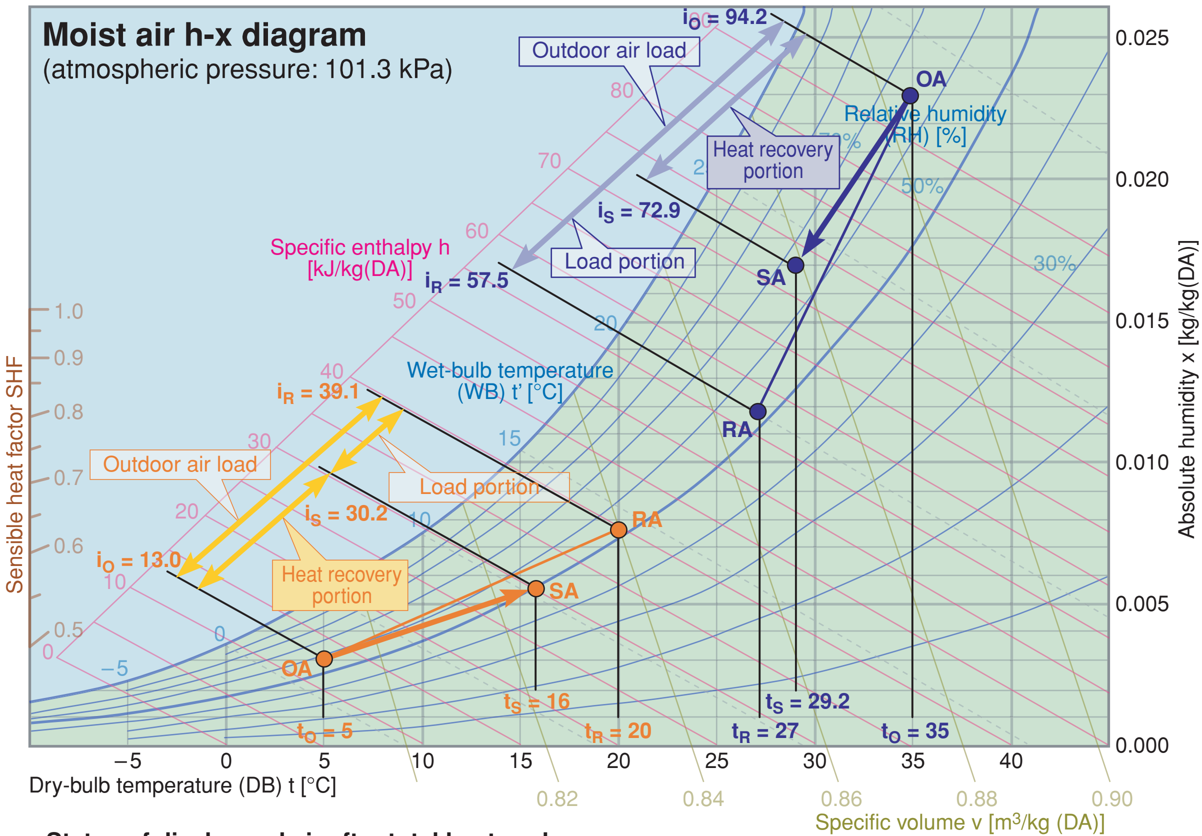
With a total heat exchanger, outdoor air that is taken in **recovers sensible heat and latent heat** from indoor exhaust air.

- Eases drafty feel and lightens burden of outdoor air load on indoor air conditioner.



Total heat exchanger: heat recovery (example)

- Sensible heat (temperature) exchange efficiency: 73%
- Total heat (enthalpy) exchange efficiency: cooling 58%, heating 66%



Efficiency computation formula

- Sensible heat exchange efficiency

$$\eta_t = \frac{t_O - t_S}{t_O - t_R} \times 100\ (\%)$$

- Total heat exchange efficiency

$$\eta_i = \frac{i_O - i_S}{i_O - i_R} \times 100\ (\%)$$

Formula above applies to cooling.
When heating, outdoor air temperature is lower; therefore:
$(t_S - t_O)$, $(t_R - t_O)$
$(i_S - i_O)$, $(i_R - i_O)$

<**Status of discharged air after total heat exchange**>
As indicated above, efficiency can be computed as shown below.
<Underlined part below corresponds to heat recovery portion>
1) Summer

- Discharge air DB: Since sensible heat exchange efficiency is 73%, 35 – (35 – 27) × 0.73 = 29.2 (°C).
- Discharge enthalpy: Since total heat exchange efficiency cooling is 58%, 94.2 – (94.2– 57.5) × 0.58 = 72.9 (kJ / kg).

2) Winter

- Discharge air DB: Since sensible heat exchange efficiency is 73%, 5 + (20 – 5) × 0.73 = 16.0 (°C).
- Discharge enthalpy: Since total heat exchange efficiency heating is 66%, 13.0 + (39.1 – 13.0) × 0.66 = 30.2 (kJ / kg).

Using the previously mentioned indoor / outdoor temperature conditions, let's look at the example of heat recovery with a total heat exchanger.

- Total heat exchanger efficiency consists of **sensible heat (temperature)** exchange efficiency and total heat (enthalpy) exchange efficiency. Please note that the winter and summer values of total heat (enthalpy) exchange efficiency are different.
- For example, a total heat exchange efficiency of 60% indicates that the heat recovery portion is 60%. The portion that can recover heat minimizes the indoor air conditioning load.
- Also, the **sensible heat (temperature)** exchange efficiency is generally the higher of the two. In the example, the difference between the room temperature and supply air temperature from total heat exchange is approximately 2 degrees when cooling and 4 degrees when heating. Thus, when heat recovery is taking place, not much of a draft is felt.
- **The air state (SA) after total heat exchange can be computed using the sensible heat exchange efficiency and total heat exchange efficiency. It can be found by creating the "t_S or i_S=" formula from the efficiency formulas shown above.**

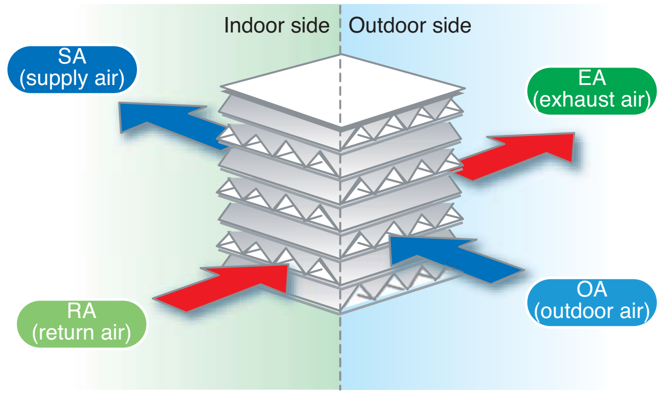
4. Total heat exchanger

This is an energy-saving device that can recover heat through type 1 mechanical ventilation.
Heat includes "sensible heat" and "latent heat," and total heat = sensible heat + latent heat.
This device exchanges heat between the exhaust air from indoors and the intake air from outdoors, and **recovers the sensible heat and latent heat**.

Static total heat exchanger

Small-size total heat exchanger

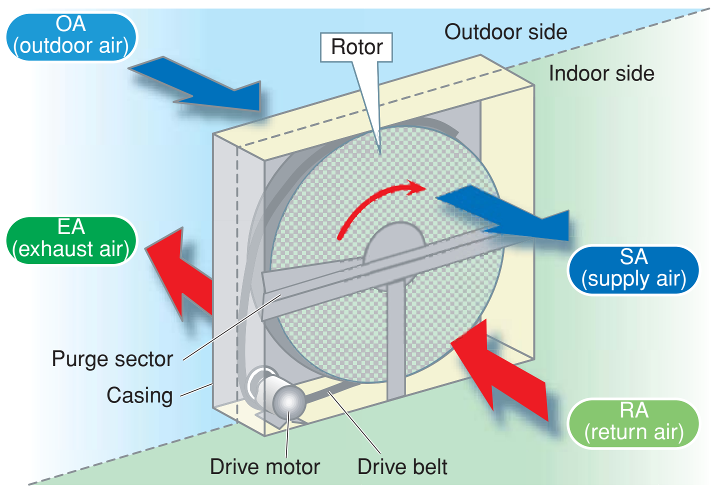
- This exchanger is typified by the Lossnay (Mitsubishi Electric trade name). Utilizing laminated moisture-permeable, specially treated paper, it exchanges the temperature and humidity of exhaust air from indoors and intake air from outdoors.
(Achieved by conduction and moisture permeability.)
- Also comes available in integrated models in which it is built into an air conditioner.



Rotary-type total heat exchanger

Normally, large-scale total heat exchanger

- Rotor rotation causes air to alternately pass through the air intake and exhaust route.
- The rotor material consists of flame-resistant paper or an aluminum surface coated with moisture absorbent.
- When air passes through the honeycomb-shaped rotor, the rotor stores heat and moisture from the indoor exhaust (recovers heat from the exhaust air). Then this is released on the outdoor air intake side.

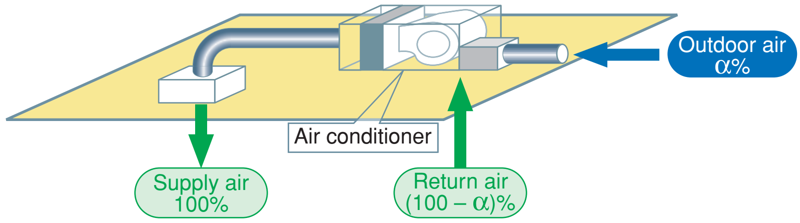


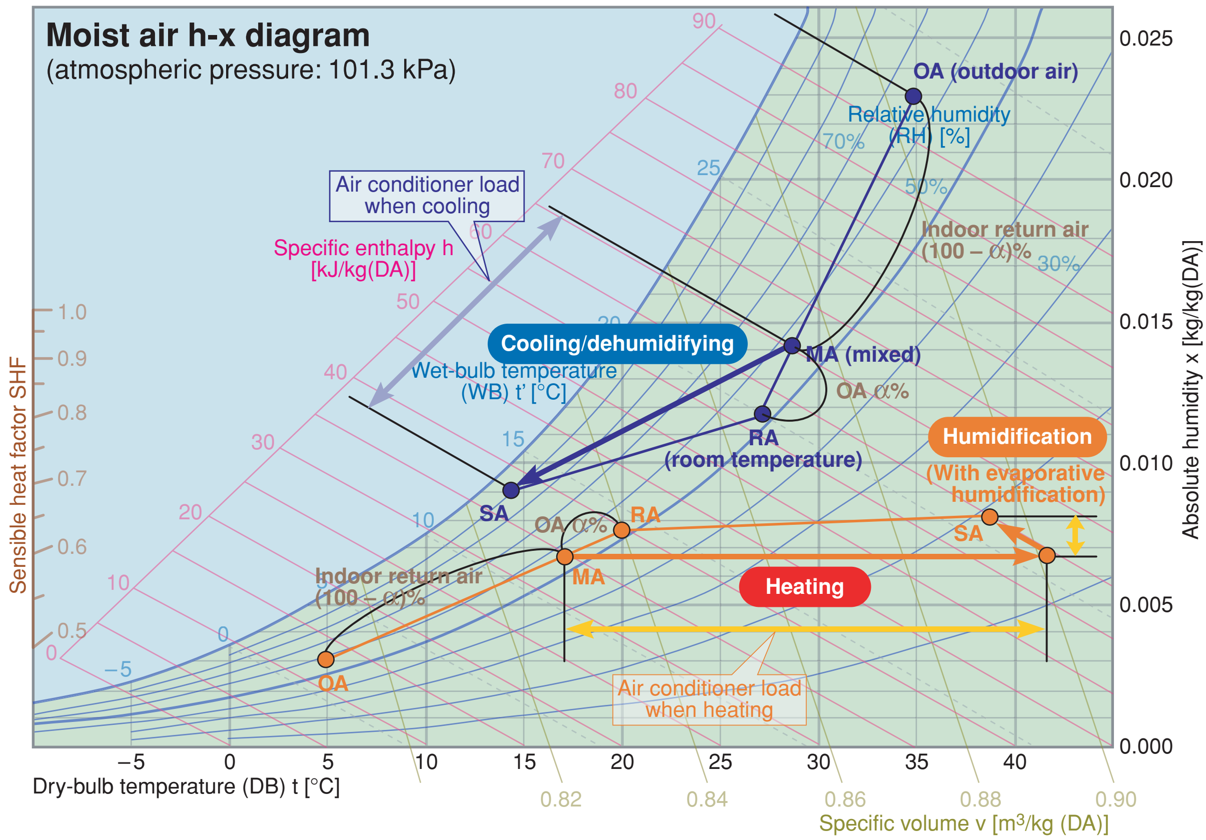
A total heat exchanger is a ventilating device that can recover the total heat of both sensible heat (the temperature-changed portion) and latent heat (the humidity-changed portion) from the indoor exhaust in a type 1 mechanical ventilation system.
Total heat exchangers can be divided into small-size "static types" and large-size "rotary types."

- The static type has a crossflow-type structure and is composed of spacing plates and partition plates made of specially treated paper having moisture permeability. The air intake and exhaust routes are separate. Temperature (sensible heat) exchange is achieved through conduction, while latent heat exchange is achieved through moisture permeation.
- The rotary type is a thermal-storage heat exchanger that utilizes rotor rotation to recover heat from the exhaust air for the supply air. As the honeycomb-shaped heat transfer element rotates, heat exchange is repeated, with heat storage and moisture absorption occurring on the exhaust side, and heat radiation and moisture release occurring on the air intake side.
- The rotary type is advantageous when the treated airflow is large. Its total heat exchange efficiency is generally higher than that of the static type. Maintenance is required, however, since it is driven by a motor.

5. Mixing with an air conditioner

Here we will find state points for mixed air in an outdoor air introduction system that mixes outdoor air and return air (from indoors) with an indoor air conditioner, cools or heats the mixed air, and then blows it indoors.





Outdoor air can be introduced with these types of indoor units: four-way / two-way ceiling cassette types, built-in and ceiling-embedded types, and ceiling-suspended types (A types). The introduced outdoor air is mixed with the return air from indoors, cooled (when cooling) or heated (when heating), and then blown in (discharged).

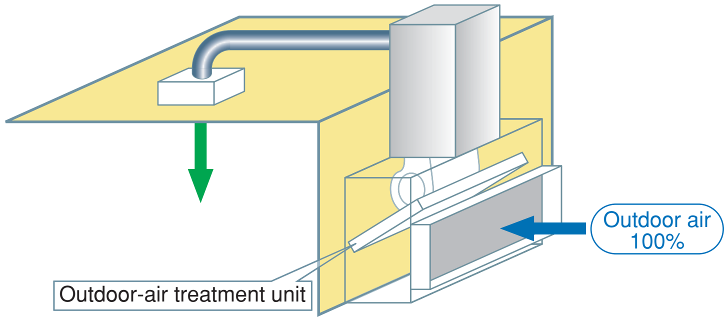
- If the quantity of the introduced outdoor air is α% of the indoor unit's rated airflow, the quantity of return air from indoors is (100 – α)%.
  (With a PAC / GHP indoor unit, the quantity of outdoor air intake is roughly 20% – 30% of the rated airflow when the air ventilation rate per person is 20 – 30 m^3 / h.)
- The state point for the mixed air is the point on the line segment <OA–RA> (joining the outdoor air and room temperature state points) where line segment <RA–MA> : <OA–MA> = α : (100 – α). In other words, if α is assumed to be 20% and the length of line segment <OA–RA> is 60 mm, then the length of line segment <RA–MA> is 60 × 20% = 12 mm. From this, mixed point MA is found.

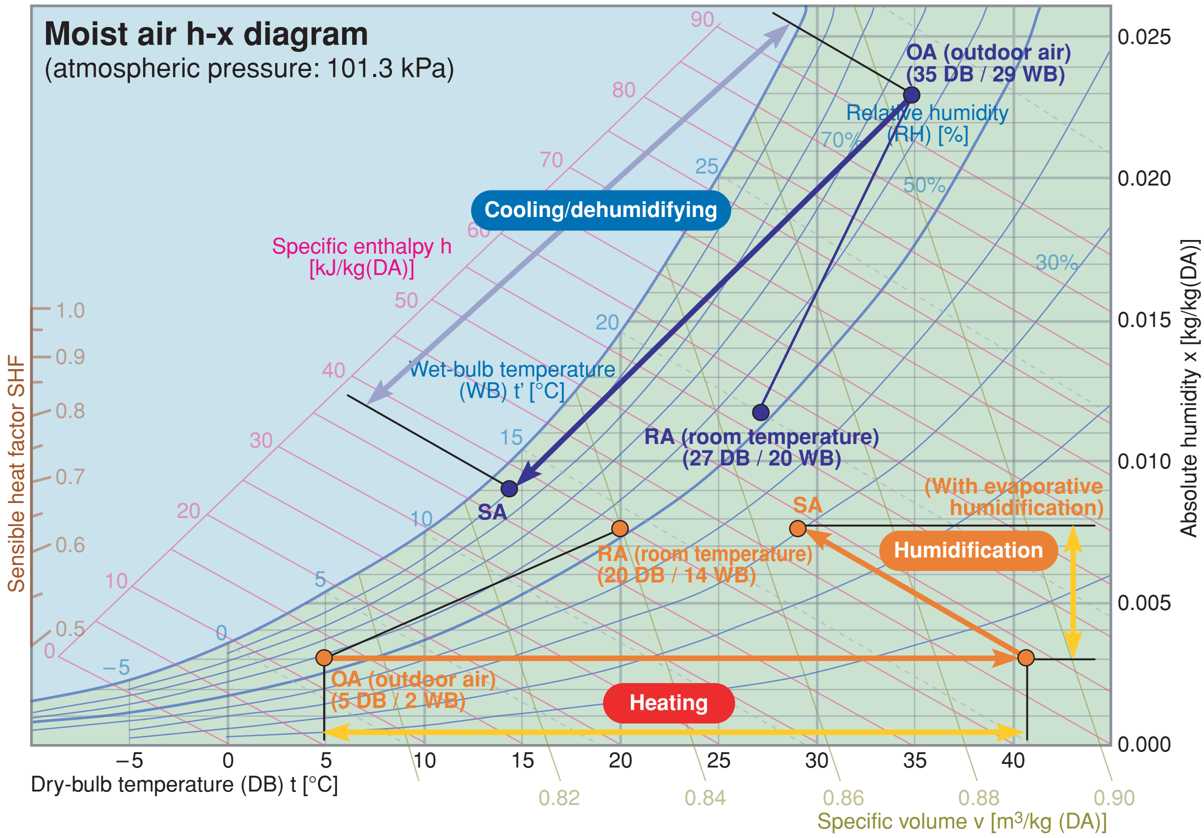
Mixed (MA) point
When outdoor air of α% of the indoor unit airflow is introduced, it is α% from the RA side of the line segment that joins the outdoor air (OA) and room temperature (RA).

6. Outdoor air treatment unit

To treat 100% of outdoor air, “All-Fresh” and “High-Fresh” units are available.

- An “All-Fresh” unit can obtain a discharge temperature equivalent to that of an ordinary air conditioner.
- A “High-Fresh” unit obtains a discharge temperature equivalent to the room temperature.





In addition to air conditioners that handle indoor loads, there are All-Fresh and High-Fresh units that treat 100% of the outdoor air.

<All-Fresh>

- Used for many years as an all-outdoor-air air conditioner in facilities such as factories and hospitals. It is available in water-cooled and air-cooled (cooling-only) models for facilities, and is generally provided with a hot-water, steam, or electric heater integrated for heating.
- **In contrast to an ordinary air conditioner, a discharge temperature equivalent to that of an ordinary air conditioner cannot be obtained unless the indoor airflow (= quantity of introduced outdoor air) is approximately 1/3 of the same equivalent horsepower model, since the temperature of the intake air during indoor heat exchange is high in summer and low in winter (due to the outdoor air).**

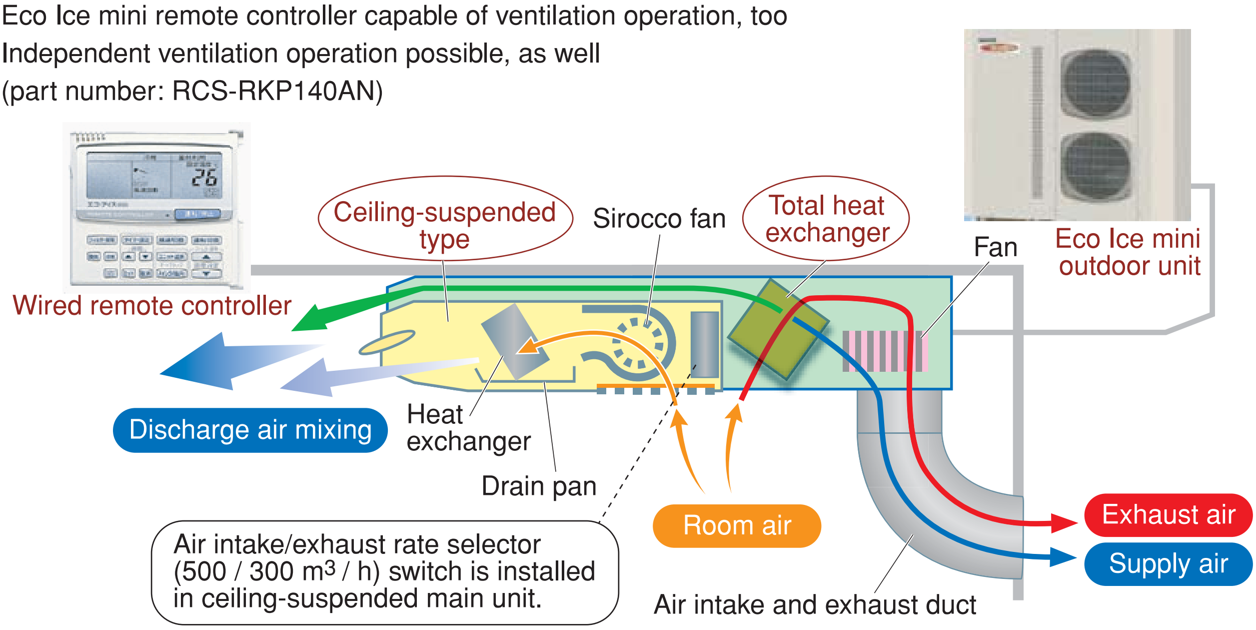
<High-Fresh> (Details given later)

- This is an All-Fresh model that was developed as an indoor unit of the Building Multi System. It was developed with a heat pump model for heating and cooling, so that the **discharge air temperature would be at the room temperature level**. Accordingly, the indoor airflow (= quantity of introduced outdoor air) is greater than the All-Fresh model, or about 40% – 45% of the same equivalent horsepower model.
- **For all models, humidification is needed when heating.**

7. Ventilation mo Guppy

Support for Eco Ice mini

- Ceiling-suspended indoor unit with integrated total heat exchanger
- Eco Ice mini remote controller capable of ventilation operation, too
  Independent ventilation operation possible, as well
  (part number: RCS-RKP140AN)



Classroom air ventilation rate and model selection (example)

Facility	Elementary School / Preschool	Jr. High School	Sr. High School
Required number of air changes *	At least 2.2 times / h	At least 3.2 times / h	At least 4.4 times / h
⇒ Converted air ventilation rate	⇒ At least 396 m^3 / h	⇒ At least 576 m^3 / h	⇒ At least 792 m^3 / h
Total heat exchanger specifications	**500 m^3 / h × 1 unit**	**300 m^3 / h × 2 units**	**500 + 300 m^3 / h × 2 units (total)**
Air conditioner capacity example (when 0.25 kW / m^2)	Indoor twin, outdoor 6 – 7 equivalent horsepower (Eco Ice mini)		

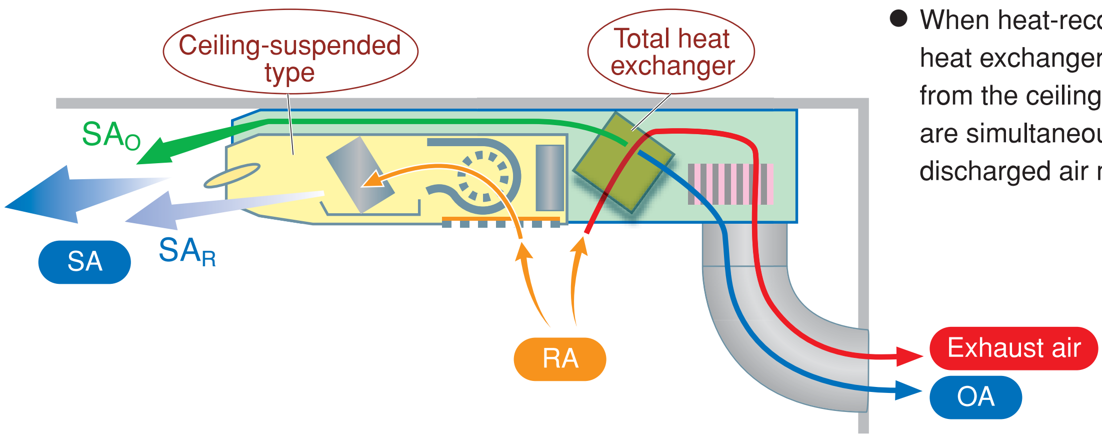
* From "School Environmental Health Standards," based on School Health Law.
<180 m^3 classroom containing 40 persons>

This model is an indoor unit that integrates a ceiling-suspended indoor unit and total heat exchanger. Compatible with the "Eco Ice mini," it enables either simultaneous or separate air conditioning and ventilation operations.

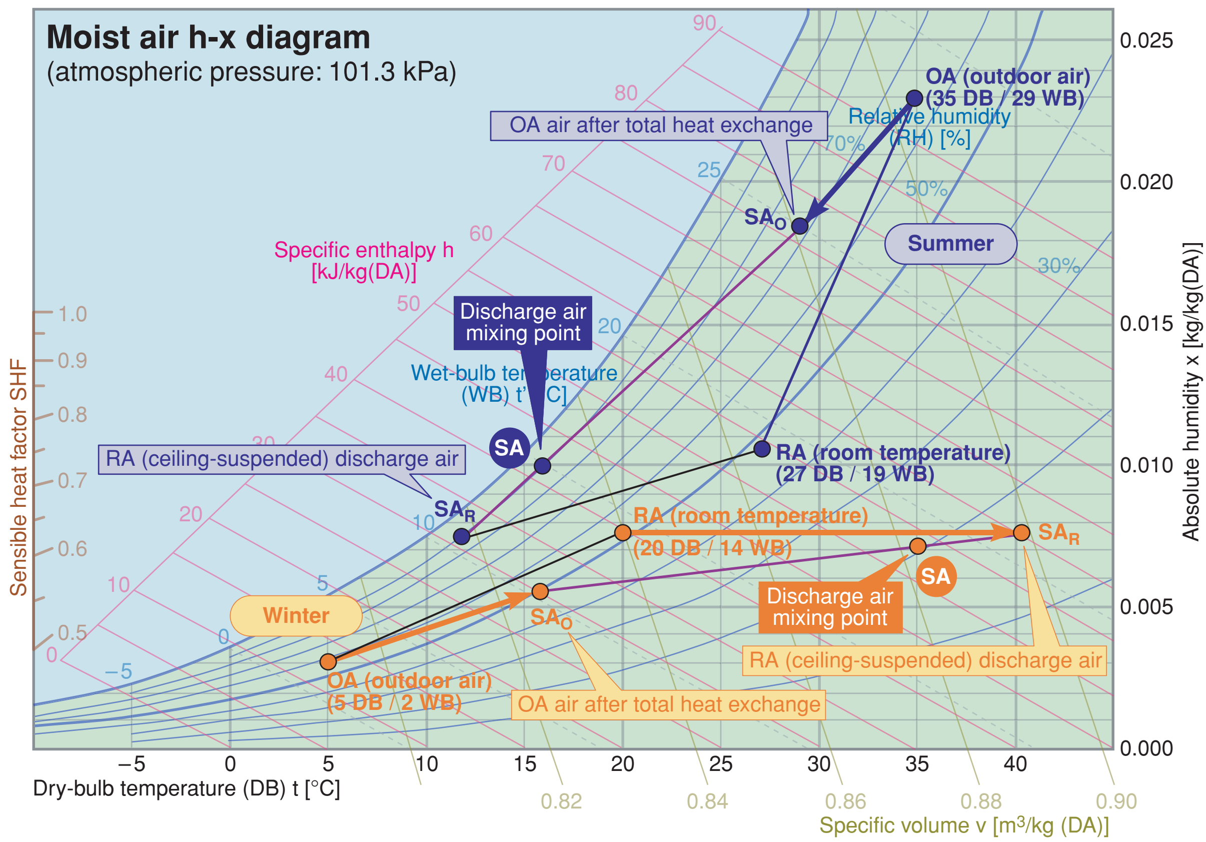
- Fresh outdoor air (OA) exchanges heat with the indoor exhaust air via the total heat exchanger, and the air is blown in (discharged) from the upper ceiling-suspended air duct. Also, the ceiling-suspended type, as with a normal indoor unit, discharges from the front. When discharged, both components of air mix together and then reach the living space. Thus, in contrast to times in which fresh outdoor air (OA) is introduced alone, it is comfortable and free of any drafty feel.
- The exclusive remote controller for the Eco Ice mini (part number: RCS-RKP140AN) can be used for both air conditioning and ventilation operations.
- The air ventilation rate can be switched between 500 and 300 m^3 / h, with the selection based on the room size and number of persons in the room.
  Setting up this model for a 180 m^3 classroom containing 40 people, based on the School Health Law's "School Environmental Health Standards," we selected a model. **Assuming a cooling load of 0.25 kW / m^2 (215 kcal / h per m^2), the air conditioner capacity becomes a 6 – 7 equivalent horsepower (i.e., it is equivalent to 6 – 7 horsepower)**. The total heat exchanger can then be selected as shown to the above.

* Later, we describe a Multi System indoor unit that integrates a total heat exchanger and direct-expansion coil for use as an outdoor air treatment unit.

8. Ventilation mo Guppy psychrometric diagram



- When heat-recovered air from the total heat exchanger (SA_O) and discharge air from the ceiling-suspended unit (SA_R) are simultaneously discharged, the discharged air mixes.



To find the state point of the mixed discharged air, we find the state point (SA_O) after the heat is recovered by the intake outdoor air (OA) via the total heat exchanger, and we find the discharge air (SA_R) from the ceiling-suspended indoor unit. After that, the state point of the mixed air is the point at which the line segment <SA_O–SA_R> is divided proportionally according to the airflow ratio.

- To find the state point (SA_O) after heat recovery by the total heat exchanger, we can use the efficiency computation formula found in the previous subsection “Heat recovery with total heat exchanger.”
- During cooling, the discharge state point (SA_R) from the ceiling-suspended type is the point of intersection between the difference in enthalpy computed from the capacity, and the discharge RH ≒ 90%. During heating, it is found from the difference in temperature computed from the capacity.
- The discharge air mixing point for an indoor unit airflow of 1800 m^3 / h (5 equivalent horsepower) and a total heat exchanger airflow of 500 m^3 / h, for example, can be found at line segment
  <SA_R–SA> = line segment <SA_R–SA_O> × {500 / (1800 + 500)}.

Ventilation mo Guppy state point computation (example)

- Summer — Outdoor air (OA): 35°C DB / 29°C WB
  Indoor (RA): 27°C DB / 19°C WB

  Winter — Outdoor air (OA): 5°C DB / 2°C WB
  Indoor (RA): 20°C DB / 14°C WB
- Total heat exchanger airflow: 500 m^3 / h
  Sensible heat exchange efficiency: 70%; total heat exchange efficiency when cooling: 45% / heating: 58%
- SPW-GTRP140A1 indoor unit airflow (Rapid): 1800 m^3 / h
  Capacity when cooling/heating = 14 / 12.5 kW

<Summer>

1) State point after heat recovery (SA_O)

- From sensible heat efficiency, dry-bulb temperature
  t = 35 – (35 – 27) × 0.7 = <u>29.4°C</u>
- From total heat efficiency, enthalpy
  i = 94.5 – (94.5 – 54) × 0.45 = <u>76.3 kJ / kg</u>

2) Discharge state point with ceiling-suspended type (SA_R)

- Δi = (14 × 3600) / (1800 × 1.2) = 23.3 kJ / kg
  Enthalpy of discharge air = 54 – 23.3 = <u>30.7 kJ / kg</u>

3) Discharge-air mixing point

- Length of line segment <SA_R–SA>
  = Line segment <SA_R–SA_O> × {500 / (1800 + 500)}
  = Line segment <SA_R–SA_O> × 0.217

<Winter> Similarly,

1) State point after heat recovery (SA_O)

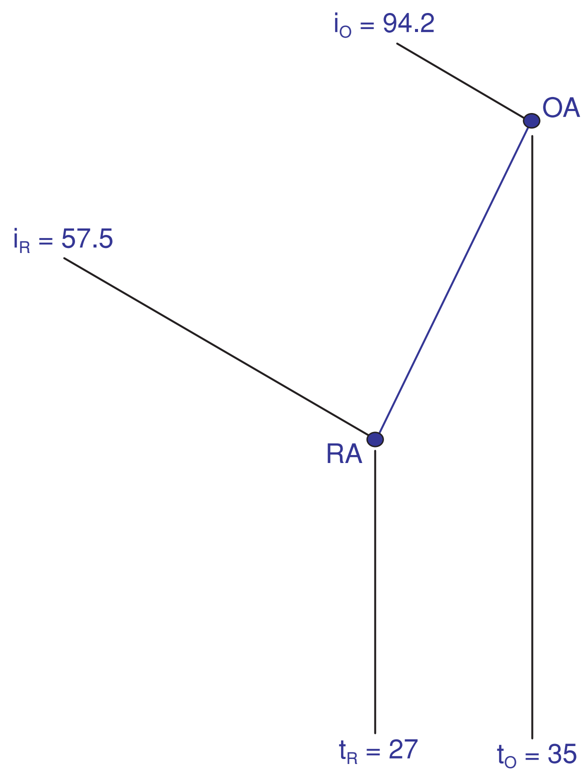
- t = 5 + (20 – 5) × 0.7 = <u>15.5°C</u>
- i = 13 + (39 – 13) × 0.58 = <u>28.1 kJ / kg</u>

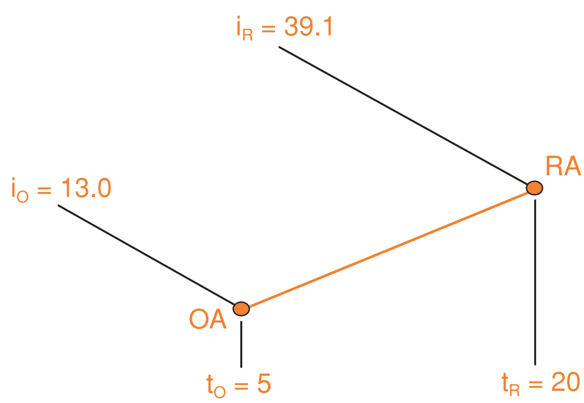
2) Discharge state point with ceiling-suspended type (SA_R)

- Δt = (12.5 × 3600) / (1800 × 1.2 × 1.006) = 20.7°C
  Discharge-air dry-bulb temperature = 20 + 20.7 = <u>40.7°C</u>

3) Discharge-air mixing point, as with cooling:

- Length of line segment <SA_R–SA>
  = Line segment <SA_R–SA_O> × 0.217





- Indoor unit airflow and ventilation rate
  - For office building

  If the cooling load is 0.14 kW / m^2 and the area per person is 5 m^2 / person, then
  - With a 5 equivalent horsepower, the cooling capacity is 14 kW.

⇒ Air conditioned area: 14 ÷ 0.14 = 100 m^2

⇒ Persons in room: 100 ÷ 5 = 20

If the per-person ventilation rate is 20 m^3 / h per person, then

⇒ Required ventilation rate: 20 × 20 = 400 m^3 / h

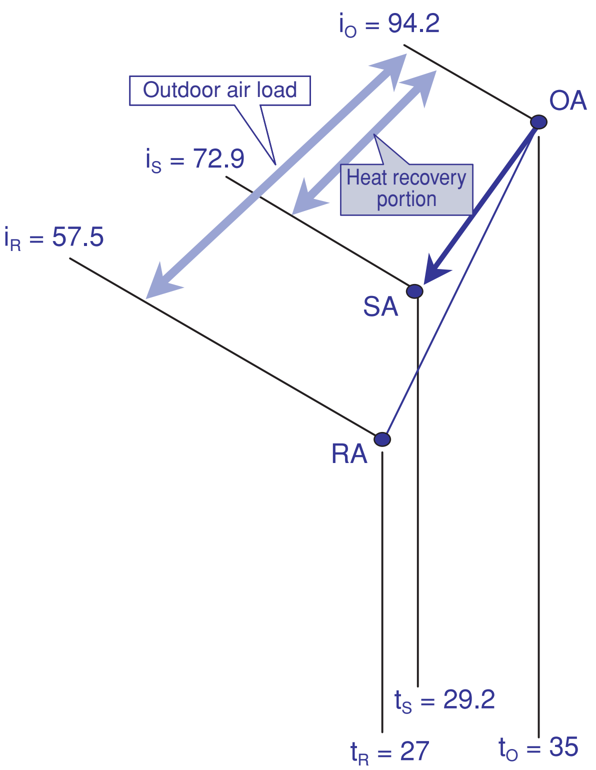
= 6.7 m^3 / min

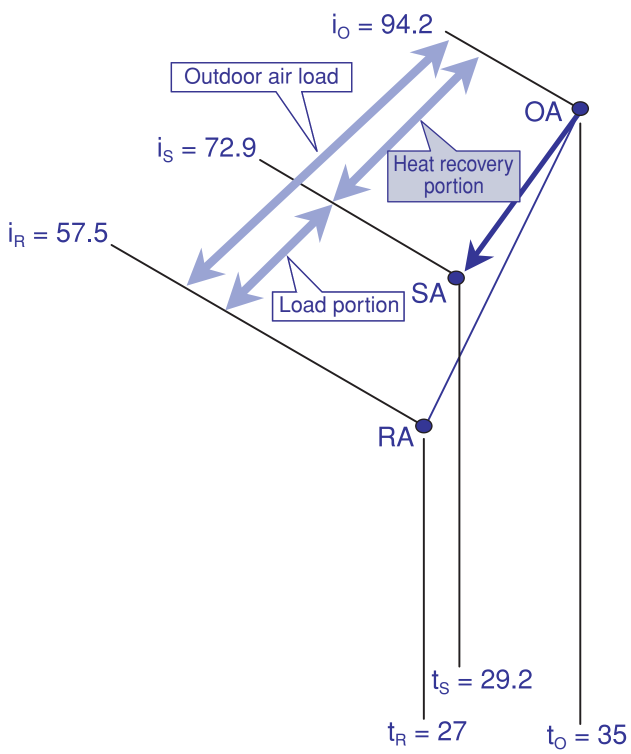
Therefore, since the airflow for a 5-equivalent-horsepower indoor unit is 33 to 35 m^3 / min, then

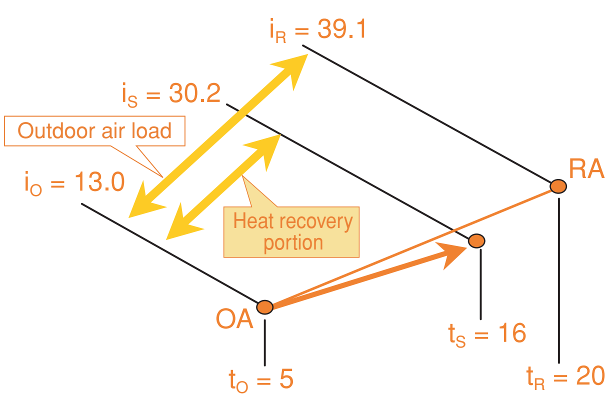
6.7 ÷ (33 to 35) = 19% to 20%

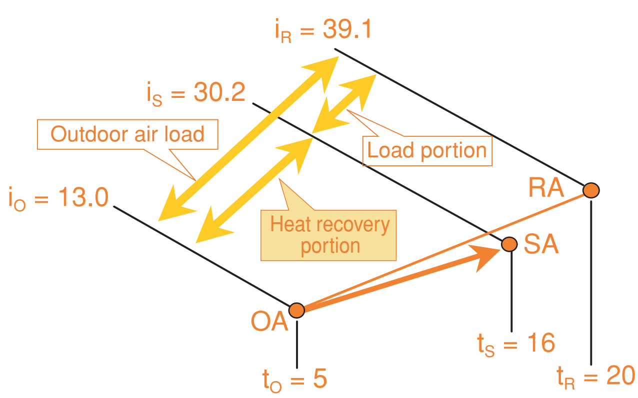
If the ventilation rate per person is 30 m^3 / h / person, it will similarly become approximately 30%.

* With floor-mounted models, the airflow per horsepower will increase (8 to 9 m^3 / h per equivalent horsepower). With these models, the value is approximately 15% to 25% of the rated airflow.

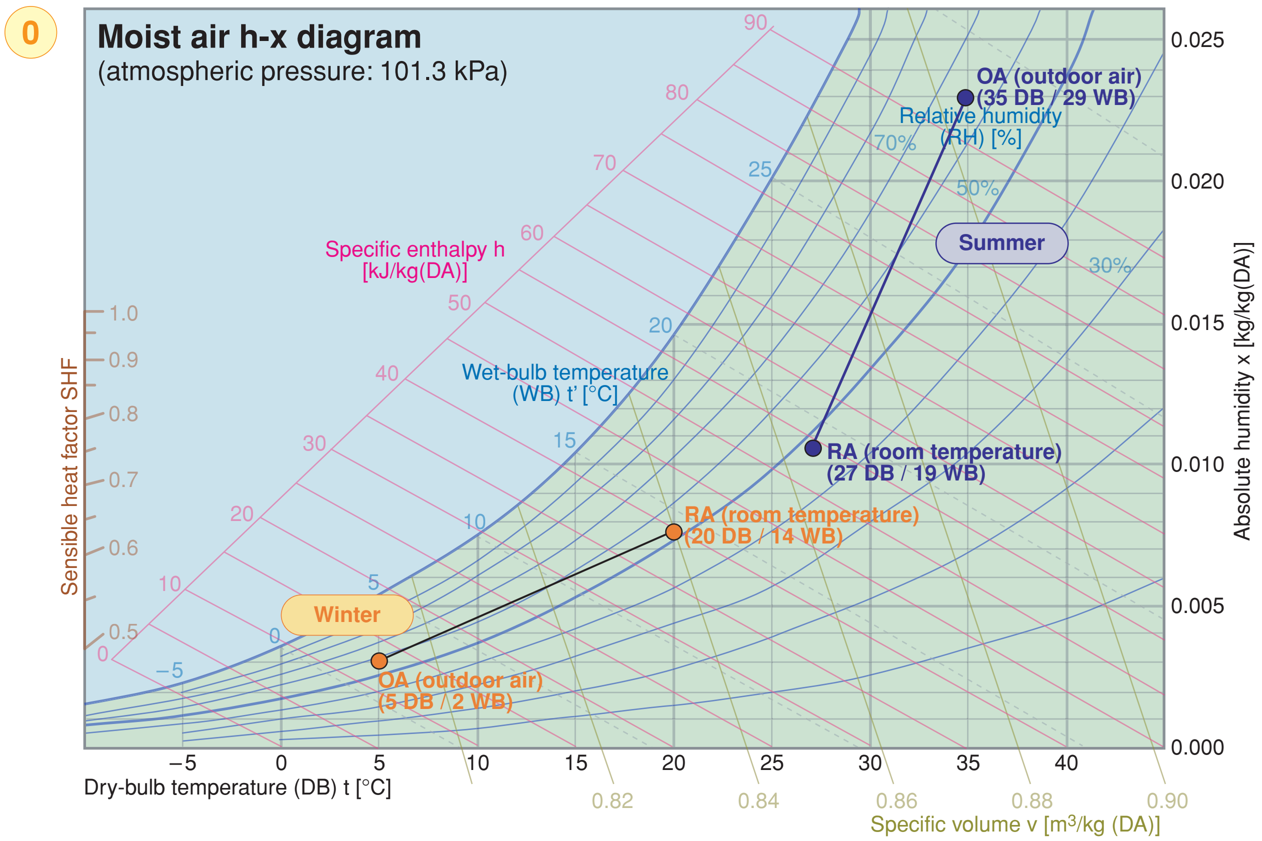


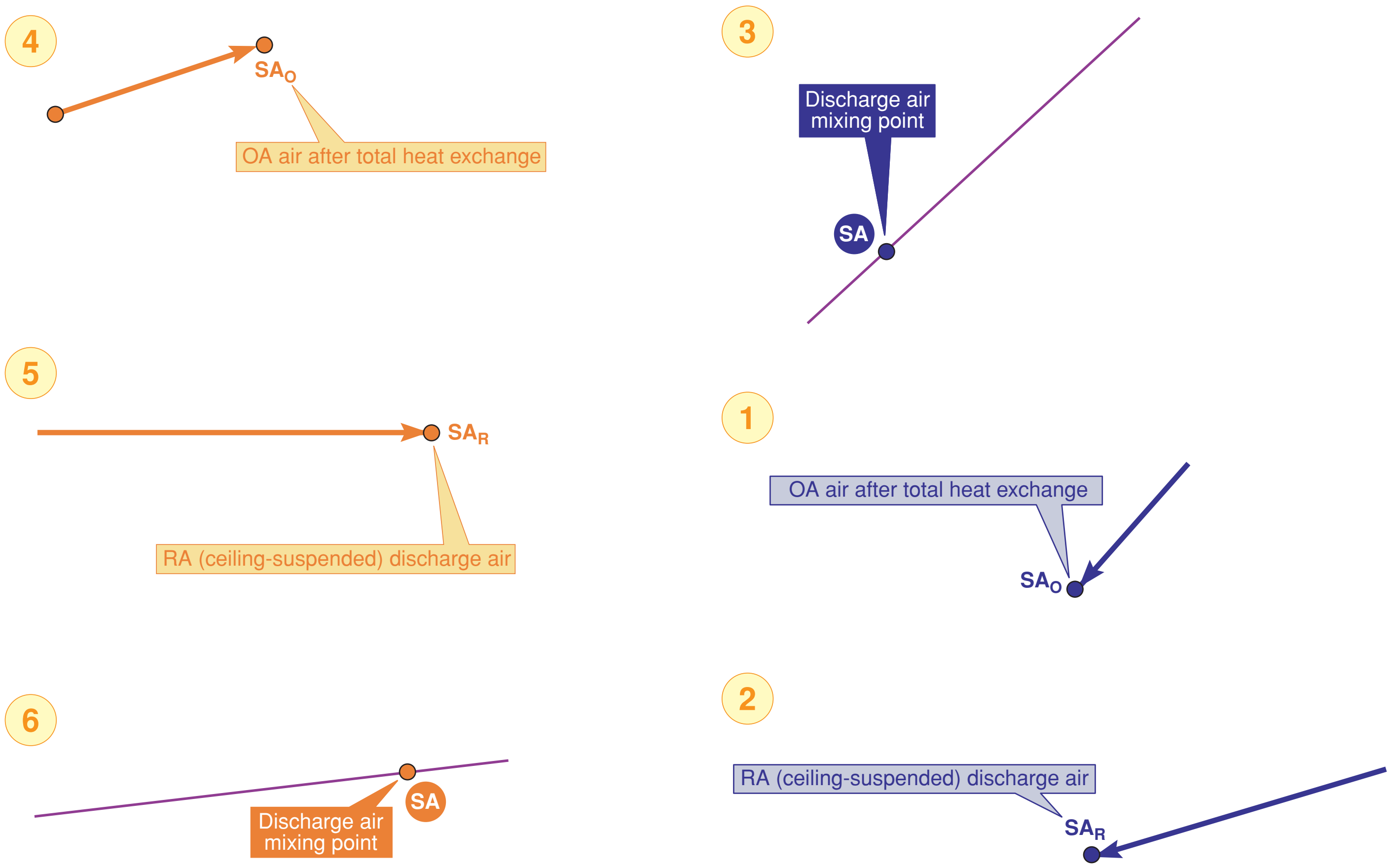






Display sequence

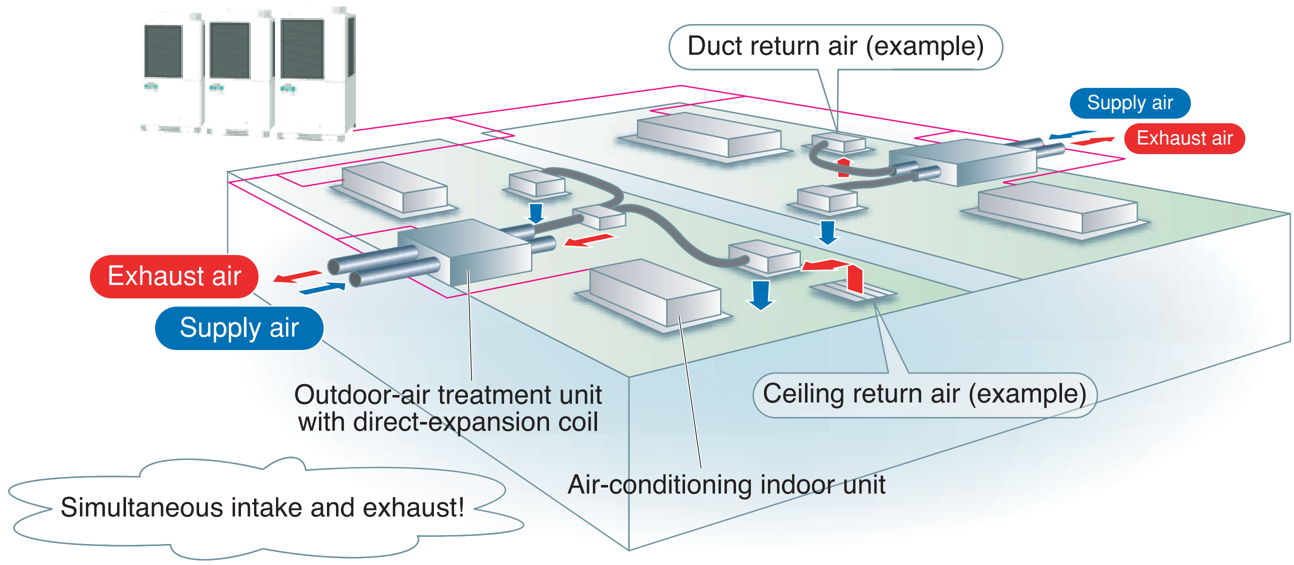




Section 2 Direct-expansion-coil outdoor air treatment unit

1. With direct-expansion coil: Overview

- Accommodates **simultaneous intake/exhaust** type 1 mechanical ventilation systems.
- **Heat-recovering** All-Fresh-type heat pump outdoor air treatment unit **with built-in total heat exchanger**
- As one of the **building Multi System indoor units**, can connect to the same refrigerant system.



* A RAP valve kit is required for the refrigerant tubing of a direct-expansion-coil outdoor air treatment unit.
Also, don’ t forget the water supply line for the evaporative humidifier (at least 8A)!

<NOTE> As one of the building Multi System indoor units, it can be controlled with a standard remote controller; however, the following points are different:

- **Temperature setting is the intake “outdoor air temperature.”**
- **Remote controller sensors cannot be used.**
  A body thermostat is always used to detect the temperature of the intake outdoor air.
- **The fan speed is constant.**
  Although the display indicates Rapid/High/Low, the fan speed does not change.

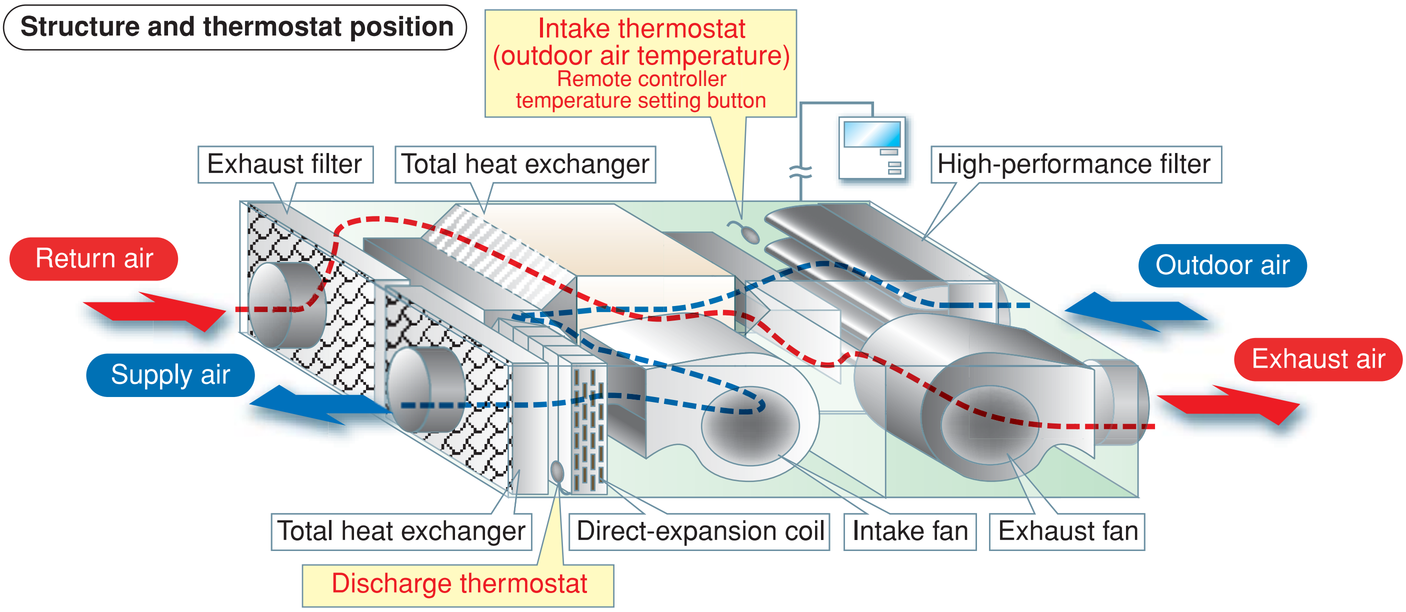
This indoor unit was developed as one of the building Multi System indoor units. If one unit is installed for each refrigerant system, it will be enable each system to have air conditioning and ventilation.

- A feature of the unit is that it supports type 1 mechanical ventilation, simultaneously providing air intake and exhaust, and recovers heat through a total heat exchanger. After the total heat exchange, it cools/dehumidifies or heats/humidifies the outdoor air and then discharges it indoors.
- Air intake and exhaust take place through a ø250/300 round duct connection, while it is also possible to return air from indoors through a return in the ceiling.
- When connected with a standard indoor unit in a building Multi System, a RAP valve kit is installed in the refrigerant main tube to prevent refrigerant from collecting inside the direct-expansion coil when the thermostat is OFF.
- Operation control is provided by a standard PAC/GHP wired remote controller and wireless remote controller (separately placed receiver type), and a central control device can also be connected as with an air conditioning indoor unit. The temperature setting, however, is the outdoor air temperature, remote controller sensors cannot be used, and the fan speed is constant. Please note these and other differences.

2. With direct-expansion coil: Structure

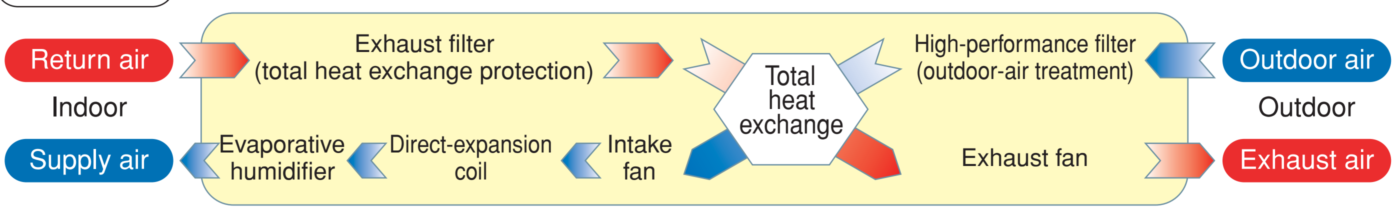
Treats outdoor air loads with <Total heat exchanger + Direct-expansion coil + Humidifier + High-performance air filter>.
As indicated by its name, it is equipped with a direct-expansion coil, treats (cools/heats) the air after it undergoes total heat exchange, and supplies the air indoors.

Structure and thermostat position



A total heat exchanger, direct-expansion coil, and humidifier are built in.

Flow of air



The direct-expansion-coil outdoor air treatment unit, as its name implies, is an outdoor air treatment unit that is equipped with a “direct-expansion coil.” (A direct-expansion coil is a heat exchanger that uses refrigerant. As a term, it is used similarly with “cooling and heating coil” and “steam coil.”)

- This unit simultaneously operates two fans, one for the supply air and one for the exhaust air. The heat of the return air from indoors and the intake air from outdoors is exchanged in the total heat exchanger. After the heat is recovered, the supply air is discharged indoors. A high-performance filter is installed on the outdoor air intake side (JIS colorimetry: 65%).
- The state of the intake outdoor air following total heat exchange is one in which heat has been recovered, but it is slightly different from room temperature. Employing a direct-expansion coil, this model cools or heats the air after the total heat exchange, and then supplies the air indoors at a discharge air temperature that is similar to that of an air conditioner. Moreover, when heating, it utilizes full-scale humidification to raise the relative humidity of the intake outdoor air.
- When the thermostat is OFF (direct-expansion coil OFF ⇒ state in which a closed electric expansion valve prevents refrigerant from flowing to the direct-expansion coil and thus prevents cooling and heating), air that has recovered heat in the total heat exchanger is blown in.
- Accordingly, since the outdoor air load is treated when air is supplied, there is almost no outdoor air load burden on other indoor units.

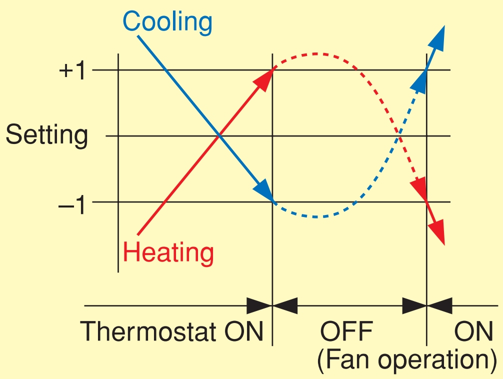
3. With direct-expansion coil: Thermostat ON/OFF control

Direct-expansion coil control is accomplished with an “intake (outdoor air temperature) thermostat” and a “discharge thermostat.”

- **Thermostat OFF: OFF by either intake thermostat or discharge thermostat.**
  Outdoor air is introduced (supplied) following heat recovery in the total heat exchanger.
- **Thermostat ON: ON by intake thermostat only.**
  Intake outdoor air is cooled/heated by coil.
- Regardless of thermostat ON/OFF status, the quantity of outdoor air introduction (supply air) during operation is always same.

Intake thermostat

- Turns OFF when the intake (outdoor air) temperature drops below the setting during cooling or above the setting during heating.
- Temperature setting range
  Cooling/dry: 18 – 30°C
  Heating: 16 – 26°C
  Automatic heating/cooling: 17 – 27°C
- Operation



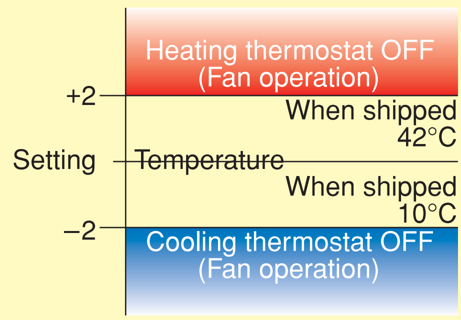
Discharge thermostat setting

Thermostat OFF setting only. (ON: none)
When temperature below is detected for 6 minutes continuously

When shipped
Cooling: 12°C (12 – 19°C)
Heating: 40°C (35 – 46°C)

Setting can be changed within range indicated in ( ).

⇒ In detailed setting mode from wired remote controller



Let’s gain an understanding of the operation and ON/OFF settings of the intake and discharge thermostats.
When the thermostat is OFF, outdoor air that has recovered heat through total heat exchange will be introduced.

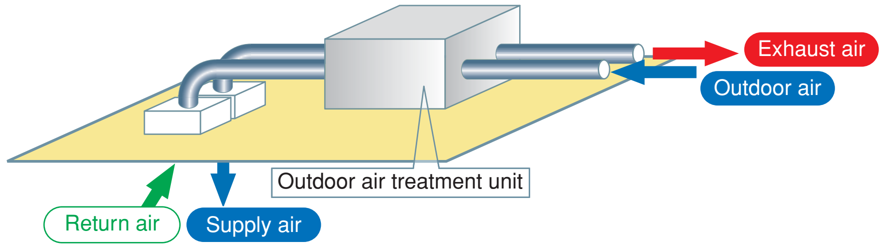
This model controls a direct-expansion coil by means of two thermostats: an intake (outdoor air temperature) thermostat and a discharge thermostat. **The temperature detected by the intake thermostat is the outdoor air temperature.**

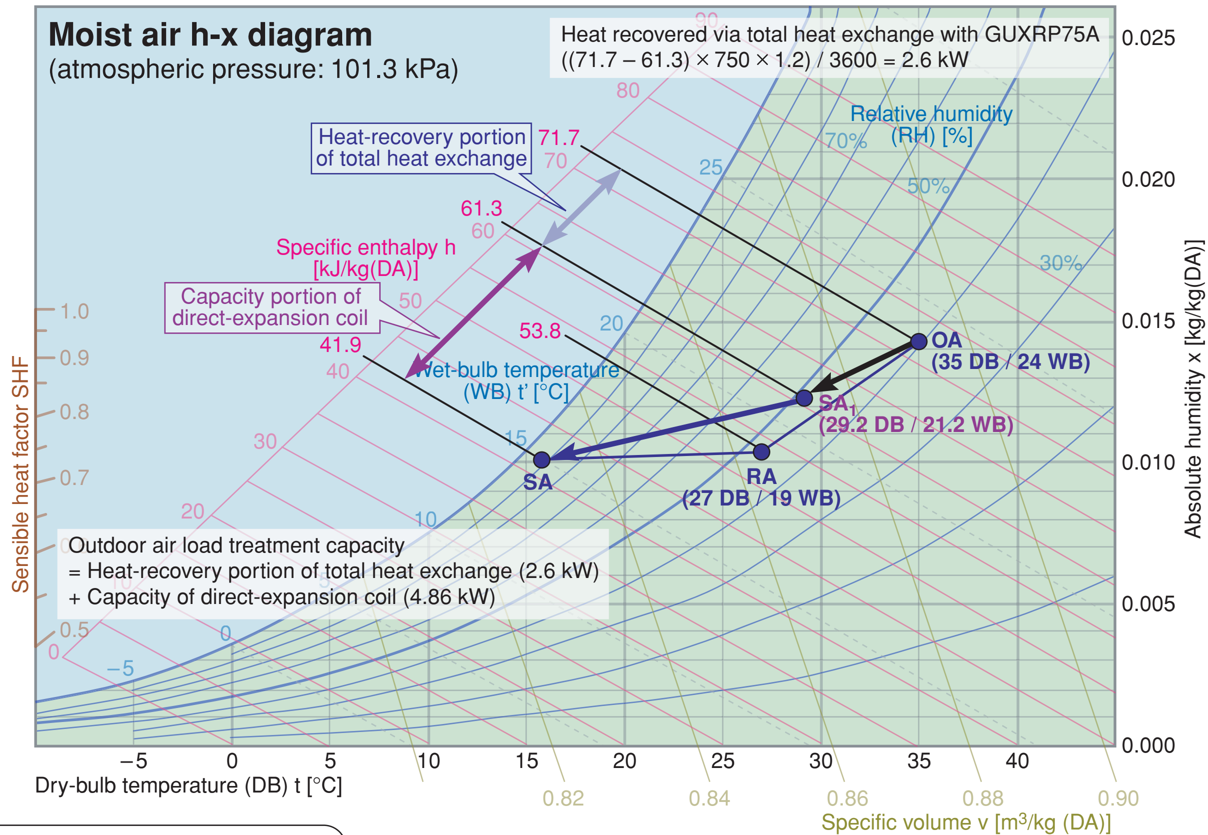
- For example, when the outdoor air temperature in summer is high, the thermostat turns ON and introduced outdoor air (after total heat exchange) will be cooled by the direct-expansion coil. When the outdoor air temperature has dropped, the thermostat turns OFF and outdoor air will be introduced only with heat recovery via the total heat exchanger.
  The thermostat’s ON/OFF status does not change the status of fan operation; thus, there is no change in the quantity of intake outdoor air (supply air). The same outdoor air introduction can occur at any time.
- When the thermostat is OFF, the refrigerant-controlling electric expansion valve is closed, and the flow of refrigerant to the coil is cut off. Moreover, to prevent refrigerant from collecting in the coil, the RAP valve also closes.
- The intake thermostat is set by means of the wired remote controller “temperature setting” button. (This is the same as a standard unit’s room temperature setting.) **Since the intake thermostat detects the temperature of the outdoor air, a remote controller thermostat cannot be used.**
- The discharge thermostat turns OFF when the preset temperature has been detected for 6 minutes continuously. The OFF temperature is set at the time of shipment. It is changed through the wired remote controller’s detailed settings (for T-type and subsequent models; DIP switch settings for earlier models).

4. With direct-expansion coil: Cooling-psychrometric diagram

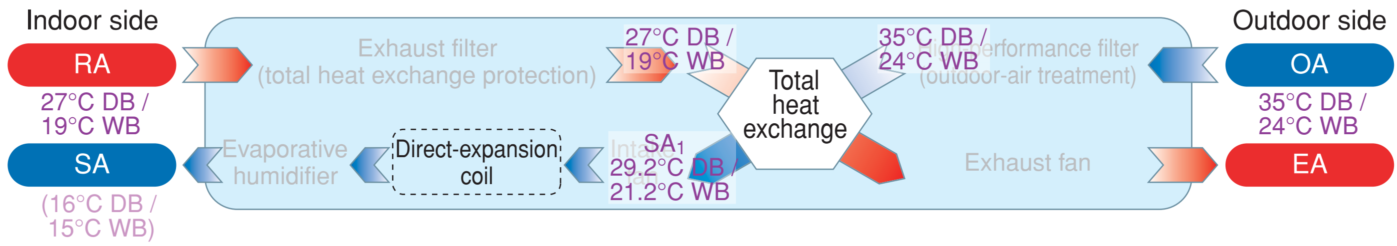
State diagram for summer cooling operations

- OA (outdoor air): 35°C DB / 24°C WB; RA (indoor): 27°C DB / 19°C WB
  Example of direct-expansion-coil outdoor air treatment unit <SPW-GUXRP75A>





Air flow and temperature change



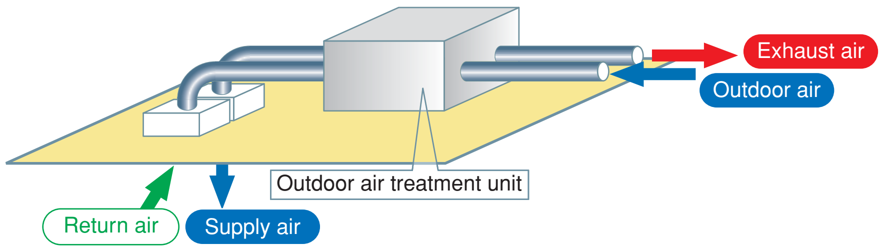
The change in air state of a direct-expansion-coil outdoor air treatment unit is shown on the psychrometric diagram. Let's look at cooling operation.

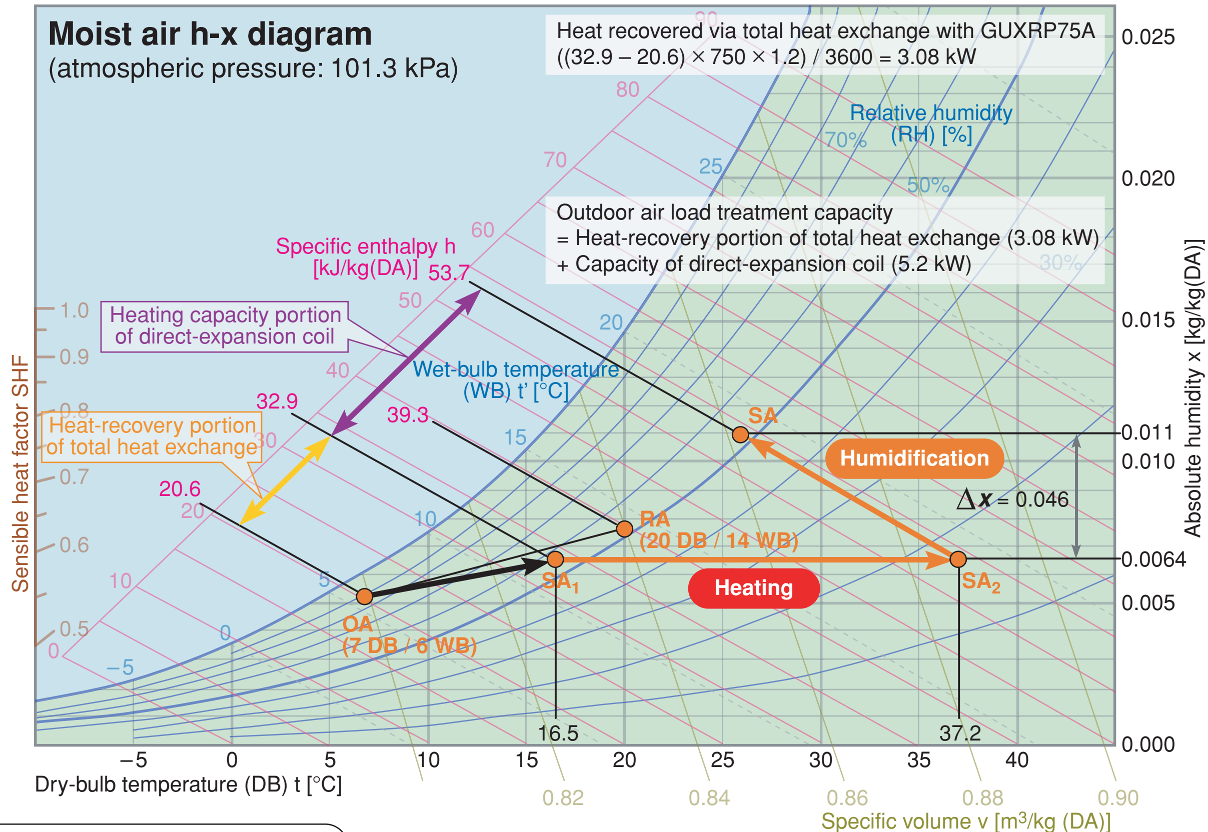
- First, heat is exchanged between the outdoor air (OA) and return air (RA) by the total heat exchanger, causing the OA to change to the SA1 state. This is the heat recovery portion. At this point both the dry-bulb temperature and absolute humidity are still higher than that of the indoor air (RA). This is the state of the **discharge air temperature** when the thermostat is OFF.
- Next, the SA1 air exchanges heat by means of the direct-expansion coil and becomes discharge air (SA).
- Its performance as an outdoor air treatment unit is the "heat recovery capacity of the total heat exchanger" plus the "capacity of the direct-expansion coil." This capacity will vary according to the conditions of the outdoor air (OA) and return air (RA); therefore, it can be found by computation.

5. With direct-expansion coil: Heating-psychrometric diagram

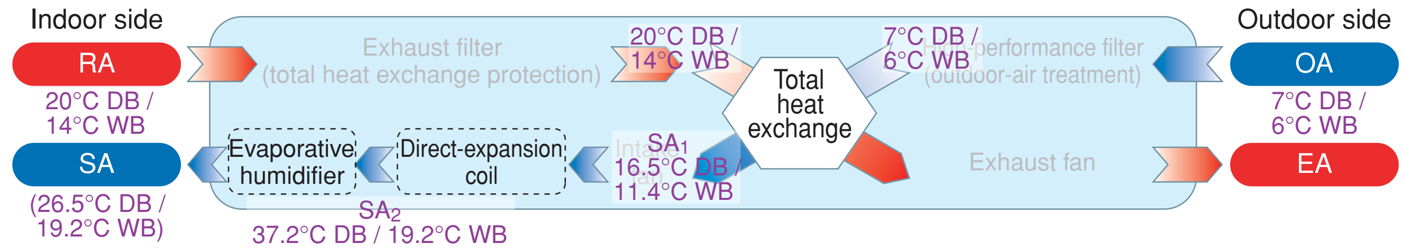
State diagram for winter heating operations

- Outdoor air (OA): 7°C DB / 6°C WB; Indoor (RA): 20°C DB / 14°C WB
  Example of direct-expansion-coil outdoor air treatment unit <SPW-GUXRP75A>





Air flow and temperature change



Next, let's look at the change in state that occurs during winter heating. The concept is the same as during cooling.

- Heat is exchanged between the outdoor air (OA) and return air (RA) by the total heat exchanger, causing the OA to change to the SA1 state. This air is heated by the direct-expansion coil and humidified by the evaporative humidifier. The air discharged from the outdoor air treatment unit (supply air = fresh outdoor air) becomes point SA. (As can be seen, the change in the evaporative humidification state was parallel to the wet-bulb temperature line.)
- The discharge thermostat detects the SA2 temperature and correspondingly turns ON/OFF.
- Humidification basically occurs when the heating thermostat is ON. When the direct-expansion coil temperature exceeds a certain temperature (for example, E2 reaches 33°C), the humidifier's water supply solenoid valve turns ON, water is supplied to the humidification element, and humidification is provided.

  * With T-type PAC/GHP-G1 and subsequent models, settings such as thermostat-OFF humidification and mild-season fan humidification (simple setting modes with wired remote controller) are also possible. Since the humidifier intake air temperature is low with such no-heat humidification, the amount of humidification is less. (This is due to the humidifier's temperature change characteristics. For instance, at 20°C the amount of humidification is about half the rated amount.)

● Points to remember when selecting a direct-expansion-coil outdoor air treatment unit model.

1. The airflow ratio of the supply air and exhaust air can change (return air damper).
   When the supply air and exhaust air duct resistance changes, the intake/exhaust airflow ratio will differ.

⇒ The efficiency will change according to the airflow ratio.
   (It is necessary to confirm with a characteristic diagram.)

2. Regarding the capacity of the direct-expansion coil, the temperature of the air following total heat exchange is the coil's intake temperature. The displayed performance of the direct-expansion coil requires correction, since the conditions are the same as those of an ordinary air conditioner.

⇒ Coefficients for corrections can be found in the indoor unit capacity characteristic diagram on the page showing the computation of the indoor unit's actual capacity in the "Design Section" of the Multi System technical manual.

3. The amount of humidification during heating will change according to the state of the airflow and humidifier inlet air.

⇒ Confirm with a characteristic diagram.

4. The capacity of the direct-expansion coil will require correction based on the tubing length and difference in elevation.

⇒ The computation is the same as that used to compute an ordinary Multi System indoor unit's actual capacity.

Computation examples for various air state points <cooling>

SPW-GUXRP75A Airflow: 750 m^3 / h

<Cooling> OA: 35°C DB / 24°C WB; enthalpy = 71.7 kJ / kg
RA: 27°C DB / 19°C WB; enthalpy = 53.8 kJ / kg

1) Temperature of air after passing through total heat exchanger: point of intersection (SA1) between temperature and enthalpy indicated below
   Cooling: Since temperature exchange efficiency is 73%,
   then 35 – (35 – 27) × 0.73 = 29.16 (°C).
   Since enthalpy exchange efficiency is 58%,
   then 71.7 – (71.7 – 53.8) × 0.58 = 61.3 (kJ / kg).

⇒ In short, **the temperature of the supply air after it passes through the total heat exchanger is 29.2°C DB / 21.2°C WB**.

2) Temperature of supply air (SA): direct-expansion coil capacity cooling = 4.5 kW
   Cooling: **Direct-expansion coil performance when coil inlet air is 27°C DB / 19°C WB and outdoor air is 35°C DB**
   As mentioned above, the temperature of the supply air after it passes through the total heat exchanger is 29.2°C DB / 21.2°C WB. Thus, from the capacity characteristic diagram*, the capacity is approximately 108% when the coil intake air WB is 19 ⇒ 21.2°C. Accordingly, the capacity of the direct-expansion coil is 4.5 × 1.08 = 4.86 (kW).
   Difference in enthalpy when cooling Δi = (4.86 × 3600) / (750 × 1.2) = 19.44 kJ / kg (DA)

⇒ The discharge (SA) enthalpy is 61.3 – 19.4 = 41.9 (kJ / kg).

Computation examples for various air state points <heating>

SPW-GUXRP75A Airflow: 750 m^3 / h

<Heating> OA: 7°C DB / 6°C WB; enthalpy = 20.6 kJ / kg
RA: 20°C DB / 14°C WB; enthalpy = 39.3 kJ / kg

1) Temperature of air after passing through total heat exchanger: point of intersection (SA1) between temperature and enthalpy indicated below
   Heating: Since temperature exchange efficiency is 73%,
   then 7 + (20 – 7) × 0.73 = 16.5 (°C).
   Since enthalpy exchange efficiency is 66%,
   then 20.6 + (39.3 – 20.6) × 0.66 = 32.9 (kJ / kg).

⇒ **The temperature of the supply air after it passes through the total heat exchanger is 16.5°C DB / 11.4°C WB.**

2) Temperature of supply air (SA): direct-expansion coil capacity heating = 5.0 kW; quantity of humidification = 4.1 kg / h
   Heating: As with cooling, from the capacity characteristic diagram*, the capacity is approximately 104% when the coil intake air WB is 20 ⇒ 16.5°C (from A-type Multi System performance change characteristics). Accordingly, the capacity of the direct-expansion coil is 5.0 × 1.04 = 5.2 (kW).
   • The temperature difference Δt when heating = (5.2 × 3600) / (750 × 1.2 × 1.006) = 20.67°C.

⇒ **The discharge air temperature (SA2) is 16.5 + 20.7 = 37.2 (°C).**

   • The humidifier inlet air (SA2) is 37.2°C DB / RH 16%.
   From the humidifier temperature change characteristics, the correction coefficient for the quantity of humidification is 1.0 (no correction required).
   The absolute humidity difference Δx = 4.1 / (750 × 1.2) = 0.0046 kg / kg(DA).

⇒ **The absolute humidity at the humidifier outlet is 0.0064 + 0.0046 = 0.011 (kg / kg(DA)).**

⇒ **The supply air (SA) temperature is 26.5°C DB / 19.2°C WB.**

* The indoor unit capacity characteristic diagram is shown on the page giving the computation of the indoor unit's actual capacity in the "Design Section" of the Multi System technical manual.

6. With direct-expansion coil: Air ventilation rate and system capacity

Since the rated airflow of a direct-expansion-coil outdoor air treatment unit equals the air ventilation rate, in the following we will find the ventilation-capable floor area, and roughly estimate the air conditioner capacity required to air condition a specified floor area.

Computation example

- The following method used to estimate ventilation-capable floor area complies with the Building Standards Law. Assuming that a general office building will be air conditioned and that

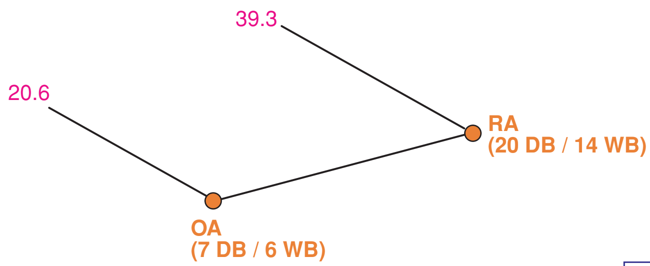
  V (air ventilation rate in m^3 / h) = 20 × (A / N), where A is the floor area (m^2) and N is the area per person, we will estimate two cases: where N = 5 m^2 / person and N = 10 m^2 / person.
- For the air conditioner capacity, assume that the air conditioning cooling load is 0.140 kW / m^2 (120 kcal / h per m^2).

Part No. example <SPW->	GUXRP50A	GUXRP75A	GUXRP100A
Rated airflow = Ventilation rate (m^3 / h)	500 m^3 / h	750 m^3 / h	1,000 m^3 / h
Ventilation-capable floor area (A m^2) N = 5 – 10 m^2 / person	250 m^2 – 125 m^2	375 m^2 – 187 m^2	500 m^2 – 250 m^2
When air conditioner capacity – Cooling (at 0.140 kW / m^2)	0.14 × 250 to 0.14 × 125 = 35 – 17.5 kW	0.14 × 375 to 0.14 × 187 = 52.5 – 26.2 kW	0.14 × 500 to 0.14 × 250 = 70 – 35 kW
Multi System outdoor unit capacity (cooling capacity of each model is added)	37.8 – 20.3 kW	57 – 30.7 kW	75.6 – 40.6 kW
System equivalent horsepower example	12 – 8 equivalent horsepower	20 – 12 equivalent horsepower	26 – 14 equivalent horsepower

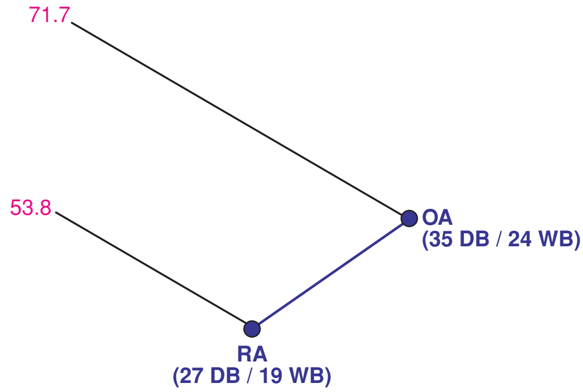
Yardstick for general office building air conditioning:
At ventilation rate of 500 m^3 / h, building Multi System <10 equivalent horsepower> (approximately).
Be sure to compute and confirm based on design conditions!

This outdoor air treatment unit can be connected as one indoor unit of a Multi System. The airflow of this model is the ventilation rate of the outdoor air intake. Based on this, the system capacity was roughly estimated from the ventilation-capable floor area and cooling air conditioning load per square meter.

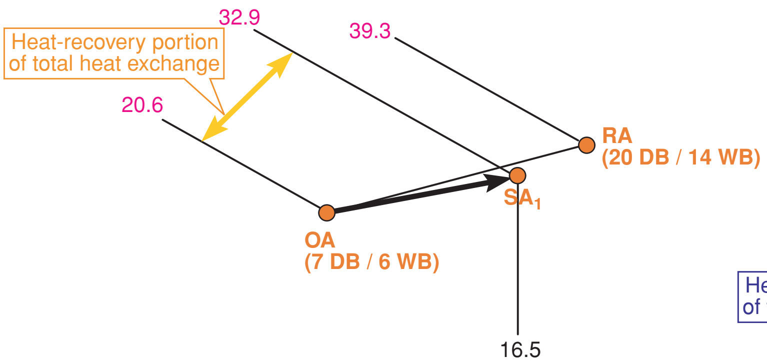
- As an example estimate, a Building Standards Law-compliant air ventilation rate can be obtained by installing one Multi System outdoor unit having a capacity of approximately 8 – 12 equivalent horsepower and air ventilation rate of 500 m^3 / h.
- The formula for the air ventilation rate, according to the Building Standards Law, is a per-person air ventilation rate of 20 m^3 / h. The ventilation-capable floor area was estimated for two cases: where the office area per person N = 5 m^2 / person and 10 m^2 / person. Of course, the floor area will change according to the size that these values are made.
- The air conditioner capacity is computed, using an air conditioning cooling load of 0.140 kW / m^2 (120 kcal / h per m^2) for the ventilation-capable floor area.



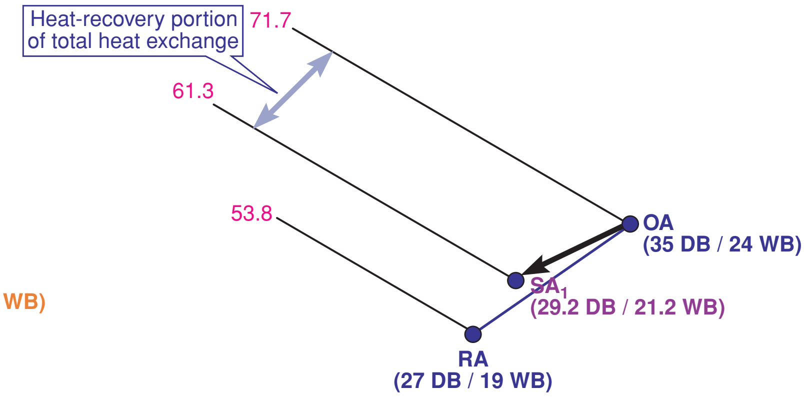
39.3
20.6
RA
(20 DB / 14 WB)
OA
(7 DB / 6 WB)



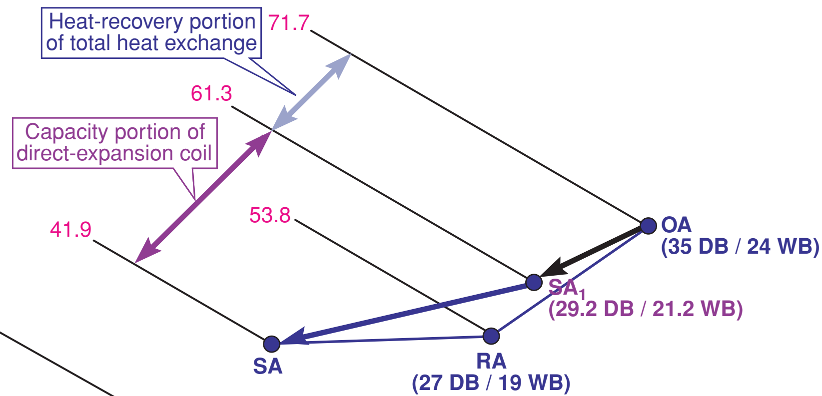
71.7
53.8
OA
(35 DB / 24 WB)
RA
(27 DB / 19 WB)



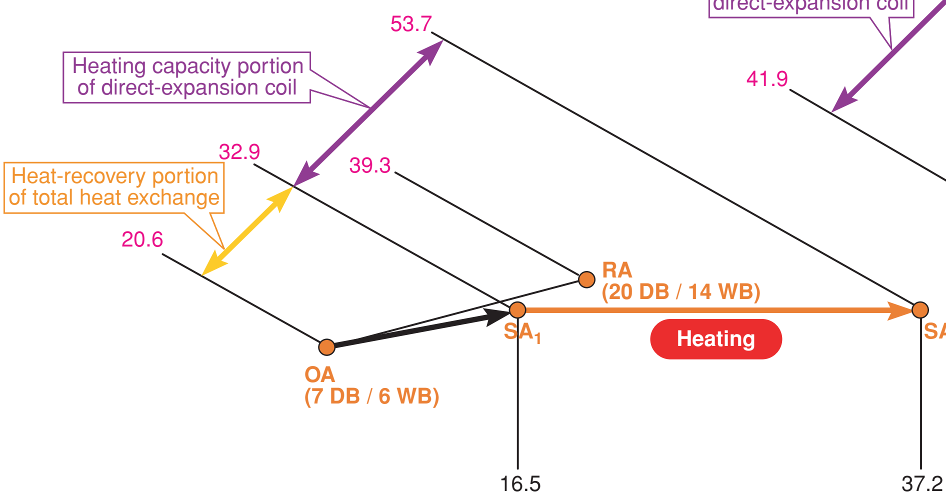
Heat-recovery portion of total heat exchange
32.9
39.3
20.6
RA
(20 DB / 14 WB)
SA_1
OA
(7 DB / 6 WB)
16.5



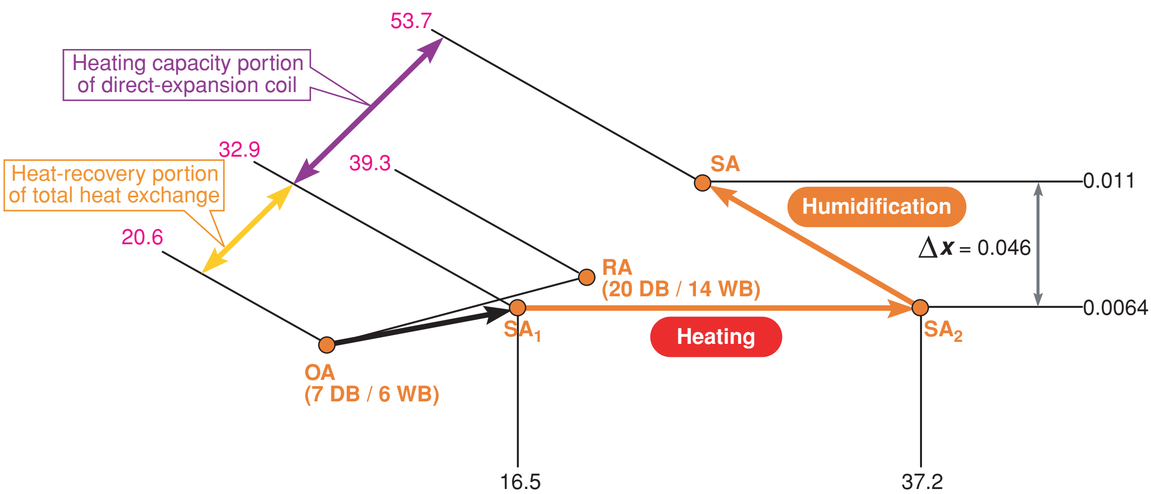
Heat-recovery portion of total heat exchange
71.7
61.3
53.8
OA
(35 DB / 24 WB)
SA_1
(29.2 DB / 21.2 WB)
RA
(27 DB / 19 WB)



Heat-recovery portion of total heat exchange
71.7
61.3
Capacity portion of direct-expansion coil
41.9
53.8
OA
(35 DB / 24 WB)
SA_1
(29.2 DB / 21.2 WB)
SA
RA
(27 DB / 19 WB)



53.7
Heating capacity portion of direct-expansion coil
32.9
Heat-recovery portion of total heat exchange
39.3
20.6
RA
(20 DB / 14 WB)
SA_1
Heating
SA_2
OA
(7 DB / 6 WB)
16.5
37.2



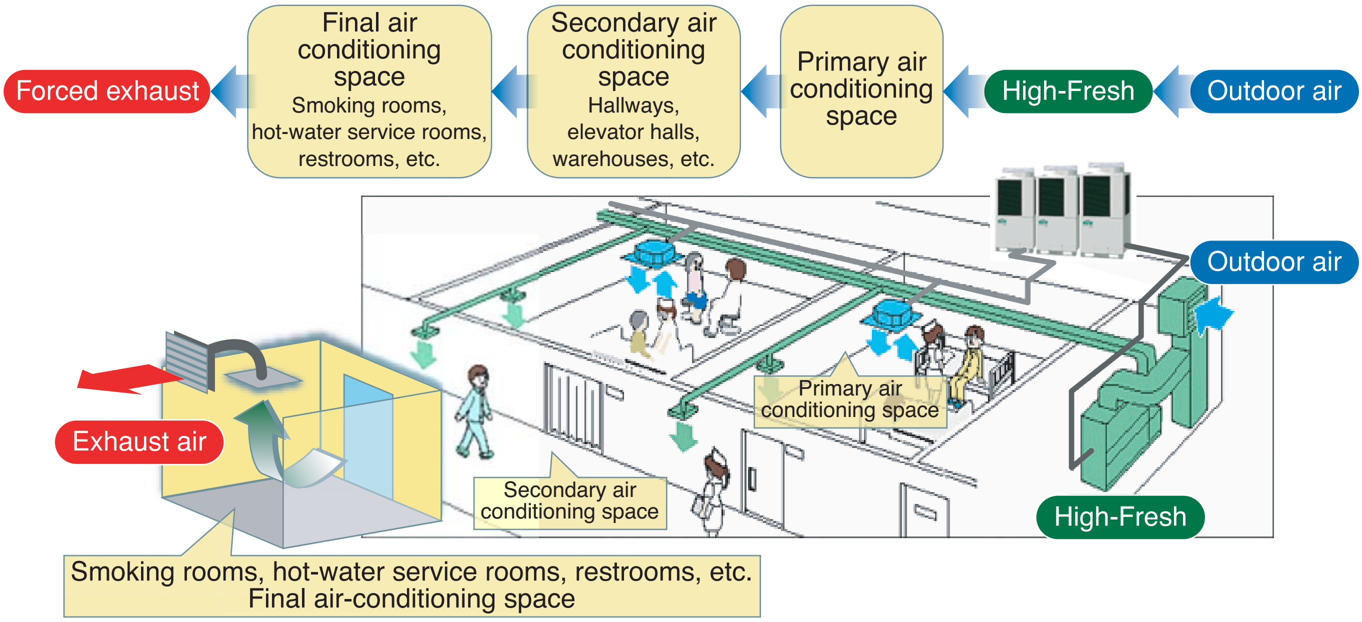
53.7
Heating capacity portion of direct-expansion coil
32.9
Heat-recovery portion of total heat exchange
39.3
20.6
SA
0.011
Humidification
$\Delta x = 0.046$
RA
(20 DB / 14 WB)
0.0064
SA_1
Heating
SA_2
OA
(7 DB / 6 WB)
16.5
37.2

Section 3 High-Fresh

1. High-Fresh: Overview

All-Fresh-type heat pump outdoor-air treatment unit that introduces outdoor air after bringing it to room air temperature/humidity

- Fresh outdoor air corresponding to forced exhaust air passes through High-Fresh and is supplied to primary air conditioning space.
- Energy-saving system that air conditions secondary and final space with exhaust of primary air-conditioning space.



<NOTE 1> **Basically, the same system refrigerant tubing is not mixed with a general air-conditioning indoor unit.** With a PAC, however, it is possible to mix with a general air-conditioning indoor unit from an A-type Super W Multi System.

<NOTE 2> **It can be controlled with a standard remote controller; however, note the following:**

- **Temperature setting is the intake outdoor-air temperature.**
- **Remote controller sensors cannot be used.**
  A body thermostat is always used to detect the temperature of the intake outdoor air.
- **The fan speed is constant.**
  Although the display will indicate Rapid/High/Low, the fan speed does not change.

This is an outdoor air treatment unit that connects to a building Multi System outdoor unit. Currently, in addition to a floor-mounted type, a ceiling-embedded type is in the lineup.

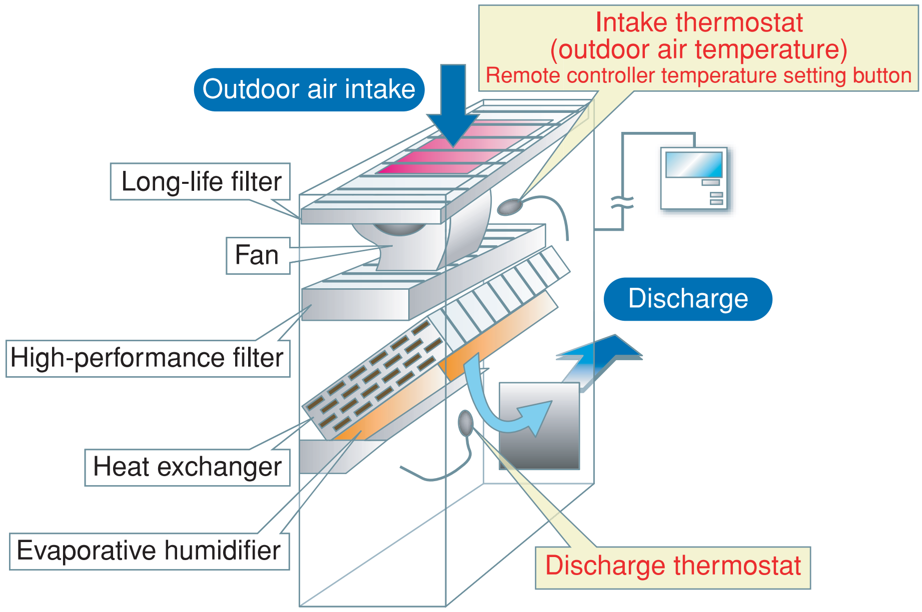
- An All-Fresh-type heat pump outdoor-air treatment unit treats and supplies 100% outdoor air to the indoor temperature/humidity level.
- It is connected to a standard Multi System outdoor unit. Basically, the same system refrigerant tubing is not mixed with a general air conditioning indoor unit, as the system configuration is that of a High-Fresh alone (for both PAC/GHP). Compared to a general air conditioning indoor unit, the High-Fresh uses 100% outdoor air intake, so the air temperature and operating pressure are different.
- With a PAC, however, it is now possible to mix with a general air conditioning indoor unit from an A-type Super W Multi System.
- At times other than when the High-Fresh is connected one-to-one with an outdoor unit, a RAP valve kit is attached to the refrigerant main tubing for each High-Fresh unit in order to prevent refrigerant from collecting in the High-Fresh when it is shut down or when the thermostat is OFF.
- Operation control is provided by standard PAC/GHP wired remote controller and wireless remote controller (separately placed receiver type), and a central control device can also be connected as with an air conditioning indoor unit.

2. High-Fresh: Structure and thermostat

High-Fresh models are equipped with an "intake (outdoor air temperature) thermostat" and "discharge thermostat."

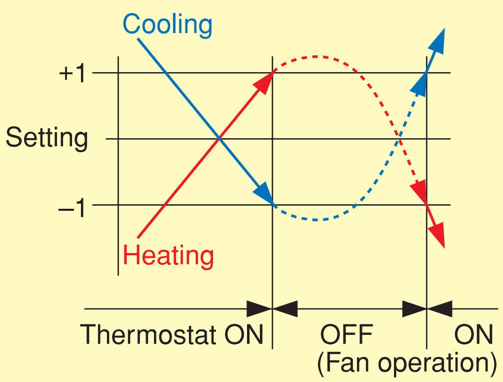
- **Thermostat OFF: OFF by either intake thermostat or discharge thermostat**
  (switches to fan operation)
- **Thermostat ON: ON by intake thermostat only**
  (For both floor-mounted and ceiling-embedded)

Floor-mounted High-Fresh structure and functional components



- **Intake thermostat temperature setting range**

  Cooling/dry: 18 – 30°C
  Heating: 16 – 26°C
  Automatic heating/cooling: 17 – 27°C



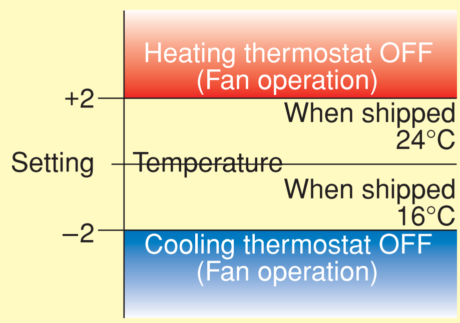
The remote controller temperature setting is the intake temperature; that is, the temperature of the outdoor air.

- **Setting of discharge thermostat when shipped**

  Thermostat OFF setting only. (ON: none)
  When temperature below is detected for six minutes continuously
  Cooling: 18°C (15 – 24°C)
  Heating: 22°C (17 – 28°C)

Setting can be changed within range indicated in ( ).

⇒ In detailed setting mode from wired remote controller



High-Fresh models are available in a floor-mounted type and ceiling-embedded type, but the basic structure is the same. The floor-mounted type is vertical with the fan on the intake side, while the ceiling-embedded type is horizontal with the fan on the discharge side.

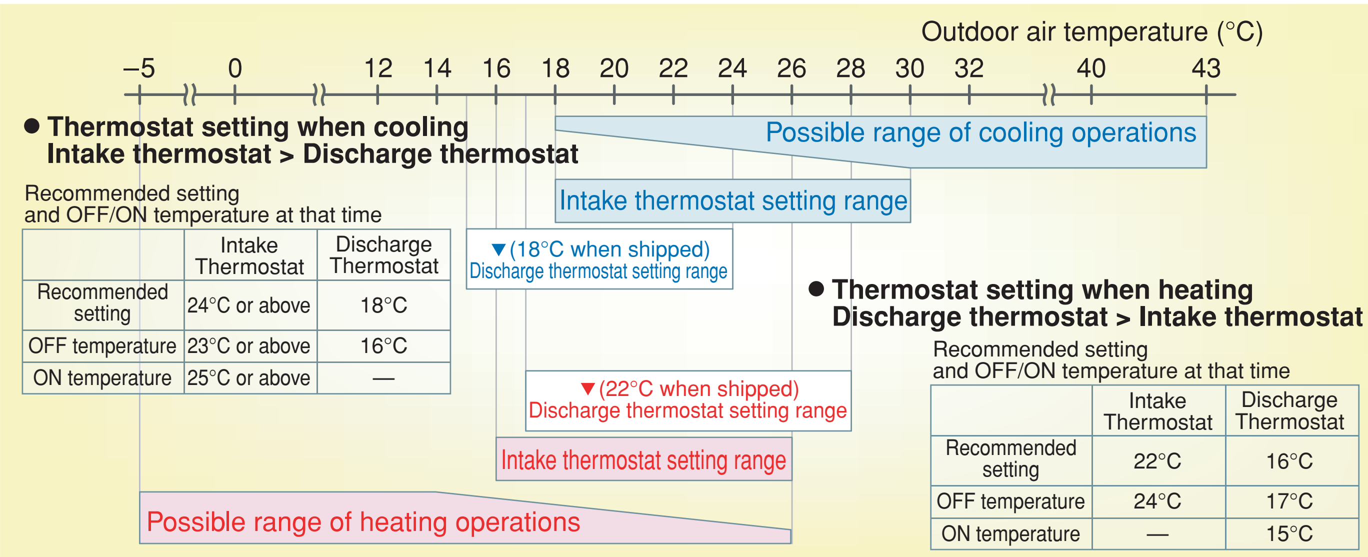
- The High-Fresh has two thermostats: an intake thermostat and discharge thermostat. **The temperature detected by the intake thermostat is the outdoor air temperature.** The intake thermostat is set by means of the wired remote controller "temperature setting" button. (It is the same as a standard unit's room temperature setting.)
- The thermostat turns OFF by means of either the intake thermostat or discharge thermostat. When the thermostat is OFF, the operation is by fan operation and the outdoor air is taken in directly, causing a draft to be felt from the temperature of the outdoor air. ⇒ For best comfort, operation with the thermostat OFF should be limited as much as possible.
- The thermostat turns ON as a result of intake thermostat ON conditions only. There are no conditions for ON by the discharge thermostat.

<CAUTION>
The position of the discharge thermostat differs from that of the direct-expansion-coil outdoor air treatment unit. Thus, the detected temperature is greatly different, and the thermostat OFF temperature setting also differs. That is, the discharge thermostat for the direct-expansion-coil outdoor air treatment unit is in the position prior to humidification, while for the High-Fresh unit it is in the position following humidification.

3. High-Fresh: Operation control

It is necessary to understand the setting ranges for the intake (outdoor air temperature) thermostat and discharge thermostat, and to set them properly.
Frequent thermostat ON/OFF actions can create a drafty feel and impair comfort, so operate with care.

Possible range of thermostat settings and operations



Thermostat setting when cooling (Intake thermostat > Discharge thermostat) — Recommended setting and OFF/ON temperature at that time:

	Intake Thermostat	Discharge Thermostat
Recommended setting	24°C or above	18°C
OFF temperature	23°C or above	16°C
ON temperature	25°C or above	—

Thermostat setting when heating (Discharge thermostat > Intake thermostat) — Recommended setting and OFF/ON temperature at that time:

	Intake Thermostat	Discharge Thermostat
Recommended setting	22°C	16°C
OFF temperature	24°C	17°C
ON temperature	—	15°C

* To prevent a drafty feel and obtain comfort, the discharge thermostat should be set near the room temperature.

When the intake thermostat and discharge thermostat settings are close, frequent thermostat ON/OFF operations will occur. **Therefore, set the intake and discharge thermostats at least "6 degrees" apart.**

Let's look at the relationship between the temperature settings of the intake thermostat and discharge thermostat. If the setting is not proper and the thermostat turns OFF, untreated outdoor air will be introduced, creating a drafty feel. In some cases, the indoor load may increase, preventing cooling or heating. Therefore, use care.

- The intake/discharge thermostat setting ranges and the possible ranges of cooling/heating operations are shown to the left. The possible operating range is the range in which the intake thermostat turns ON.
- Frequent thermostat ON/OFF operations may be repeated, depending on the thermostat setting.
  Here is the thermostat's minimum operation cycle: continuous detection time of 6 minutes ON by discharge thermostat, and minimum OFF time of 1 minute.
- For example, with a discharge thermostat setting of 18°C/intake thermostat setting of 20°C during cooling, and discharge thermostat setting of 22°C/intake thermostat setting of 20°C during heating, the system will start up but be quickly shut OFF by the discharge thermostat (after the discharge thermostat's continuous detection time reaches 6 minutes), since the intake and discharge thermostat settings are close. If, at this time, the intake thermostat reaches the ON condition, the thermostat will turn ON after the minimum OFF time 1 minute later.
- To avoid such situations, set the intake thermostat and discharge thermostat at least 6 degrees apart, as shown by the recommendations to the left.

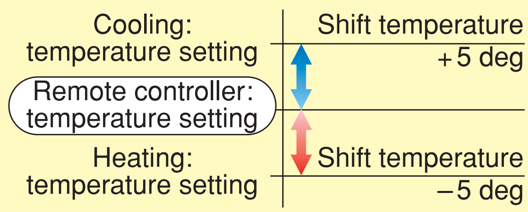
4. High-Fresh: Automatic heating/cooling

Automatic heating/cooling operation is possible when there is a one-to-one combination with a Multi System outdoor unit, or when there is a 3-WAY Multi System.

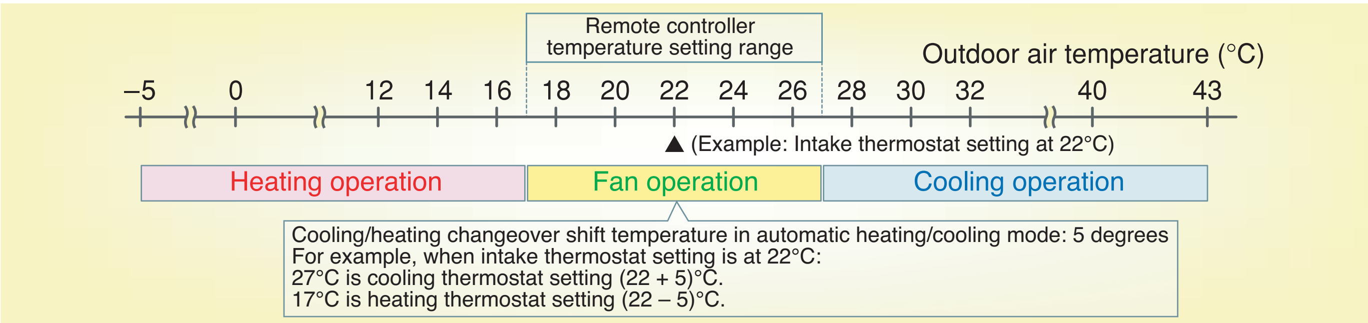
Automatic heating/cooling

- "Auto heat/cool" is selected with changeover of remote controller operation.
- The shift temperature (described to the right) is taken into account when the remote controller's temperature setting (intake thermostat setting) is determined. This temperature setting is displayed.
- "Fan operation" (direct outdoor air intake) is employed in this range: temperature setting ± 5 degrees.

Temperature setting and shift temperature



Automatic heating/cooling operation setting (example)



Discharge thermostat setting when shipped: 18°C when cooling, 22°C when heating.
⇒ The heating setting should be changed to 23°C or above.

A High-Fresh indoor unit can be used in automatic heating/cooling operations when there is a one-to-one combination with a Multi System outdoor unit, or when there is a 3-WAY Multi System.

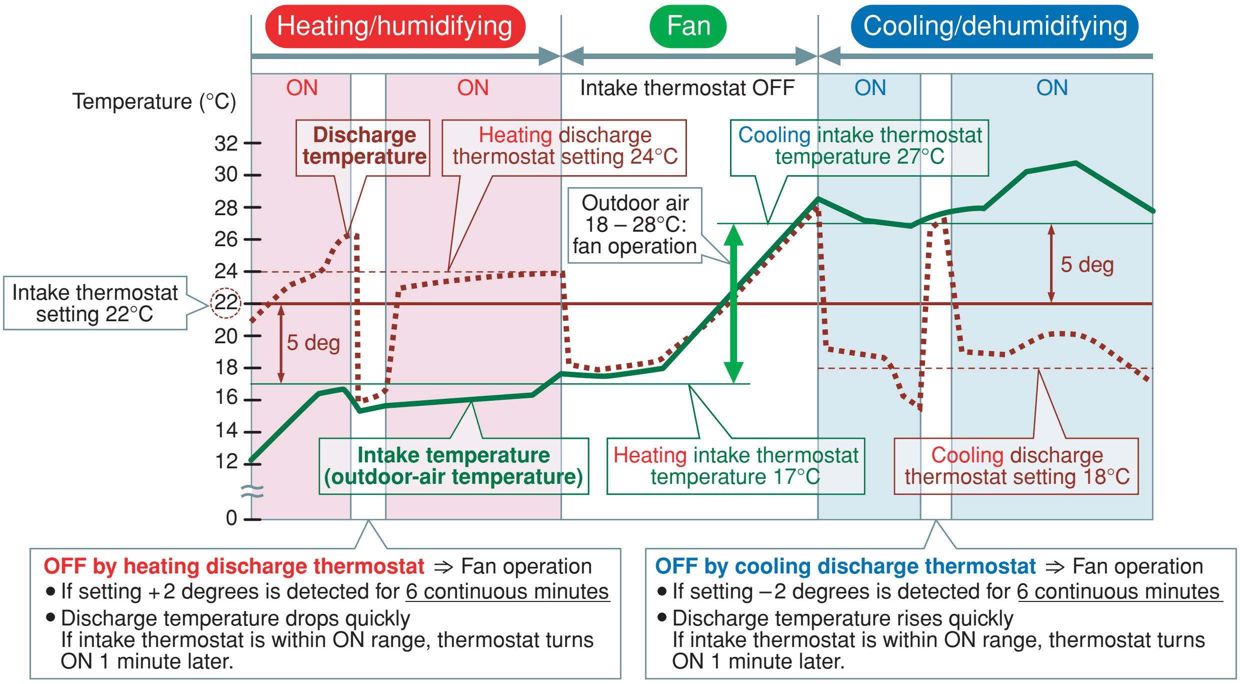
- In automatic heating/cooling operations, the thermostat setting will be +5 degrees for cooling and –5 degrees for heating with respect to the intake (outdoor air) thermostat temperature setting.
  (Heating/cooling changeover shift temperature: 5 degrees.)
  For example, **if the remote controller thermostat setting is set at 22°C, the intake air (outdoor air) temperature of 22 + 5 = 27°C is the cooling thermostat setting, while 22 – 5 = 17°C is the heating thermostat setting**.
- Within the remote controller temperature setting ± 5 degrees, outdoor air is introduced directly by fan operation.
- The remote controller temperature setting range is 17 – 27°C. But considering the shift temperature, a setting of about 20 – 22°C would be good.

5. **High-Fresh: Automatic heating/cooling operation (example)**

Let's look at intake/discharge temperature changes and thermostat ON/OFF.

- **Intake thermostat setting: 22°C**
  From 5-degree heating/cooling changeover temperature shift, **intake thermostat ON occurs for cooling at 27°C and heating at 17°C setting.**
- **Discharge thermostat: When setting changed to 18°C when cooling (setting when shipped)** and **24°C when heating**

Auto heating/cooling operation (example)

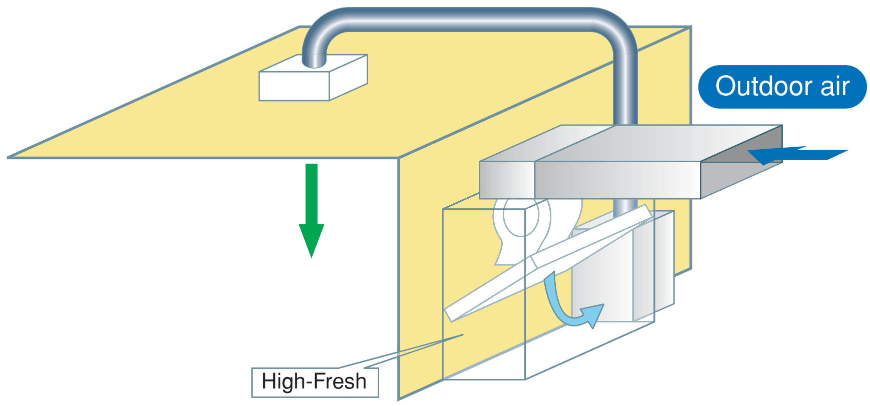


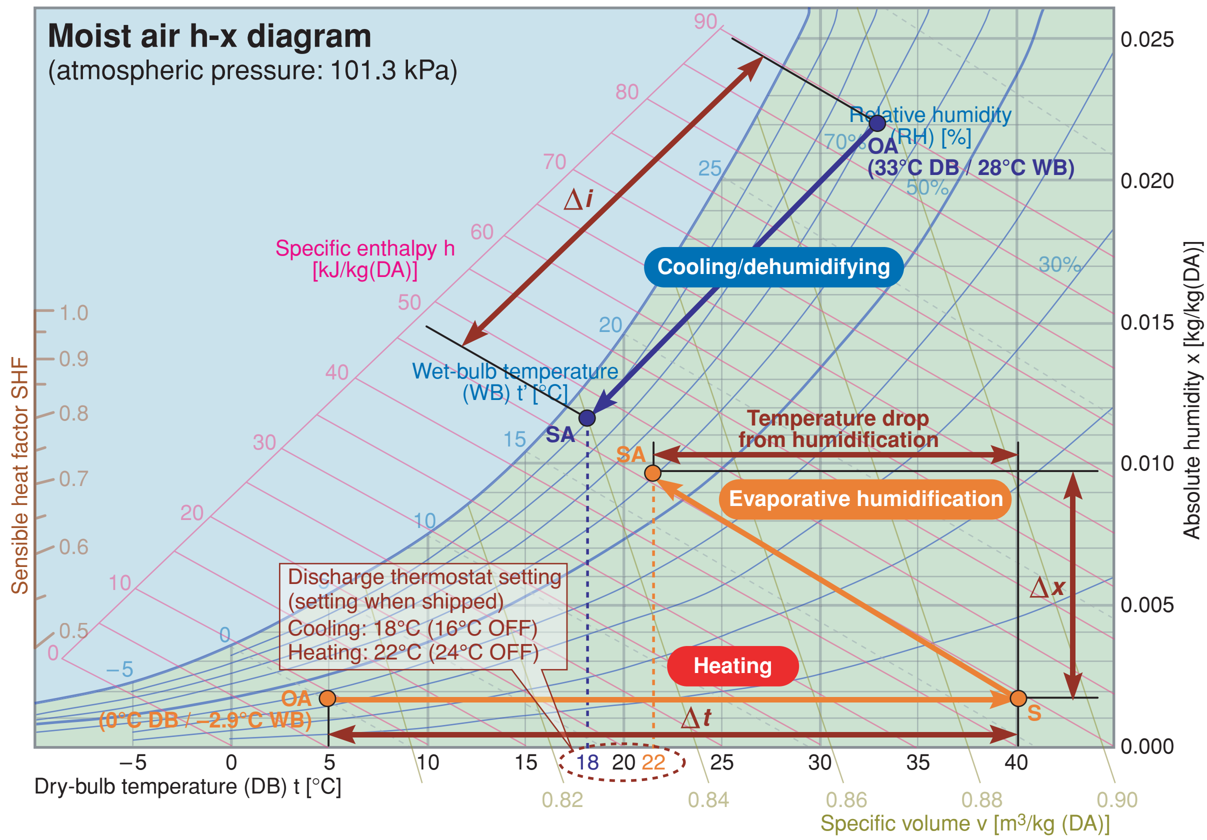
Let's take a look at how the intake/discharge temperature changes and how the thermostat turns ON/OFF during automatic heating/cooling operations.

- The figure shows an operation example in which the intake (outdoor air temperature) thermostat setting is 22°C and the discharge thermostat setting was changed to 18°C when cooling **(actual OFF temperature = Setting – 2 degrees = 16°C)** and 24°C when heating **(actual OFF temperature = Setting + 2 degrees = 26°C)**. (The above figure is an image diagram.)
  Incidentally, in this example, the intake temperature (outdoor air temperature) is assumed to be rising.
- As you can see from the above figure, when OFF by the discharge thermostat, the discharge temperature quickly becomes the intake temperature (= outdoor air temperature). When the outdoor air temperature is within the intake thermostat temperature setting ON range, the thermostat turns ON after the minimum OFF time 1 minute later.
- **Next, ON/OFF operations by the intake thermostat occur in accordance with the settings. When the intake temperature (outdoor air temperature) reaches 18°C (the heating setting plus 1 degree), heating thermostat OFF causes the fan to operate. Also, when the intake temperature (outdoor air temperature) rises to 28°C (the cooling setting plus 1 degree), cooling thermostat ON causes the system to begin cooling operation.**

6. High-Fresh: Psychrometric diagram

Outdoor air conditions:
Cooling: 33°C DB / 28°C WB (RH 68%)
Heating: 0°C DB / –2.9°C WB (RH 50%)
This example shows the operating state of the SPW-GUFXRP200A (floor-mounted) under the above conditions.





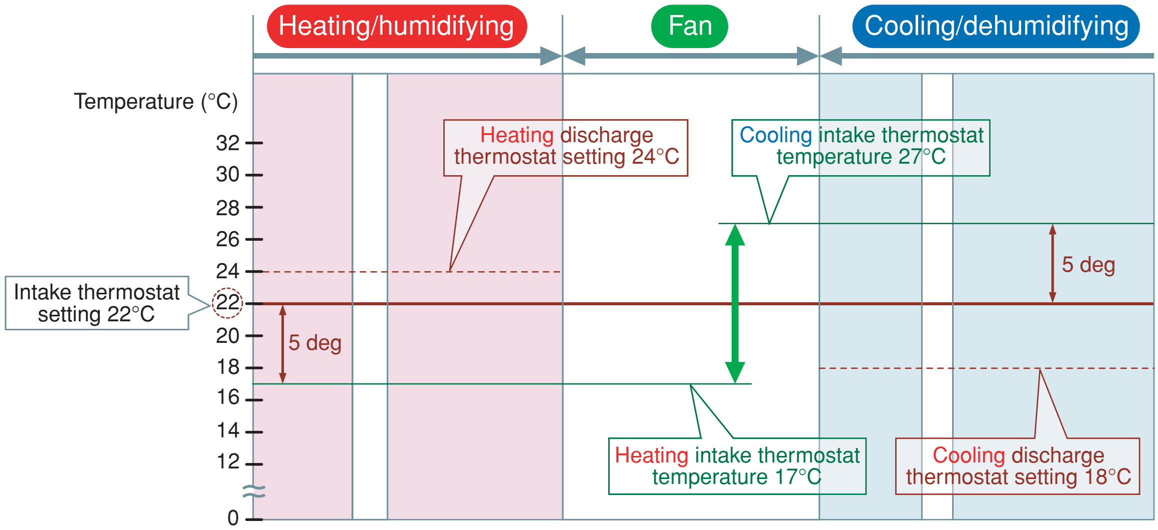
Model SPW-GUFXRP200A discharge air (SA) point

Airflow: 2,000 m^3 / h; Capacity: cooling = 28 kW / heating = 26.7 kW; Humidification = 18.5 kg / h
· Difference in enthalpy when cooling Δi = (28 × 3600) / (2000 × 1.2) = 42 kJ / kg (DA)
· Difference in temperature when heating Δt = (26.7 × 3600) / (2000 × 1.2 × 1.006) = 39.8°C
· Difference in absolute humidity Δx = 18.5 / (2000 × 1.2) = 0.0077 kg / kg (DA)
The discharge air (SA) point is found under the above conditions.

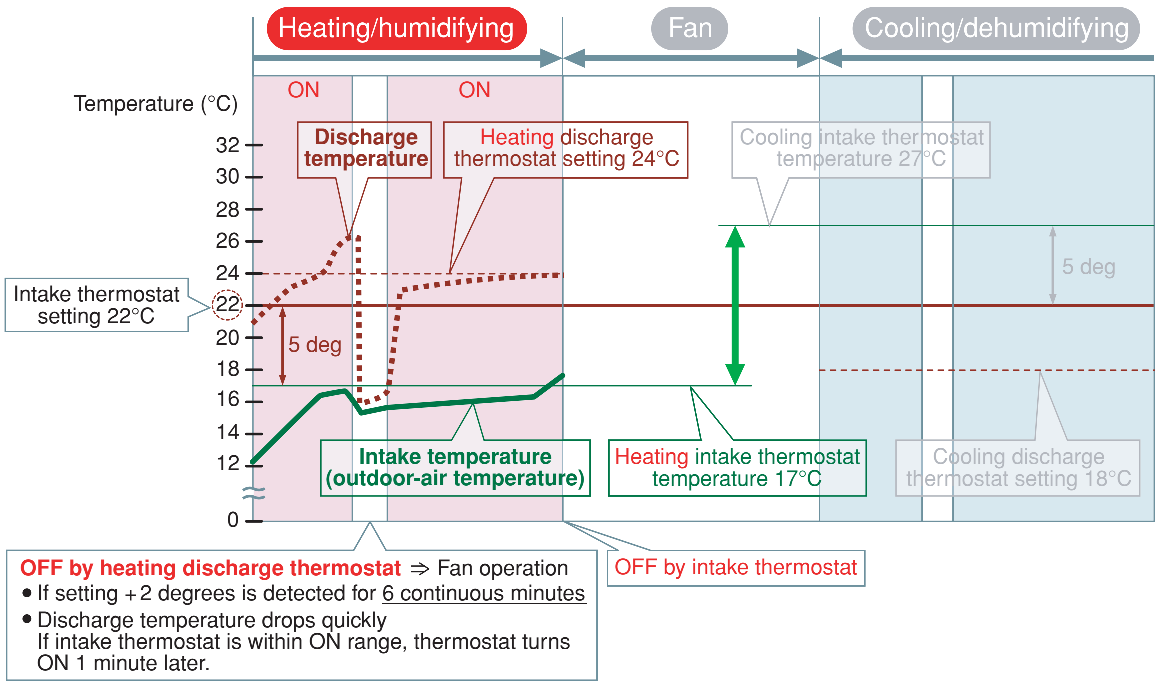
An operating state point under High-Fresh performance conditions can be found by computation as shown. It can be found from the respective intake points by adding or subtracting the difference in enthalpy when cooling Δi, difference in temperature when heating Δt, and difference in absolute humidity Δx.

- The cooling discharge point is at the intersection of Δi and approximately 90% RH. (Strictly speaking, the cooling discharge point is found from the heat exchanger bypass factor after the heat exchanger surface temperature is found on the saturation curve. But even at approximately RH 90%, there is no large difference.)
- When heating, “S” is the discharge point from the difference in temperature due to heating Δt, and the discharge temperature is the point that rises by an amount equal to the difference in absolute humidity Δx along the wet-bulb temperature line due to evaporative humidification.
- Thus, with evaporative humidification, there is a drop in temperature. With the High-Fresh, this temperature drop is taken into account when the discharge temperature is set. If humidification is not provided, the discharge thermostat will cause frequent OFF/ON cycle operations.

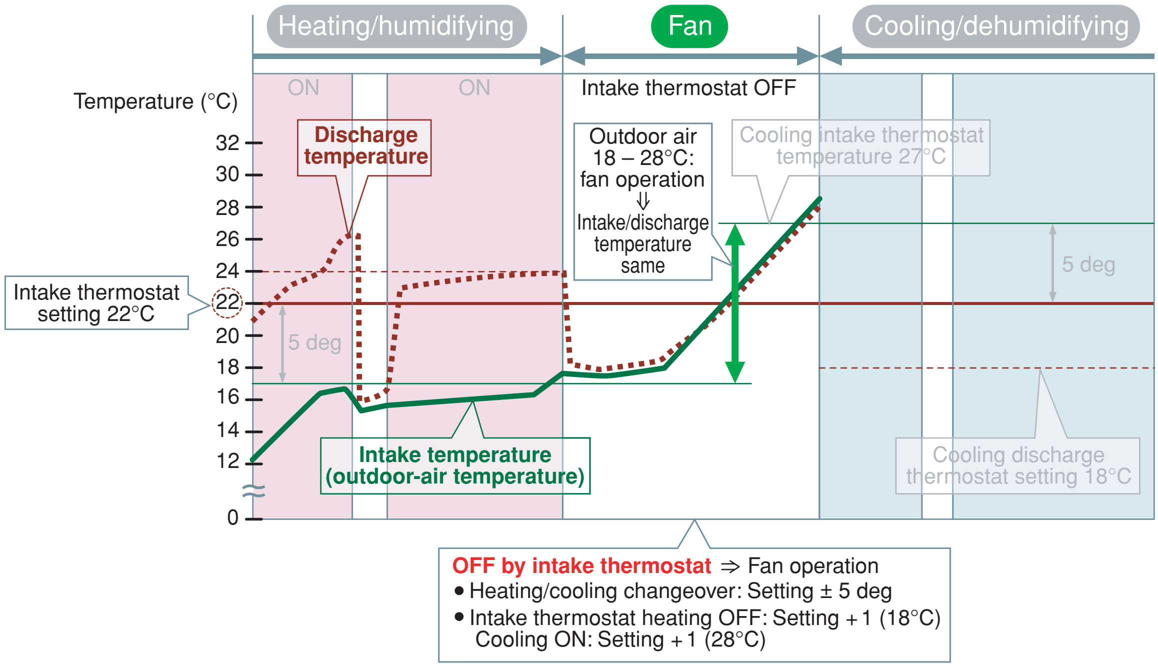
1. Thermostat setting (example)



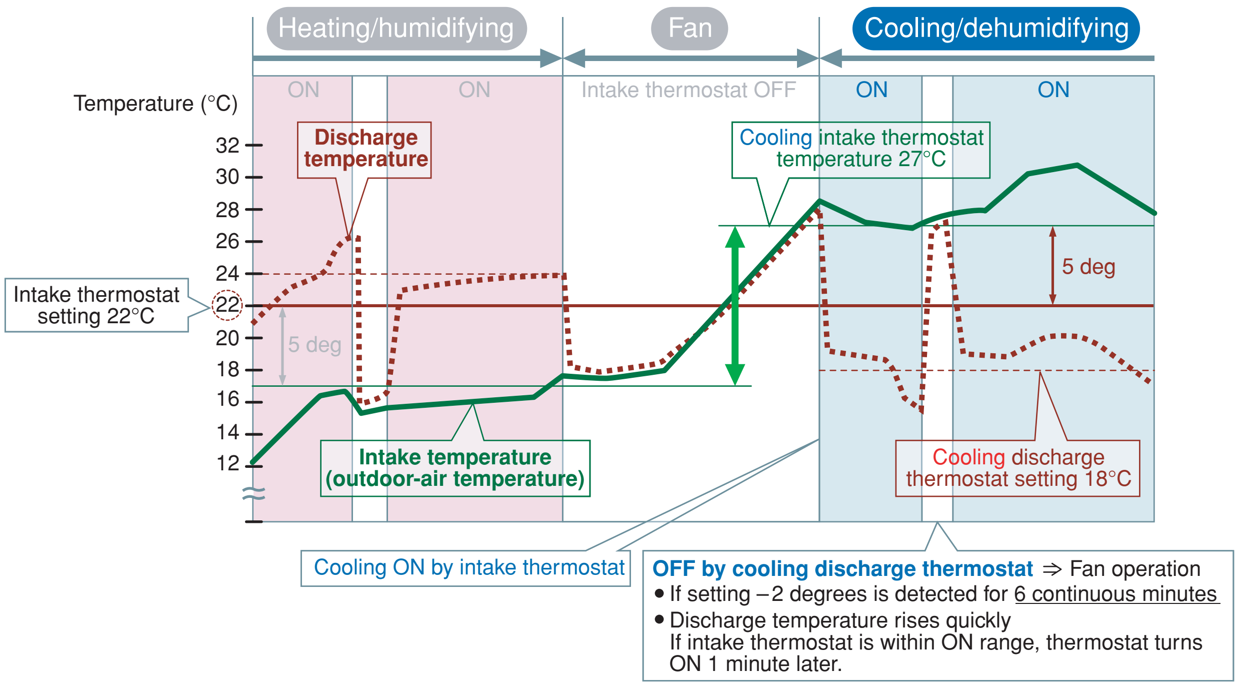
2. Heating and humidification operation (example)



3. Thermostat OFF fan operation (example)



4. Cooling/dehumidifying operation (example)



Evaporative humidifier computation

● For four-way cassette type

Indoor unit type	28 – 45	56	71	90	112	140	160
Airflow (m^3 / min)	15.5	16	20	22	28	33	34
Humidification (kg / h)	0.62	0.63	0.7	0.74	1.33	1.4	1.41
Water supply	2.6	2.6	2.6	2.6	2.6	2.6	2.6
Δx (kg /kg)	0.00056	0.00055	0.00049	0.00047	0.00066	0.00059	0.00058
x2 (x1 = 0.00575)	0.00631	0.00630	0.00624	0.00622	0.00641	0.00634	0.00633
Using 2 units (both sides)	0.00111	0.00109	0.00097	0.00093	0.00132	0.00118	0.00115
Heating capacity (kW)	5	6.3	8	10	12.5	16	18
Temperature difference Intake 20°C	16.0	19.6	19.9	22.6	22.2	24.1	26.3
Discharge temperature	36.0	39.6	39.9	42.6	42.2	44.1	46.3
Temperature drop from humidifying	1.4	1.3	1.2	1.1	1.6	1.4	1.4

● Built-in

Indoor unit type	36	56	71	90	112	140	160
Airflow (m^3 / min)	10	12	19	20	30	34	34
Humidification (kg / h)	0.7	0.8	1	1.05	2	2.05	2.05
Water supply	3				3.8		
Δx (kg /kg)	0.00097	0.00093	0.00073	0.00073	0.00093	0.00084	0.00084
x2 (x1 = 0.00575)	0.00672	0.00668	0.00648	0.00648	0.00668	0.00659	0.00659
Using 2 units (both sides)							
Heating capacity (kW)	4.2	6.3	8	10	12.5	16	18
Temperature difference Intake 20°C	20.9	26.1	20.9	24.9	20.7	23.4	26.3
Discharge temperature	40.9	46.1	40.9	44.9	40.7	43.4	46.3
Temperature drop from humidifying	2.4	2.3	1.8	1.8	2.3	2.0	2.0

● Wall built-in

Indoor unit type	140	224	280
Airflow (m^3 / min)	44	64	80
Humidification (kg / h)	2.4	3.6	4.8
Water supply	8	18	18
Δx (kg /kg)	0.00076	0.00078	0.00083
x2 (x1 = 0.00575)	0.00651	0.00653	0.00658
Using 2 units (both sides)			
Heating capacity (kW)	16	25	31.5
Temperature difference Intake 20°C	18.1	19.4	19.6
Discharge temperature	38.1	39.4	39.6
Temperature drop from humidifying	1.8	1.9	2.0

● With direct-expansion coil

Indoor unit type	50	75	100
Airflow (m^3 / min)	500	750	1000
Humidification (kg / h)	2.7	4.1	5.4
Water supply	4.1	6.2	8.1
Δx (kg /kg)	0.00450	0.00456	0.00450
x2 (x1 = 0.00575)			
Using 2 units (both sides)			
Heating capacity (kW)	3.2	5	6.3
Temperature difference Intake 20°C	19.1	19.9	18.8
Discharge temperature	33.7	34.5	33.4
Temperature drop from humidifying	11.0	11.1	11.0

This capacity should apply after total heat exchanger is passed ≒ 100%
(for example, outdoor air: 0°C;
indoor intake: 14.6°C)

⇒ Capacity characteristics, air after indoor intake air passes through total heat exchanger

Temperature of air after passing through total heat exchanger = 14.6°C

● Ceiling-embedded High-Fresh

Floor-mounted type

Indoor unit type	110	170	210	200
Airflow (m^3 / min)	1100	1700	2100	2000
Humidification (kg / h)	5	12	14	18.5
Water supply	20	30	30	32
Δx (kg /kg)	0.00379	0.00588	0.00556	0.00771
x2 (x1 = 0.00575)				
Using 2 units (both sides)				
Heating capacity (kW)	13.2	21.2	26.5	26.7
Temperature difference Intake 0°C	35.8	37.2	37.6	39.8
Discharge temperature	26.5	22.8	24.1	21.0
Temperature drop from humidifying	9.2	14.3	13.6	18.8

Summary

1. A number of outdoor air intake methods are available. The size of the outdoor air intake (ventilation) load is associated with the capacity of the air conditioner.
   Also, energy is conserved when the supply air first recovers heat from the indoor exhaust air, an action accomplished by a total heat exchanger, for instance.
   For various outdoor air intake methods, we studied changes in the state points of outdoor air (OA), room air (RA), and discharge air (SA) on psychrometric diagrams.
2. Using the total heat exchanger efficiency computation formula, we can find the status of the air supply through computation.
3. We gained an understanding of the structure and functions of the Eco-Ice-mini-supporting “Ventilation mo Guppy” indoor units, and of the changes that occur on psychrometric diagrams.
   With a ceiling-suspended-type air conditioner with integrated total heat exchanger, ventilation becomes a “simultaneous intake/exhaust” operation.
4. A “direct-expansion-coil outdoor air treatment unit” is available as an indoor unit of a building Multi System. With integrated total heat exchanger, this indoor unit provides “simultaneous intake/exhaust” operation and, after total heat exchange, treats and discharges supply air with a direct-expansion coil.
5. “High-Fresh” is available as an All-Fresh unit that is connected to the outdoor unit of a building Multi System.
   This indoor unit treats and discharges outdoor air at room temperature level. Ventilation fans are used to exhaust smoking rooms, hot-water service rooms, and restrooms, for example.
6. We studied the structure and functions of a “direct-expansion-coil outdoor air treatment unit” and “High-Fresh,” as well as control by thermostat.
   Remember that there is an intake (outdoor air temperature) thermostat and discharge thermostat, and be sure to understand their ON/OFF statuses.

Next is the final test.
Once you pass the test and answer the questionnaire survey, you are finished. Congratulations!